Job Number: 131026
Date 14th November 2013

CROFT STRUCTURAL ENGINEERS

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Basement Structural Method Statement

51 Fitzjohn's Ave
Camden NW3 6PH

John Hough
Oakley Hough Limited
The Barn, Stebbing Farm,
Fishers Green, Stevenage,
Hertfordshire SG1 2JB

Revision	Date	Comment
-	15/11/2013	Issued for comments

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1. Basement Formation Suggested Method Statement.

The Local geological drift sheets imply the ground to be London Clays

2. Enabling works
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4. Underpinning – Cantilevered Wall Creation
5. Approval

Standard Lap Trench Sheeting

KD4 sheets

Appendix D

Soil Investigation Reports

1. Design Information - Structural

Structural Summary

51 Fitzjohn's Avenue is a multi occupancy, 6 storey high property with load bearing external masonry walls, internal load bearing masonry walls. The floors on each floor appear to be timber, spanning from left to right between the walls and the roof is of a timber structure. The lower ground floor is already present to the right front side and the left rear side of the building. The floor above the rear lower ground part is a thick concrete/precast slab and to the front there are timber joists.

Figure 1:Front View

Proposed works

The proposed work constitutes amendments to the internal walls layout and a new lower ground development under the part of the property which at present stops at the ground level. This will be constructed in reinforced concrete retaining walls underpinning the existing external walls. Light wells will be created to the front of the property. The light wells will have a grille over them.

Croft Structural Engineers Ltd has extensive knowledge of the design and construction of new basements. Over the last 4 years we have completed over 150 basements in and around the local area. The method developed is:

1. Excavate front to allow conveyor to be inserted.
2. Form 'front of basement' with cantilevered retaining walls
3. Slowly work from the front to the rear inserting 1200 long cantilevered retaining walls sequentially.
4. Cast ground slab

5. Waterproof internal space with a drained cavity system.

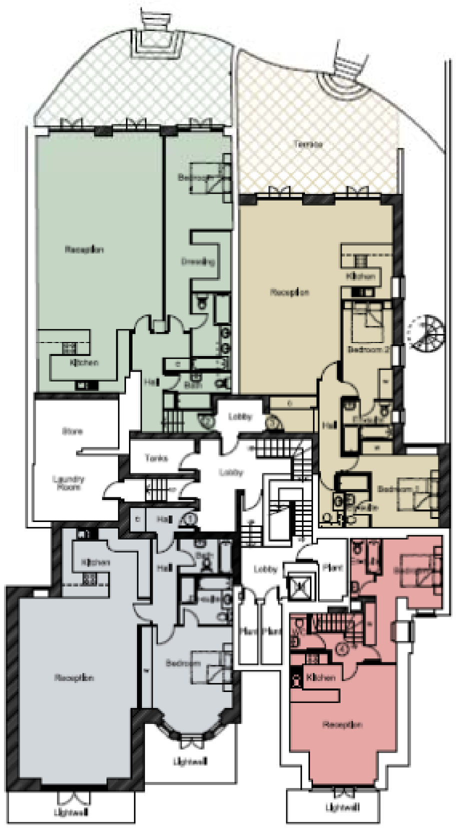

Figure 2: Proposed Lower Ground Floor Plan

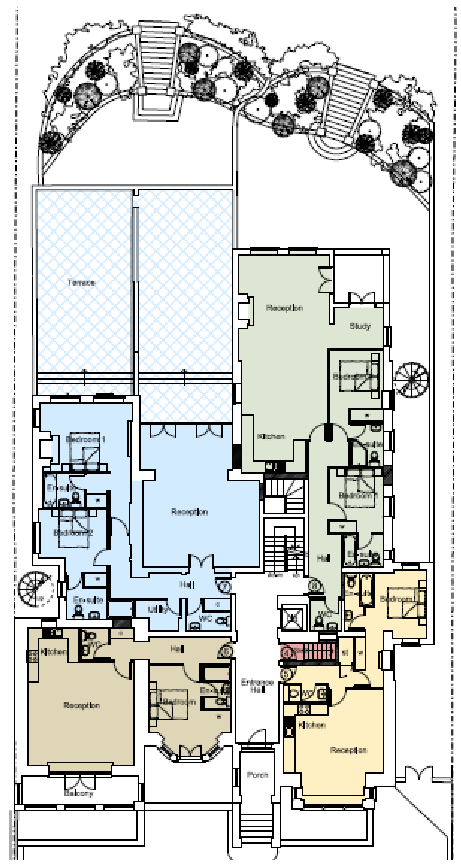

Figure 3: Proposed Ground Floor Plan

Structural Defects Noted

No defects were noted during the Chartered Engineers first visit.

Intended use of structure and user requirements	Family/domestic use
Loading Requirements	

	UDL kN/m²	Concentrated Loads kN
Domestic Single Dwellings	1.5	2.0

The basement does not lie within a 45 angle of the highway and is more than 5m from the road.

5kN/m² if within 45° of Pavement

Garden Surcharge 2.5kN/m²

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Surcharge for adjacent property 1.5kN/m² + 4kN/m² for concrete ground bearing slab

Adjacent Properties:
All adjacent property's footings within 45° to have additional geotechnical engineers input

Number of storeys

6

Is Live Load Reduction included in design — No

Progressive Collapse

Design for consequences of localized failure in building from an unspecified cause

Is the Building Multi Occupancy?

No

Part A3 Progressive collapse

EN 1991-1-7:1996 Table A1

Class 2B	Hotels, flats, apartments and other residential buildings greater than 4 storeys but not exceeding 15 storeys

Progressive collapse Change of use

To NHBC guidance compliance is only required to other floors if a material change of use occurs to the property.

Initial Building Class	2B
Proposed Building Class	2B
If class has changed material change has occurred	No

Additional Design Requirements to Comply with Progressive Collapse

Class 2B – Design provision of effective horizontal and vertical ties to all areas increased in class.

Exposure and wind loading conditions

Lateral Stability

0.6 kN/m²

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Stability design	The main existing masonry stability walls are not being altered. The reinforced concrete retaining walls are designed to carry the lateral loading applied from above. The lateral earth pressure exerts a horizontal force on the retaining walls. The retaining walls will be checked for resistance to the overturning force this produces.
Lateral Actions	Lateral Forces applied from; Soil loads Hydrostatic pressure Surcharge loading These produce retaining wall thrust; this is restrained by the opposing retaining wall.

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DP27	
A	**Maintain Structural Stability of the building & Neighbouring Properties.** The attached drawing shows the reinforcement and construction required by maintain stability of the property, the neighbouring buildings and the road. Calculations results are shown in the Impact Assessment Part.
B	**Avoid Adversely Affecting drainage and Run off.** The area of hard standing remains unchanged and run off will not be altered. The property will not affect the main aquifer as the site does not lay above an aquifer. See Screening Stage information
C	Avoid Cumulative Impact upon Structural Stability or the water environment. See Scoping stage that indicates location in relations to water course and Hampstead heath catchment. See Impact Assessment and drawings. Additional drainage layer has been placed under the building. The structure is designed to take account of Hydrostatic head on the basement.
D	**Harm the Amenity of Neighbours** Noise and nuisance have been considered in Impact Assessment stage.
E	**Loss of Open Space or Trees** There is no loss of open space. Trees are unaffected. The current roots will be above the existing foundations and therefore the new foundations will not cut through significant roots.

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2. Basement Impact: Screening

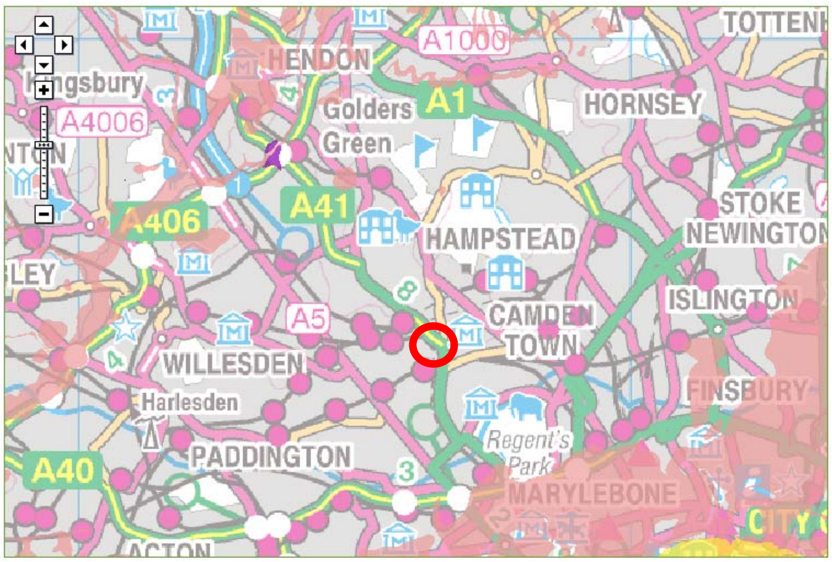
The questions below are taken from the Camden CPG 4 – Basements and Lightwells.

Questions have been taken from Appendix E of the Arup Hydrology report

Groundwater flow

1a. Is the site located directly above an aquifer?

No. The Environment Agency maps do not show the site to lie above an aquifer.



1b. Will the proposed basement extend beneath the water table surface?
The soil investigation was not completed directly on site, but there is an existing basement present underneath half of the building. Additionally, in appendix D there are attached reports from three different sites approximately 200-300meters away from the site and all of them show no water present up to 30 meters down.

2. Is the site within 100m is a watercourse, well used/disused or potential spring line?
No. OS maps and local walkover survey show no wells, watercourses or potential spring lines within 100m of the site.

3. Is the site within the catchment of the pond chains on Hampstead Heath?
No. The site lies outside the areas of the pond chains on Hampstead Heath.

4. Will the proposals basement development result in a change in the proportion of hard surfaced/ paved areas?
No. The surfaces to the front & rear are to remain unchanged.

5. As part of the site drainage will more surface water (e.g. rainfall and run-off) than at present be discharged to the ground (e.g. via. Soakaways and or SUDS)?

No. Existing roof Drainage will run into the existing drainage system. Surface water will still discharge to ground.

6. Is the lowest point of the proposed excavation (allowing for any drainage and foundation space under the basement floor) close to or lower than, the mean water level in and local pond (not just the pond chains on Hampstead Heath) or spring line?
No. From walkover and OS maps, there are no local ponds or springs of significance.

The site is near the London Clay and Claygate boundary, which may produce a boundary line, but is higher than the boundary.

Slope Stability

Figure 2 – Slope Stability screening flowchart

1. Does the existing site include slopes, natural or man made greater than 7° (approximately 1 in 8)?
No. Difference in height between the rear garden and front is less than 1 in 8 slope (approx flat)

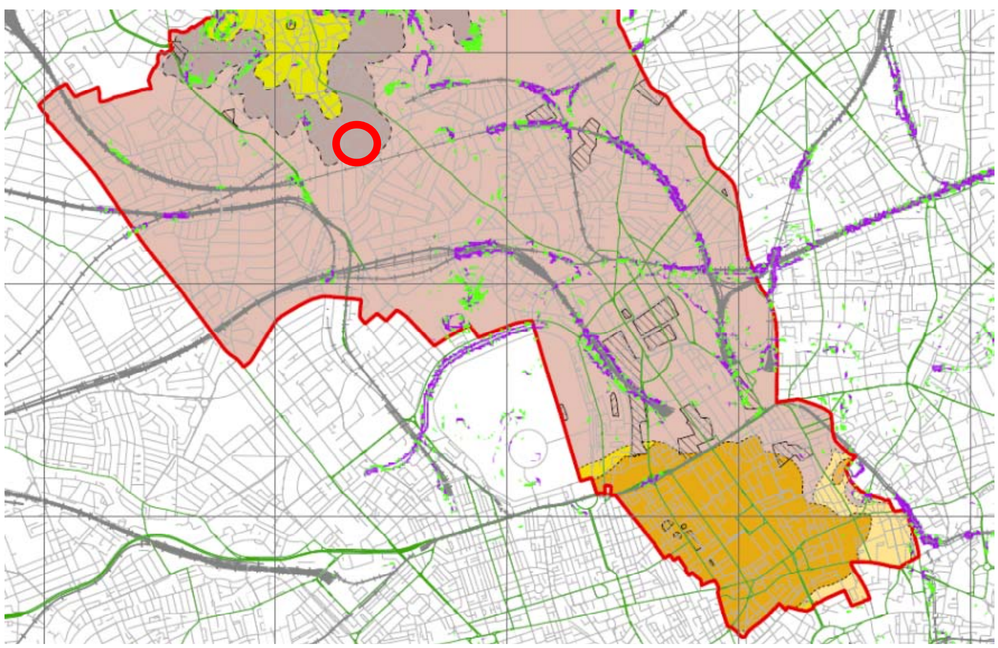


Figure 4: Arup Report Figure 16

2. Will the proposed re profiling of landscaping at site change slopes at the property boundary to more than 7° (approximately 1in 8)?
No. Proposed landscaping does not affect the slope.

3. Does the development neighbour land including railway cuttings and the like

with a slope greater than 7^{o} (approximately 1 in 8)?
No. Proposed landscaping does not affect the slope.

4. Is the site within a wider hillside setting in which the general slope is greater than 7^{o} (approximately 1 in 8)?
No. The slope of the wider hillside setting is as per the property, less than 7^{o}

5. Is the London Clay the shallowest strata on site?
Yes. The site sits on the Claygate beds part of the London Clay formation. The Claygate beds site above the London Clay.

6. Will any tree/s be felled as part of the proposed development and/or are any of the works proposed within any tree protection zones where trees are to be retained?
No. No local trees are to be felled. The impact of the basement on these trees should be considered
Carry forward to scoping stage.

7. Is there a history of seasonal shrink-swell subsidence in the local area, and/ or evidence of such effects at the site?
No. From the walk over survey Subsidence was not considered as an issue on this site.

The site is on Shrinkable ground and as such has an increased risk to subsidence. The basement and all foundations will be designed to take account of the ground conditions. The basement construction places the loads of the property on to deep ground. The depth further protects the building from the seasonal changes in the ground.

8. Is the site within 100m of a watercourse or a potential spring line?
No. OS maps and local walkover survey show no wells, watercourses.

9. Is the site within an area of previously worked ground?
No. From the historical maps, the site has been residential for the past 150 years.

10. Is the site within an aquifer? If so will the proposed basement extend beneath the water table such that dewatering may be required during construction?
No. The Environment Agency maps do not show the site to lie above an aquifer.

Arups report shows the site to be am unproductive strata.

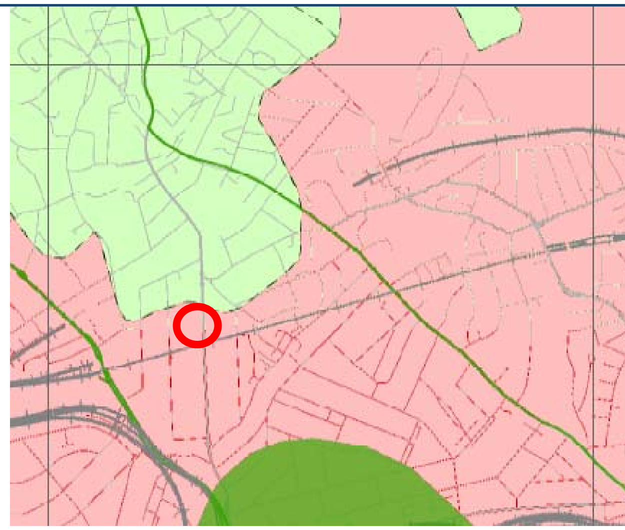


Figure 5: Arup Report Figure 8

11. Is the site within 50m of the Hampstead Heath ponds?
No.

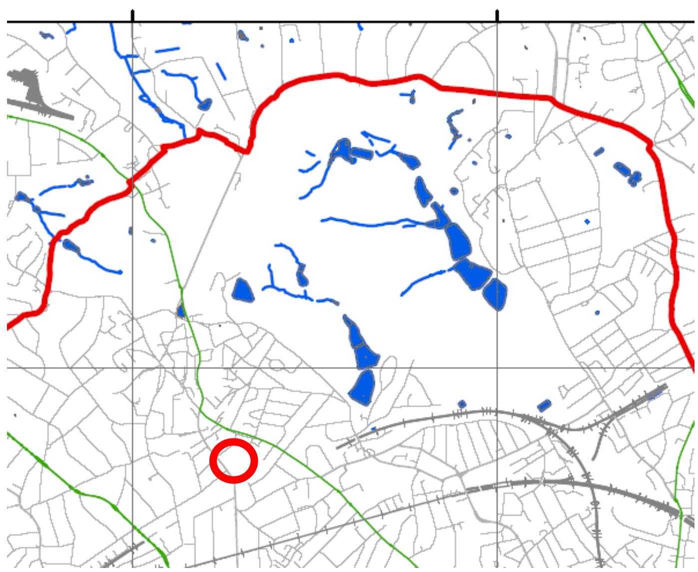


Figure 6: Arup Report Figure 12

12. Is the site within 5m of a highway or pedestrian footway?
Yes. Site is within 5m of the footpath/alleyway.

Carry forward to scoping stage. The design will need to take account of the highway loading.

13. Will the proposed basement significantly increase the differential depth of foundations relative to the neighbouring properties?
No. Existing building already has a lower ground level, and proposed development is to extend the lower ground floor under the full footprint of the building. Party wall will not be underpinned as the building is free standing.

	Existing footings are expected to be corbelled masonry approx. 1000mm below ground level. **Carry forward to scoping stage.: Overall design to be considered.** **14. Is the site over (or within the exclusion zone) of any tunnels, e.g. railway lines?** **No**. Nearest is the LUL Line, approximately 100m from site. Confirmation at design stage from LUL is required to confirm their assets are not affected.
Surface flow and flooding	**1. Is the site within a catchment of the pond chains on Hampstead Heath?** The site lies outside the catchment areas of the Hampstead heath ponds as shown on figure 14 of the Camden Hydrological Study **2. As part of the proposed site drainage, will surface water flows (e.g. volume of rainfall and peak run-off) be materially changed from the existing route?** **No**. The area of hard standing remains unchanged by the development. **3. Will the proposed basement development result in a change to the hard surfaced /paved external areas?** **No.** The amount of hard standing will remain unchanged **4. Will the proposed basement result in changes to the inflows (instantaneous and long term of surface water being received by adjacent properties or downstream watercourses?** **No**. The proposed development will enter the current drainage system. **5. Will the proposed basement result in changes to the quality of surface water being received by adjacent properties or downstream watercourses?** **No**. The quality of water is unlikely to be altered. **6. Is the site in an area known to be at risk from surface water flooding, such as South Hampstead, West Hampstead Gospel Oak and King's Cross or is it at risk form flooding, for example because the proposed basement is below the static water lever of a nearby surface water feature?**

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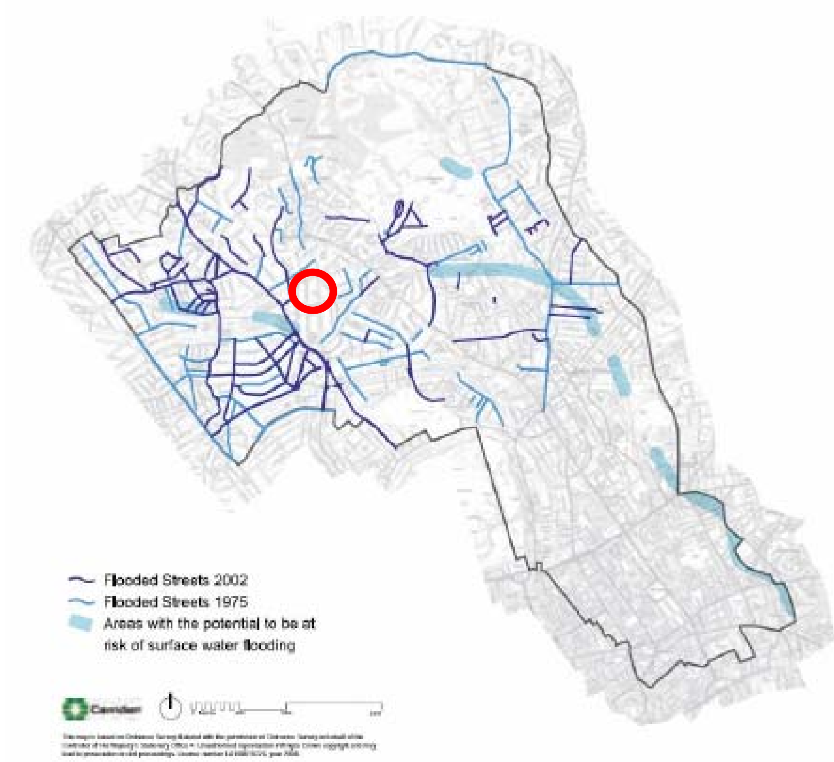

Fitzjohn's Ave is not noted on the previously flooded streets in Camdens fig 5 core Strategy. The soil investigation reports attached at appendix E show no water up to 30 meters down.

