CampbellReith
consulting engineers

13 Langland Gardens, NW3 6QD

Basement Impact Assessment Audit

For

London Borough of Camden

Project Number: 12066-94
Revision: F1

March 2016

Campbell Reith Hill LLP
Friars Bridge Court
41-45 Blackfriars Road
London
SE1 8NZ

T:+44 (0)20 7340 1700
F:+44 (0)20 7340 1777
E:london@campbellreith.com
W:www.campbellreith.com

Document History and Status

Revision	Date	Purpose/Status	File Ref	Author	Check	Review
D1	29/01/2016	Comment	AGjw12066-94-290116-13 Langland Gardens-D1.doc	A Gleeson	A J Marlow	A J Marlow
F1	30/03/2016	Planning	AJMav12066-94-300316-13 Langland Gardens-F1.doc	A J Marlow	E Brown	E Brown

Document Details

Last saved	30/03/2016 14:32
Path	AJMav12066-94-300316-13 Langland Gardens-F1.doc
Author	A J Marlow
Project Partner	E M Brown, BSc MSc CGeol FGS
Project Number	12066-94
Project Name	13 Langland Gardens, NW3 6QD
Planning Reference	2015/4547/P

Contents

Appendix

1.0 NON-TECHNICAL SUMMARY

1.1. CampbellReith was instructed by London Borough of Camden, (LBC) to carry out an audit on the Basement Impact Assessment submitted as part of the Planning Submission documentation for 13 Langland Gardens, NW3 6QD (planning reference 2015/4547/P). The basement is considered to fall within Category A as defined by the Terms of Reference.

1.2. The Audit reviewed the Basement Impact Assessment for potential impact on land stability and local ground and surface water conditions arising from basement development in accordance with LBC's policies and technical procedures.

1.3. CampbellReith was able to access LBC's Planning Portal and gain access to the latest revision of submitted documentation and reviewed it against an agreed audit check list. Additional information was provided to allow a further review of available information.

1.4. The Basement Impact Assessment (BIA) has been carried out by Taylor Whalley Spyra Consulting Civil and Structural Engineers. The author is a Fellow of the Institution of Civil Engineers and has extensive experience of basement developments, which is accepted as complying with requirements of CPG4.

1.5. The proposal is to increase the depth of the existing basement by underpinning the existing footings and carrying out a reduced dig varying between 1.0-2.0m to the entire basement, to allow for the space to be converted into a two bedroom flat. It is also proposed to extend the basement to form two front light wells for use as a bike store. A new concrete retaining wall will be constructed to the rear of the building to allow for the basement to be extended up to 2.23m into the rear garden with the construction of two rear light wells and an extension to the upper ground floor.

1.6. It is recommended that the impact from the basement excavation and construction on the neighbouring properties is undertaken during the Party Wall Award Process, in particularly No.11 Langland Gardens which shares the party wall which is to be underpinned and No. 15 Langland Gardens which is within 6m of the proposed basement alternations. Further investigation of the foundations to the surrounding properties is also recommended. Proposals should be put in place for providing a movement monitoring strategy during excavation and construction, to the neighbouring properties and infrastructure. Prediction of the damage category to the neighbouring properties and upper floor flats should also be assessed.

1.7. It is accepted that the street is at low risk of surface water flooding and that there are no concerns with respect to slope stability and the water environment.

2.0 INTRODUCTION

2.1. CampbellReith was instructed by London Borough of Camden (LBC) on 16 December 2015 to carry out a Category A Audit on the Basement Impact Assessment (BIA) submitted as part of the Planning Submission documentation for 13 Langland Gardens, London, NW3 6QD (planning reference 2015/4547/P).

2.2. The Audit was carried out in accordance with the Terms of Reference set by LBC. It reviewed the Basement Impact Assessment for potential impact on land stability and local ground and surface water conditions arising from basement development.

2.3. A BIA is required for all planning applications with basements in Camden in general accordance with policies and technical procedures contained within

- Guidance for Subterranean Development (GSD). Issue 01. November 2010. Ove Arup & Partners.
- Camden Planning Guidance (CPG) 4: Basements and Lightwells.
- Camden Development Policy (DP) 27: Basements and Lightwells.
- Camden Development Policy (DP) 23: Water.

2.4. The BIA should demonstrate that schemes:

a) maintain the structural stability of the building and neighbouring properties;

b) avoid adversely affecting drainage and run off or causing other damage to the water environment; and,

c) avoid cumulative impacts upon structural stability or the water environment in the local area.

2.5. The BIA should evaluate the impacts of the proposed basement considering the issues of hydrology, hydrogeology and land stability via the process described by the GSD and to make recommendations for the detailed design.

2.6. LBC's Audit Instruction described the planning proposal as *"Excavation of the existing basement to create a 2-bed unit including an extension at upper ground level to the rear of the property incorporating new windows to the rear and side elevation and light well to the front."*

2.7. The Audit Instruction also confirmed 13 Langland Gardens does not involve, or neighbour, listed buildings.

2.8. CampbellReith accessed LBC's Planning Portal on 13 January 2016 and gained access to the following relevant documents for audit purposes:

- Basement Impact Assessment Report (BIA) – Taylor Whalley Spyra dated June 2015
- Planning Application Drawings, dated January 2014, consisting of
  - Location Plan
  - Existing Plans, Sections and Elevations
  - Proposed Plans, Sections and Elevations
- Design & Access Statement dated October 2015
- Planning Comments and Response
- BIA – Letter from TWS with Additional Information dated 7 January 2016

2.9. CampbellReith received a letter dated 7 March 2016 from Taylor Whalley Spyra responding to the comments contained in our earlier audit of their BIA, which has resulted in a further review of the available information and the issue of this final report.

3.0 BASEMENT IMPACT ASSESSMENT AUDIT CHECK LIST

Item	Yes/No/NA	Comment
Are BIA Author(s) credentials satisfactory?	No	The BIA Author's qualifications have not been stated.
Is data required by Cl.233 of the GSD presented?	Yes	
Does the description of the proposed development include all aspects of temporary and permanent works which might impact upon geology, hydrogeology and hydrology?	Yes	
Are suitable plan/maps included?	Yes	
Do the plans/maps show the whole of the relevant area of study and do they show it in sufficient detail?	Yes	
Land Stability Screening: Have appropriate data sources been consulted? Is justification provided for 'No' answers?	No	Justification has not been provided for all 'No' answers. Q6: Architectural Report referenced but not provided. Q13: No information provided on foundations to neighbouring properties.
Hydrogeology Screening: Have appropriate data sources been consulted? Is justification provided for 'No' answers?	Yes	
Hydrology Screening: Have appropriate data sources been consulted? Is justification provided for 'No' answers?	Yes	
Is a conceptual model presented?	No	
Land Stability Scoping Provided? Is scoping consistent with screening outcome?	No	BIA does not identify need for scoping; however this is not accepted.

