CampbellReith
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# 26 Lyndhurst Road, London, NW3 5PB

## Basement Impact Assessment Audit

For

London Borough of Camden

Project Number: 12066-76
Revision: F1

January 2016

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## Document History and Status

| Revision | Date | Purpose/Status | File Ref | Author | Check | Review |
|---|---|---|---|---|---|---|
| D1 | December 2015 | Comment | TAMjw12066-76-241115-D1.doc | T Marsland | S Ash | S Ash |
| F1 | January 2016 | Final | SDAjw12066-76-26 Lyndhurst Road-070116-F1.doc | S Ash | S Ash | T Marsland |
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## Document Details

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| Last saved | 07/01/2016 12:38 |
| Path | SDAjw12066-76-26 Lyndhurst Road-070116-F1.doc |
| Author | S Ash, CEng MIStructE MICE |
| Project Partner | E M Brown, BSc MSc CGeol FGS |
| Project Number | 12066-76 |
| Project Name | 26 Lyndhurst Road, London, NW3 5PB |
| Planning Reference | 2015/2548/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 26 Lyndhurst Road, London, NW3 5PB (planning reference 2015/2548/P). The basement is considered to fall within Category B 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.

1.4. There is an overarching BIA report by Site Analytical Services Ltd which includes a construction method statement. There is in addition supplementary supporting information submitted in the form of the following separate reports:-

- Existing structure assessment by Hockley & Dawson.
- 'Factual Report on a Ground Investigation' by Site Analytical Services Ltd.
- 'Phase 1 Preliminary Risk Assessment' by Site Analytical Services Ltd.

The authors of these documents have suitable credentials.

1.5. The Basement Impact Assessments at 26 Lyndhurst Road relate to the proposed development of a partially buried swimming pool in the rear garden and a new lightwell at the front of the property. Excavation depths are approximately 2.5m and 3.0m below local garden levels respectively.

1.6. The proposed basements will be constructed using reinforced concrete 'L' shaped underpins dowelled together and will be founded within the Made ground or Claygate member. There is a construction methodology in Appendix C of the main BIA report in word form, but no accompanying technical calculations or drawings. Structural calculations to support the planning have been subsequently received and reviewed.

1.7. Both basements are likely to be just above the water table level and groundwater is not expected to be encountered. If groundwater is encountered it is not likely to be significant and the proposed excavation works are not considered to have an impact on the local groundwater regime.

1.8. Analysis has been undertaken of estimated horizontal and vertical ground movements based on the above construction technique and are contained within Appendix D of the main report. The analysis shows that the effect on the neighbouring properties is predicted to be very low (c2mm). This corresponds to categories 1 or 2 after Burland 1995 provided workmanship is controlled carefully and the surrounding properties are in sound condition. No proposals are provided for a movement monitoring strategy during excavation and construction, however this is not considered necessary.

1.9. The proposed scheme will result in a net increase in permeable surface area on site (additional 17 $m^2$ permeable areas). The area is not known to experience flooding. The BIA concludes there will be no adverse impact on surface flows from the proposed basement.

1.10. It is accepted that the BIA has identified the potential impacts from the basement construction and proposes sufficient mitigation.

## 2.0 INTRODUCTION

2.1. CampbellReith was instructed by London Borough of Camden (LBC) on 13/10/2015 to carry out a Category B Audit on the Basement Impact Assessment (BIA) submitted as part of the Planning Submission documentation for 26 Lyndhurst Road, London, NW3 5PB (2015/2548/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

and 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.

2.5. LBC's Audit Instruction described the planning proposal as *"Conversion of existing 4x flats into 1x6bed maisonette and 2x1bed flat. Alterations at rear to include single storey extension and part first floor extension; enlargement of terraces, creation of inset roof terrace and excavation for swimming pool. Alterations at front to include excavation of lightwell."*

2.6. CampbellReith accessed LBC's Planning Portal on 19th November 2015 and gained access to the following relevant documents for audit purposes:

- 'Basement Impact Assessment' report by Site Analytical Services Ltd.
- Existing structure assessment by Hockley & Dawson.
- 'Factual report on a ground investigation' by Site Analytical Services Ltd.
- 'Phase 1 Preliminary Risk Assessment' by Site Analytical Services Ltd.
- Planning Application Drawings consisting of:-
- Existing and Proposed plans and sections by Carden & Godfrey Architects.