3. Basement Impact: Screening Maps

	Attached maps support Screening information

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4. Basement Impact: Scoping

Groundwater flow	**Subterranean flow** There is an existing basement already present underneath half of the property, the refurbishment will drop the level only to the existing lower ground floor. Additionally, the attached soil investigation reports done in close proximity to the site in different direction, approximately 200-300m away show that there is no water present up to 30meters.
Slope Stability	The Claygate beds are expected to be the top layer. The slope stability of theses beds is in the region of 40˚. The design of the RC retaining walls will take this into account. The basement is within 5m of the footpath, and will therefore be designed with a 5kN/m^2 surcharge.
Surface flow and flooding	This proposal is not considered to be in an area a risk of flooding. The flow of surface water above the basement (top 1m of soil) will need to be considered.

5. Desk Study and Walkover Survey

Subsoil conditions

The Geology of Britain viewer Map Indicates the site is underlain by Claygate member. This is as expected in the area.

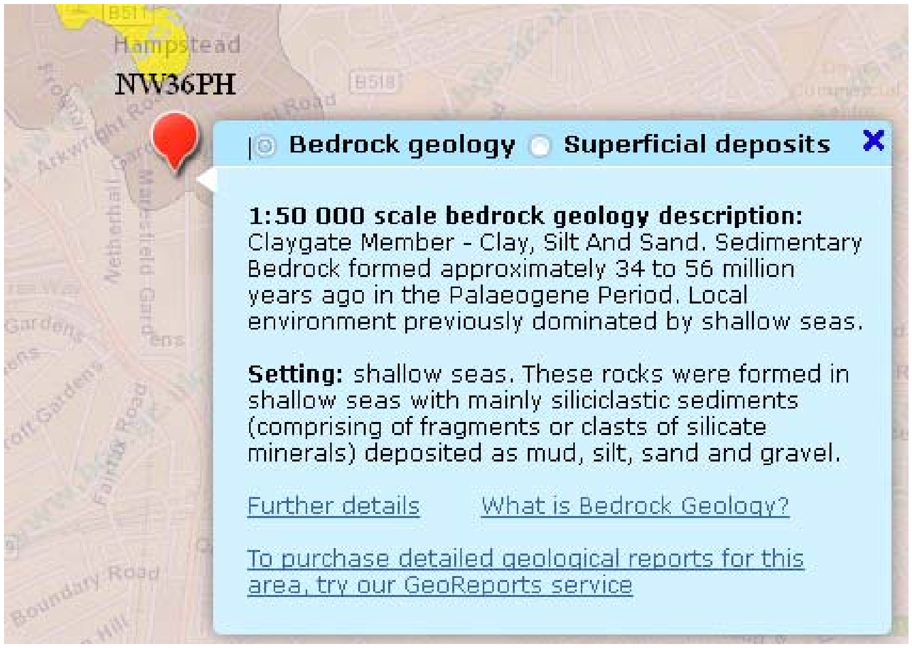

Figure 7 Extract From North London Drift Sheet

Walk over Survey

Figure 8: Adjacent property on left side

Figure 9: Adjacent property on right side

The existing building did not exhibit any signs of subsidence not movement. The building is free standing, with adjacent buildings approximately 1.5m away. The effects of the development on the adjacent properties will need to be considered.

Drainage effects on Structure	No build over agreements known of.
Under ground	Underground line is approximately 100m away.
Sources of Contaminates	From the Historic Maps it can be seen that the ground use has not been conducive to activities leading to poor ground. During the walk over survey no items were noted that may lead to contamination.
Water Course	No wells were noted on site The site is not shown within the areas of recent local flooding in the Arup's report. The site is not within the Hampstead pond catchment area as shown in the Arup's report. The site is not within any local water course noted in the Arup's report.

6. Impact Assessment

Slope Stability

From the walk over survey, the OS map and the Arups report the slopes around the site are less than 7º.

Land slip is not a problem due to any circular failure patterns.

The retaining walls must be designed to accommodate the lateral pressures from the soils.

Foundation type

Reinforced concrete cantilevered retaining walls

The designs for the retaining walls have been calculated using TEDDS software. The software is specifically designed for retaining walls and ensures the design is kept to a limit to prevent damage to the adjacent property.

Attached printout of Calculations can be found in Appendix B.

The overall stability of the walls are design using K_a & K_p values, while the design of the wall uses K_o values. This approach minimise the level of movement from the concrete affecting the adjacent properties.

The walls are designed to cope with the hydrostatic pressure. It is possible that a water main may break causing local high water table. To account for this the wall is designed for water to the full height fo the retaining wall.

The Design also considers floatation as a risk. The design of has considered the weight of the building and the uplift forces from the water. The weight of the building is greater than the uplift resulting in a stable structure.

Below are the design pressures and loadings.

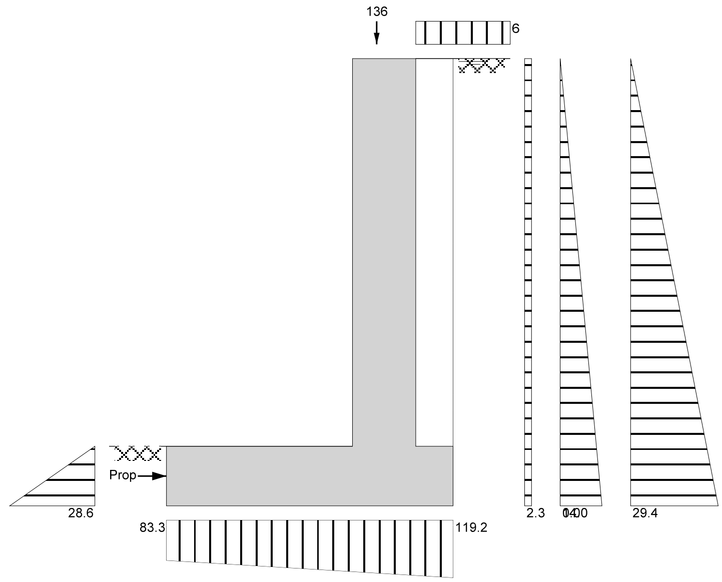

Figure 10: RC Retianing wall 1 design

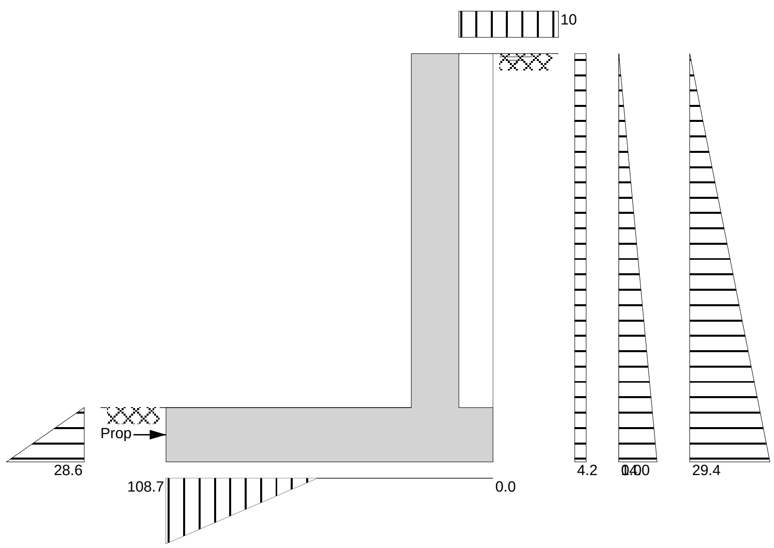

Figure 11: RC Retaining wall 2 design

Full calculations for RC retaining walls 1 & 2 can be found in appendix C.

Special precautions due to trees	Design using NHBC guidance Basement depth will allow for footings to be placed outside the effects of the trees. The current trees roots will be limited by the existing foundations. The new basements excavations will not significantly/ adversely affect the root protection zones of the neighbouring trees.
Drainage effects on Structure	No build over agreements known of. Flooding. The site is not in an area of high risk flooding.
Roads	The building does not undermine the highway, but car parking is present to the front of the property. It is possible for heavier goods vehicles to reverse on to the property to allow for this risk loadings are to be taken from the Highways loading code. $10kN/m^2$ to front light well Garden Surcharge $2.5kN/m^2$ Surcharge for adjacent property $1.5kN/m^2$ + $4kN/m^2$ for concrete ground bearing slab

Adjacent Properties	***Any ground works pose an elevated risk to adjacent properties. The proposed works undermines the adjacent property along the party wall line:*** The party wall is to be underpinned. Underpinning the party wall will remove the risk of the movement to the adjacent property. The works must be carried out in accordance with the party wall act and condition surveys will be necessary at the beginning and end of the works. The method statement provided at the end of this report has been formulated with our experience of over 150 basements completed without error. The design of the retaining walls is completed to K_O lateral design stress values. This increases the design stresses on the concrete retaining walls and limits the overall deflection of the retaining wall. It is not expected that any cracking will occurring during the works. However our experience informs us that there is a risk of movement to the neighbours. To reduce the risk the development: • Employ a reputable firm for extensive knowledge of basement works. • Employ suitably qualified consultants. Croft Structural engineer has completed over 150 basements in the last 4 years. • Design the underpins to the stable without the need for elaborate temporary propping or needing the floor slab to be present. • Provide method statements for the contractors to follow • Investigate the ground, now completed. • Record and monitor the external properties. This is completed by a condition survey on under the Party Wall Act before and after the works are completed. See end of method statement. • Allow for unforeseen ground conditions: Loose ground is always a concern. The method statement and drawings show the use of precast lintels to areas of soft ground; this follows the guidance by the underpinning association.

With the above the maximum level of cracking anticipated is Hairline cracking which can be repaired with decorative cracking and can be repaired with decorative repairs. Under the party wall Act damage is allowed (although unwanted) to occur to a neighbouring property as long as repairs are suitability undertaken to rectify this. To mitigate this risk The Party Wall Act is to be followed and a Party Wall Surveyor will be appointed.

Extract from The Institution of Structural Engineers "Subsidence of Low-Rise Buildings"

Table 6.2 Classification of visible damage to walls with particular reference to type of repair, and rectification consideration

Category of Damage	Approximate crack width	Definitions of cracks and repair types/considerations
0	**Up to 0.1**	**HAIRLINE – Internally cracks can be filled or covered by wall covering, and redecorated. Externally, cracks rarely visible and remedial works rarely justified.**
1	0.2 to 2	FINE – Internally cracks can be filled or covered by wall covering, and redecorated. Externally, cracks may be visible, sometimes repairs required for weather tightness or aesthetics. NOTE: Plaster cracks may, in time, become visible again if not covered by a wall covering.
2	2 to 5	MODERATE – Internal cracks are likely to need raking out and repairing to a recognised specification. May need to be chopped back, and repaired with expanded metal/plaster, then redecorated. The crack will inevitably become visible again in time if these measures are not carried out. External cracks will require raking out and repointing, cracked bricks may require replacement.
3	5 to 15	SERIOUS – Internal cracks repaired as for MODERATE, plus perhaps reconstruction if seriously cracked. Rebonding will be required. External cracks may require reconstruction perhaps of panels of brickwork. Alternatively, specialist resin bonding techniques may need to be employed and/or joint reinforcement.
4	15 to 25	SEVERE Major reconstruction works to both internal and external wall skins are likely to be required. Realignment of windows and doors may be necessary.
5	Greater than 25	VERY SEVERE –Major reconstruction works, plus possibly structural lifting or sectional demolition and rebuild may need to be considered.

		Replacement of windows and doors, plus other structural elements, possibly necessary. NOTE – Building & CDM Regulations will probably apply to this category of work, see sections 10.4, 10.6 and Appendix F.

Monitoring and Predicted Category of Damage

Monitoring - In order to safeguard the existing structures during underpinning and new basement construction movement monitoring is to be undertaken. Surveying studs are to be attached to the adjacent structures at ground, first, seconds, third, fourth & fifth floor levels at front and rear.

The surveying points on the adjacent structures are to be set up using an EDM prior to commencement of the works and to be read daily and reported against the following control values.

Limits on ground and adjacent structures movement during underpinning and throughout the construction works.

Movement of survey points must not exceed:

Settlement:
Action values: 5mm (stop work)
Trigger values: 65% of action values (submit proposals for ensuring action values are not exceeded)

Lateral displacement:
Action values: 6mm (stop work)
Trigger values: 65% of action values (submit proposals for ensuring action values are not exceeded)

Movement approaching critical values: Trigger: Submit proposals for ensuring action values are not exceeded Action: Stop work

The reporting format will be in the form of a table as attached.

Predicted Category of Damage

The predicted category of damage is likely to be within BRE Category Slight, with possible localised crack widths 2mm to 5mm Classification Aesthetic.

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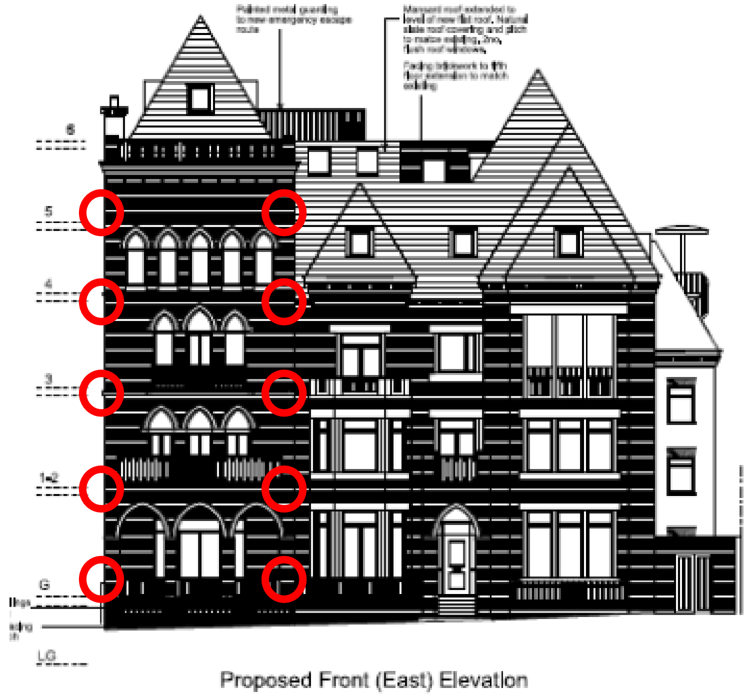

Figure 12: Monitoring Points to the front elevation

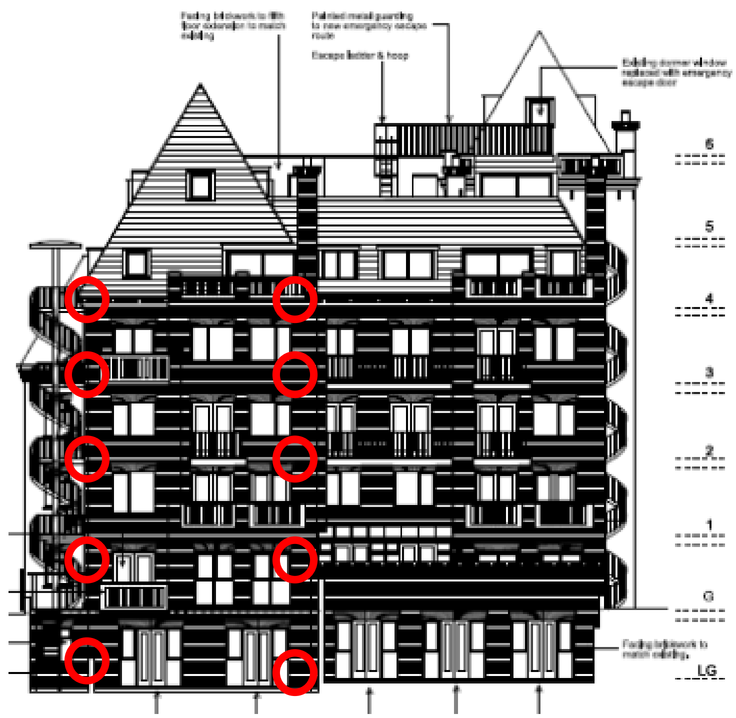

Figure 13: Monitoring Points to the Front Elevation

Drainage and Damp proofing	Assumed that drainage and damp proofing is by others: Details are not provided within our brief. Our recommendation is that drained cavity systems are used to habitable basements with pumped sumps. This is a specialist contractor design item. Concrete is not designed BS 8007. But where possible BS 8007 detailing is observed to help limit crack widths of concrete

Party Wall	Underpinning basement works has a risk associated to it. To mitigate these risks a Party wall surveyor must be appointed

Temporary Works	Temporary works are the contractor's responsibility. Loads can be provided on request. Foundations; All trenches deeper than 1.0m must be shored. Where works undermine existing foundations contractor must allow for additional support. The Method statement lays out the process for constructing the basement

Noise and Nuisance	The contractor is to follow the good working practices and guidance laid down in the "Considerate Constructors Scheme". The hours of working will be limited to those allowed; 8am to 5pm Monday to Friday and Saturday Morning 8am to 1pm. None of the practices cause undue noise that one would typically expect from a construction site. The conveyor belt typically runs at around 70dB. The site has car parking to the front to which the skip will be stored. The site will be hoarded with soil 8' site hoarding to prevent access. The hours of working will further be defined within the Party Wall Act. The site is to be hoarded to minimise the level of direct noise from the site.

	Ground floor slab is not being removed minimising the vibration and sound to adjacent properties. While working in the basement the work generally requires hand tools to be used. The level of noise generally will be no greater than that of digging of soil. The noise is reduced and muffled by the works being undertaken underground. A level of noise from a basement is lower than typical ground level construction due to this.