Item	Yes/No/NA	Comment
Hydrogeology Scoping Provided? Is scoping consistent with screening outcome?	No	BIA does not identify need for scoping.
Hydrology Scoping Provided? Is scoping consistent with screening outcome?	No	BIA does not identify need for scoping.
Is factual ground investigation data provided?	No	Limited site investigation in the form of foundation investigation pits has been carried out. Geological information based on desk study.
Is monitoring data presented?	No	No groundwater was noted in trial holes.
Is the ground investigation informed by a desk study?	Yes	
Has a site walkover been undertaken?	Yes	
Is the presence/absence of adjacent or nearby basements confirmed?	No	The impact on neighbouring properties has not been taken into consideration; and the presence/absence of neighbouring basements has not been stated.
Is a geotechnical interpretation presented?	No	
Does the geotechnical interpretation include information on retaining wall design?	No	
Are reports on other investigations required by screening and scoping presented?	No	Screening refers to 'Architectural Report'; this report has not been provided.
Are baseline conditions described, based on the GSD?	Yes	
Do the base line conditions consider adjacent or nearby basements?	No	Clarification is required
Is an Impact Assessment provided?	No	

Item	Yes/No/NA	Comment
Are estimates of ground movement and structural impact presented?	No	
Is the Impact Assessment appropriate to the matters identified by screen and scoping?	No	
Has the need for mitigation been considered and are appropriate mitigation methods incorporated in the scheme?	No	The need for mitigation has been considered; however a ground movement assessment should be provided to inform the mitigation measures required to the adjoining property.
Has the need for monitoring during construction been considered?	No	Proposals for monitoring of neighbouring properties and infrastructure should be included in the BIA.
Have the residual (after mitigation) impacts been clearly identified?	No	No assessment of the residual impact on neighbouring properties has been considered.
Has the scheme demonstrated that the structural stability of the building and neighbouring properties and infrastructure will be maintained?	Yes	However, predicted ground movements require further consideration.
Has the scheme avoided adversely affecting drainage and run-off or causing other damage to the water environment?	Yes	
Has the scheme avoided cumulative impacts upon structural stability or the water environment in the local area?	Yes	
Does report state that damage to surrounding buildings will be no worse than Burland Category 2?	No	Limited to the party wall. Predicted damage assessment for all neighbouring properties required.
Are non-technical summaries provided?	No	

4.0 DISCUSSION

4.1. The Basement Impact Assessment (BIA) has been carried out by Taylor Whalley Spyra Consulting Civil and Structural Engineers. The qualifications of the author have not been stated, therefore it is not known if the author's qualifications are in compliance with the requirements of CPG4.

4.2. The author is a Fellow of the Institution of Civil Engineers and has extensive experience of basement developments, which is accepted as complying with requirements of CPG4.

4.3. The LBC Instruction to proceed with the audit identified that the basement proposal neither involved a listed building nor is adjacent to listed buildings. The Design & Access Statement identified that 13 Langland Gardens is located in the Redington Frognal Conservation Area.

4.4. 13 Langland Gardens is semi-detached house divided into three flats. The upper ground floor flat has direct access to the existing basement, which has a restricted ceiling height. The proposal is to increase the depth of the existing basement by underpinning the existing footings in a 'hit and miss' sequence, installing temporary propping and carrying out a reduced dig varying between 1.0-2.0m to the entire basement. The proposal is to allow for the space to be converted into a two bedroom flat. It is also proposed to extend the basement to form two front light wells with a bike store. A new concrete retaining wall will be constructed to the rear of the building to allow for the basement to be extended up to 2.23m into the rear garden with the construction of two rear light wells and an extension to the upper ground floor.

4.5. Limited site investigations in the form of foundation investigation pits have been carried out to a maximum depth of 2.0m. The BIA states that the pits show Made Ground up to a depth of 0.6m underlain by Claygate Beds. This is in line with local geological maps and British Geological Survey borehole records for the area.

4.6. Trial holes undertaken did not encounter any groundwater. Groundwater monitoring has not been carried out. It is accepted that the proposed basement is unlikely to encounter the groundwater table.

4.7. Claygate Beds have a high shrink-swell potential however this is not deemed to be significant with regard to the proposed works.

4.8. The damage category to the existing building for the proposed development is estimated to be Category 1 on the Burland Damage Scale. Prediction of the damage category to the neighbouring properties and upper floor flats should also be assessed.

4.9. It is accepted that the scope of underpinning works is not significant and that damage is unlikely to be in excess of Burland Damage Category 1 – Very Slight.

4.10. It is noted on the 'Proposed Lower Ground Floor' drawing 13CLANPL100, that a number of columns and walls are to be removed. It is recommended that a review of these superstructure alterations be undertaken, to assess their impact on the existing foundation loadings.

4.11. TWS have provided their latest structural layout drawings no. 8803/PA0IA, PA03A and PA05 which identify that there appears to be no significant impact on the existing foundations due to changes in superstructure loading.

4.12. It is accepted that the street is at low risk of surface water flooding. It is noted that according to the Camden Geological, Hydrogeological and Hydrological Study Flood Map, the street flooded in 1975 but not in 2002. The BIA states that within Camden Flood Risk Management Strategy that works by Thames Water have been undertaken to alleviate flood risk within this area. The EA flood plan also confirms that the property is in an area of low to medium risk with no specific local issues highlighted.

4.13. It is recommended that the impact from the basement excavation and construction on the neighbouring properties be assessed in further detail, in particularly No.11 Langland Gardens which shares the party wall which is to be underpinned and No. 15 Langland Gardens which is within 6m of the proposed basement alternations. Further investigation of the foundations to the surrounding properties is also recommended. Proposals should be put in place for providing a movement monitoring strategy during excavation and construction, to the neighbouring properties.

4.14. It is accepted that additional trailpits to investigate the foundations of No.11 and No.15 Langland Gardens can take place once planning approval is obtained in order to inform the Party Wall Award Process. A prediction of the damage category to the neighbouring properties can then be undertaken as part of this Award Process and a suitable movement monitoring strategy can be agreed.

4.15. It is accepted that there are no slope stability concerns regarding the proposed development.

4.16. It is accepted that any increase in hardstanding will be negligible and is unlikely to affect the adjacent properties and will not impact the wider hydrogeology of the area.

4.17. Indicative calculations and associated temporary works for the retaining wall design to the lightwells should be submitted with the BIA.