2.7. Following comments contained in revision D1 of the BIA audit, structural calculations of the retaining wall were received by email on 14/12/2015, as described below. An instruction to update the audit was received on 5 January 2016.

- Structural Calculation

  (Basement design)

  (Planning Application) by Martin Redston Associates.

## 3.0 BASEMENT IMPACT ASSESSMENT AUDIT CHECK LIST

| Item | Yes/No/NA | Comment |
|---|---|---|
| Are Individual report (from Section 1.4) Author(s) credentials satisfactory? | Yes | Chartered Geologists, Chartered Engineers and Chartered Institute of Water and Environmental Management members. |
| Is data required by Cl.233 of the GSD presented? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Does the description of the proposed development include all aspects of temporary and permanent works which might impact upon geology, hydrogeology and hydrology? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Are suitable plan/maps included? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Do the plans/maps show the whole of the relevant area of study and do they show it in sufficient detail? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Land Stability Screening:<br>Have appropriate data sources been consulted?<br>Is justification provided for 'No' answers? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Hydrogeology Screening:<br>Have appropriate data sources been consulted?<br>Is justification provided for 'No' answers? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Hydrology Screening:<br>Have appropriate data sources been consulted?<br>Is justification provided for 'No' answers? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |

| Item | Yes/No/NA | Comment |
|---|---|---|
| Is a conceptual model presented? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Land Stability Scoping Provided?<br>Is scoping consistent with screening outcome? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Hydrogeology Scoping Provided?<br>Is scoping consistent with screening outcome? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Hydrology Scoping Provided?<br>Is scoping consistent with screening outcome? | No | Screening is sufficient. |
| Is factual ground investigation data provided? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Is monitoring data presented? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Is the ground investigation informed by a desk study? | No | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Has a site walkover been undertaken? | Unknown | Not mentioned in any of the reports. Level of detail in reports suggests that a site walkover is likely to have occurred. |
| Is the presence/absence of adjacent or nearby basements confirmed? | Yes | Ground Movement Assessment contained within Appendix D states that neighbouring properties Nos 25 and 27 are understood to have lower ground floors, which are taken to lie at the same level as existing lower ground floor of No. 26. |

| Item | Yes/No/NA | Comment |
|---|---|---|
| Is a geotechnical interpretation presented? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Does the geotechnical interpretation include information on retaining wall design? | No | Not specifically, although this document informs the Construction Method statement which does detail the retaining wall design. |
| Are reports on other investigations required by screening and scoping presented? | No | Not required. |
| Are baseline conditions described, based on the GSD? | Yes | To extent commensurate with scale of basement proposals. |
| Do the base line conditions consider adjacent or nearby basements? | Yes | Neighbouring properties lower ground floors are discussed. |
| Is an Impact Assessment provided? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Are estimates of ground movement and structural impact presented? | Yes | See Appendix D Ground Movement Assessment. |
| Is the Impact Assessment appropriate to the matters identified by screen and scoping? | Yes | See accompanying overarching BIA report by 'Site Analytical Services Ltd' and accompanying documents and drawings. |
| Has the need for mitigation been considered and are appropriate mitigation methods incorporated in the scheme? | No | Not considered necessary. |
| Has the need for monitoring during construction been considered? | No | Not proposed however the short plus long term movements anticipated are very low (<5mm) thus movement monitoring is not thought necessary. |

| Item | Yes/No/NA | Comment |
|---|---|---|
| Have the residual (after mitigation) impacts been clearly identified? | No | Not applicable. |
| Has the scheme demonstrated that the structural stability of the building and neighbouring properties and infrastructure will be maintained? | Yes | Construction Method Statement and Ground Movement Assessment are thorough well considered reports. |
| Has the scheme avoided adversely affecting drainage and run-off or causing other damage to the water environment? | Yes | Surface water run-off will not be increased. In fact the proposals show an increase in permeable areas of 17.6 $m^2$. |
| Has the scheme avoided cumulative impacts upon structural stability or the water environment in the local area? | Yes | Yes in both areas. |
| Does report state that damage to surrounding buildings will be no worse than Burland Category 2? | Yes | Based on Ground Movement Assessment contained within Appendix D |
| Are non-technical summaries provided? | Yes | |