Appendix A

Structural Scheme Drawings

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Job Number: 131026
Date: 14th November 2013

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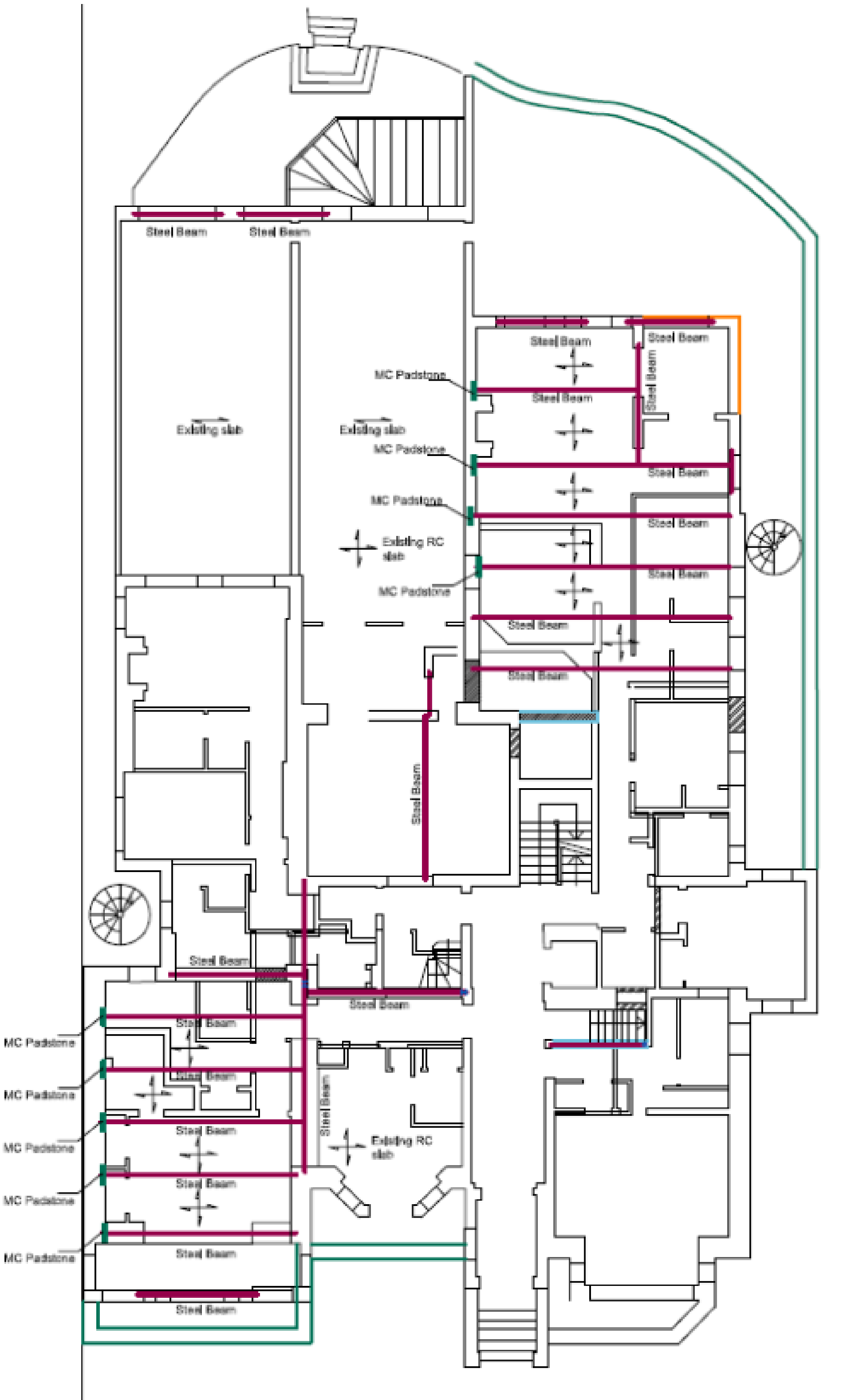
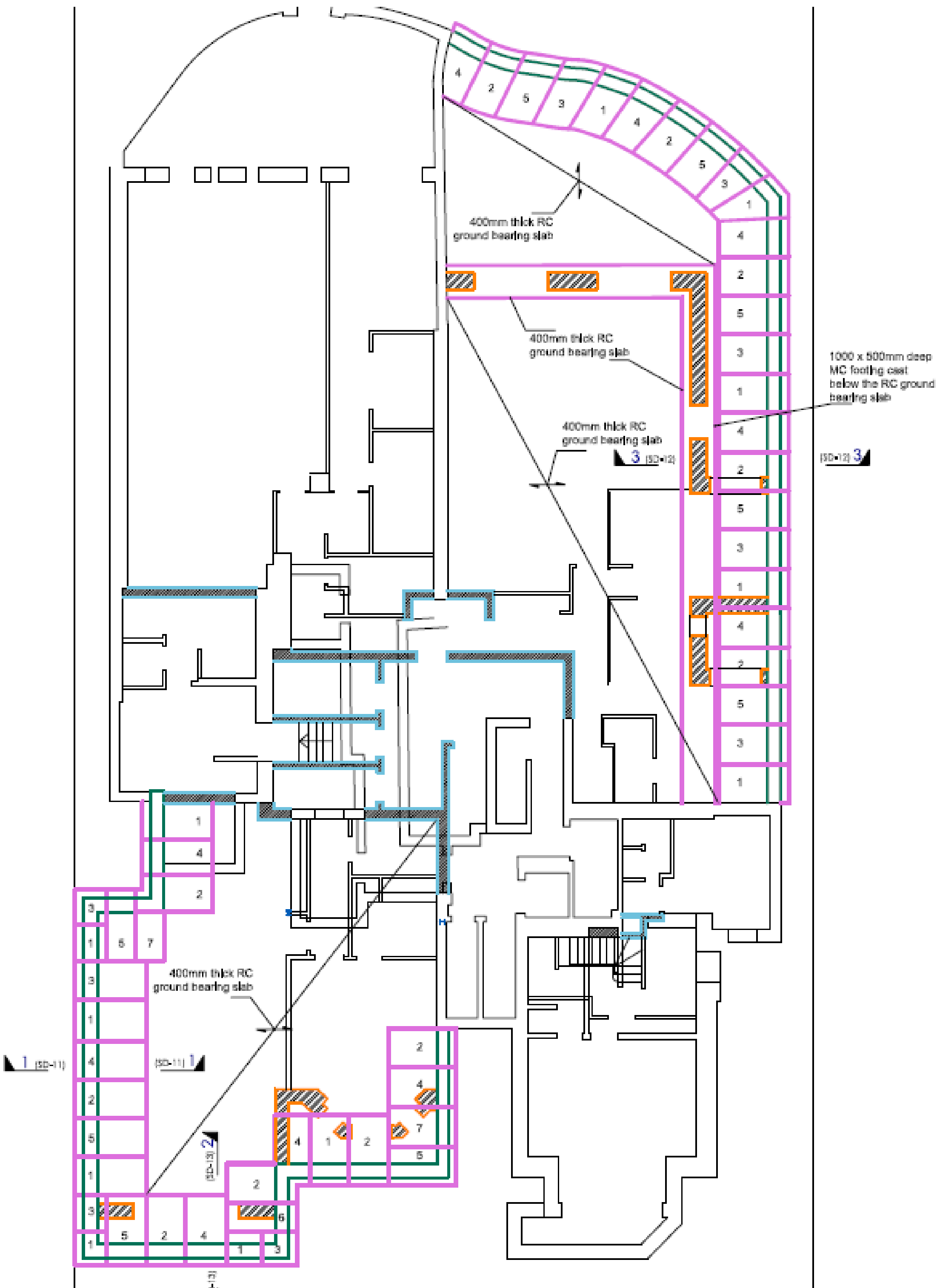
Ground Floor Plan



Ground Floor Plan
(1:100)

Basement Plan



Lower Ground Floor Plan
(1:100)

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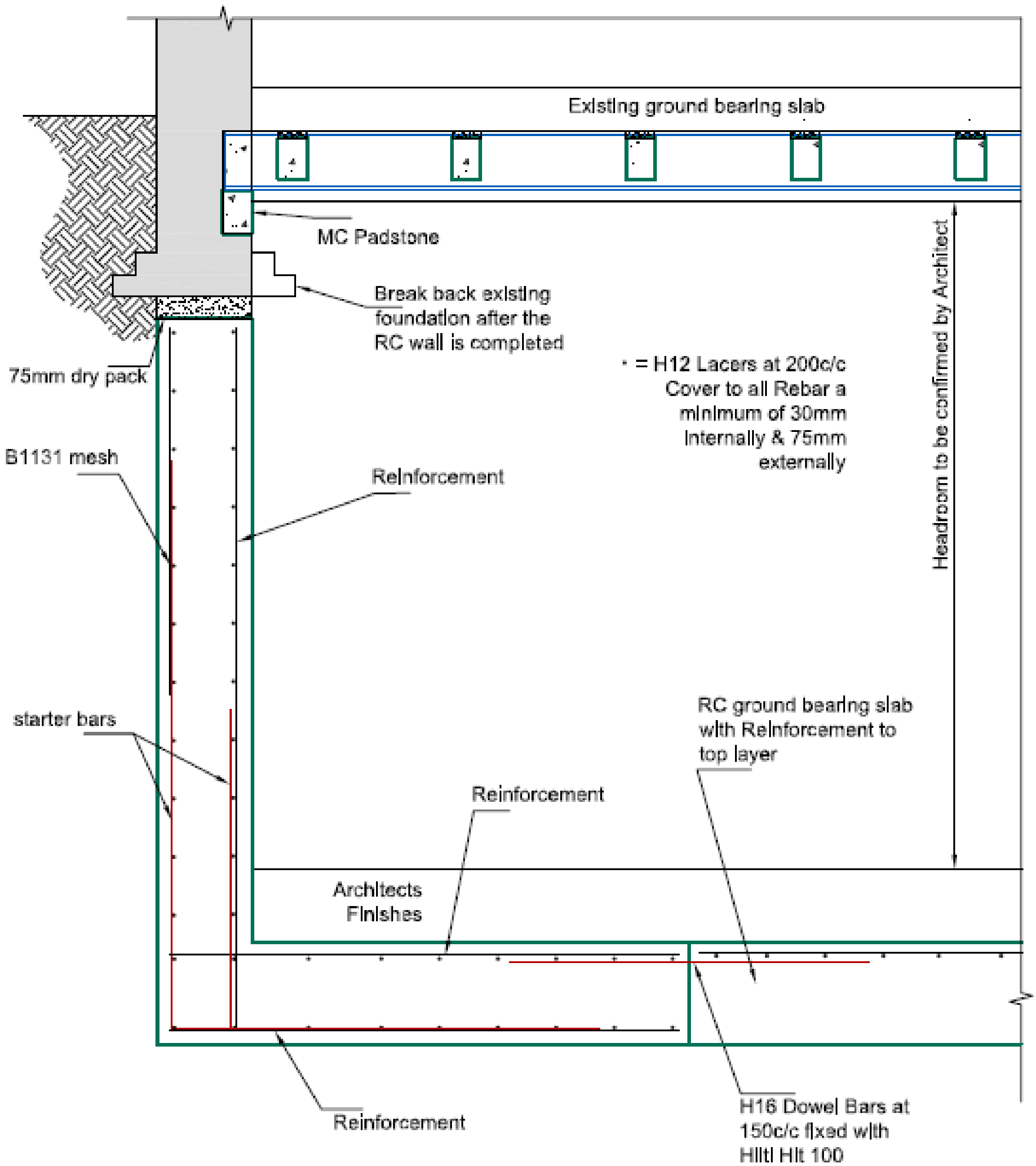
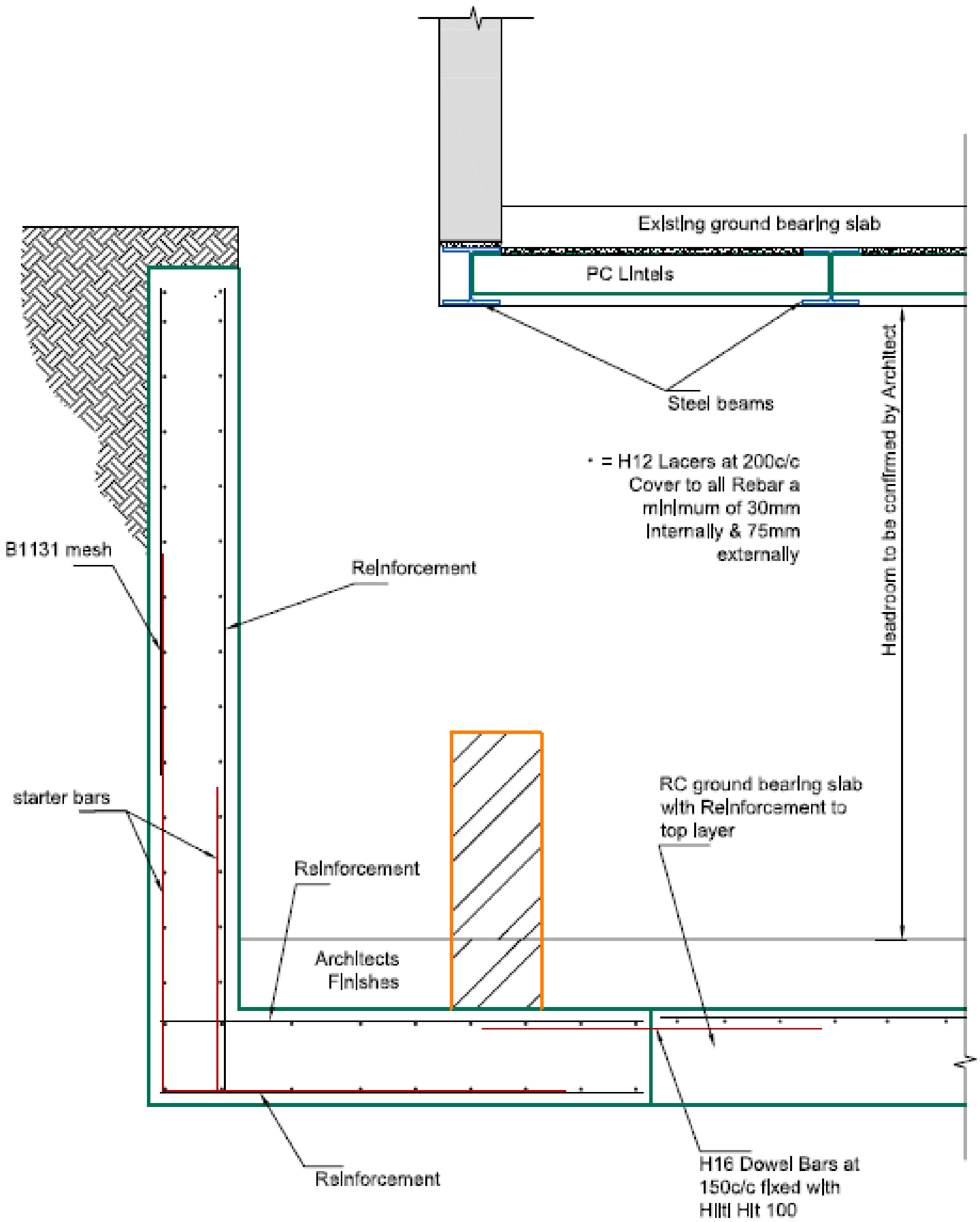
Section 1-1



Section 1-1:
Typical RC retaining wall section
scale 1:20

Section 2-2



Section 2-2:
Typical RC retaining wall section
scale 1:20

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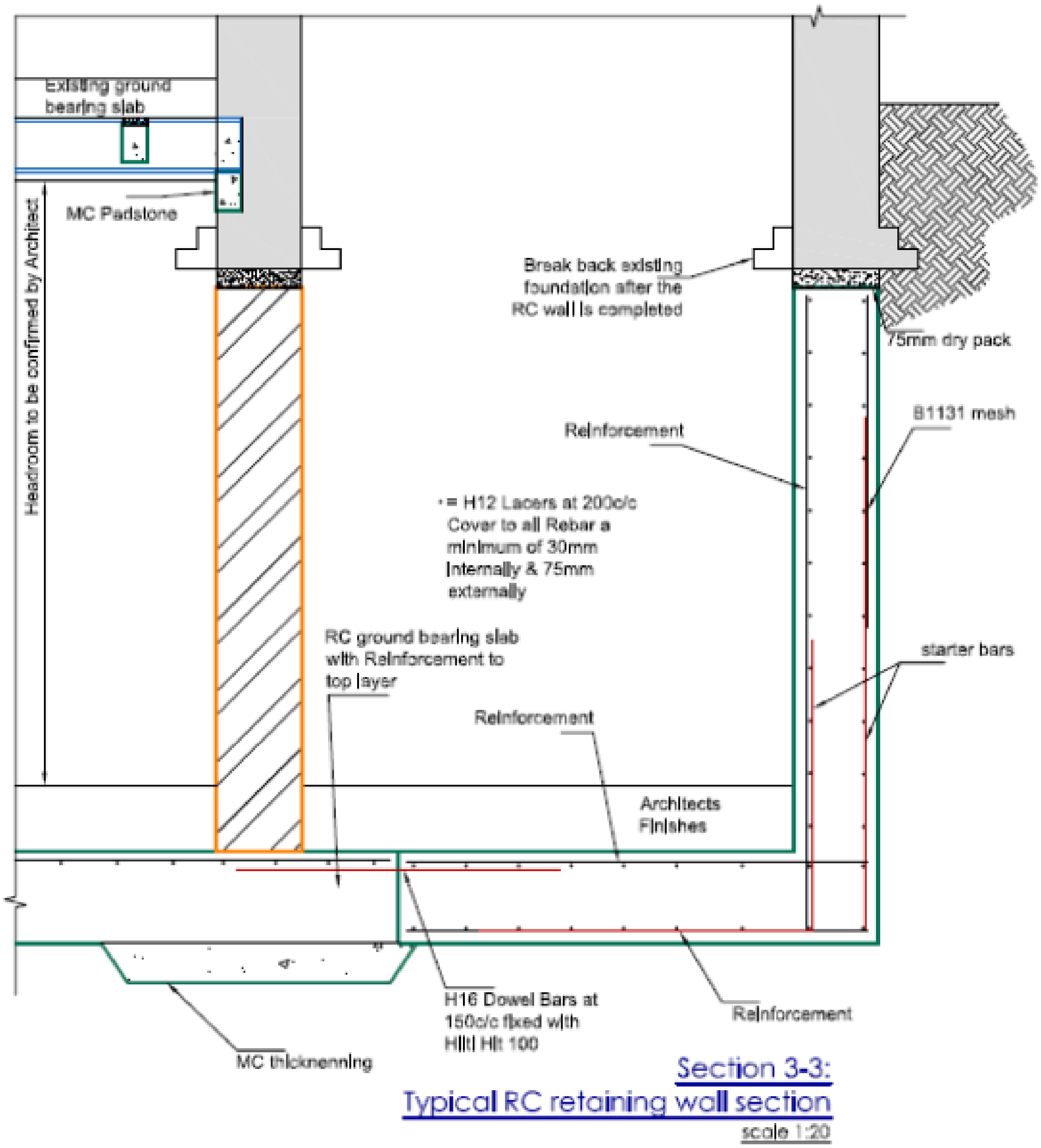
Section 3-3



Appendix B

Structural Basement Calculations

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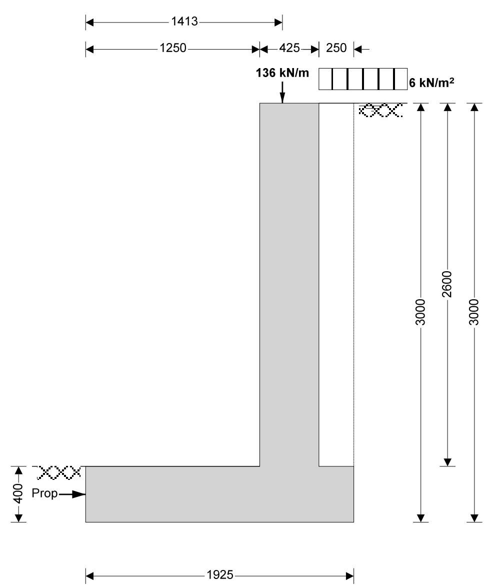
RC retaining wall 1 design

Loading:

325mm thick masonry wall	DL325 = 7kN/m^2 × 8.3m = **58.100**kN/m
225mm thick masonry wall	DL225 = 5kN/m^2 × 9m = **45.000**kN/m
Floor DL (1st, 2nd, 3rd , 4th, 5th floors)	DLfloor = 0.7kN/m^2 × 5.5m / 2 × 5 = **9.625**kN/m
Ground floor	DLground = 24kN/m^3 × 0.2m × 5.5m / 2 = **13.200**kN/m
Roof DL	DLroof = 1.1kN/m^2 × 3.3m = **3.630**kN/m
Total Dead Load	DL = DL325+DL225+DLfloor+DLground+DLroof=**129.555**kN/m
Floor LL (1st, 2nd, 3rd , 4th, 5th floors)	LLfloor = 1.5kN/m^2 × 5.5m / 2 × 5 = **20.625**kN/m
Roof LL	LLroof = 0.6kN/m^2 × 3.3m = **1.980**kN/m
Total Live Load	LL = LLfloor + LLroof = **22.605**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} = **2600** mm
Thickness of wall stem	t_{wall} = **425** mm
Length of toe	l_{toe} = **1250** mm
Length of heel	l_{heel} = **250** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **1925** mm
Thickness of base	t_{base} = **400** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **1225** mm
Thickness of downstand	t_{ds} = **400** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3000** mm
Depth of cover in front of wall	d_{cover} = **0** mm