4.18. Additional retaining wall structural calculations provided with TWS's letter dated 7 March 2016 are accepted.

5.0 CONCLUSIONS

5.1. The Basement Impact Assessment (BIA) has been carried out by Taylor Whalley Spyra Consulting Civil and Structural Engineers. The qualifications and experience of the author are now in compliance with the requirements of CPG4.

5.2. The BIA states that the underpins will be founded in the Claygate Beds.

5.3. The Claygate Beds have a high shrink-swell potential however this is not deemed to be significant with regard to the proposed works.

5.4. It is accepted that the proposed basement is unlikely to encounter the groundwater table.

5.5. Further investigation of the foundations to the surrounding properties should be carried out to inform the Party Wall Award Process.

5.6. Prediction of the damage category to the neighbouring properties, upper floor flats and adjoining infrastructure should be untaken as part of the Party Wall Award Process, which should also include a movement monitoring strategy during excavation and construction.

5.7. Indicative calculations for the retaining wall design to the lightwells are accepted.

5.8. It is accepted that the effect of the superstructure alterations will not impact on the existing foundation loadings.

5.9. It is accepted that the street is at low risk of surface water flooding.

5.10. It is accepted that there are no slope stability concerns regarding the proposed development.

5.11. It is accepted that any increase in hardstanding will be negligible and is unlikely to affect the adjacent properties and will not impact the wider hydrogeology of the area.

Appendix 1: Residents' Consultation Comments

Residents' Consultation Comments

Surname	Address	Date	Issue raised	Response
Chung	15 Langland Gardens, NW3	10/12/15	Subsidence and damp Potential damage to adjoining buildings	Further information required with respect to building damage assessment and temporary and permanent works. The proposed development is unlikely to encounter the groundwater table hence the proposed works will not impact the wider hydrogeology of the area.
The Heath & Hampstead Society	NW3 1XD	3/11/15	Subsoil Problems	The existing and proposed foundations are founded in the Claygate Beds. The proposed underpinning is unlikely to encounter the groundwater table. The Claygate Beds have a high shrink-swell potential however this is not significant with regard to the proposed works. There are no slope stability concerns regarding the proposed development.
The Heath & Hampstead Society	NW3 1XD	3/11/15	Flooding	The street is at low risk of surface water flooding. It is noted that according to the Camden Geological, Hydrogeological and Hydrological Study Flood Map that the street flooded in 1975 but not in 2002. The BIA states that within Camden Flood Risk Management Strategy that works by Thames Water have been undertaken to alleviate flood risk within this area. The EA flood plan also confirms that the property is in an area of low to medium risk with no specific local issues highlighted.
The Heath & Hampstead Society	NW3 1XD	3/11/15	Potential damage to adjoining buildings	Refer to similar comment above.

Appendix 2: Audit Query Tracker

Audit Query Tracker

Query No	Subject	Query	Status	Date closed out
1	BIA	Qualifications of the BIA author	CV and past project experience accepted.	07/03/16
2	Stability	Damage Category Assessment for neighbouring properties within 6.0m of the proposed development.	To be undertaken as part of the Party Wall Award Process.	07/03/16
3	Stability	Movement Monitoring Strategy to neighbouring properties and upper floor flats to be provided.	To be undertaken as part of the Party Wall Award process.	07/03/16
4	Stability	Indicative calculations and associated temporary works for the retaining wall design to the lightwells should be submitted.	Indicative Structural calculations accepted.	07/03/16
5	Stability	Assessment of superstructure alterations on existing foundation loadings	Additional Structural layout drawings accepted.	07/03/16

Appendix 3: Supplementary Supporting Documents

TWS Letter Dated 7 March 2016

Our ref: SCL/PC/8803

Your ref:

Date: 7th March 2016

Mr Ian Gracie
London Borough of Camden

BY EMAIL: ian.gracie@camden.gov.uk

Dear Sir,

re: **13 Langland Gardens, London, NW3 6QD**
Ref: Basement Impact Assessment Audit by Campbell Reith – 12066-94 Rev D1
Date: January 2016

We are in receipt of Audit Report as referenced above and would respond to the outstanding points as follows.

It would seem that our letter dated 7th January 2016 never came to the attention of Campbell Reith as many of the issues are already dealt therein. Letter attached for reference.

In answer to the more specific points in the Discussion and Conclusions, using the same number reference for simplicity:

4.1 Please refer to item no. 1.2 in our letter of 7th January 2016.

4.2 Noted and confirmed.

4.3 Noted and confirmed.

4.4 Noted and confirmed.

4.5 Noted and confirmed.

4.6 Noted and confirmed.

4.7 As already stated this work is best assessed by precedent and experience. Similar scale of works have been successfully implemented on numerous occasions without detrimental effect. The most important factor is sound design and implementation by those with the relevant experience. On this basis predicted ground movements will be confined within the property and its party wall. Some horizontal strain will develop and we predict that maximum settlements are likely to be in the order of 2mm with distortions of less than 1mm and horizontal strains of around 0.03%. Any potential damage caused would be aesthetic in nature resulting, in the worst case, in fine cracks which may easily be treated by normal decoration (Category 1 damage as defined within the attached guide, contained within our letter of 7th January 2016). We consider the level of predicted movements normal and acceptable in terms of risk and that further mitigation measures are not possible or necessary.

With this value of movement we do not predict any damage to upper floors or structural implication.

4.8 Please find attached latest structural layout drawings no. 8803/PA01A, 8803/PA03A and 8803/PA05. The change in loading is assessed and we do not see any significant implication or settlement of foundation due to the new construction.

4.9 Noted and confirmed.

4.10 As the predicted movement is extremely small we do not see any reason to further carry out trial holes at such a distance from the property and works. This request can only be formed once planning is confirmed and party wall agreement is in place.

3 Dufferin Avenue,
Barbican, London, EC1Y 8PQ
T: 020 7253 2626
F: 020 7253 2767
E: tws@tws.uk.com
W: www.tws.uk.com

4.11 Noted and confirmed.

4.12 Noted and confirmed.

4.13 Please find attached indicative calculations as requested. This is an initial stage, further calculations and design will be done as part of the building control and party wall agreement.

5.1 Please find attached my CV and brief examples relating to our basement experience (contained within our letter of 7th January 2016). During the last 10 years in particular we have undertaken many successful basement installations in London a number of which have been multi-storey in nature. As my point within the initial part of this letter and as you know, ground engineering is largely based on precedent and experience and the scale of development concerned here has been undertaken on numerous occasions in similar conditions without detrimental effect.

5.2 Noted and confirmed.

5.3 Noted and confirmed.

5.4 Noted and confirmed.

5.5 Please refer to my comment in point 4.7 – prediction of movement and damage is negligible and can be repaired by decoration work. Monitoring can be assessed and carried out as part of the party wall agreement.