## 4.0 DISCUSSION

4.1. The Basement Impact Assessment is an overarching report concerning all aspects of the project. The report authors appear to have suitable qualifications.

4.2. The BIA indicates that the front and rear proposed basements (approximately 3.0 – 2.5m bgl respectively, front basement as a lightwell and rear basement as a partially buried swimming pool) will be constructed using reinforced concrete 'L' shaped underpins dowelled together, and will be founded within the made ground or Claygate member. The exploratory holes extended to a maximum depth of 15m below ground level, with other boreholes extending to 8m below ground level.

4.3. The conclusions reached in the subterranean groundwater assessment is that both proposed basements are founded above the reported ground water level, achieve via testing in one of the boreholes. Whilst there is no guarantee that water table levels will not rise above the tested level, the proposed basements are not thought to have an impact on the existing groundwater regime.

4.4. Subsequent to the initial audit report, structural designs for the retaining wall were provided to confirm assumptions in the ground movement assessment. The GMA in Appendix D discusses neighbouring properties lower ground floors and provides an assessment of vertical and horizontal ground movements which estimates that the effect on neighbouring properties will be negligible.

4.5. No ground movement monitoring has been proposed which as the short plus long term movements to neighbouring properties are predicted to be very low is not thought necessary.

4.6. The surface water assessment notes that there is a nominal proposed increase in permeable areas.

4.7. It is accepted that there are no slope stability concerns regarding the proposed development and it is not in an area prone to flooding.

## 5.0 CONCLUSIONS

5.1. The Basement Impact Assessment has been carried out by an established firm of consultants using individuals who possess suitable qualifications.

5.2. The proposed front and rear basements (c3m below respective existing ground levels) are to be founded in the made ground or Claygate member and are predicted to be above the water table level. The deepest exploratory hole extended significantly below the proposed basement levels.

5.3. It is not likely that the ground water table will be encountered during basement foundation excavation, although the Construction Method Statement advices the contractor to have a contingency plan in case should the need arise.

5.4. The BIA states proposed basement will be constructed using reinforced concrete 'L' shaped underpins dowelled together, and will be founded within the made ground or Claygate member.

5.5. Following comments on the D1 revision of the audit 'Planning Applications' structural calculations for the basement design proposals have been received. These cover retaining wall design and stability checks and slab design for both basements with the assumptions clearly described.

5.6. Horizontal and vertical ground movement analysis predicts negligible impact (c2mm) on neighbouring properties. It is accepted that damage should not exceed Burland Category 2 provided there is good control of workmanship and the properties are in sound condition.

5.7. No proposals are provided for a movement monitoring strategy during excavation and construction but for the magnitude of movements anticipated it is not thought necessary.

5.8. It is accepted that there are no adverse impacts on slope stability, surface water flows or flooding.

5.9. It is accepted that the BIA has identified the potential impacts from the basement construction and proposes sufficient mitigation.

# Appendix 1: Residents' Consultation Comments

None

# Appendix 2: Audit Query Tracker

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Audit Query Tracker

| Query No | Subject | Query | Status | Date closed out |
|---|---|---|---|---|
| 1 | Stability | Lack of job specific structural design calculations and drawings for the reinforced concrete underpins. | Closed | 07/01/16 |
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# Appendix 3: Supplementary Supporting Documents

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# STRUCTURAL CALCULATION

For

(Basement Design)
(Planning Application)

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NW3

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| Date | Dec-15 | Sheet No. |
|---|---|---|
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| Job No. | 15-390 | |