Depth of unplanned excavation d_{exc} = **0** mm
Height of ground water behind wall h_{water} = **3000** mm
Height of saturated fill above base $h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\text{ mm})$ = **2600** mm
Density of wall construction γ_{wall} = **23.6** kN/m^3
Density of base construction γ_{base} = **23.6** kN/m^3
Angle of rear face of wall α = **90.0** deg
Angle of soil surface behind wall β = **0.0** deg
Effective height at virtual back of wall $h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3000** mm

Retained material details

Mobilisation factor M = **1.5**
Moist density of retained material γ_m = **18.0** kN/m^3
Saturated density of retained material γ_s = **21.0** kN/m^3
Design shear strength ϕ' = **24.2** deg
Angle of wall friction δ = **0.0** deg

Base material details

Moist density γ_{mb} = **18.0** kN/m^3
Design shear strength ϕ'_b = **24.2** deg
Design base friction δ_b = **18.6** deg
Allowable bearing pressure $P_{bearing}$ = **125** kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.419}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.187}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi')$ = **0.590**

Loading details

Surcharge load on plan Surcharge = **5.5** kN/m^2
Applied vertical dead load on wall W_{dead} = **129.6** kN/m
Applied vertical live load on wall W_{live} = **6.1** kN/m
Position of applied vertical load on wall l_{load} = **1413** 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

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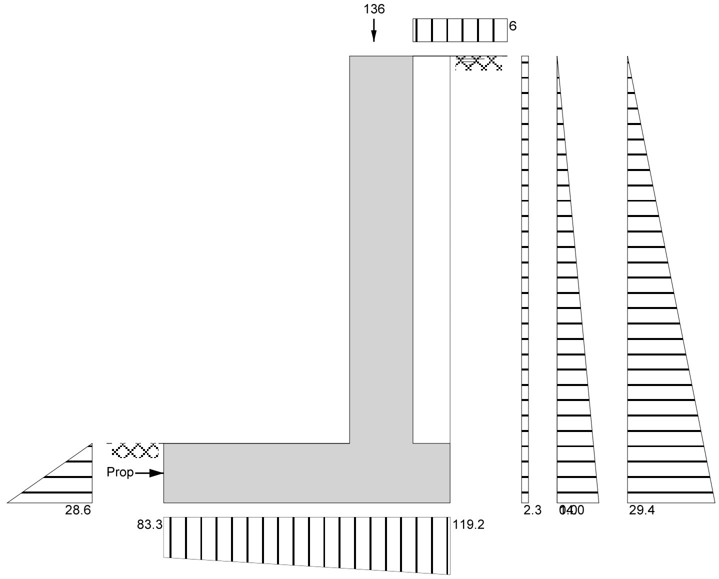

Loads shown in kN/m, pressures shown in kN/m^2

Vertical forces on wall

Wall stem	$w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall}$ = **26.1** kN/m
Wall base	$w_{base} = l_{base} \times t_{base} \times \gamma_{base}$ = **18.2** kN/m
Surcharge	w_{sur} = Surcharge $\times l_{heel}$ = **1.4** kN/m
Saturated backfill	$w_s = l_{heel} \times h_{sat} \times \gamma_s$ = **13.7** kN/m
Applied vertical load	$W_v = W_{dead} + W_{live}$ = **135.7** kN/m
Total vertical load	$W_{total} = w_{wall} + w_{base} + w_{sur} + w_s + W_v$ = **194.9** kN/m

Horizontal forces on wall

Surcharge	$F_{sur} = K_a \times$ Surcharge $\times h_{eff}$ = **6.9** 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	$F_{total} = F_{sur} + F_s + F_{water}$ = **72.1** kN/m

Calculate propping force

Passive resistance of soil in front of wall: $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **5.7** kN/m

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

F_{prop} = **3.3** kN/m

Overturning moments

Surcharge	$M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **10.4** 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	$M_{ot} = M_{sur} + M_s + M_{water}$ = **75.6** kNm/m

Restoring moments

Wall stem	$M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **38.1** kNm/m
Wall base	$M_{base} = w_{base} \times l_{base} / 2$ = **17.5** kNm/m
Saturated backfill	$M_{s\_r} = w_s \times (l_{base} - l_{heel} / 2)$ = **24.6** kNm/m
Design vertical dead load	$M_{dead} = W_{dead} \times l_{load}$ = **183** kNm/m
Total restoring moment	$M_{rest} = M_{wall} + M_{base} + M_{s\_r} + M_{dead}$ = **263.2** kNm/m

Check bearing pressure

Surcharge	$M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2)$ = **2.5** kNm/m
Design vertical live load	$M_{live} = W_{live} \times l_{load}$ = **8.6** kNm/m

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Total moment for bearing	$M_{total} = M_{rest} - M_{ot} + M_{sur\_r} + M_{live}$ = **198.7** kNm/m
Total vertical reaction	$R = W_{total}$ = **194.9** kN/m
Distance to reaction	$x_{bar} = M_{total} / R$ = **1019** mm
Eccentricity of reaction	$e = abs((l_{base} / 2) - x_{bar})$ = **57** mm
	Reaction acts within middle third of base
Bearing pressure at toe	$p_{toe} = (R / l_{base}) - (6 \times R \times e / l_{base}^2)$ = **83.3** kN/m^2
Bearing pressure at heel	$p_{heel} = (R / l_{base}) + (6 \times R \times e / l_{base}^2)$ = **119.2** 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	$w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall}$ = **36.5** kN/m
Wall base	$w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base}$ = **25.4** kN/m
Surcharge	$w_{sur\_f} = \gamma_{f\_l} \times$ Surcharge $\times l_{heel}$ = **2.2** kN/m
Saturated backfill	$w_{s\_f} = \gamma_{f\_d} \times l_{heel} \times h_{sat} \times \gamma_s$ = **19.1** kN/m
Applied vertical load	$W_{v\_f} = \gamma_{f\_d} \times W_{dead} + \gamma_{f\_l} \times W_{live}$ = **191.1** kN/m
Total vertical load	$W_{total\_f} = w_{wall\_f} + w_{base\_f} + w_{sur\_f} + w_{s\_f} + W_{v\_f}$ = **274.4** kN/m

Factored horizontal at-rest forces on wall

Surcharge	$F_{sur\_f} = \gamma_{f\_l} \times K_0 \times$ Surcharge $\times h_{eff}$ = **15.6** kN/m
Saturated backfill	$F_{s\_f} = \gamma_{f\_e} \times 0.5 \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{water}^2$ = **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	$F_{total\_f} = F_{sur\_f} + F_{s\_f} + F_{water\_f}$ = **119** kN/m

Calculate propping force

Passive resistance of soil in front of wall	$F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **8** kN/m
Propping force	$F_{prop\_f} = \max(F_{total\_f} - F_{p\_f} - (W_{total\_f} - w_{sur\_f} - \gamma_{f\_l} \times W_{live}) \times \tan(\delta_b)$, 0 kN/m)
	F_{prop_f} = **22.7** kN/m

Factored overturning moments

Surcharge	$M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **23.4** 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	$M_{ot\_f} = M_{sur\_f} + M_{s\_f} + M_{water\_f}$ = **126.8** kNm/m

Restoring moments

Wall stem	$M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2)$ = **53.4** kNm/m
Wall base	$M_{base\_f} = w_{base\_f} \times l_{base} / 2$ = **24.5** kNm/m
Surcharge	$M_{sur\_r\_f} = w_{sur\_f} \times (l_{base} - l_{heel} / 2)$ = **4** kNm/m
Saturated backfill	$M_{s\_r\_f} = w_{s\_f} \times (l_{base} - l_{heel} / 2)$ = **34.4** kNm/m
Design vertical load	$M_{v\_f} = W_{v\_f} \times l_{load}$ = **270** kNm/m
Total restoring moment	$M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{s\_r\_f} + M_{v\_f}$ = **386.2** kNm/m

Factored bearing pressure

Total moment for bearing	$M_{total\_f} = M_{rest\_f} - M_{ot\_f}$ = **259.5** kNm/m
Total vertical reaction	$R_f = W_{total\_f}$ = **274.4** kN/m
Distance to reaction	$x_{bar\_f} = M_{total\_f} / R_f$ = **946** mm
Eccentricity of reaction	$e_f = \text{abs}((l_{base} / 2) - x_{bar\_f})$ = **17** mm
	Reaction acts within middle third of base
Bearing pressure at toe	$p_{toe\_f} = (R_f / l_{base}) + (6 \times R_f \times e_f / l_{base}^2)$ = **150.1** kN/m^2
Bearing pressure at heel	$p_{heel\_f} = (R_f / l_{base}) - (6 \times R_f \times e_f / l_{base}^2)$ = **135** kN/m^2
Rate of change of base reaction	rate = $(p_{toe\_f} - p_{heel\_f}) / l_{base}$ = **7.83** kN/m^2/m
Bearing pressure at stem / toe	$p_{stem\_toe\_f} = \max(p_{toe\_f} - (\text{rate} \times l_{toe}), 0\text{ kN/m}^2)$ = **140.3** kN/m^2
Bearing pressure at mid stem	$p_{stem\_mid\_f} = \max(p_{toe\_f} - (\text{rate} \times (l_{toe} + t_{wall} / 2)), 0\text{ kN/m}^2)$ = **138.6** kN/m^2

Bearing pressure at stem / heel — $p_{stem\_heel\_f} = max(p_{toe\_f} - (rate \times (l_{toe} + t_{wall})), 0\ kN/m^2) =$ **137** kN/m^2

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

Material properties

Characteristic strength of concrete — $f_{cu} =$ **35** 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 — $c_{toe} =$ **75** mm

Calculate shear for toe design

Shear from bearing pressure — $V_{toe\_bear} = (p_{toe\_f} + p_{stem\_toe\_f}) \times l_{toe} / 2 =$ **181.5** kN/m

Shear from weight of base — $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base} =$ **16.5** kN/m

Total shear for toe design — $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base} =$ **165** kN/m

Calculate moment for toe design

Moment from bearing pressure — $M_{toe\_bear} = (2 \times p_{toe\_f} + p_{stem\_mid\_f}) \times (l_{toe} + t_{wall} / 2)^2 / 6 =$ **156.4** kNm/m

Moment from weight of base — $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2) =$ **14.1** kNm/m

Total moment for toe design — $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base} =$ **142.3** kNm/m

Check toe in bending

Width of toe — $b =$ **1000** mm/m

Depth of reinforcement — $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2) =$ **319.0** mm

Constant — $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu}) =$ **0.040**

Compression reinforcement is not required

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

$z_{toe} =$ **303** mm

Area of tension reinforcement required — $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe}) =$ **1079** mm^2/m

Minimum area of tension reinforcement — $A_{s\_toe\_min} = k \times b \times t_{base} =$ **520** mm^2/m

Area of tension reinforcement required — $A_{s\_toe\_req} = Max(A_{s\_toe\_des}, A_{s\_toe\_min}) =$ **1079** mm^2/m

Reinforcement provided — **B1131 mesh**

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

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe}) =$ **0.517** N/mm^2

Allowable shear stress — $v_{adm} = min(0.8 \times \sqrt{(f_{cu} / 1\ N/mm^2)}, 5) \times 1\ N/mm^2 =$ **4.733** 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 — $v_{c\_toe} =$ **0.530** N/mm^2

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

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

Material properties

Characteristic strength of concrete — $f_{cu} =$ **35** N/mm^2

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

Base details

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

Cover to reinforcement in heel — $c_{heel} =$ **75** mm

Calculate shear for heel design

Shear from bearing pressure $V_{heel\_bear} = (p_{heel\_f} + p_{stem\_heel\_f}) \times l_{heel} / 2 =$ **34** kN/m

Shear from weight of base $V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base} =$ **3.3** kN/m

Shear from weight of saturated backfill $V_{heel\_wt\_s} = w_{s\_f} =$ **19.1** kN/m

Shear from surcharge $V_{heel\_sur} = w_{sur\_f} =$ **2.2** kN/m

Total shear for heel design $V_{heel} = - V_{heel\_bear} + V_{heel\_wt\_base} + V_{heel\_wt\_s} + V_{heel\_sur} =$ **-9.4** kN/m

Calculate moment for heel design

Moment from bearing pressure $M_{heel\_bear} = (2 \times p_{heel\_f} + p_{stem\_mid\_f}) \times (l_{heel} + t_{wall} / 2)^2 / 6 =$ **14.6** kNm/m

Moment from weight of base $M_{heel\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) =$ **1.4** kNm/m

Moment from weight of saturated backfill $M_{heel\_wt\_s} = w_{s\_f} \times (l_{heel} + t_{wall}) / 2 =$ **6.4** kNm/m

Moment from surcharge $M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2 =$ **0.7** kNm/m

Total moment for heel design $M_{heel} = - M_{heel\_bear} + M_{heel\_wt\_base} + M_{heel\_wt\_s} + M_{heel\_sur} =$ **-6** kNm/m

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

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

Material properties

Characteristic strength of concrete $f_{cu} =$ **35** N/mm^2

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

Wall details

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

Cover to reinforcement in stem $c_{stem} =$ **75** mm

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

Factored horizontal at-rest forces on stem

Surcharge $F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) =$ **13.5** kN/m

Saturated backfill $F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2 =$ **31.2** kN/m

Water $F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2 =$ **46.4** kN/m

Calculate shear for stem design

Shear at base of stem $V_{stem} = F_{s\_sur\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f} =$ **68.5** kN/m

Calculate moment for stem design

Surcharge $M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2 =$ **20.3** kNm/m

Saturated backfill $M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3 =$ **27.1** kNm/m

Water $M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3 =$ **40.2** kNm/m

Total moment for stem design $M_{stem} = M_{s\_sur} + M_{s\_s} + M_{s\_water} =$ **87.6** kNm/m

Check wall stem in bending

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

Depth of reinforcement $d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) =$ **342.0** mm

Constant $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu}) =$ **0.021**

Compression reinforcement is not required

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

$z_{stem} =$ **325** mm

Area of tension reinforcement required $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem}) =$ **620** mm^2/m

Minimum area of tension reinforcement $A_{s\_stem\_min} = k \times b \times t_{wall} =$ **553** mm^2/m

Area of tension reinforcement required $A_{s\_stem\_req} = \text{Max}(A_{s\_stem\_des}, A_{s\_stem\_min}) =$ **620** 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 $v_{stem} = V_{stem} / (b \times d_{stem}) = \mathbf{0.200}$ N/mm^2

Allowable shear stress $v_{adm} = \min(0.8 \times \sqrt{}(f_{cu} / 1 \text{ N/mm}^2), 5) \times 1 \text{ N/mm}^2 = \mathbf{4.733}$ 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 $v_{c\_stem} = \mathbf{0.538}$ N/mm^2

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

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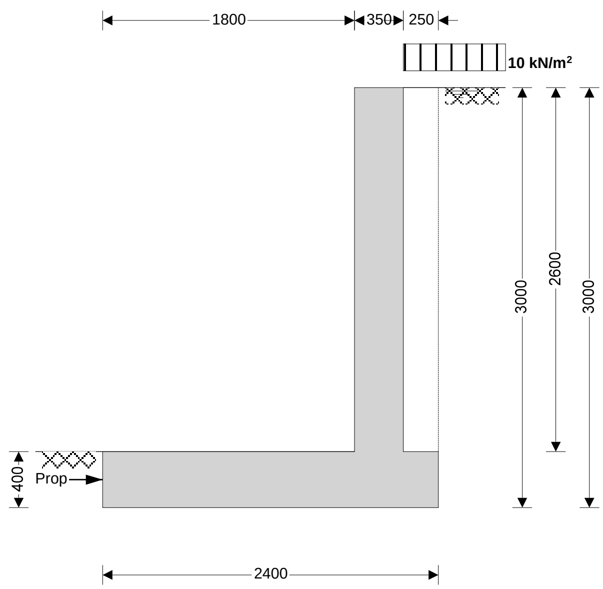
RC retaining wall design 2

Retaining wall analysis (BS 8002:1994)

TEDDS calculation version 1.2.01.06



Wall details

Retaining wall type	**Cantilever propped at base**
Height of retaining wall stem	h_{stem} = **2600** mm
Thickness of wall stem	t_{wall} = **350** mm
Length of toe	l_{toe} = **1800** mm
Length of heel	l_{heel} = **250** mm
Overall length of base	$l_{base} = l_{toe} + l_{heel} + t_{wall}$ = **2400** mm
Thickness of base	t_{base} = **400** mm
Depth of downstand	d_{ds} = **0** mm
Position of downstand	l_{ds} = **1700** mm
Thickness of downstand	t_{ds} = **400** mm
Height of retaining wall	$h_{wall} = h_{stem} + t_{base} + d_{ds}$ = **3000** mm
Depth of cover in front of wall	d_{cover} = **0** mm
Depth of unplanned excavation	d_{exc} = **0** mm
Height of ground water behind wall	h_{water} = **3000** mm
Height of saturated fill above base	$h_{sat} = \max(h_{water} - t_{base} - d_{ds}, 0\ mm)$ = **2600** mm
Density of wall construction	γ_{wall} = **23.6** kN/m^3
Density of base construction	γ_{base} = **23.6** kN/m^3
Angle of rear face of wall	α = **90.0** deg
Angle of soil surface behind wall	β = **0.0** deg
Effective height at virtual back of wall	$h_{eff} = h_{wall} + l_{heel} \times \tan(\beta)$ = **3000** mm

Retained material details

Mobilisation factor	M = **1.5**
Moist density of retained material	γ_m = **18.0** kN/m^3
Saturated density of retained material	γ_s = **21.0** kN/m^3

Design shear strength $\phi' = \mathbf{24.2}$ deg

Angle of wall friction $\delta = \mathbf{0.0}$ deg

Base material details

Moist density $\gamma_{mb} = \mathbf{18.0}$ kN/m^3

Design shear strength $\phi'_b = \mathbf{24.2}$ deg

Design base friction $\delta_b = \mathbf{18.6}$ deg

Allowable bearing pressure $P_{bearing} = \mathbf{125}$ kN/m^2

Using Coulomb theory

Active pressure coefficient for retained material

$$K_a = \sin(\alpha + \phi')^2 / (\sin(\alpha)^2 \times \sin(\alpha - \delta) \times [1 + \sqrt{(\sin(\phi' + \delta) \times \sin(\phi' - \beta) / (\sin(\alpha - \delta) \times \sin(\alpha + \beta)))}]^2) = \mathbf{0.419}$$

Passive pressure coefficient for base material

$$K_p = \sin(90 - \phi'_b)^2 / (\sin(90 - \delta_b) \times [1 - \sqrt{(\sin(\phi'_b + \delta_b) \times \sin(\phi'_b) / (\sin(90 + \delta_b)))}]^2) = \mathbf{4.187}$$

At-rest pressure

At-rest pressure for retained material $K_0 = 1 - \sin(\phi') = \mathbf{0.590}$

Loading details

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

Applied vertical dead load on wall $W_{dead} = \mathbf{0.0}$ kN/m

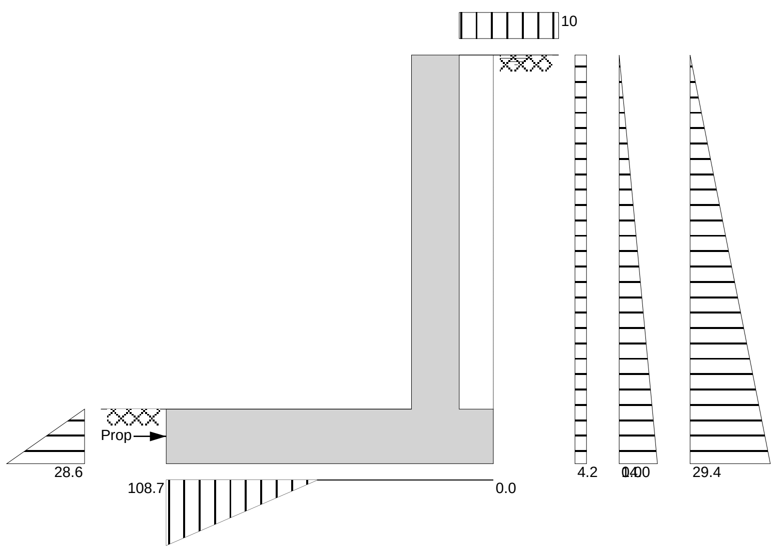
Applied vertical live load on wall $W_{live} = \mathbf{0.0}$ kN/m