5.6 This is not necessary due to the scale of excavation and depth of underpinning, please refer to my comment under point 4.10.

5.7 Please find attached indicative calculations.

5.8 Yes this will be part of the detailed design once planning is granted.

5.9 Noted and confirmed.

5.10 Noted and confirmed.

5.11 Noted and confirmed.

In conclusion, and as stated, it is our opinion that the thorough screening process as undertaken is fully in compliance with LBC guidelines.

The basement is of modest depth and a combination of normal sequenced underpinning and temporary earthworks and pin support will be employed until the structural box is complete and integrity provided.

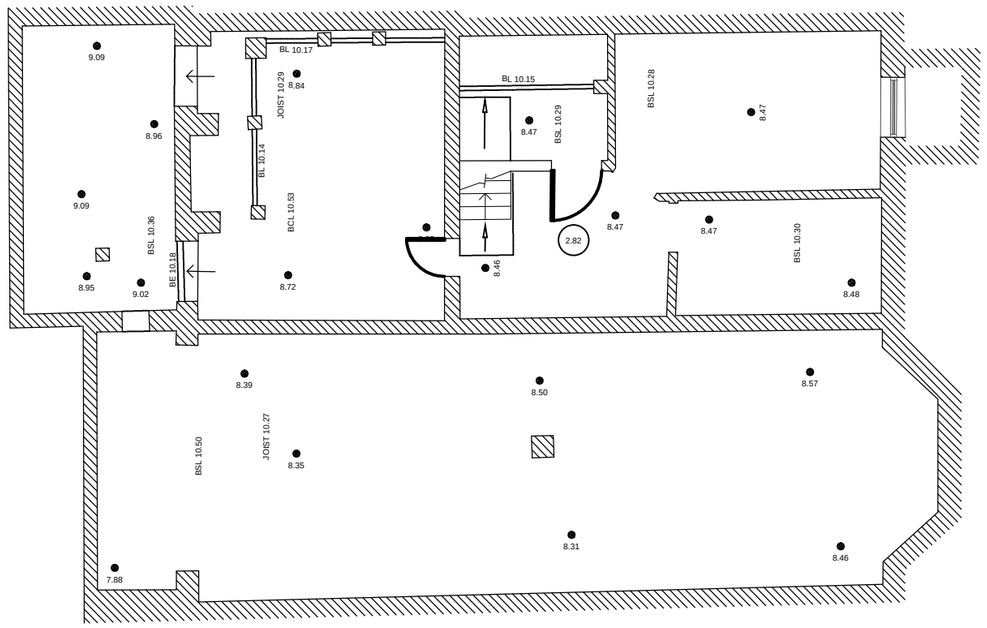
The sequence will be agreed with the chosen contractor who will prepare full method statements and calculations as may be required for agreement and incorporation into the Party Wall Agreement.

We trust that this additional information will enable you to complete your audit with a positive conclusion.

For and on behalf of
TAYLOR WHALLEY SPYRA

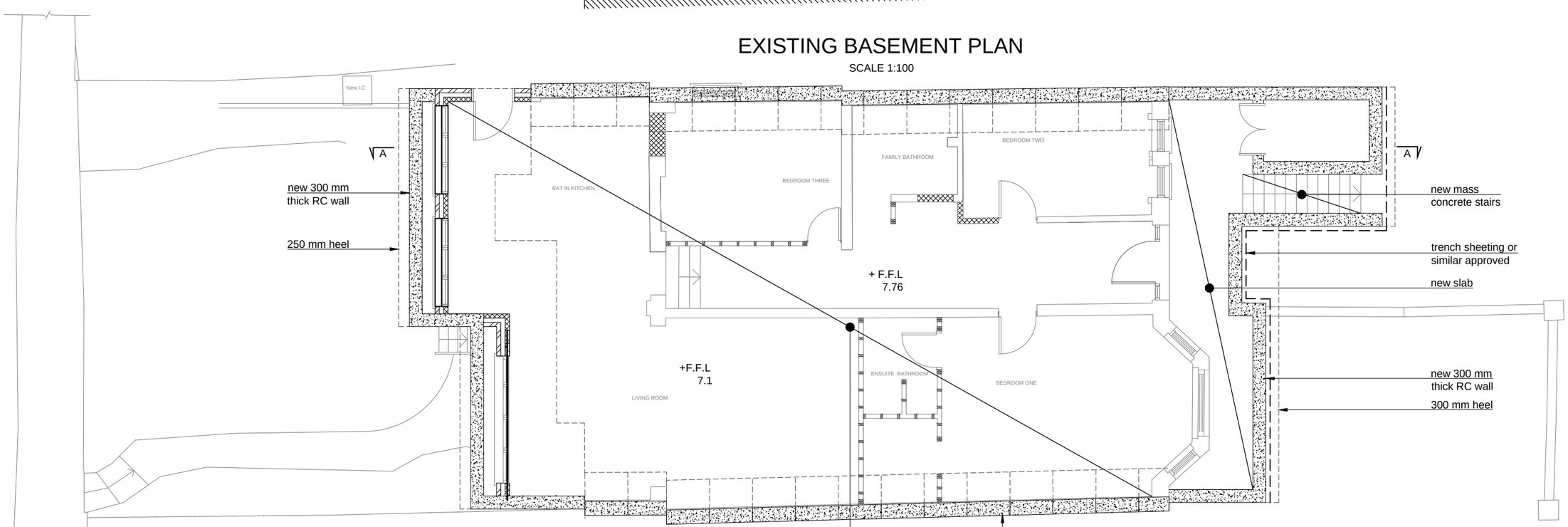
SIMON LANE
BSc(Eng), CEng, FICE, FIStructE

Encs: TWS letter dated 7.1.16 / Drawings no. 8803/PA01A/PA03A/PA05 / Calculations
c.c. Nick Zangwill / Elinoar Haseen



EXISTING BASEMENT PLAN

SCALE 1:100



PROPOSED BASEMENT PLAN

SCALE 1:100

Finishes & Insulation to Arch details
On New 150 thk RC slab
with Mesh A252 top and bottom
On 1200 Visqueen
On 50mm Blinding
On 150thk Hardcore well compacted

1m wide x330mm thick min.
underpins in agreed sequence
with rebar cage reinforcement
and dowels between pins

Rev.A - drawing amended - SA - 04.03.16

taylor whalley spyra
consulting civil and structural engineers
3 Dufferin Avenue, Barbican, LONDON EC1Y 8PQ
Tel (020) 7253 2626 Fax (020) 7253 2767
E-mail: tws@tws.uk.com Website: www.tws.uk.com