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## Basement Design

Design consideration

Surcharge, Earth and Water

## Loading

### Surcharge

From BS 8002 1994 3.3.4.1
Surcharge $q_1$ = 10.00 kN/m²
Using 5.00 kN/m² for Build-up Earth → Garden
2.00 kN/m² for Internal House → Imposed

## Earth Pressure

From Site Analytical Services LTd
Basement Impact Assessment +
Factual Report Ground Investigation

Soil:- Made ground overlaying the claygate member over clay formation

Bearing Pressure :- 74kN/m² at 3.00m increasing to 125 kN/m² at 4.0m
Using = 80.00 kN/m²

$\gamma = 18.50$ ; $\phi = 25°$

$$K_a = \frac{1-\sin 25}{1+\sin 25} = 0.40$$

## Water Pressure

From site Analytical Services Ltd
Factual Ground Investigation Report

Water is found at about 4.50m below ground
Design is based on water pressure of two-third design RC Retaining water.

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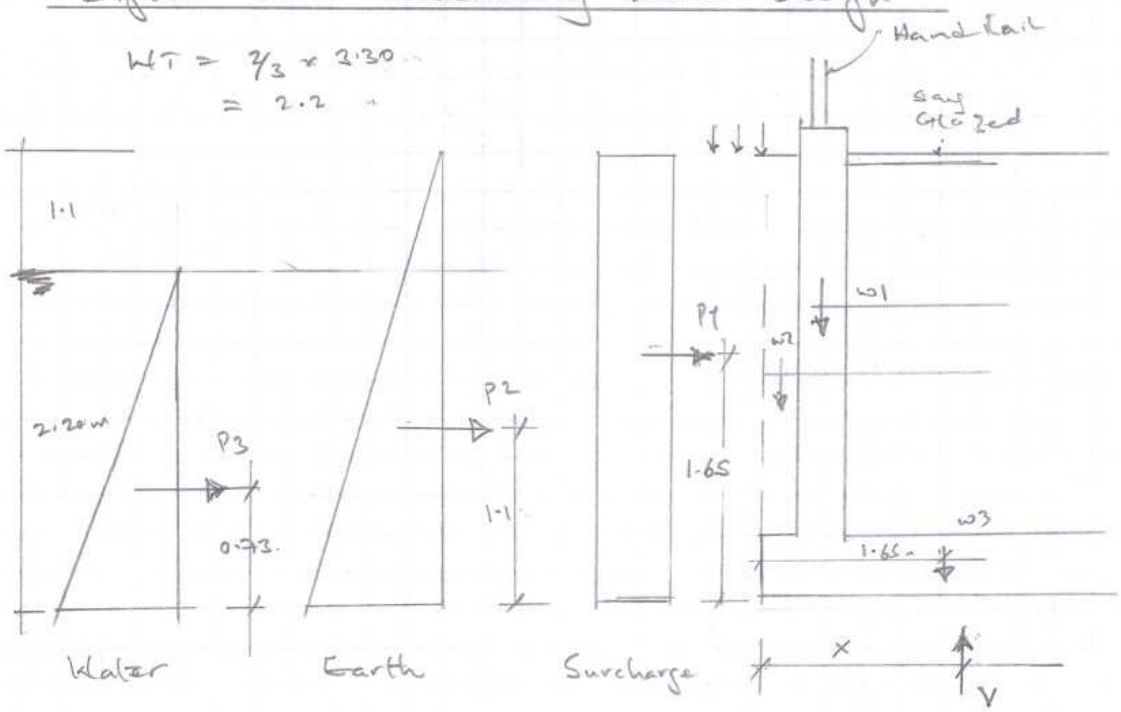
## Light Well Retaining Wall Design