Position of applied vertical load on wall $l_{load} = \mathbf{0}$ mm

Applied horizontal dead load on wall $F_{dead} = \mathbf{0.0}$ kN/m

Applied horizontal live load on wall $F_{live} = \mathbf{0.0}$ kN/m

Height of applied horizontal load on wall $h_{load} = \mathbf{0}$ mm



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

Vertical forces on wall

Wall stem $w_{wall} = h_{stem} \times t_{wall} \times \gamma_{wall} = \mathbf{21.5}$ kN/m

Wall base $w_{base} = l_{base} \times t_{base} \times \gamma_{base} = \mathbf{22.7}$ kN/m

Surcharge w_{sur} = Surcharge $\times\, l_{heel} = \mathbf{2.5}$ kN/m

Saturated backfill $w_s = l_{heel} \times h_{sat} \times \gamma_s = \mathbf{13.7}$ kN/m

Total vertical load $W_{total} = w_{wall} + w_{base} + w_{sur} + w_s = \mathbf{60.3}$ kN/m

Horizontal forces on wall

Surcharge $F_{sur} = K_a \times$ Surcharge $\times\, h_{eff} = \mathbf{12.6}$ kN/m

Saturated backfill $F_s = 0.5 \times K_a \times (\gamma_s - \gamma_{water}) \times h_{water}^2 = \mathbf{21.1}$ kN/m

Water $F_{water} = 0.5 \times h_{water}^2 \times \gamma_{water}$ = **44.1** kN/m

Total horizontal load $F_{total} = F_{sur} + F_s + F_{water}$ = **77.8** kN/m

Calculate propping force

Passive resistance of soil in front of wall $F_p = 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb}$ = **5.7** 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} = **52.6** kN/m

Overturning moments

Surcharge $M_{sur} = F_{sur} \times (h_{eff} - 2 \times d_{ds}) / 2$ = **18.8** 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 $M_{ot} = M_{sur} + M_s + M_{water}$ = **84.1** kNm/m

Restoring moments

Wall stem $M_{wall} = w_{wall} \times (l_{toe} + t_{wall} / 2)$ = **42.4** kNm/m

Wall base $M_{base} = w_{base} \times l_{base} / 2$ = **27.2** kNm/m

Saturated backfill $M_{s\_r} = w_s \times (l_{base} - l_{heel} / 2)$ = **31.1** kNm/m

Total restoring moment $M_{rest} = M_{wall} + M_{base} + M_{s\_r}$ = **100.7** kNm/m

Check bearing pressure

Surcharge $M_{sur\_r} = w_{sur} \times (l_{base} - l_{heel} / 2)$ = **5.7** kNm/m

Total moment for bearing $M_{total} = M_{rest} - M_{ot} + M_{sur\_r}$ = **22.3** kNm/m

Total vertical reaction $R = W_{total}$ = **60.3** kN/m

Distance to reaction $x_{bar} = M_{total} / R$ = **370** mm

Eccentricity of reaction $e = \text{abs}((l_{base} / 2) - x_{bar})$ = **830** mm

Reaction acts outside middle third of base

Bearing pressure at toe $p_{toe} = R / (1.5 \times x_{bar})$ = **108.7** kN/m^2

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

PASS - Maximum bearing pressure is less than allowable bearing pressure

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Retaining wall design (BS 8002:1994)

TEDDS calculation version 1.2.01.06

Ultimate limit state load factors

Dead load factor — $\gamma_{f\_d} = \mathbf{1.4}$

Live load factor — $\gamma_{f\_l} = \mathbf{1.6}$

Earth and water pressure factor — $\gamma_{f\_e} = \mathbf{1.4}$

Factored vertical forces on wall

Wall stem — $w_{wall\_f} = \gamma_{f\_d} \times h_{stem} \times t_{wall} \times \gamma_{wall} = \mathbf{30.1}$ kN/m

Wall base — $w_{base\_f} = \gamma_{f\_d} \times l_{base} \times t_{base} \times \gamma_{base} = \mathbf{31.7}$ kN/m

Surcharge — $w_{sur\_f} = \gamma_{f\_l} \times \text{Surcharge} \times l_{heel} = \mathbf{4}$ kN/m

Saturated backfill — $w_{s\_f} = \gamma_{f\_d} \times l_{heel} \times h_{sat} \times \gamma_s = \mathbf{19.1}$ kN/m

Total vertical load — $W_{total\_f} = w_{wall\_f} + w_{base\_f} + w_{sur\_f} + w_{s\_f} = \mathbf{84.9}$ kN/m

Factored horizontal at-rest forces on wall

Surcharge — $F_{sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times h_{eff} = \mathbf{28.3}$ kN/m

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

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

Total horizontal load — $F_{total\_f} = F_{sur\_f} + F_{s\_f} + F_{water\_f} = \mathbf{131.7}$ kN/m

Calculate propping force

Passive resistance of soil in front of wall — $F_{p\_f} = \gamma_{f\_e} \times 0.5 \times K_p \times \cos(\delta_b) \times (d_{cover} + t_{base} + d_{ds} - d_{exc})^2 \times \gamma_{mb} =$ **8** kN/m

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

$F_{prop\_f} = \mathbf{96.5}$ kN/m

Factored overturning moments

Surcharge — $M_{sur\_f} = F_{sur\_f} \times (h_{eff} - 2 \times d_{ds}) / 2 = \mathbf{42.5}$ kNm/m

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

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

Total overturning moment — $M_{ot\_f} = M_{sur\_f} + M_{s\_f} + M_{water\_f} = \mathbf{145.9}$ kNm/m

Restoring moments

Wall stem — $M_{wall\_f} = w_{wall\_f} \times (l_{toe} + t_{wall} / 2) = \mathbf{59.4}$ kNm/m

Wall base — $M_{base\_f} = w_{base\_f} \times l_{base} / 2 = \mathbf{38.1}$ kNm/m

Surcharge — $M_{sur\_r\_f} = w_{sur\_f} \times (l_{base} - l_{heel} / 2) = \mathbf{9.1}$ kNm/m

Saturated backfill — $M_{s\_r\_f} = w_{s\_f} \times (l_{base} - l_{heel} / 2) = \mathbf{43.5}$ kNm/m

Total restoring moment — $M_{rest\_f} = M_{wall\_f} + M_{base\_f} + M_{sur\_r\_f} + M_{s\_r\_f} = \mathbf{150}$ kNm/m

Factored bearing pressure

Total moment for bearing — $M_{total\_f} = M_{rest\_f} - M_{ot\_f} = \mathbf{4.1}$ kNm/m

Total vertical reaction — $R_f = W_{total\_f} = \mathbf{84.9}$ kN/m

Distance to reaction — $x_{bar\_f} = M_{total\_f} / R_f = \mathbf{49}$ mm

Eccentricity of reaction — $e_f = \text{abs}((l_{base} / 2) - x_{bar\_f}) = \mathbf{1151}$ mm

Reaction acts outside middle third of base

Bearing pressure at toe — $p_{toe\_f} = R_f / (1.5 \times x_{bar\_f}) = \mathbf{1163}$ kN/m^2

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

Rate of change of base reaction — $rate = p_{toe\_f} / (3 \times x_{bar\_f}) = \mathbf{7966.42}$ kN/m^2/m

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

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

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

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

Material properties

Characteristic strength of concrete — f_{cu} = **35** 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} = **75** mm

Calculate shear for toe design

Shear from bearing pressure — $V_{toe\_bear} = 3 \times p_{toe\_f} \times x_{bar\_f} / 2$ = **84.9** kN/m

Shear from weight of base — $V_{toe\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{toe} \times t_{base}$ = **23.8** kN/m

Total shear for toe design — $V_{toe} = V_{toe\_bear} - V_{toe\_wt\_base}$ = **61.1** kN/m

Calculate moment for toe design

Moment from bearing pressure — $M_{toe\_bear} = 3 \times p_{toe\_f} \times x_{bar\_f} \times (l_{toe} - x_{bar\_f} + t_{wall} / 2) / 2$ = **163.5** kNm/m

Moment from weight of base — $M_{toe\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{toe} + t_{wall} / 2)^2 / 2)$ = **25.8** kNm/m

Total moment for toe design — $M_{toe} = M_{toe\_bear} - M_{toe\_wt\_base}$ = **137.8** kNm/m

Check toe in bending

Width of toe — b = **1000** mm/m

Depth of reinforcement — $d_{toe} = t_{base} - c_{toe} - (\phi_{toe} / 2)$ = **319.0** mm

Constant — $K_{toe} = M_{toe} / (b \times d_{toe}^2 \times f_{cu})$ = **0.039**

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} = **303** mm

Area of tension reinforcement required — $A_{s\_toe\_des} = M_{toe} / (0.87 \times f_y \times z_{toe})$ = **1045** mm^2/m

Minimum area of tension reinforcement — $A_{s\_toe\_min} = k \times b \times t_{base}$ = **520** mm^2/m

Area of tension reinforcement required — $A_{s\_toe\_req} = \mathrm{Max}(A_{s\_toe\_des}, A_{s\_toe\_min})$ = **1045** mm^2/m

Reinforcement provided — **B1131 mesh**

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

PASS - Reinforcement provided at the retaining wall toe is adequate

Check shear resistance at toe

Design shear stress — $v_{toe} = V_{toe} / (b \times d_{toe})$ = **0.192** N/mm^2

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1\ \mathrm{N/mm^2})}, 5) \times 1\ \mathrm{N/mm^2}$ = **4.733** 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} = **0.530** N/mm^2

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

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

Material properties

Characteristic strength of concrete — f_{cu} = **35** N/mm^2

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

Base details

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

Cover to reinforcement in heel — c_{heel} = **75** mm

Calculate shear for heel design

Shear from weight of base — $V_{heel\_wt\_base} = \gamma_{f\_d} \times \gamma_{base} \times l_{heel} \times t_{base}$ = **3.3** kN/m

Shear from weight of saturated backfill — $V_{heel\_wt\_s} = w_{s\_f}$ = **19.1** kN/m

Shear from surcharge — $V_{heel\_sur} = w_{sur\_f}$ = **4** kN/m

Total shear for heel design — $V_{heel} = V_{heel\_wt\_base} + V_{heel\_wt\_s} + V_{heel\_sur}$ = **26.4** kN/m

Calculate moment for heel design

Moment from weight of base	$M_{heel\_wt\_base} = (\gamma_{f\_d} \times \gamma_{base} \times t_{base} \times (l_{heel} + t_{wall} / 2)^2 / 2) =$ **1.2** kNm/m
Moment from weight of saturated backfill	$M_{heel\_wt\_s} = w_{s\_f} \times (l_{heel} + t_{wall}) / 2 =$ **5.7** kNm/m
Moment from surcharge	$M_{heel\_sur} = w_{sur\_f} \times (l_{heel} + t_{wall}) / 2 =$ **1.2** kNm/m
Total moment for heel design	$M_{heel} = M_{heel\_wt\_base} + M_{heel\_wt\_s} + M_{heel\_sur} =$ **8.1** kNm/m

Check heel in bending

Width of heel	b = **1000** mm/m
Depth of reinforcement	$d_{heel} = t_{base} - c_{heel} - (\phi_{heel} / 2) =$ **319.0** mm
Constant	$K_{heel} = M_{heel} / (b \times d_{heel}^2 \times f_{cu}) =$ **0.002**

Compression reinforcement is not required

Lever arm	$z_{heel} = \min(0.5 + \sqrt{(0.25 - (\min(K_{heel}, 0.225) / 0.9))},0.95) \times d_{heel}$
	$z_{heel} =$ **303** mm
Area of tension reinforcement required	$A_{s\_heel\_des} = M_{heel} / (0.87 \times f_y \times z_{heel}) =$ **62** mm^2/m
Minimum area of tension reinforcement	$A_{s\_heel\_min} = k \times b \times t_{base} =$ **520** mm^2/m
Area of tension reinforcement required	$A_{s\_heel\_req} = \max(A_{s\_heel\_des}, A_{s\_heel\_min}) =$ **520** mm^2/m
Reinforcement provided	**12 mm dia.bars @ 150 mm centres**
Area of reinforcement provided	$A_{s\_heel\_prov} =$ **754** mm^2/m

PASS - Reinforcement provided at the retaining wall heel is adequate

Check shear resistance at heel

Design shear stress	$v_{heel} = V_{heel} / (b \times d_{heel}) =$ **0.083** N/mm^2
Allowable shear stress	$v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5) \times 1 \text{ N/mm}^2 =$ **4.733** N/mm^2

PASS - Design shear stress is less than maximum shear stress

From BS8110:Part 1:1997 – Table 3.8

Design concrete shear stress	$v_{c\_heel} =$ **0.463** N/mm^2

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

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

Material properties

Characteristic strength of concrete	$f_{cu} =$ **35** N/mm^2
Characteristic strength of reinforcement	$f_y =$ **500** N/mm^2

Wall details

Minimum area of reinforcement	k = **0.13** %
Cover to reinforcement in stem	$c_{stem} =$ **75** mm
Cover to reinforcement in wall	$c_{wall} =$ **30** mm

Factored horizontal at-rest forces on stem

Surcharge	$F_{s\_sur\_f} = \gamma_{f\_l} \times K_0 \times \text{Surcharge} \times (h_{eff} - t_{base} - d_{ds}) =$ **24.5** kN/m
Saturated backfill	$F_{s\_s\_f} = 0.5 \times \gamma_{f\_e} \times K_0 \times (\gamma_s - \gamma_{water}) \times h_{sat}^2 =$ **31.2** kN/m
Water	$F_{s\_water\_f} = 0.5 \times \gamma_{f\_e} \times \gamma_{water} \times h_{sat}^2 =$ **46.4** kN/m

Calculate shear for stem design

Shear at base of stem	$V_{stem} = F_{s\_sur\_f} + F_{s\_s\_f} + F_{s\_water\_f} - F_{prop\_f} =$ **5.7** kN/m

Calculate moment for stem design

Surcharge	$M_{s\_sur} = F_{s\_sur\_f} \times (h_{stem} + t_{base}) / 2 =$ **36.8** kNm/m
Saturated backfill	$M_{s\_s} = F_{s\_s\_f} \times h_{sat} / 3 =$ **27.1** kNm/m
Water	$M_{s\_water} = F_{s\_water\_f} \times h_{sat} / 3 =$ **40.2** kNm/m
Total moment for stem design	$M_{stem} = M_{s\_sur} + M_{s\_s} + M_{s\_water} =$ **104.1** kNm/m

Check wall stem in bending

Width of wall stem	b = **1000** mm/m
Depth of reinforcement	$d_{stem} = t_{wall} - c_{stem} - (\phi_{stem} / 2) =$ **267.0** mm

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Constant — $K_{stem} = M_{stem} / (b \times d_{stem}^2 \times f_{cu})$ = **0.042**

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} = **254** mm

Area of tension reinforcement required — $A_{s\_stem\_des} = M_{stem} / (0.87 \times f_y \times z_{stem})$ = **944** mm^2/m

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

Area of tension reinforcement required — $A_{s\_stem\_req} = \mathrm{Max}(A_{s\_stem\_des}, A_{s\_stem\_min})$ = **944** 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 — $v_{stem} = V_{stem} / (b \times d_{stem})$ = **0.021** N/mm^2

Allowable shear stress — $v_{adm} = \min(0.8 \times \sqrt{(f_{cu} / 1 N/mm^2)}, 5) \times 1 N/mm^2$ = **4.733** 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} = **0.622** N/mm^2

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

Appendix C

Method Statement

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Revision	Date	Comments
-	15.11.13	First Issue for Comment

1. Basement Formation Suggested Method Statement.

1.1. This method statement provides an approach which will allow the basement design to be correctly considered during construction, and the temporary support to be provided during the works. The contractor is responsible for the works on site and the final temporary works methodology and design on this site and any adjacent sites.

1.2. This method statement 51 Fitzjohn's Ave has been written by a Chartered Engineer and in accordance with the recommendations stated in the Royal Borough of Kensington and Chelsea Town Planning policy on Subterranean Development & Camden New Basement Development Guidance Notes. The sequencing has been developed considering guidance from ASUC.

1.3. This method has been produced to allow for improved costings and for inclusion in the party wall Award. Should the contractor provide alternative methodology the changes shall be at their own costs, and an Addendum to the Party Wall Award will be required.

1.4. Contact party wall surveyors to inform them of any changes to this method statement.

1.5. The approach followed in this design is; to remove load from above and place loads onto supporting steelwork, then to cast cantilever retaining walls in underpin sections at the new basement level.

1.6. The cantilever pins are designed to be inherently stable during the construction stage without temporary propping to the head. The base benefits from propping, this is provided in the final condition by the ground slab. In the temporary condition the edge of the slab is buttressed against the soil in the middle of the property, also the skin friction between the concrete base and the soil provides further resistance. The central slab is to be poured in a maximum of a 1/3 of the floor area.

The Local geological drift sheets imply the ground to be London Clays

1.7. The bearing pressures have been limited to 125kN/m^2. This is standard loadings for local ground conditions and acceptable to building control and their approvals.

2. Enabling works

2.1. The site is to be hoarded with ply sheet to 2.2m to prevent unauthorised public access.

2.2. Licenses for Skips and conveyors to be posted on hoarding

3. Basement Sequencing

3.1. Excavate Light well to front of property down to 600mm below external ground level.

3.2. Excavate first front corner of light well. (Follow methodology in section 4)

3.3. Excavate second front corner of light well. (Follow methodology in section 4)

3.4. Continue excavating section pins to form front light well. (Follow methodology in section 4)

3.5. Place cantilevered retaining wall to the left side of front opening. After 72 hours place cantilevered retaining wall to the right side of front opening.

3.6. Needle and prop bay. Insert support

3.7. Excavate out first 1.2m around front opening prop floor and erect conveyor.

3.8. Continue cantilevered wall formation around perimeter of basement following the numbering sequence on the drawings.

3.8.1. Excavation for the next numbered sections of underpinning shall not commence until at least 8 hours after drypacking of previous works. Excavation of adjacent pin to not commence until 24 hours after drypacking. (24hours possible due to inclusion of Conbextra 100 cement accelerator to dry pack mix)

3.8.2. Floor over to be propped as excavations progress. Steelwork to support Floor to be inserted as works progress.

3.9. Excavate a maximum of a 1/3 of the middle section of basement floor. Place reinforcement to central section of ground bearing slab and pour concrete. Excavate next third and cast slab. Excavate and cast final third and cast.

3.10. Provide structure to ground floor and water proofing to retaining walls as required.

4. Underpinning – Cantilevered Wall Creation

4.1. Excavate first section of retaining wall (no more than 1200mm wide). Where excavation is greater than 1.2m deep provide temporary propping to sides of excavation to prevent earth collapse (Health and Safety). A 1200mm width wall has a lower risk of collapse to the heel face.