Contract	Title	Scale	Date	Drawn
13C Langland Gardens, London, NW3 6QD	Existing and Proposed Basement Plan	1:100	08.06.15	SA
		Job No. 8803	Drawing No. PA01	Rev. A

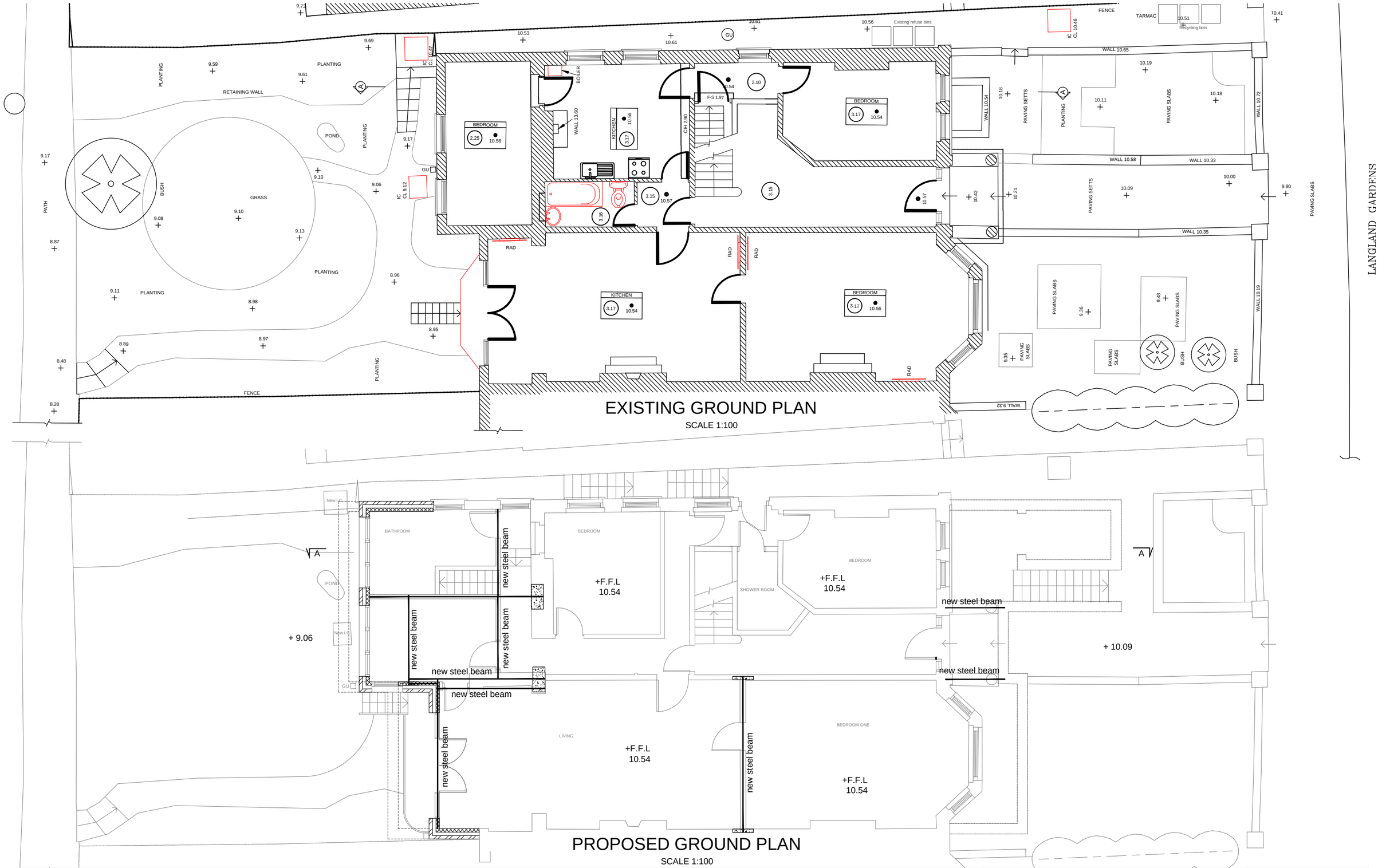
PROPOSED SECTION A-A

SCALE 1:100

Rev.A - drawing amended - SA - 04.03.16

taylor whalley spyra
consulting civil and structural engineers
3 Dufferin Avenue, Barbican, LONDON EC1Y 8PQ
Tel (020) 7253 2626 Fax (020) 7253 2767
E-mail: tws@tws.uk.com Website: www.tws.uk.com

Contract	Title	Scale	Date	Drawn
13C Langland Gardens, London, NW3 6QD	Proposed Section A-A	1:100	08.06.15	AK
		Job No. 8803	Drawing No. PA03	Rev. A



EXISTING GROUND PLAN

SCALE 1:100

PROPOSED GROUND PLAN

SCALE 1:100

taylor whalley spyra
consulting civil and structural engineers
3 Dufferin Avenue, Barbican, LONDON EC1Y 8PQ
Tel (020) 7253 2626 Fax (020) 7253 2767
E-mail: tws@tws.uk.com Website: www.tws.uk.com

Contract	Title	Scale	Date	Drawn
13C Langland Gardens, London, NW3 6QD	Existing and Proposed Ground Plan	1:100	04.03.16	SA
		Job No. 8803	Drawing No. PA05	Rev. -

Project				Job no.	
13c Langland Gardens, London,NW3 6QD				8803	
Calcs for				Start page no./Revision	
Frontbay Lightwell - RC Wall Design				1	
Calcs by	Calcs date	Checked by	Checked date	Approved by	Approved date
NB	04/03/2016	UM	04/03/2016		

RETAINING WALL

Retaining wall analysis in accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.3.00

Retaining wall details

Stem type	Cantilever
Stem height	h_{stem} = **1600** mm
Prop height	h_{prop} = **1600** mm
Stem thickness	t_{stem} = **300** mm
Angle to rear face of stem	α = **90** deg
Stem density	γ_{stem} = **25** kN/m^3
Toe length	l_{toe} = **1020** mm
Heel length	l_{heel} = **250** mm
Base thickness	t_{base} = **350** mm
Base density	γ_{base} = **25** kN/m^3
Height of retained soil	h_{ret} = **1600** mm
Angle of soil surface	β = **0** deg
Depth of cover	d_{cover} = **0** mm
Height of water	h_{water} = **1000** mm
Water density	γ_w = **10** kN/m^3