| Load | DL | LL | DL + LL |
|---|---|---|---|
| Hand rail<br>DL:- 1.00 kN/m² x Sag 1.50 m = | 1.50 | | |
| Retaining wall<br>DL:- 24 kN/m³ x 0.30m x 3.10m = | 22.32 | | |
| * Glazed Floor<br>DL:- Sag 1.50 kN/m² x Sag 1.00 m | 1.50 | | |
| IL:- 2.50 kN/m² x 1.00 m | | 2.50 | |
| Total W1 | 25.32 kN/m | 2.50 kN/m | (SLS) 27.82 kN/m |
| Granular Material<br>* DL: 20.00 kN/m³ x 0.20 x 2.95m = | 11.80 kN/m | | (SLS) 11.80 kN/m |
| Total W2 | | | |
| Base slab<br>DL:- 24 kN/m³ x 0.35 x Sag 3.00m = | 25.20 kN/m | | (SLS) 25.20 kN/m |
| Total W3 | | | |
| Total V = W1 + W2 + W3 = | | | 64.82 kN/m |

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Base Pressure

| | DL | LL | DL+LL |
|---|---|---|---|
| P1 Surcharge = 5.00 kN/m² × 0.4 × 3.30 | | 6.60 kN/m | |
| P2 Earth = ½ × 0.40 × 18.5 × 3.30² = | 40.293 kN/m | | |
| P3 water = ½ × 9.81 × 2.20² = | 23.70 kN/m | | |

## Stability Check

### Overturning

Overturning Moment @ Base = (6.60 × 1.65) + (40.293 × 1.10) + (23.70 × 0.73)
= 72.51 kNm

Stabilising Moment = (27.62 × 3.125) + (11.60 × 3.35) + (21.6 × 1.65)
= 162.10 kNm

F.O.S overturning = $\frac{162.10}{72.51}$ = 2.24 ∴ ok

### Sliding

RC wall cannot slide as it is tied to (Part of) RC slab.

### Bearing Pressure

Vx = (6.60 × 1.65) + (40.293 × 1.10) + (23.70 × 0.73) + (27.62 × 0.35)
+ (11.60 × 0.1) + (25.20 × 1.65) = 125.01 kNm

$x = \frac{125.01}{64.82} = 1.928 \Rightarrow \frac{3.30}{2} - 1.928 = -0.278$

Bearing Pressure @ max $= \frac{V}{A} \pm \frac{Ve}{Z}$

$= \frac{64.82}{3.00} \pm \frac{64.82 \times 6 \times (-0.278)}{3.0^2}$

= 33.62 kN/m² ∴ ok

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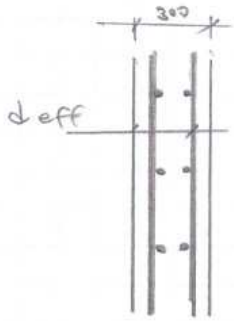
## Reinforcement in Wall

BM @ Base = 72.51 kN m

$BM_{ULT}$ = 72.51 × 1.4 = 101.514 kN m




Wall thickness = 300 mm

d eff = 300 − 35 − 16/2

= 257 mm

$$K = \frac{M}{bd^2 f_{cu}} \Rightarrow \frac{101.514 \times 10^6}{1000 \times 257^2 \times 35} = 0.044 < K'$$

$$z = d\left\{0.5\left[\sqrt{\left(0.25 - \frac{0.044}{0.90}\right)}\right]\right\} = 0.95\,d$$

$$A_s = \frac{101.514 \times 10^6}{0.95 \times 460 \times 0.95 \times 257} = 952\ mm^2/m$$

∴ PROVIDE H16 BARS @ 150 mm c/c ($A_s$ = 1340 $mm^2/m$)

FRONT & BACK

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## Reinforcement in Base

$BM_{out} = 33.62\ kN/m^2 \times \frac{2.60^2}{2} \times 1.4 = 159.10\ kN\,m$

Base = 350 mm

$d_{eff} = 350 - 40 - 16/2 = 302$ mm

$K = \frac{159.10 \times 10^6}{1000 \times 302^2 \times 35} = 0.0498 < K'$

$z = d\left\{0.5 + \left[\sqrt{\left(0.25 - \frac{0.0498}{0.90}\right)}\right]\right\} = 0.94d < 0.95d$

$A_s = \frac{159.10 \times 10^6}{0.95 \times 460 \times 0.94 \times 302} = 1282$

∴ PROVIDE H16 BARS @ 150mm c/c ($A_s = 1340\ mm^2/m$)
TOP & BOTTOM + BOTH WAYS

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## Base Slab Design (Basement)