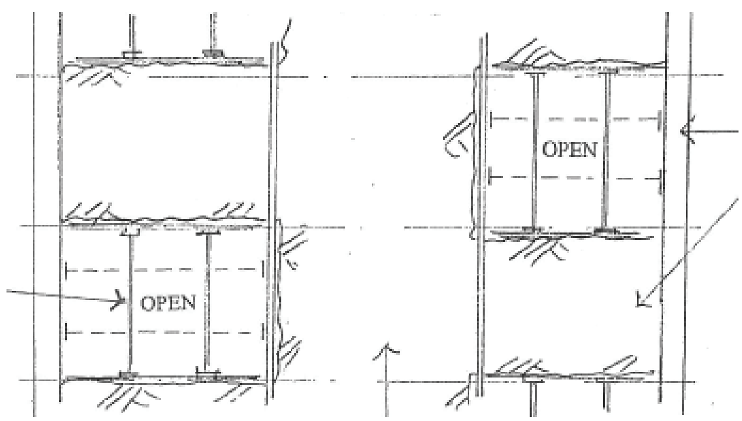
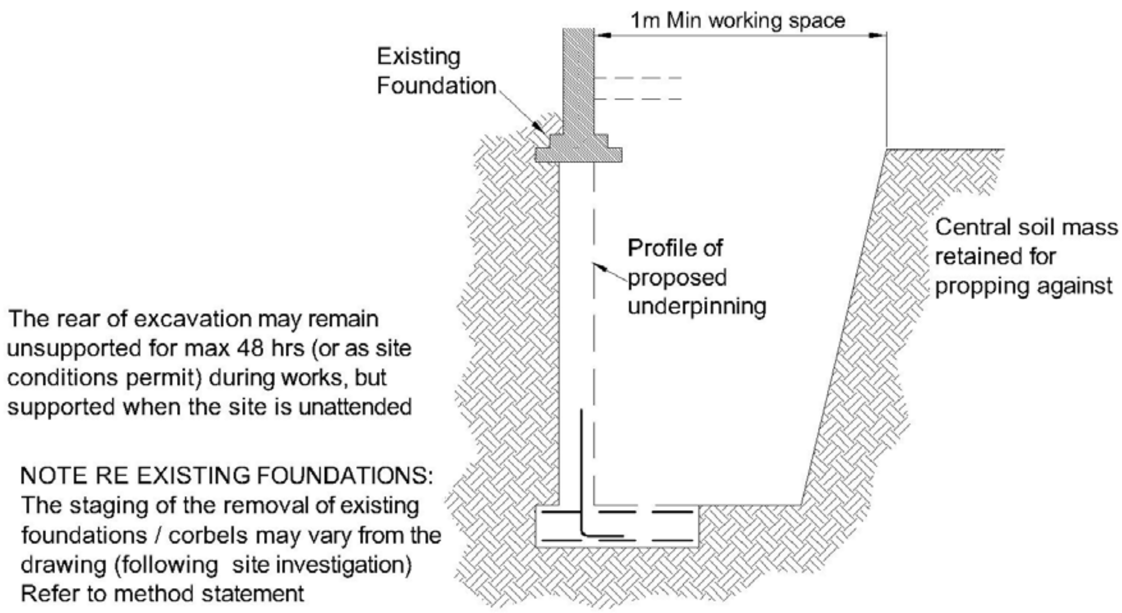


Figure 14 – Schematic Plan view of Soil Propping

Figure 15 Propping



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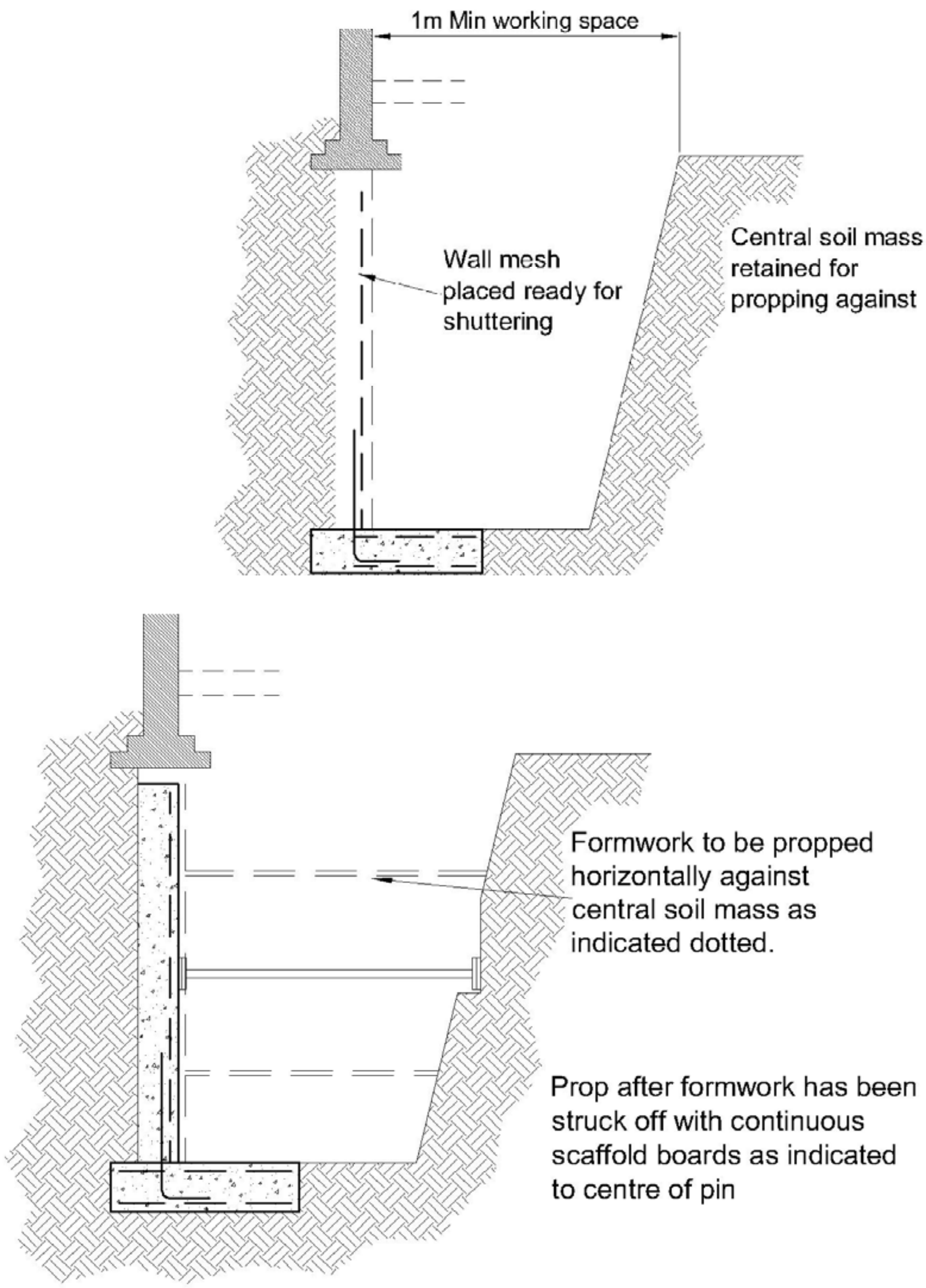
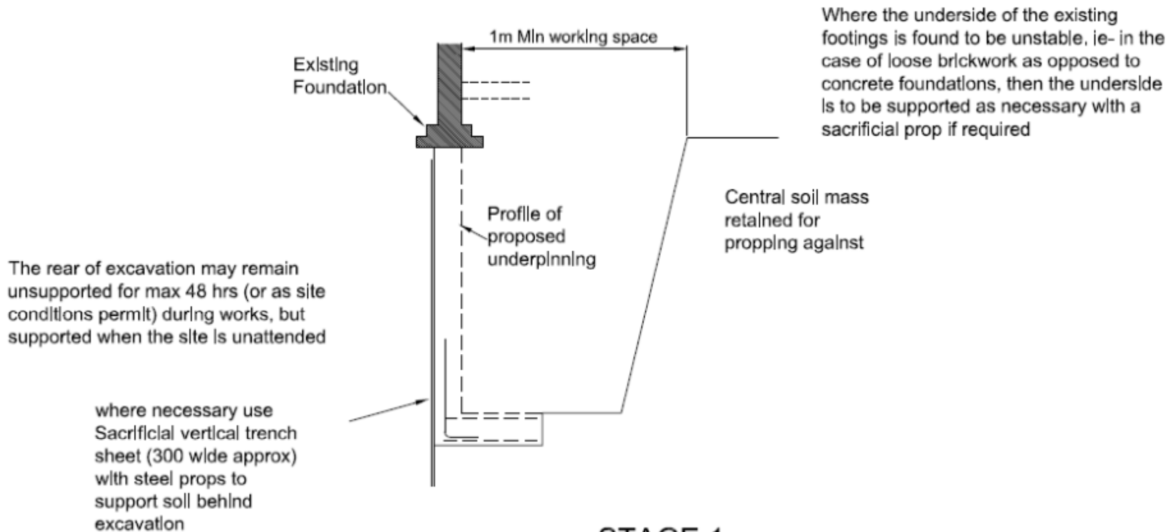
case of loose brickwork as opposed to concrete foundations, then the underside is to be supported as necessary with a sacrificial prop if required

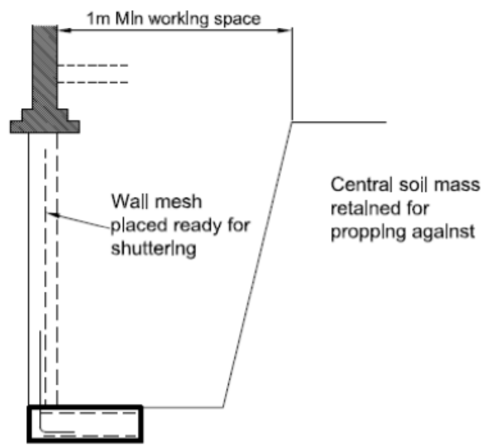


CLAY SOILS - STAGE 3

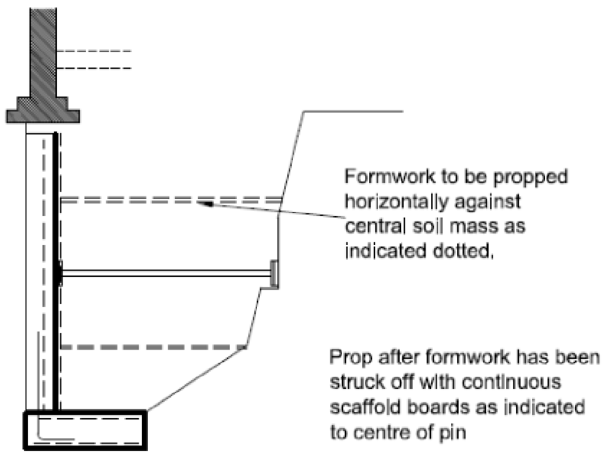
Granular soils:



STAGE 1

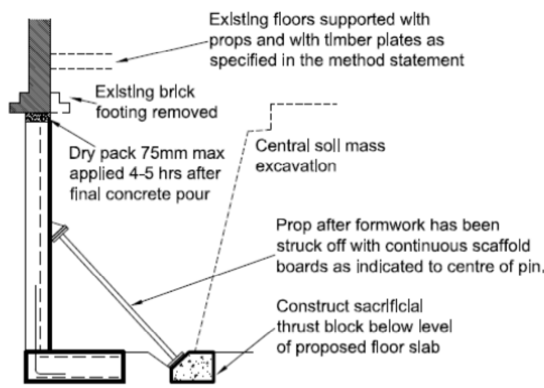


STAGE 2



STAGE 3

Image of Stage 3 on Site



STAGE 4

4.1.1. Where soft spots are encountered back prop with Precast lintels or trench sheeting. Where voids are present behind the lintels (or trench sheeting) grout behind. Prior to casting place layer of DPM between PC lintels (or trench sheeting) and new concrete. The lintels are to be cut into the soil by 150mm either side of the pin. A site stock of a minimum of 10 lintels to be present for to prevent delays due to ordering. . .

4.1.2. If the soil support to the ends of the lintels is insufficient then brace the ends of the PC lintels with 150x150 C24 Timbers and prop with Acrows diagonally back to the floor.

4.2. Visually inspect the footings and provide propping to local brickwork, if necessary props to be sacrificial and cast into the retaining wall.

4.3. Provide propping to floor where necessary.

4.4. Excavate base. Mass concrete heels to be excavated. If soil over unstable prop top with PC lintel and sacrificial prop.

4.5. Clear underside of existing footing.

4.6. Local authority inspection to be carried for approval of excavation base.

4.7. Place blinding.

4.8. Place reinforcement for retaining wall base & toe. Site supervisor to inspect and sign off works for proceeding to next stage.

4.9. Cast base. (on short stems it is possible to cast base and wall at same time)

4.10. Take 2 cubes of concrete and store for testing. Test one at 28 days if result is low test second cube. Provide results to client and design team on request or if values are below those required.

4.11. Horizontal temporary prop to base of wall to be inserted. Alternatively cast base against soil.

4.12. Place reinforcement for retaining wall stem. Site supervisor to inspect and sign off works for proceeding to next stage.

4.13. Drive H16 Bars U-Bars into soil along centre line of stem to act as shear ties to adjacent wall.

4.14. Place shuttering & pour concrete for retaining wall. Stop a minimum of 75mm from the underside of existing footing. Take 2 cubes of concrete and store for testing

4.15. Ram in drypack between retaining wall and existing masonry. (24 hours after pouring the concrete pin the gap shall be filled using a dry pack mortar.)

4.16. Trim back existing masonry corbel and concrete on internal face.

4.17. Site supervisor to inspect and sign off for proceeding to the next stage.

5. Approval

5.1. Building control officer/approved inspector to inspect pin bases and reinforcement prior to casting concrete.

5.2. Contractor to keep list of dates pins inspected & cast

5.3. One month after work completed the contractor is to contact adjacent party wall surveyor to attend site and complete final condition survey and to sign off works.

CROFT STRUCTURAL ENGINEERS

This calcualtion has been provided for the trench sheet and prop design of standard underpins in the temporary condition. There are gaps left between the sheeting and as such no water pressure will occur. Any water present will flow through the gaps betweenthe sheeting and will be required to pump out.

Trecnh sheets should be placed at centers to deal with the ground. It is expected that the soil between the trench sheeting will arch. Looser soil will required tighter centers. It is typical for udnerpins to be placed at 1200c/c, in this condition the highest load on a trench sheet is when 2 nos trench sheets are used. It is for this design that these calculations have been provided.

Soil and ground conditions are variable. Typically one finds that in the temporary condition clays are more stable and the C_u (cohesive) values in clay reduce the risk of collapse. It is this cohesive nature that allows clays to be cut into a vertical slope. For these calculations weak snad and gravels have been assummed The soil properties are:

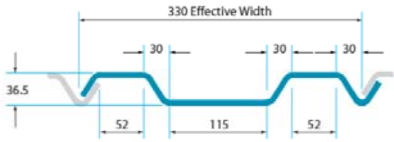
Surcharge	sur = **10.** kN/m^2	
Soil density	δ = **20** kN/m^3	
Angle of friction	ϕ = **25** °	
Soil depth	Dsoil = **3000.000** mm	
	$k_a = (1 - \sin(\phi)) / (1 + \sin(\phi))$	= **0.406**
	$k_p = 1 / k_a$	= **2.464**
Soil Pressure bottom	soil = $k_a * \delta *$ Dsoil	= **21.916**kN/m^2
Surcharge pressure	surcharge = sur * k_a	= **4.059** kN/m^2

CROFT STRUCTURAL ENGINEERS

Standard Lap Trench Sheeting

STANDARD LAP

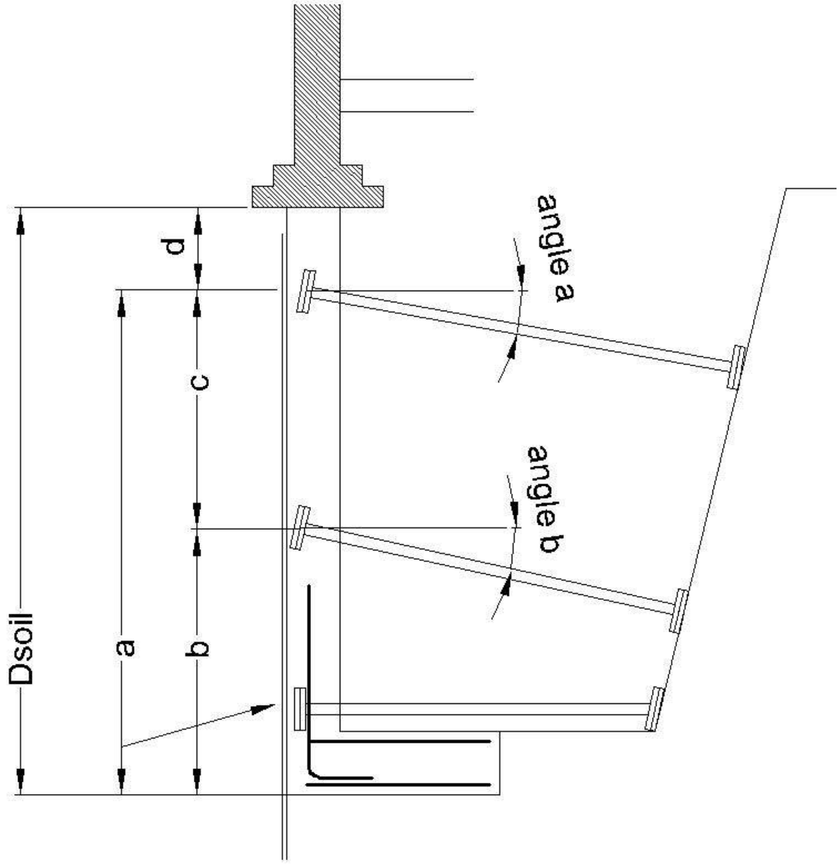
The overlapping trench sheeting profile is designed primarily for construction work and also temporary deployment.



Technical Information

Effective width per sheet (mm)	330
Thickness (mm)	3.4
Depth (mm)	35
Weight per linear metre (kg/m)	10.8
Weight per m² (kg)	32.9
Section modulus per metre width (cm³)	48.3
Section modulus per sheet (cm³)	15.9
I value per metre width (cm⁴)	81.7
I value per sheet (cm⁴)	26.9
Total rolled metres per tonne	92.1

Sxx = 15.9 cm^3
py = 275N/mm^2
Ixx = 26.9cm^4
A = ($1m^2$ * 32.9kg/m^2) / (330mm * 7750kg/m^3) = **12864.125**mm^2

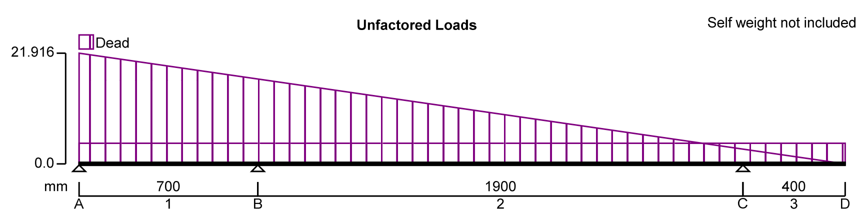


Length a a = **2.600** m

Length b bottom b = **0.700** m

Length c Middle c = a – b = **1.900**m

Length d top d = Dsoil – a = **0.400**m



CONTINUOUS BEAM ANALYSIS - INPUT

BEAM DETAILS

Number of spans = **3**

Material Properties:

Modulus of elasticity = **205** kN/mm^2 Material density = **7860** kg/m^3

Support Conditions:

Support A	Vertically **"Restrained"**	Rotationally **"Free"**
Support B	Vertically **"Restrained"**	Rotationally **"Free"**
Support C	Vertically **"Restrained"**	Rotationally **"Free"**

CROFT STRUCTURAL ENGINEERS

Support D Vertically **"Free"** Rotationally **"Free"**

Span Definitions:

Span 1 Length = **700** mm Cross-sectional area = **12864** mm^2 Moment of inertia = **269.×10³** mm^4

Span 2 Length = **1900** mm Cross-sectional area = **12864** mm^2 Moment of inertia = **269.×10³** mm^4

Span 3 Length = **400** mm Cross-sectional area = **12864** mm^2 Moment of inertia = **269.×10³** mm^4

LOADING DETAILS

Beam Loads:

Load 1 UDL Dead load **4.1** kN/m

Load 2 VDL Dead load **21.9** kN/m to **0.0** kN/m

LOAD COMBINATIONS

Load combination 1

Span 1 1×Dead

Span 2 1×Dead

Span 3 1×Dead

CONTINUOUS BEAM ANALYSIS - RESULTS

Unfactored support reactions

	Dead (kN)							
Support A	**-1.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Support B	**-32.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Support C	**-10.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Support D	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Support Reactions - Combination Summary

Support A Max react = **-1.4** kN Min react = **-1.4** kN Max mom = **0.0** kNm Min mom = **0.0** kNm

Support B Max react = **-32.8** kN Min react = **-32.8** kN Max mom = **0.0** kNm Min mom = **0.0** kNm

