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# Underpinning Design

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## Underpinning Design:

It is being proposed to underpin the rear perimeter wall, from the site above, in order to allow the excavation and creation of a new basement area

The case will be analysed in this design, the first case accounts for the underpinning bases to the party walls number 31 and 33, section A-A and B-B, and the second case for the rear boundary wall, section 1-1.

### Load Take Down from the party wall (Sections A and B)

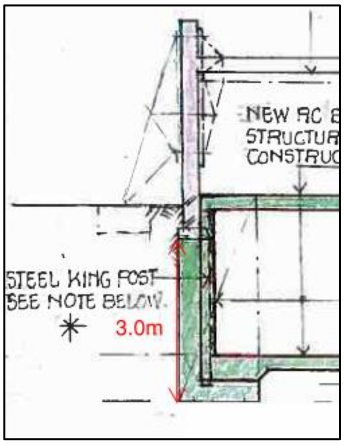
This is based on a conservative load condition.

- Underpinning stem = 0.35m thick;
- Underpinning toe = 1.0m long;
- Concrete strength = C28/35;

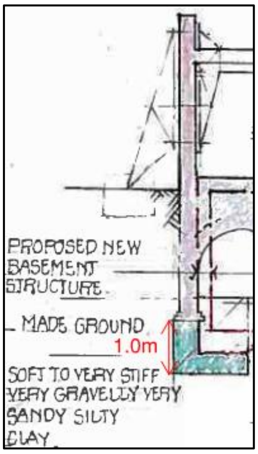
| Imposed Load | | | |
|---|---|---|---|
| Roof | 7/2 x 0.6 = | 2.1 | KN/m |
| Ground Floor | 7/2x2 = | 7 | KN/m |
| LG Floor | 7/2x2 = | 7 | KN/m |
| | Total = | 16.1 | KN/m |

| Dead Load | | | |
|---|---|---|---|
| Roof | | | |
| Timber | | | |
| Slate | 1.6x7/2 = | 5.6 | KN/m |
| Insulation | | | |
| GF Slab | 0.25x24x7/2 = | 21 | KN/m |
| LGF Slab | 0.25x24x7/2 = | 21 | KN/m |
| Lining Wall | 0.25x24x3 = | 18 | KN/m |
| Exist Wall | 0.35x19x3.5 = | 23.3 | KN/m |
| U/P SW | 0.35x24x3 = | 25.2 | KN/m |
| | Total = | 114.1 | KN/m |

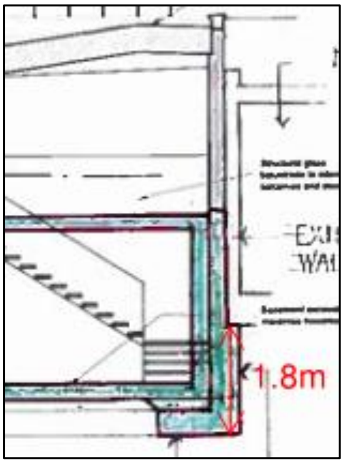
| | | |
|---|---|---|
| Total = | 130 | KN/m |




Section A - A




Section B - B




Section 1 - 1

*Section drawings above were extracted from ESD drawings L150805-Sheets 1 and 3-4 rev A.*

Underpinning formation level = 45.270moD

### Ground water level:

Underpinning toe is above water table, therefore not a retaining water structure.

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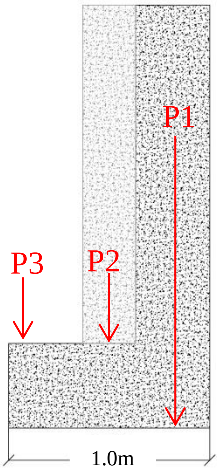
## Underpinning Toe (Sections A and B)

Allowable Bearing Pressure = 150KN/$m^2$

Underpinning Toe length = 130.0 / 150 = 0.866mm, say 1000mm




Due to eccentric load consider an overall width of 1.0m.

Find the eccentricity caused by the different load paths.
P1 = 2.1 + 5.6 + 23.3 + 25 = 56KN/m
P2 = 7 + 21 + 18 = 46KN/m
P3 = 7 + 21 = 28KN/m

Px = (0.0x28) + (46x0.475) + (56x0.775) = 65.2KNm/m
x = 65.2 / 130 = 0.501m

Eccentricity = (1.0/2) – 0.501 = 1mm

Middle third rule = L/6 > e, hence 1000/6 = 167mm > 1mm, therefore the load distribution will be trapezoidal.