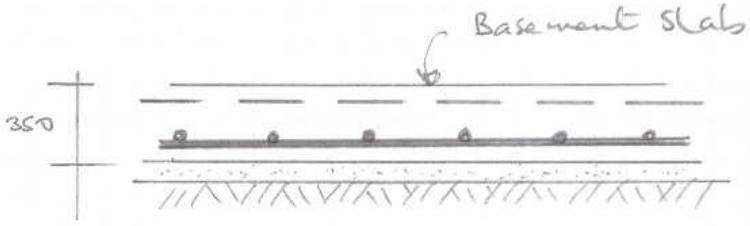
slab = 350 mm

Uplift force

$F = 2.20 \times 9.81 = 21.582$ kN/m

Factored $= 22.00 \times 1.4 = 30.80$ kN/m

$BM_{max} = \frac{31.00 \times 3.50^2}{8} = 47.50$ kN m




$d_{eff} = 350 - 40 - 8 = 302$ mm

$K = \frac{50.00 \times 10^6}{1000 \times 302^2 \times 35} = 0.0157$

$z = d\left\{0.5 + \left[\sqrt{\left(0.25 - \frac{0.0157}{0.9}\right)}\right]\right\} = 0.95d$

$A_s = \frac{50 \times 10^6}{0.95 \times 460 \times 0.95 \times 302} = 400$ mm²/m

∴ PROVIDE H12 BARS @ 150 mm c/c (754 mm²/m)

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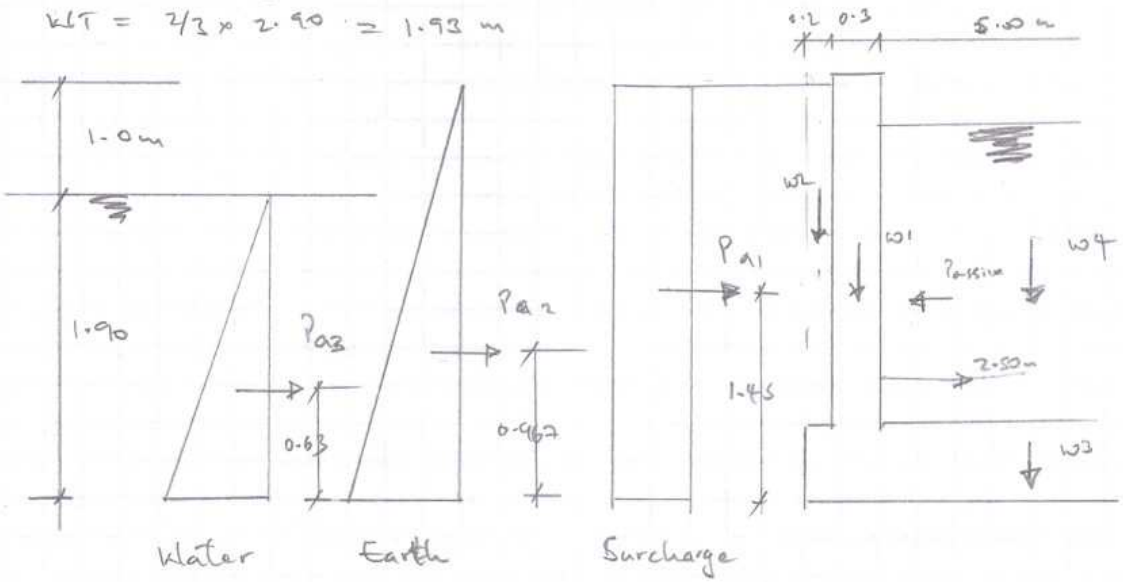
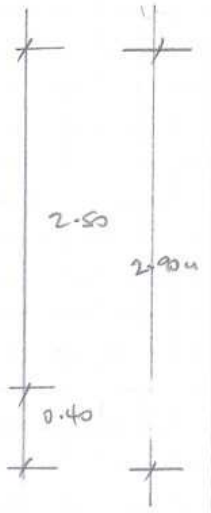
# Swimming Pool Retaining Wall Design