Support C Max react = **-10.8** kN Min react = **-10.8** kN Max mom = **0.0** kNm Min mom = **0.0** kNm

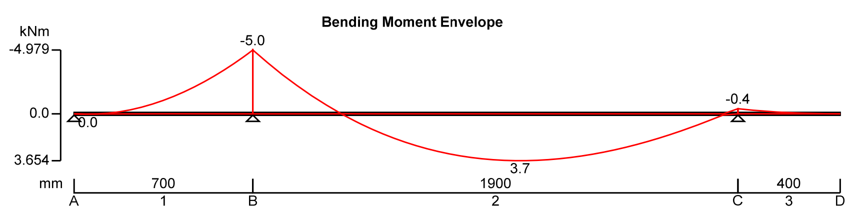
Support D Max react = **0.0** kN Min react = **0.0** kN Max mom = **0.0** kNm Min mom = **0.0** kNm

Beam Max/Min results - Combination Summary

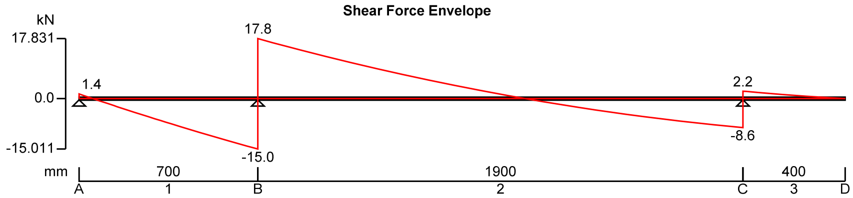
Maximum shear = **17.8** kN Minimum shearF_{min} = **-15.0** kN

Maximum moment = **3.7** kNm Minimum moment = **-5.0** kNm

Maximum deflection = **21.0** mm Minimum deflection = **-14.3** mm



CROFT STRUCTURAL ENGINEERS



Number of sheets Nos = 2

Mallowable = Sxx * py * Nos = **8.745**kNm

SRU 4.0

Safe working loads for Acrow Props — loads given in kN

For normal purposes 1 kilo Newton (kN) = 100 kg	Height	m ft	2.0 6.6	2.25 7.4	2.5 8.2	2.75 9.0	3.0 9.8	3.25 10.7	3.5 11.5	3.75 12.3	4.0 13.1	4.25 13.9	4.5 14.8	4.75 15.6
TABLE A Props loaded concentrically and erected vertically	Prop size 1 or 2		35	35	35	34	27	23						
	Prop size 3					34	27	23	21	19	17			
	Prop size 4							32	25	21	18	16	14	12
TABLE B Props loaded concentrically and erected 1½° max. out of vertical	Prop size 1 or 2 or 3		35	32	26	23	19	17	15	13	12			
	Prop size 4							24	19	15	12	11	10	9
TABLE C Props loaded 25 mm eccentricity and erected 1½° max. out of vertical	Prop size 1 or 2 or 3		17	17	17	17	15	13	11	10	9			
	Prop size 4							17	14	11	10	9	8	7
TABLE D Props loaded concentrically and erected 1½° out of vertical and laced with scaffold tubes and fittings	Prop size 3					35	33	32	28	24	20			
	Prop size 4							35	35	35	35	27	25	21

Shear V = (14.6kN + 13.4kN) /2 = 14.000kN

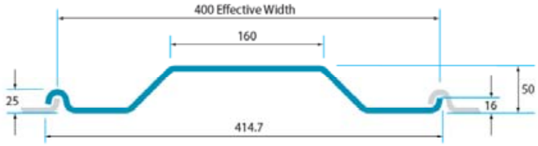
Any Acro Prop is accetpable

CROFT STRUCTURAL ENGINEERS

KD4 sheets

KD4

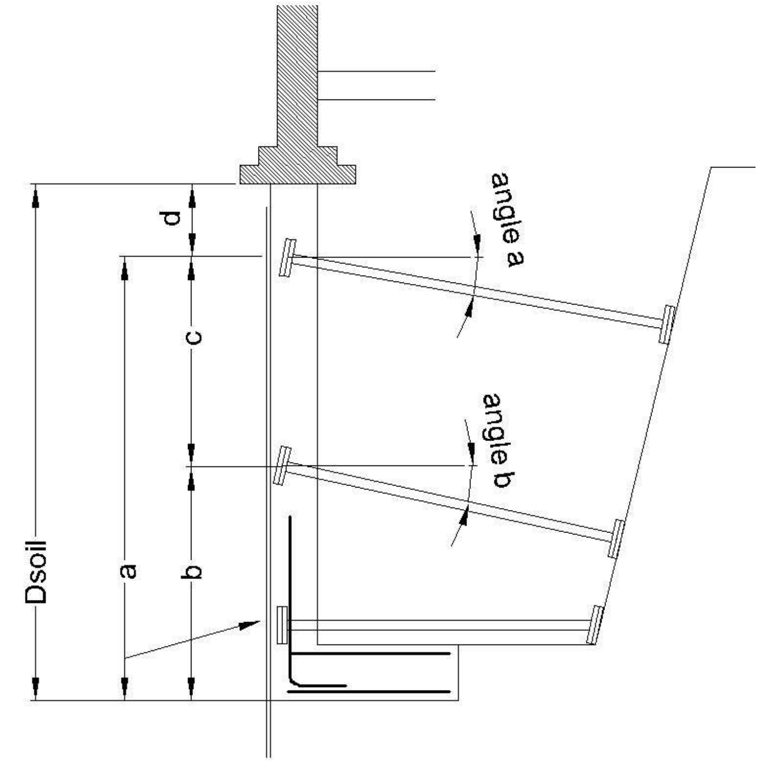
The overlapping trench sheeting profile is a heavier version of the Standard Lap, with a wider gauge and width coverage, designed in large for construction work.



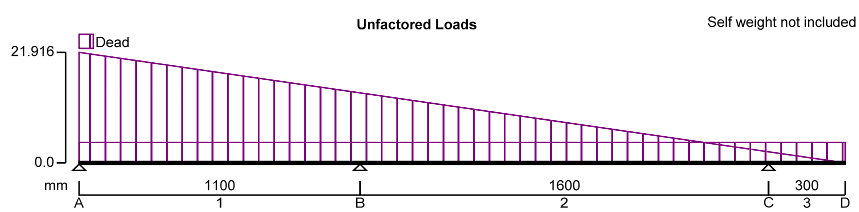
Technical Information

Effective width per sheet (mm)	400
Thickness (mm)	6.0
Depth (mm)	50
Weight per linear metre (kg/m)	21.90
Weight per m^2 (kg)	55.2
Section modulus per metre width (cm^3)	101
Section modulus per sheet (cm^3)	40.34
I value per metre width (cm^4)	250
I value per sheet (cm^4)	101
Total rolled metres per tonne	45.659

Sxx = 48.3cm^3
py = 275N/mm^2
Ixx = 26.9cm^4
A = ($1m^2$ * 55.2kg/m^2) / (400mm * 7750kg/m^3) = **17806.452**mm^2



Length a	a = **2.700** m
Length b bottom	b = **1.100** m
Length c Middle	c = a – b = **1.600**m
Length d top	d = Dsoil – a = **0.300**m



CONTINUOUS BEAM ANALYSIS - INPUT

BEAM DETAILS

Number of spans = **3**

Material Properties:

Modulus of elasticity = **205** kN/mm^2 | Material density = **7860** kg/m^3

Support Conditions:

Support A	Vertically **"Restrained"**	Rotationally **"Free"**
Support B	Vertically **"Restrained"**	Rotationally **"Free"**
Support C	Vertically **"Restrained"**	Rotationally **"Free"**
Support D	Vertically **"Free"**	Rotationally **"Free"**

Span Definitions:

Span 1	Length = **1100** mm	Cross-sectional area = **17806** mm^2	Moment of inertia = **269.×10^3** mm^4
Span 2	Length = **1600** mm	Cross-sectional area = **17806** mm^2	Moment of inertia = **269.×10^3** mm^4

CROFT STRUCTURAL ENGINEERS

Span 3 Length = **300** mm Cross-sectional area = **17806** mm^2 Moment of inertia = **269.×10^3** mm^4

LOADING DETAILS

Beam Loads:

Load 1 VDL Dead load **21.9** kN/m to **0.0** kN/m

Load 2 UDL Dead load **4.1** kN/m

LOAD COMBINATIONS

Load combination 1

Span 1 1×Dead

Span 2 1×Dead

Span 3 1×Dead

CONTINUOUS BEAM ANALYSIS - RESULTS

Support Reactions - Combination Summary

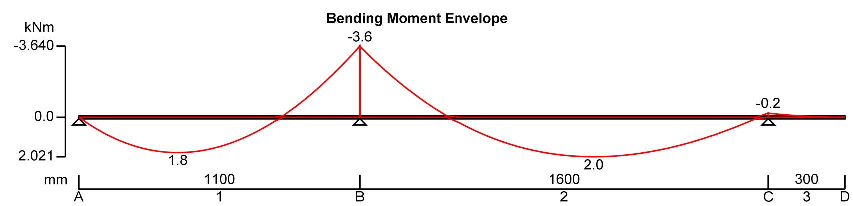
Support A	Max react = **-9.5** kN	Min react = **-9.5** kN	Max mom = **0.0** kNm	Min mom = **0.0** kNm
Support B	Max react = **-28.0** kN	Min react = **-28.0** kN	Max mom = **0.0** kNm	Min mom = **0.0** kNm
Support C	Max react = **-7.5** kN	Min react = **-7.5** kN	Max mom = **0.0** kNm	Min mom = **0.0** kNm
Support D	Max react = **0.0** kN	Min react = **0.0** kN	Max mom = **0.0** kNm	Min mom = **0.0** kNm

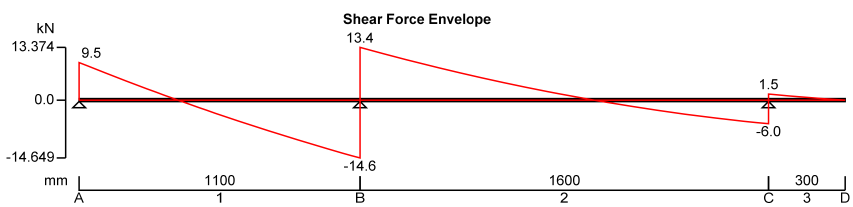
Beam Max/Min results - Combination Summary

Maximum shear = **13.4** kN Minimum shearF_{min} = **-14.6** kN

Maximum moment = **2.0** kNm Minimum moment = **-3.6** kNm

Maximum deflection = **7.7** mm Minimum deflection = **-4.9** mm





Number of sheets Nos = 2

Mallowable = Sxx * py * Nos = **26.565**kNm

SRU4.0

Safe working loads for Acrow Props — loads given in kN

For normal purposes 1 kilo Newton (kN) = 100 kg	Height	m / ft	2.0 / 6.6	2.25 / 7.4	2.5 / 8.2	2.75 / 9.0	3.0 / 9.8	3.25 / 10.7	3.5 / 11.5	3.75 / 12.3	4.0 / 13.1	4.25 / 13.9	4.5 / 14.8	4.75 / 15.6
TABLE A Props loaded concentrically and erected vertically	Prop size 1 or 2		35	35	35	34	27	23						-
	Prop size 3					34	27	23	21	19	17			
	Prop size 4							32	25	21	18	16	14	12
TABLE B Props loaded concentrically and erected 1½° max. out of vertical	Prop size 1 or 2 or 3		35	32	26	23	19	17	15	13	12			
	Prop size 4							24	19	15	12	11	10	9
TABLE C Props loaded 25 mm eccentricity and erected 1½° max. out of vertical	Prop size 1 or 2 or 3		17	17	17	17	15	13	11	10	9			
	Prop size 4							17	14	11	10	9	8	7
TABLE D Props loaded concentrically and erected 1½° out of vertical and laced with scaffold tubes and fittings	Prop size 3					35	33	32	28	24	20			
	Prop size 4							35	35	35	35	27	25	21

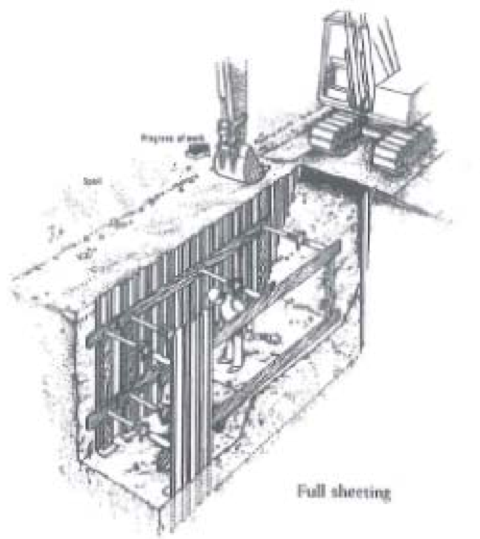
Shear V = (14.6kN + 13.4kN) /2 = 14.000kN

Any Acro Prop is accetpable

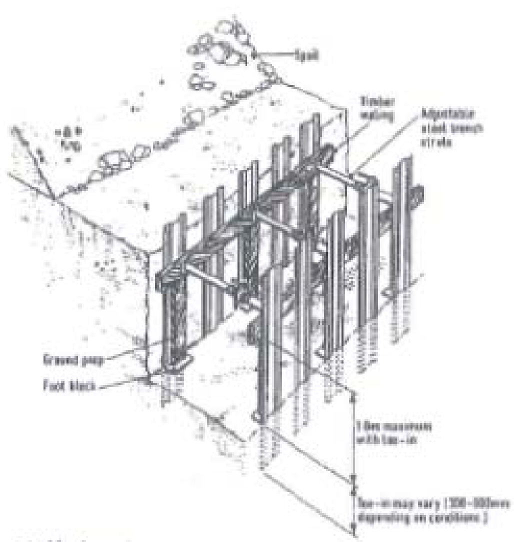
Sheeting requirements

Ground Type	Trench Depth, D: less than 1.2m(1)	1.2 to 3m	3 to 4.5m	4.5 to 6m
Sands and gravels Silt Soft Clay High compressibility Peat	Close, ½, ¼, ⅛ or nil	Close	Close	Close
Firm/stiff Clay Low compressibility Peat	¼, ⅛ or nil	½ or ¼	½ or ¼	Close or ½
Rock(2)	From ½ for incompetent rock to nil for competent rock(3)			

Sheeting requirements

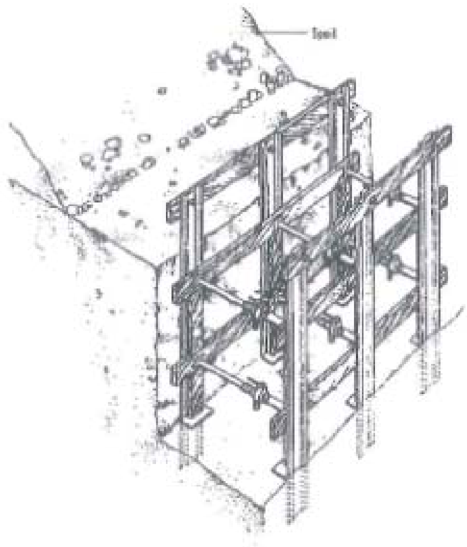


Sheeting requirements



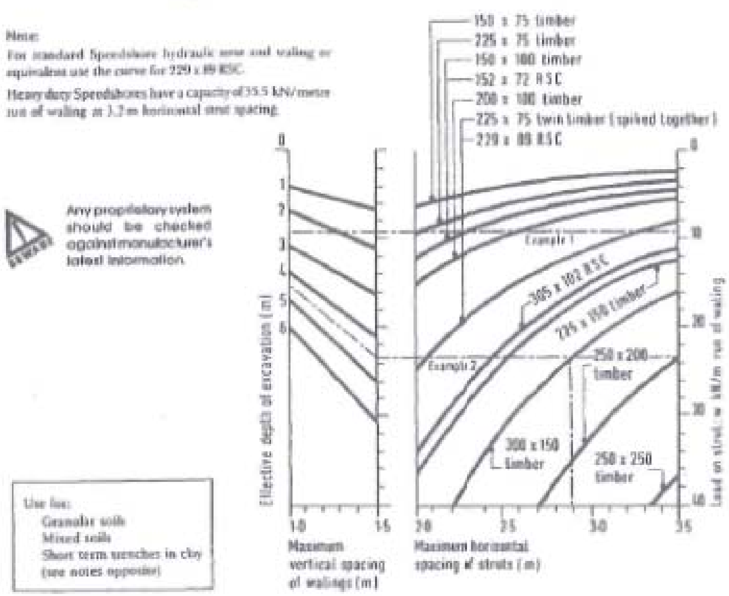
Half sheeting
shown for 1.5 m deep trench

Sheeting requirements

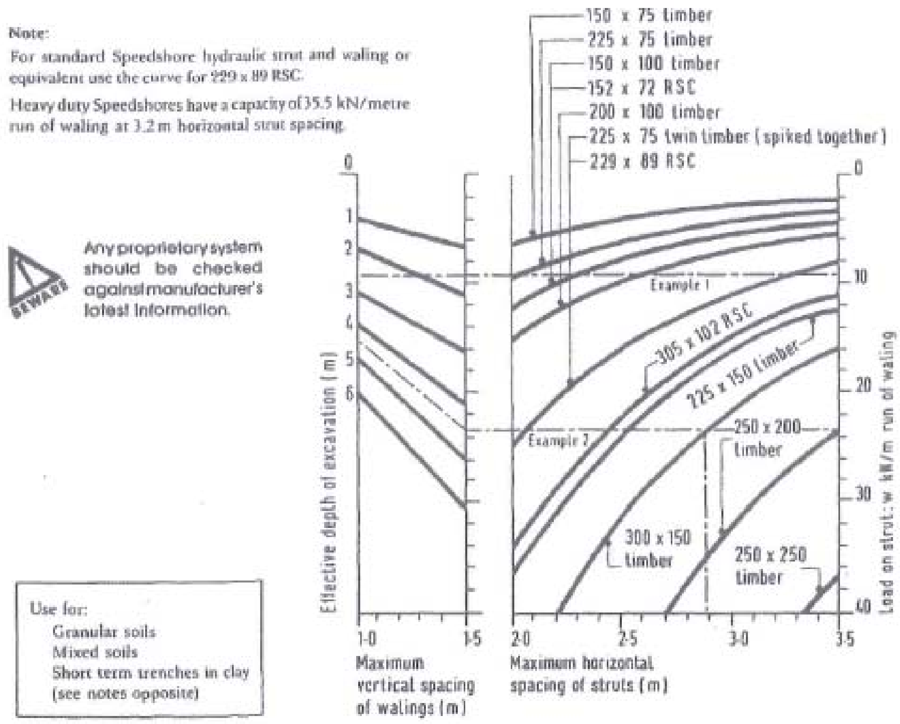


Quarter sheeting

Design to CIRIA 97



CROFT STRUCTURAL ENGINEERS



Appendix D

Soil Investigation Reports

CROFT STRUCTURAL ENGINEERS

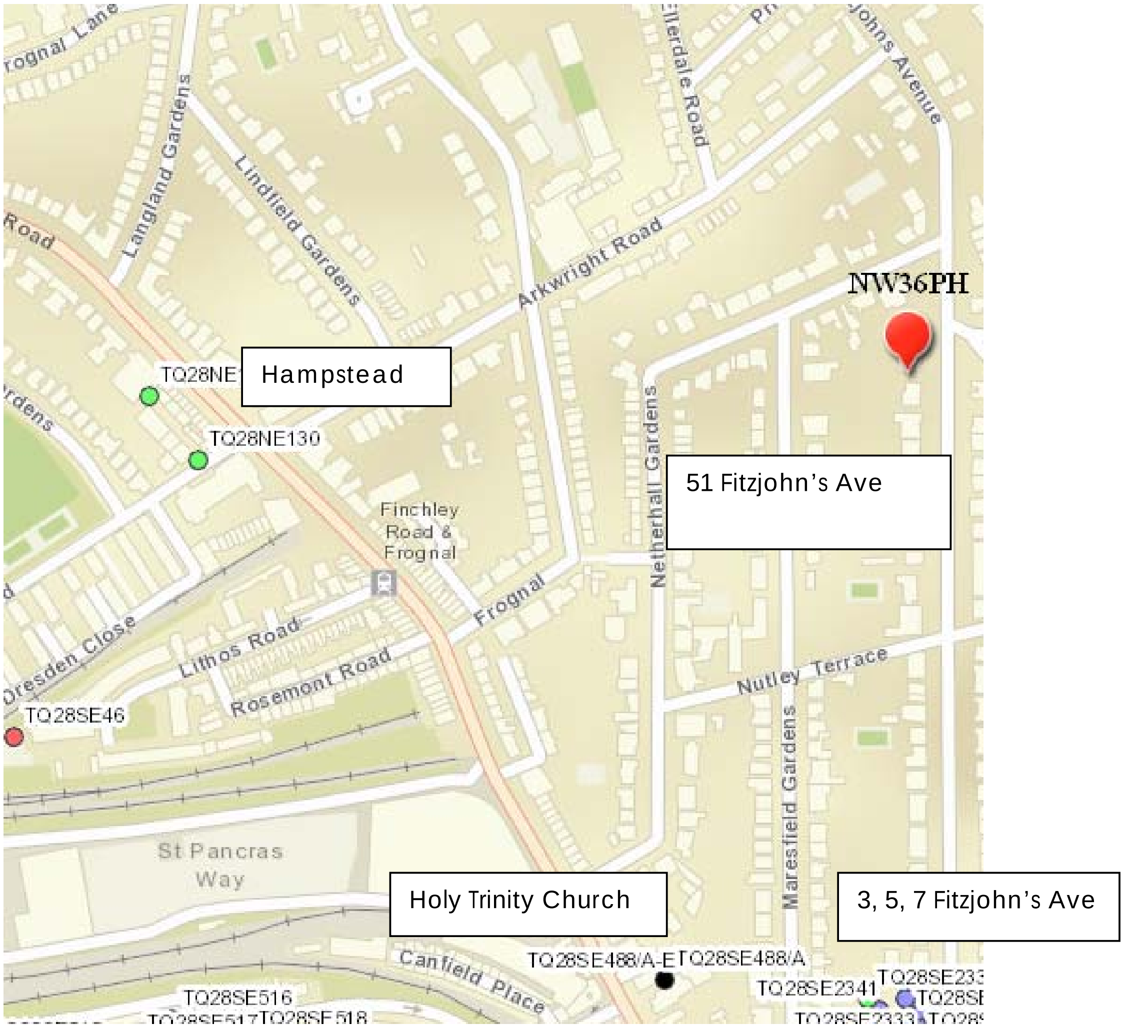


Figure 16: Soil Report's locations

Department of the Environment CIVIL ENGINEERING LABORATORY Cardington	Investigation No. FGE/1491	Appendix A Sheet No. 5
T.E. Extension	HAMPSTEAD	