Retained soil properties

Moist density	γ_{mr} = **21** kN/m^3
Saturated density	γ_{sr} = **23** kN/m^3

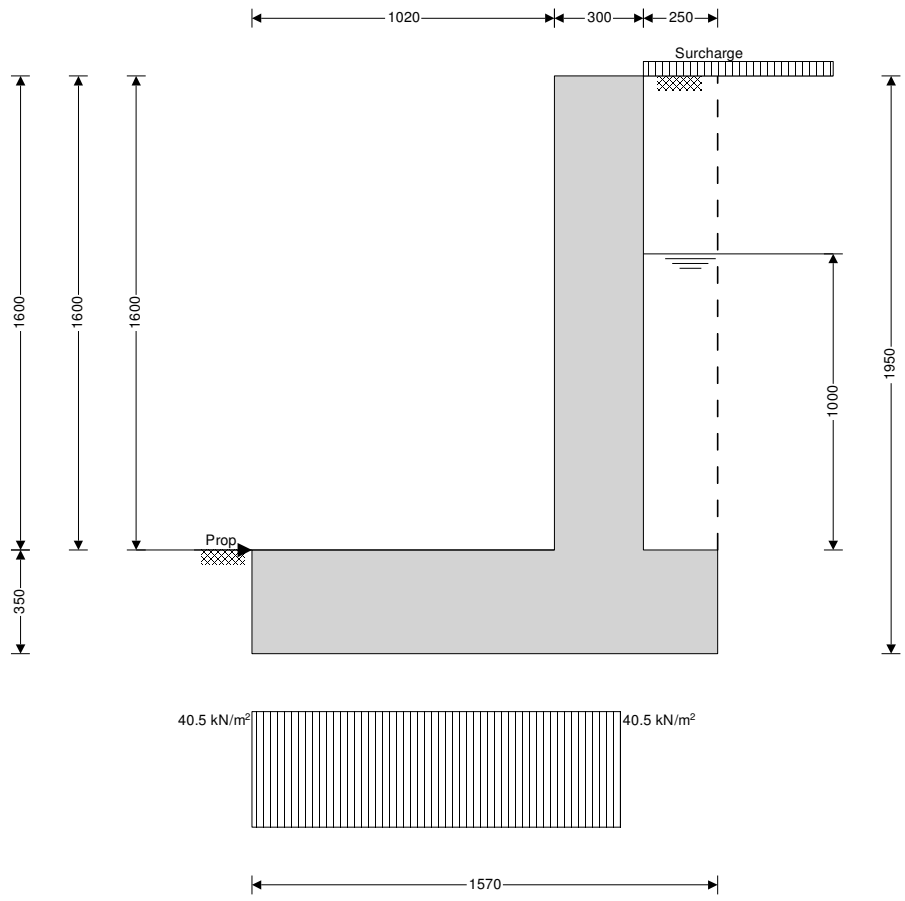
Base soil properties

Moist density	γ_{mb} = **18** kN/m^3

Loading details

Permanent surcharge load	$Surcharge_G$ = **5** kN/m^2
Variable surcharge load	$Surcharge_Q$ = **5** kN/m^2

Tedds	Project: 13c Langland Gardens, London,NW3 6QD				Job no.: 8803	
	Calcs for: Frontbay Lightwell - RC Wall Design				Start page no./Revision: 2	
	Calcs by: NB	Calcs date: 04/03/2016	Checked by: UM	Checked date: 04/03/2016	Approved by:	Approved date:



Calculate retaining wall geometry

Base length	$l_{base} = l_{toe} + t_{stem} + l_{heel} =$ **1570** mm
Saturated soil height	$h_{sat} = h_{water} + d_{cover} =$ **1000** mm
Moist soil height	$h_{moist} = h_{ret} - h_{water} =$ **600** mm
Length of surcharge load	$l_{sur} = l_{heel} =$ **250** mm
- Distance to vertical component	$x_{sur\_v} = l_{base} - l_{heel} / 2 =$ **1445** mm
Effective height of wall	$h_{eff} = h_{base} + d_{cover} + h_{ret} =$ **1950** mm
- Distance to horizontal component	$x_{sur\_h} = h_{eff} / 2 =$ **975** mm
Area of wall stem	$A_{stem} = h_{stem} \times t_{stem} =$ **0.48** m²
- Distance to vertical component	$x_{stem} = l_{toe} + t_{stem} / 2 =$ **1170** mm
Area of wall base	$A_{base} = l_{base} \times t_{base} =$ **0.55** m²
- Distance to vertical component	$x_{base} = l_{base} / 2 =$ **785** mm
Area of saturated soil	$A_{sat} = h_{sat} \times l_{heel} =$ **0.25** m²
- Distance to vertical component	$x_{sat\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat} =$ **1445** mm
- Distance to horizontal component	$x_{sat\_h} = (h_{sat} + h_{base}) / 3 =$ **450** mm
Area of water	$A_{water} = h_{sat} \times l_{heel} =$ **0.25** m²
- Distance to vertical component	$x_{water\_v} = l_{base} - (h_{sat} \times l_{heel}^2 / 2) / A_{sat} =$ **1445** mm
- Distance to horizontal component	$x_{water\_h} = (h_{sat} + h_{base}) / 3 =$ **450** mm
Area of moist soil	$A_{moist} = h_{moist} \times l_{heel} =$ **0.15** m²
- Distance to vertical component	$x_{moist\_v} = l_{base} - (h_{moist} \times l_{heel}^2 / 2) / A_{moist} =$ **1445** mm
- Distance to horizontal component	$x_{moist\_h} = (h_{moist} \times (t_{base} + h_{sat} + h_{moist} / 3) / 2 + (h_{sat} + t_{base})^2/2) / (h_{sat} + t_{base} + h_{moist} / 2) =$ **834** mm

Partial factors on actions - Table A.3 - Combination 1

Permanent unfavourable action	γ_G = **1.35**
Permanent favourable action	γ_{Gf} = **1.00**
Variable unfavourable action	γ_Q = **1.50**
Variable favourable action	γ_{Qf} = **0.00**

Partial factors for soil parameters – Table A.4 - Combination 1

Angle of shearing resistance	$\gamma_{\phi'}$ = **1.00**
Effective cohesion	$\gamma_{c'}$ = **1.00**
Weight density	γ_γ = **1.00**

Soil coefficients

Coefficient of friction to back of wall	K_{fr} = **0.325**
Coefficient of friction to front of wall	K_{fb} = **0.325**
Coefficient of friction beneath base	K_{fbb} = **0.325**
Active pressure coefficient	K_A = **0.333**
Passive pressure coefficient	K_P = **3.700**