KT = 2/3 × 2.90 = 1.93 m




| Load | DL | LL | DL+LL |
|---|---|---|---|
| RC Retaining wall<br>DL- 24kN/m³ × 0.30 × 2.50 m =<br>Total W1 | 18.00 kN | | 18.00 kN/m |
| Granular W2<br>DL- 20kN/m³ × 0.20 × 2.5<br>Total W2 | 10.00 kN | | 10.00 kN/m |
| Base<br>DL- 24 kN/m³ × 0.40m × 3.00 m<br>Total W 3 | 28.80 kN | | 28.80 kN |
| * Swimming Pool (when full) W4<br>DL- 9.81 × 2.4 × 2.50 =<br>Total W 4 | 58.86 kN | | 58.86 kN/m |
| Total V = With Swimming Pool water | | | 56.80 kN/m |
| Without swimming Pool water | | | 115.66 kN/m |

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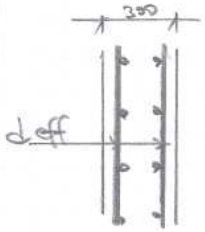
| | DL | LL | DL+LL |
|---|---|---|---|
| P1 surcharge<br>Base = 5.00 × 0.40 × 2.90 = | | 5.80 kN/m | |
| P2 Earth Pressure<br>Base = ½ × 0.4 × 18.5 × 2.90² = | 31.12 kN/m | | |
| P3 Water Pressure<br>Base = ½ × 9.81 × 1.90² = | 17.71 kN/m | | |
| Passive Pressure<br>P4 = ½ × 9.81 × 2.60² = | 28.25 kN/m | | |

Reinforcement in Wall (Swimming Pool)

BM@ Base = (5.80 × 1.45) + (31.12 × 0.967) + (17.71 × 0.63) = 49.66 kNm

BM ULT = 50 × 1.4 = 70.00 kNm (ULS)




wall thickness = 300 mm

deff = 300 − 35 − 6 = 257 mm

$$K = \frac{70.0 \times 10^6}{1000 \times 257^2 \times 35} = 0.030 < K'$$

$$z = d\left\{0.5 + \left[\sqrt{\left(0.25 - \frac{0.030}{0.90}\right)}\right]\right\} = 0.96d$$

$$A_s = \frac{70.00 \times 10^6}{0.96 \times 460 \times 0.95 \times 257} = 657 \text{ mm}^2/\text{m}$$

∴ PROVIDE H16 BARS @ 150 mm c/c ($A_s$ = 1340 mm²/m)

FRONT & BACK

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| Date Dec-15 | Sheet No. 9 |
|---|---|
| Eng. SG | |
| Job No. 15-390 | |

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## Stability check

Overturning

Overturning Moment @ Base = $(5.80 \times 1.45) + (31.12 \times 0.967) + (17.71 \times 0.63)$

= 49.66 kNm

Stabilising Moment = $(15.00 \times 2.65) + (10.00 \times 2.90) + (26.60 \times 1.50m)$

= 119.90 kNm

F.O.S Overturning = $\frac{119.90}{49.66}$ = 2.40 ∴ ok

Sliding
Wall cannot slide as it is tied to (Part of) RC slab.

## Bearing Pressure

$V_x = (5.80 \times 1.45) + (31.12 \times 0.967) + (17.71 \times 0.63) + (15.00 \times 0.35) + (10.0 \times 0.1) + (26.60 \times 1.50) = 100.16$ kN/m

$X = \frac{100.16}{56.80} = 1.76 \Rightarrow \frac{3.00}{2} - 1.76 = -0.263$

Bearing Pressure $q_{max} = \frac{56.80}{3.0} \pm \frac{56.80 \times 6 \times (-0.263)}{3.0^2}$

= 28.90 kN/m² ∴ ok

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| | |
|---|---|
| Date Dec-15 | Sheet No. 10 |
| Eng. SG | |
| Job No. 15-390 | |