BOREHOLE LOG

TQ 28 NE|130
2598 8510

Borehole No. 3
Ground Level 60·7 m A.O.D (approx)
Date 23rd – 25th June 1981

Note:–
1. Light Cable Percussion Borehole
2. Casing – 200mm dia. to 1·8m below G.L
Open hole boring from 1·8m to 15·0m below G.L
3. Standpipe installed – details below

	Description of Strata	Legend	Sample	Depth (m)	O.D. (m)	Remarks
				G.L	60·7	Standpipe installed to 15·0m below G.L
	REINFORCED CONCRETE			0·3	60·4	Pipe slotted over whole length
MGRP	MADE GROUND; Clay, very sandy, soft and organic with flints and brick fragments etc.			0·7		
			22	0·9	59·8	Hole backfilled with gravel
?	CLAY, Orange brown, slightly sandy, structureless with scattered rounded stones (SOLIFLUCTION DEPOSIT?)	C		1·2		Ground water level at 1·5m below G.L on 27·8·81
				1·5	59·2	
LC (w)	CLAY, Brown, stiff, slightly silty, extremely fissured and brittle with occasional small carbonaceous pockets. Class? CH	LW	22	2·0		
				2·5		
	CLAY, as above but fissuring so pronounced as to cause samples from 3·5 to 6·5m to fall apart during extrusion. There was no evidence of any polishing along the fissure surfaces. Class? CH		22	3·5		
				4·0		Water added in small quantities to assist boring from 4·0m below G.L onwards
			50	5·0		
				5·5		
			42	6·5		
				7·0		
	CLAY, Dark brown, stiff, silty, very fissured with numerous small Gypsum crystals. Contained a few thin layers of weakly cemented yellow iron pan		45	8·0		
				8·5		
	(WEATHERED LONDON CLAY)		40	9·5		Borehole dia. 200mm throughout
				10·0	50·7	

contd.

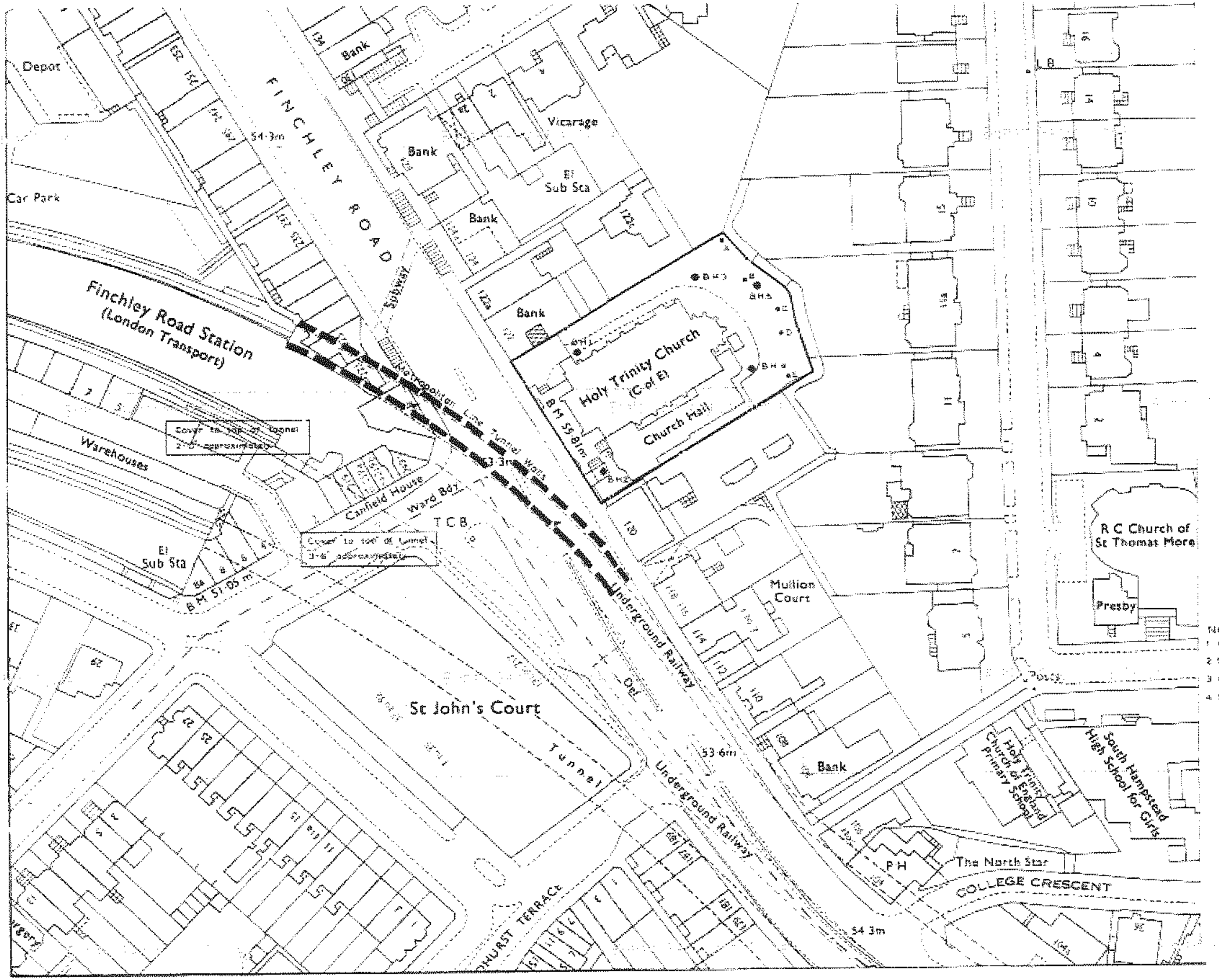
Department of the Environment CIVIL ENGINEERING LABORATORY Cardington	Investigation No. FGE/1491	Appendix A Sheet No. 6
T. E. Extension	HAMPSTEAD	

BOREHOLE LOG

TQ 28 NE/130
2698 8510

Borehole No. 3 contd.
Ground Level
Date
Note:-

	Description of Strata	Legend	Sample	Depth (m)	O.D. (m)	Remarks
LC (w)	CLAY, as previous sheet (WEATHERED LONDON CLAY)	LW		10·0	50·7	
				10·5	50·2	
LC	CLAY, Grey, stiff, extremely fissured, slightly silty with isolated small lenses and layers of brown silt. Contains scattered fossil fragments and small nodules of Pyrites throughout. Class? CH	L	38	11·0		
				11·5		
			71	13·0		
				13·5		
	(LONDON CLAY)					No water entries observed during boring
			35	14·5		Borehole dry on completion of boring
				15·0	45·7	End of boring



NOTES
1 Proposed borehole shown thus ⊕ B H 1
2 Site boundary shown thus ——
3 Completed borehole shown thus ● B H 3
4 Slip indicator shown thus • A

Holy Trinity, Finchley Road.	Mitchell McFarlane & Partners
	Site Investigation – Sheet 1
17-4-72 / 17-5-72	Scale 1:500 / Date 27-12-71 — 758 – 1

GROUND EXPLORATIONS LTD.

TQ 28 SE/80x 488A
2636. 8470
1" 256

BOREHOLE NO. 1

Contract Name Holy Trinity, Finchley Rd. Report No. 5583/BW/IAB

Client Mitchell, McFarlane & Partners, Site Address

Address 136 Buckingham Palace Road, Westminster, London SW1W 9SA.

Site Address: Holy Trinity Church, Finchley Road, London, N.W.3.

Standing Water Level -

Method of Boring Shell and auger

Water Struck -

Diameter 150mm.

Ground Level O.D. 55·43m.

Start 29.2.72. Finish 1.3.72.

Perforated Casing -

Remarks

JARS m.			CORES m.		BULK m.	
9576 0·3	9595 11·6		9578 0·9	9598 13·1		
9577 0·6	9597 12·8		9580 2·1	9600 14·3		
9579 1·8	9599 14·0		9582 3·4			
9581 3·0	9601 15·2		9584 4·6			
9583 4·3			9586 5·8			
9585 5·5			9588 7·0			
9587 6·7			9590 8·2			
9589 7·9			9592 9·4			
9591 9·1			9594 10·7			
9593 10·0			9596 11·9			

Description	Thickness m.	Depth m.
Made ground : grey-blue sandy clay with bricks, stones, etc.	0·5	0·5
Brown fissured clay with crystals.	9·8	10·3
Dark brown fissured clay	4·9	15·2
TOTALS	15·2	15·2

Notes 1. Descriptions are in accordance with B.S. Code of Practice C.P. 2001
Clients are requested to compare with samples submitted.
2. Core samples are nominally 102mm (4 ins.) diameter and 460mm (18 ins.) long.
Depths shown are to top of sample.

PR2519

CASING DEPTH (m)	WATER (m)	STRATA DESCRIPTION	LEGEND	DEPTH (m)	TEST RESULTS: TYPE AND DEPTH	TEST RESULTS: RESULT	SAMPLING: FROM (m)	SAMPLING: TO (m)	SAMPLING: TYPE
		Grass onto soft dark brown slightly sandy slightly gravelly CLAY. Gravel consists of brick and flint. (MADE GROUND)		0.0					
							0.3		D
				0.4					
				0.6			0.6		D
1.5	Dry	Soft grey mottled orange brown slightly sandy slightly gravelly CLAY with occasional rootlets. Gravel consists of quartz, flint and occasional brick. (MADE GROUND)			SPT 1.1-1.55m	(1) 4	1.1	1.55	D
1.5	Dry			2.0	SPT (c) 2.0-2.45m	(7) 17			
		Soft grey orange brown CLAY with occasional rootlets. (MADE GROUND)					2.2		D
1.5	Dry	Firm light brown slightly gravelly slightly sandy CLAY with occasional cobbles of flint. Gravel consists of flint and ash. (MADE GROUND)		3.0	SPT 3.0-3.45m	(5) 18	3.0	3.45	D
		Stiff brown slightly sandy CLAY. (LONDON CLAY)					3.8		D
1.5	Dry				SPT 4.6-5.05m	(4) 16	4.6		D
1.5	Dry	Firm brown CLAY with occasional fine gravel sized selenite crystals. (LONDON CLAY)			SPT 6.0-6.45m		6.0		D
				7.0			7.0		D

DRILLING: TYPE (DIAMETER)	FROM	TO	GROUNDWATER: DEPTH STRUCK	BEHAVIOUR	DEPTH SEALED	DATE	DEPTH OF CASING
101mm	0.0m	30.0m	Dry				

REFER TO KEY AT BEGINNING OF THIS APPENDIX FOR EXPLANATION OF SYMBOLS

BOREHOLE RECORD SHEET 1 OF 5

SOILTECHNICS

GEOTECHNICAL ENGINEERS, ENVIRONMENTAL CONSULTANTS

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GROUND LEVEL:

CO-ORDINATES:

LOCATION PLAN ON DRAWING No: STD0953U-02

DATE OF EXCAVATION: 13.03.07

PROJECT: No's 3, 5 & 7, Fitzjohn's Avenue, London Proposed Residential Development

PROJECT REF.: STD0953U

BOREHOLE No: BH01

CASING DEPTH (m)	WATER (m)	STRATA DESCRIPTION	LEGEND	DEPTH (m)	TEST RESULTS TYPE AND DEPTH	RESULT	SAMPLING FROM (m)	TO (m)	TYPE
1.5	Dry			7.5	SPT 7.5-7.95m	(5) 18	7.5	7.95	D
		Stiff brown CLAY with occasional fine gravel sized selenite crystals. (LONDON CLAY)							
1.5	Dry				SPT 9.1-9.55m	(6) 20	9.1	9.55	D
				10.1					
		Stiff dark grey CLAY with occasional fine gravel sized selenite crystals and rare gravel of pyrite. (LONDON CLAY)					10.3		D
1.5	Dry				SPT 10.5-10.95m	(6) 21	10.5	10.95	D
1.5							12.0	12.4	U 100 (24)
1.5	Dry			12.5	SPT 12.6-13.05m	(6) 21	12.6	13.05	D
		Stiff dark grey CLAY. (LONDON CLAY)							
1.5	Dry				SPT 13.6-14.05	(6) 23	13.6	14.05	D

DRILLING			GROUNDWATER				
TYPE (DIAMETER)	FROM	TO	DEPTH STRUCK	BEHAVIOUR	DEPTH SEALED	DATE	DEPTH OF CASING
150mm	0.0m	30.0m	Dry				

REFER TO KEY AT BEGINNING OF THIS APPENDIX FOR EXPLANATION OF SYMBOLS

BOREHOLE RECORD SHEET 2 OF 5

SOILTECHNICS

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GROUND LEVEL	CO-ORDINATES
LOCATION PLAN ON DRAWING No STD0953U-02	DATE OF EXCAVATION 13.03.07
PROJECT No's 3, 5 & 7, Fitzjohn's Avenue, London Proposed Residential Development	
PROJECT REF. STD0953U	BOREHOLE No BH01

BH01.1

CASING DEPTH (m)	WATER (m)	STRATA DESCRIPTION	LEGEND	DEPTH (m)	TEST RESULTS TYPE AND DEPTH	RESULT	SAMPLING FROM (m)	TO (m)	TYPE
		Stiff dark grey CLAY. (LONDON CLAY)							
1.5	Dry				SPT 15.0-15.45m	(6) 23	15.0	15.45	D
							16.1		D
1.5	Dry				SPT 16.6-17.05m	(6) 28	16.6	17.05	D
1.5	Dry				SPT 18.1-18.55m	(7) 32	18.1	18.55	D
1.5							20.0	20.4	U 100 (29)
							20.5		D

DRILLING TYPE (DIAMETER)	FROM	TO	GROUNDWATER DEPTH STRUCK	BEHAVIOUR	DEPTH SEALED	DATE	DEPTH OF CASING
150mm	0.0m	30.0m	Dry				

REFER TO KEY AT BEGINNING OF THIS APPENDIX FOR EXPLANATION OF SYMBOLS

BOREHOLE RECORD SHEET 3 OF 5

SOILTECHNICS

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GROUND LEVEL	CO-ORDINATES
LOCATION PLAN ON DRAWING No STD0953U-02	DATE OF EXCAVATION 13.03.07
PROJECT No's 3, 5 & 7, Fitzjohn's Avenue, London Proposed Residential Development	
PROJECT REF. STD0953U	BOREHOLE No BH01

BH01.2

CASING DEPTH (m)	WATER (m)	STRATA DESCRIPTION	LEGEND	DEPTH (m)	TEST RESULTS: TYPE AND DEPTH	TEST RESULTS: RESULT	SAMPLING: FROM (m)	SAMPLING: TO (m)	SAMPLING: TYPE
		Stiff dark grey CLAY. (LONDON CLAY)							
1.5	Dry	Very stiff dark grey CLAY. (LONDON CLAY)		21.1	SPT 21.1-21.55m	(7) 34	21.1	21.55	D
1.5	Dry				SPT 22.5-22.95m	(8) 37	22.5	22.95	D
							23.5		D
1.5	Dry				SPT 24.0-24.45m	(8) 40	24.0	24.45	D
							25.1		D
1.5	Dry				SPT 25.4-25.85m	(9) 40	25.4	25.85	D
1.5	Dry				SPT 27.0-27.45m	(10) 43	27.0	27.45	D

DRILLING			GROUNDWATER				
TYPE (DIAMETER)	FROM	TO	DEPTH STRUCK	BEHAVIOUR	DEPTH SEALED	DATE	DEPTH OF CASING
150mm	0.0m	30.0m	Dry				

REFER TO KEY AT BEGINNING OF THIS APPENDIX FOR EXPLANATION OF SYMBOLS

BOREHOLE RECORD SHEET 4 OF 5

SOILTECHNICS	GROUND LEVEL	CO-ORDINATES
	LOCATION PLAN ON DRAWING No STD0953U-02	DATE OF EXCAVATION 13.03.07
	PROJECT No's 3, 5 & 7, Fitzjohn's Avenue, London Proposed Residential Development	
	PROJECT REF. STD0953U	BOREHOLE No BH01

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CASING DEPTH (m)	WATER (m)	STRATA DESCRIPTION	LEGEND	DEPTH (m)	TEST RESULTS		SAMPLING		
					TYPE AND DEPTH	RESULT	FROM (m)	TO (m)	TYPE
		Very stiff dark grey CLAY. (LONDON CLAY)							
1.5							28.0	28.4	U 100 (29)
							28.5		D
1.5	Dry				SPT 29.1-29.55m	(10) 43	29.1	29.55	D
1.5	Dry			30.0	SPT 30.0-30.45m	(11) 46	30.0	30.45	D
		BOREHOLE TERMINATED at 30.0m							

DRILLING			GROUNDWATER				
TYPE (DIAMETER)	FROM	TO	DEPTH STRUCK	BEHAVIOUR	DEPTH SEALED	DATE	DEPTH OF CASING
150mm	0.0m	30.0m	Dry				

REFER TO KEY AT BEGINNING OF THIS APPENDIX FOR EXPLANATION OF SYMBOLS

BOREHOLE RECORD SHEET 5 OF 5

SOILTECHNICS

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GROUND LEVEL	CO-ORDINATES
LOCATION PLAN ON DRAWING No STD0953U-02	DATE OF EXCAVATION 13.03.07
PROJECT **No's 3, 5 & 7, Fitzjohn's Avenue, London** **Proposed Residential Development**	
PROJECT REF. STD0953U	BOREHOLE No BH01