$t_{min}$ = (T/A) – ($M_T$/Z) = (130/1) - ((130x0.001)/(1x$1^2$/6)) = 129.2KN/$m^2$
$t_{max}$ = (T/A) + ($M_T$/Z) = 130.8KN/$m^2$

Bending moment = 0.001x130 = 0.13KNm/m run

Considering a 1.2m base bending moment = 0.13 x 1.20 = 0.156KNm
Ultimate Bending Moment = 0.156 x 1.45 = 0.226KNm
This moment is negligible and within the concrete tensile strength.

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## Load Take Down from the party wall (Section 1)

This is based on a conservative load condition.

- Underpinning stem = 0.700m thick;
- Underpinning toe = 1.5m long;
- Concrete strength = C28/35;

| Imposed Load | | |
|---|---|---|
| Roof | 10/2 x 0.6 = | 3.0 KN/m |
| Ground Floor | 10/2x2 = | 10 KN/m |
| LG Floor | 10/2x2 = | 10 KN/m |
| | Total = | 23.0 KN/m |

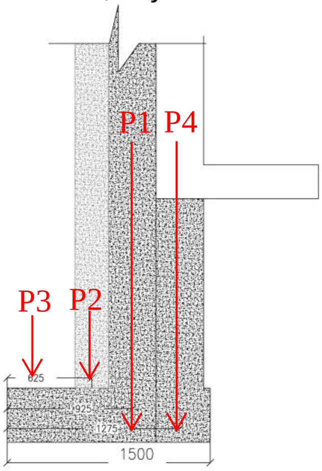
| Imposed Load | fromParty wall | |
|---|---|---|
| Roof | 8/2 x 0.6 = | 2.4 KN/m |
| Ground Floor | 8/2x2 = | 8 KN/m |
| Dead Load | fromParty wall | |
| GF Slab | 0.25x24x8/2 = | 24 KN/m |
| Lining Wall | 0.25x24x3 = | 18 KN/m |
| | Total = | 52.4 KN/m |

| Dead Load | | | |
|---|---|---|---|
| Roof | | | |
| Timber | | | |
| Slate | 1.6x10/2 = | 8 | KN/m |
| Insulation | | | |
| GF Slab | 0.25x24x10/2 = | 30 | KN/m |
| LGF Slab | 0.25x24x10/2 = | 30 | KN/m |
| Lining Wall | 0.25x24x3 = | 18 | KN/m |
| Exist Wall | 0.35x19x3.5 = | 23.3 | KN/m |
| U/P SW | 0.70x24x1.8 = | 30.24 | KN/m |
| | Total = | 139.5 | KN/m |

| | | |
|---|---|---|
| Total = | 215 | KN/m |

Allowable Bearing Pressure = 150KN/$m^2$

Underpinning Toe length = 215/ 150 = 1.43m, say 150mm




Due to eccentric load consider an overall width of 1.5m.

Find the eccentricity caused by the different load paths.
P1 = 3 + 8 + 23.3 + 30.2 = 64.5KN/m
P2 = 10 + 30 + 18 = 58KN/m
P3 = 10 + 30 = 40KN/m
P4 = 52.4KN/m

Px = (0.0x40) + (58x0.625) + (64.5x0.925) + (52.4x1.275) = 163KNm/m
x = 163 / 215 = 0.757m

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eccentricity = (1.5/2) – 0.757 = -7mm

Middle third rule = L/6 > e, hence 1500/6 = 250mm > 7mm, therefore the load distribution will be trapezoidal.

$t_{min}$ = (T/A) – ($M_T$/Z) = (215/1.5) - ((215x0.007)/(1x$1.5^2$/6)) = 147.4KN/$m^2$
$t_{max}$ = (T/A) + ($M_T$/Z) = 139.2KN/$m^2$

Bending moment = 0.007x215 = 1.51KNm/m run

Considering a 1.2m base bending moment = 1.51 x 1.20 = 1.81KNm

Ultimate Bending Moment = 1.81 x 1.45 = 2.62KNm

This moment is negligible and within the concrete tensile strength.