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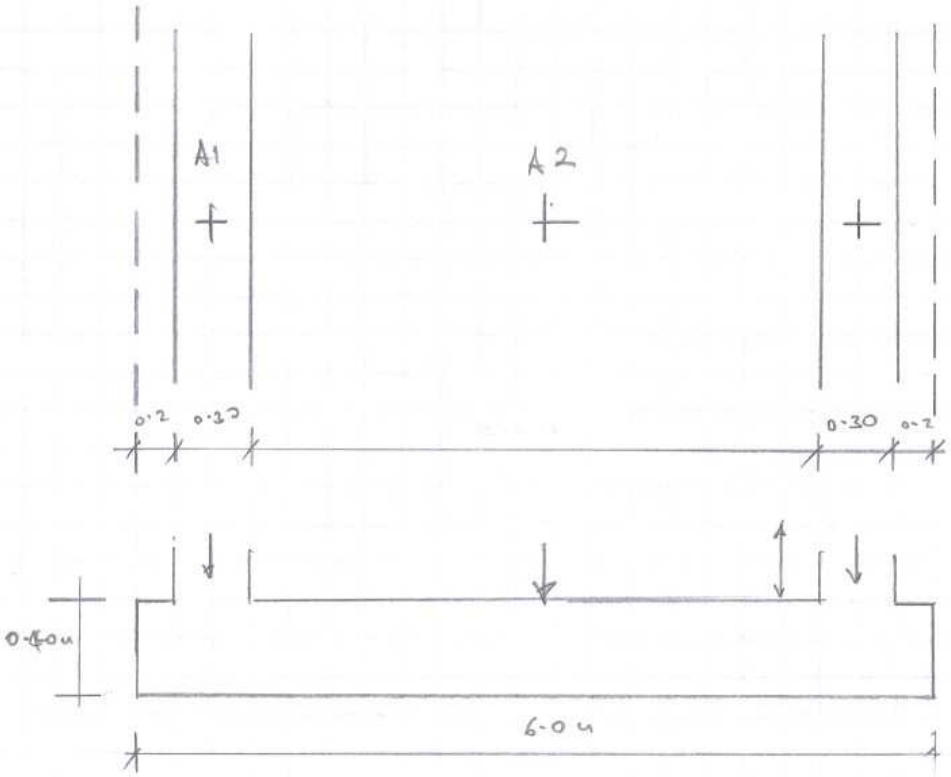
## Base Design (With water in swimming Pool)




A1 = RC Retaining w = 15.00

A1 = " " 15.00

A2 = Swimming Pool water (9.81 × 5.0 × 2.50m) = 122.625

Base Slab S/w = 24 × 6.0 × 0.40 57.60

Granular : 20kN/m³ × 0.20 × 2.4m × 2m's = 23.04

Total UDL = 239.265 kN/m

Bearing Pressure = $\frac{250.00 \text{ kN/m}}{6.00 \text{m}}$

= 41.70 kN/m² ∴ OK

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| Date | Dec-15 | Sheet No. |
|---|---|---|
| Eng. | SG | 11 |
| Job No. | 15-390 | |

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## Reinforcement in Base (Swimming Pool)

$$BM_{ULS} = 42.00 \times \frac{3.60^2}{2} \times 1.4$$

$$= 264.60 \text{ kNm}$$

Base thickness = 400 mm

$d$ eff = $400 - 40 - 16/2 = 352$ mm

$$K = \frac{264.60 \times 10^6}{1000 \times 352^2 \times 35} = 0.061$$

$$z = d\left\{0.5 + \left[\sqrt{\left(0.25 - \frac{0.061}{0.9}\right)}\right]\right\} = 0.93d$$

$$A_s = \frac{264.60 \times 10^6}{0.95 \times 460 \times 0.93 \times 352}$$

$$= 1850 \text{ mm}^2/\text{m}$$

∴ PROVIDE H20 BARS @ 150 mm c/c ($2094 \text{ mm}^2/\text{m}$)
TOP & BOTTOM + BOTH WAYS

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