Overturning check

Vertical forces on wall

Wall stem	$F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **12** kN/m
Wall base	$F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **13.7** kN/m
Saturated retained soil	$F_{sat\_v} = \gamma_{Gf} \times A_{sat} \times (\gamma_{sr} - \gamma_w)$ = **3.3** kN/m
Water	$F_{water\_v} = \gamma_{Gf} \times A_{water} \times \gamma_w$ = **2.5** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}$ = **3.2** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{sat\_v} + F_{moist\_v} + F_{water\_v}$ = **34.6** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_A \times (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times h_{eff}$ = **9.3** kN/m
Saturated retained soil	$F_{sat\_h} = \gamma_G \times K_A \times (\gamma_{sr} - \gamma_w) \times (h_{sat} + h_{base})^2 / 2$ = **5.3** kN/m
Water	$F_{water\_h} = \gamma_G \times \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2$ = **12.3** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr} \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base}))$ = **9.4** kN/m
Total	$F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{water\_h} + F_{sur\_h}$ = **36.3** kN/m

Overturning moments on wall

Surcharge load	$M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h}$ = **9** kNm/m
Saturated retained soil	$M_{sat\_OT} = F_{sat\_h} \times x_{sat\_h}$ = **2.4** kNm/m
Water	$M_{water\_OT} = F_{water\_h} \times x_{water\_h}$ = **5.5** kNm/m
Moist retained soil	$M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **7.8** kNm/m
Total	$M_{total\_OT} = M_{sat\_OT} + M_{moist\_OT} + M_{water\_OT} + M_{sur\_OT}$ = **24.8** kNm/m

Restoring moments on wall

Wall stem	$M_{stem\_R} = F_{stem} \times x_{stem}$ = **14** kNm/m
Wall base	$M_{base\_R} = F_{base} \times x_{base}$ = **10.8** kNm/m
Saturated retained soil	$M_{sat\_R} = F_{sat\_v} \times x_{sat\_v}$ = **4.7** kNm/m
Water	$M_{water\_R} = F_{water\_v} \times x_{water\_v}$ = **3.6** kNm/m
Moist retained soil	$M_{moist\_R} = F_{moist\_v} \times x_{moist\_v}$ = **4.6** kNm/m
Total	$M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{sat\_R} + M_{moist\_R} + M_{water\_R}$ = **37.7** kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT} = \mathbf{1.521}$

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem} = \mathbf{16.2}$ kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base} = \mathbf{18.5}$ kN/m

Surcharge load $F_{sur\_v} = (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times l_{heel} = \mathbf{3.6}$ kN/m

Saturated retained soil $F_{sat\_v} = \gamma_G \times A_{sat} \times (\gamma_{sr} - \gamma_w) = \mathbf{4.4}$ kN/m

Water $F_{water\_v} = \gamma_G \times A_{water} \times \gamma_w = \mathbf{3.4}$ kN/m

Moist retained soil $F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr} = \mathbf{4.3}$ kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{sat\_v} + F_{moist\_v} + F_{water\_v} + F_{sur\_v} = \mathbf{50.3}$ kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times h_{eff} = \mathbf{9.3}$ kN/m

Saturated retained soil $F_{sat\_h} = \gamma_G \times K_A \times (\gamma_{sr} - \gamma_w) \times (h_{sat} + h_{base})^2 / 2 = \mathbf{5.3}$ kN/m

Water $F_{water\_h} = \gamma_G \times \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2 = \mathbf{12.3}$ kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr} \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) = \mathbf{9.4}$ kN/m

Total $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{water\_h} + F_{sur\_h} = \mathbf{36.3}$ kN/m

Moments on wall

Wall stem $M_{stem} = F_{stem} \times x_{stem} = \mathbf{19}$ kNm/m

Wall base $M_{base} = F_{base} \times x_{base} = \mathbf{14.6}$ kNm/m

Surcharge load $M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h} = \mathbf{-3.9}$ kNm/m

Saturated retained soil $M_{sat} = F_{sat\_v} \times x_{sat\_v} - F_{sat\_h} \times x_{sat\_h} = \mathbf{3.9}$ kNm/m

Water $M_{water} = F_{water\_v} \times x_{water\_v} - F_{water\_h} \times x_{water\_h} = \mathbf{-0.7}$ kNm/m

Moist retained soil $M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h} = \mathbf{-1.7}$ kNm/m

Total $M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{water} + M_{sur} = \mathbf{31.3}$ kNm/m

Check bearing pressure

Propping force $F_{prop\_base} = F_{total\_h} = \mathbf{36.3}$ kN/m

Distance to reaction $\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} = \mathbf{621}$ mm

Eccentricity of reaction $e = \bar{x} - l_{base} / 2 = \mathbf{-164}$ mm

Loaded length of base $l_{load} = 2 \times \bar{x} = \mathbf{1242}$ mm

Bearing pressure at toe $q_{toe} = F_{total\_v} / l_{load} = \mathbf{40.5}$ kN/m^2

Bearing pressure at heel $q_{heel} = \mathbf{0}$ kN/m^2

Factor of safety $FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) = \mathbf{3.702}$

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Partial factors on actions - Table A.3 - Combination 2

Permanent unfavourable action $\gamma_G = \mathbf{1.00}$

Permanent favourable action $\gamma_{Gf} = \mathbf{1.00}$

Variable unfavourable action $\gamma_Q = \mathbf{1.30}$

Variable favourable action $\gamma_{Qf} = \mathbf{0.00}$

Partial factors for soil parameters – Table A.4 - Combination 2

Angle of shearing resistance $\gamma_{\phi'} = \mathbf{1.25}$

Effective cohesion $\gamma_{c'} = \mathbf{1.25}$

Weight density γ_Y = **1.00**

Soil coefficients

Coefficient of friction to back of wall K_{fr} = **0.325**

Coefficient of friction to front of wall K_{fb} = **0.325**

Coefficient of friction beneath base K_{fbb} = **0.325**

Active pressure coefficient K_A = **0.333**

Passive pressure coefficient K_P = **3.700**

Overturning check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_{Gf} \times A_{stem} \times \gamma_{stem}$ = **12** kN/m

Wall base $F_{base} = \gamma_{Gf} \times A_{base} \times \gamma_{base}$ = **13.7** kN/m

Saturated retained soil $F_{sat\_v} = \gamma_{Gf} \times A_{sat} \times (\gamma_{sr} - \gamma_w)$ = **3.3** kN/m

Water $F_{water\_v} = \gamma_{Gf} \times A_{water} \times \gamma_w$ = **2.5** kN/m

Moist retained soil $F_{moist\_v} = \gamma_{Gf} \times A_{moist} \times \gamma_{mr}$ = **3.2** kN/m

Total $F_{total\_v} = F_{stem} + F_{base} + F_{sat\_v} + F_{moist\_v} + F_{water\_v}$ = **34.6** kN/m

Horizontal forces on wall

Surcharge load $F_{sur\_h} = K_A \times (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times h_{eff}$ = **7.5** kN/m

Saturated retained soil $F_{sat\_h} = \gamma_G \times K_A \times (\gamma_{sr} - \gamma_w) \times (h_{sat} + h_{base})^2 / 2$ = **3.9** kN/m

Water $F_{water\_h} = \gamma_G \times \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2$ = **9.1** kN/m

Moist retained soil $F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr} \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base}))$ = **6.9** kN/m

Total $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{water\_h} + F_{sur\_h}$ = **27.5** kN/m

Overturning moments on wall

Surcharge load $M_{sur\_OT} = F_{sur\_h} \times x_{sur\_h}$ = **7.3** kNm/m

Saturated retained soil $M_{sat\_OT} = F_{sat\_h} \times x_{sat\_h}$ = **1.8** kNm/m

Water $M_{water\_OT} = F_{water\_h} \times x_{water\_h}$ = **4.1** kNm/m

Moist retained soil $M_{moist\_OT} = F_{moist\_h} \times x_{moist\_h}$ = **5.8** kNm/m

Total $M_{total\_OT} = M_{sat\_OT} + M_{moist\_OT} + M_{water\_OT} + M_{sur\_OT}$ = **18.9** kNm/m

Restoring moments on wall

Wall stem $M_{stem\_R} = F_{stem} \times x_{stem}$ = **14** kNm/m

Wall base $M_{base\_R} = F_{base} \times x_{base}$ = **10.8** kNm/m

Saturated retained soil $M_{sat\_R} = F_{sat\_v} \times x_{sat\_v}$ = **4.7** kNm/m

Water $M_{water\_R} = F_{water\_v} \times x_{water\_v}$ = **3.6** kNm/m

Moist retained soil $M_{moist\_R} = F_{moist\_v} \times x_{moist\_v}$ = **4.6** kNm/m

Total $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{sat\_R} + M_{moist\_R} + M_{water\_R}$ = **37.7** kNm/m

Check stability against overturning

Factor of safety $FoS_{ot} = M_{total\_R} / M_{total\_OT}$ = **1.989**

PASS - Maximum restoring moment is greater than overturning moment

Bearing pressure check

Vertical forces on wall

Wall stem $F_{stem} = \gamma_G \times A_{stem} \times \gamma_{stem}$ = **12** kN/m

Wall base $F_{base} = \gamma_G \times A_{base} \times \gamma_{base}$ = **13.7** kN/m

Surcharge load $F_{sur\_v} = (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times l_{heel}$ = **2.9** kN/m

Saturated retained soil $F_{sat\_v} = \gamma_G \times A_{sat} \times (\gamma_{sr} - \gamma_w)$ = **3.3** kN/m

Water	$F_{water\_v} = \gamma_G \times A_{water} \times \gamma_w =$ **2.5** kN/m
Moist retained soil	$F_{moist\_v} = \gamma_G \times A_{moist} \times \gamma_{mr} =$ **3.2** kN/m
Total	$F_{total\_v} = F_{stem} + F_{base} + F_{sat\_v} + F_{moist\_v} + F_{water\_v} + F_{sur\_v} =$ **37.5** kN/m

Horizontal forces on wall

Surcharge load	$F_{sur\_h} = K_A \times (\gamma_G \times Surcharge_G + \gamma_Q \times Surcharge_Q) \times h_{eff} =$ **7.5** kN/m
Saturated retained soil	$F_{sat\_h} = \gamma_G \times K_A \times (\gamma_{sr} - \gamma_w) \times (h_{sat} + h_{base})^2 / 2 =$ **3.9** kN/m
Water	$F_{water\_h} = \gamma_G \times \gamma_w \times (h_{water} + d_{cover} + h_{base})^2 / 2 =$ **9.1** kN/m
Moist retained soil	$F_{moist\_h} = \gamma_G \times K_A \times \gamma_{mr} \times ((h_{eff} - h_{sat} - h_{base})^2 / 2 + (h_{eff} - h_{sat} - h_{base}) \times (h_{sat} + h_{base})) =$ **6.9** kN/m
Total	$F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{water\_h} + F_{sur\_h} =$ **27.5** kN/m

Moments on wall

Wall stem	$M_{stem} = F_{stem} \times x_{stem} =$ **14** kNm/m
Wall base	$M_{base} = F_{base} \times x_{base} =$ **10.8** kNm/m
Surcharge load	$M_{sur} = F_{sur\_v} \times x_{sur\_v} - F_{sur\_h} \times x_{sur\_h} =$ **-3.1** kNm/m
Saturated retained soil	$M_{sat} = F_{sat\_v} \times x_{sat\_v} - F_{sat\_h} \times x_{sat\_h} =$ **2.9** kNm/m
Water	$M_{water} = F_{water\_v} \times x_{water\_v} - F_{water\_h} \times x_{water\_h} =$ **-0.5** kNm/m
Moist retained soil	$M_{moist} = F_{moist\_v} \times x_{moist\_v} - F_{moist\_h} \times x_{moist\_h} =$ **-1.2** kNm/m
Total	$M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{water} + M_{sur} =$ **22.9** kNm/m

Check bearing pressure

Propping force	$F_{prop\_base} = F_{total\_h} =$ **27.5** kN/m
Distance to reaction	$\bar{x} = (M_{total} + M_{prop}) / F_{total\_v} =$ **610** mm
Eccentricity of reaction	$e = \bar{x} - l_{base} / 2 =$ **-175** mm
Loaded length of base	$l_{load} = 2 \times \bar{x} =$ **1221** mm
Bearing pressure at toe	$q_{toe} = F_{total\_v} / l_{load} =$ **30.7** kN/m^2
Bearing pressure at heel	$q_{heel} =$ **0** kN/m^2
Factor of safety	$FoS_{bp} = P_{bearing} / \max(q_{toe}, q_{heel}) =$ **4.881**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

London

Friars Bridge Court
41- 45 Blackfriars Road
London, SE1 8NZ

T: +44 (0)20 7340 1700
E: london@campbellreith.com

Birmingham

Chantry House
High Street, Coleshill
Birmingham B46 3BP

T: +44 (0)1675 467 484
E: birmingham@campbellreith.com

Surrey

Raven House
29 Linkfield Lane, Redhill
Surrey RH1 1SS

T: +44 (0)1737 784 500
E: surrey@campbellreith.com

Manchester

No. 1 Marsden Street
Manchester
M2 1HW

T: +44 (0)161 819 3060
E: manchester@campbellreith.com

Bristol

Wessex House
Pixash Lane, Keynsham
Bristol BS31 1TP

T: +44 (0)117 916 1066
E: bristol@campbellreith.com

UAE

Office 705, Warsan Building
Hessa Street (East)
PO Box 28064, Dubai, UAE

T: +971 4 453 4735
E: uae@campbellreith.com