**Summary:**

- Underpinning to be carried out in a sequence of 1-3-5-2-4;

- Concrete strength C28/35 – DS-2 - 20mm aggregate;

- Provide vertical steel post will be provided to the face of the underpinning to resist the ground pressure exerted at the back of the underpinning bases, as per the temporary works requirement, refer to propping arrangement section. The steel posts will be cast within the lining wall and become part of the permanent works;

- Provide 600mm long M16 dowel bars (shear links) at 0.5m c/c to adjacent bases;

- Allow for 75mm, 1 part of cement and 3 parts of sand – 1:3 drypack mortar between the existing footing and the top of the new underpin base;

- Allow drypack to cure for a minimum of 48hrs before excavating the adjacent bays.



7 Blenheim Court, Brownfields, Welwyn Garden City, Herts AL7 1AD
Tel: 01707 260022 Fax: 01707 260099

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# Underpinning – Propping Arrangement

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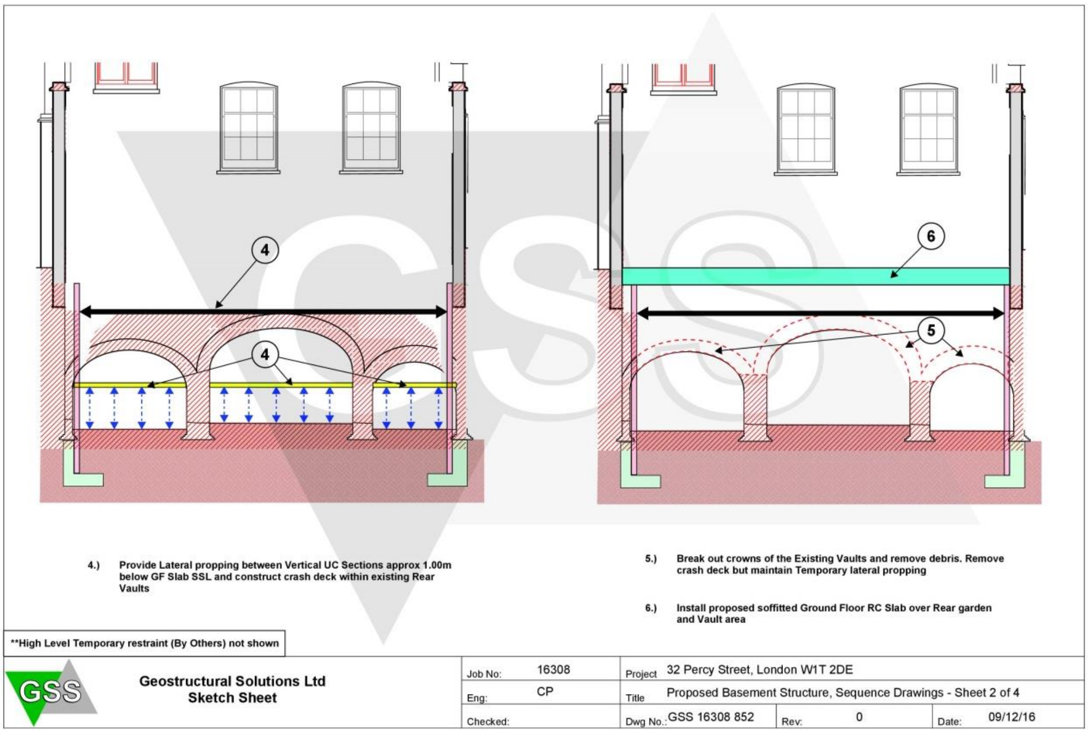
## Design Brief

Vertical Props will be provided to the face of each underpin base to resist the active soil pressure against the underpinning, as seen below. A top waler and a flying prop will be provides to restrain the top of the underpinning bases and transfer the load across to the opposite underpinning bases, item 4.




## Vertical Post

The active soil surcharge from section A-A will be used, this is the worst condition.

Earth pressure UDL from 49.970moD to bottom of underpinning at 45.270moD, min 0 KN/m$^2$, to max 35.9 KN/m$^2$.

The vertical post will be considered to be laterally restrained at the bottom and at 200mm below the proposed slab soffit, slab thickness has been assumed to be 0.3m.

Vertical post length = 4.0m

| <u>Propping depth from Top of the Slab</u> | <u>Ground Pressure</u> |
|---|---|
| 1$^{st}$ Prop at 0.5m | 0 KPa |
| 2$^{nd}$ Prop at 4.0m | 35.9 x 1.2 = 43.1KPa |

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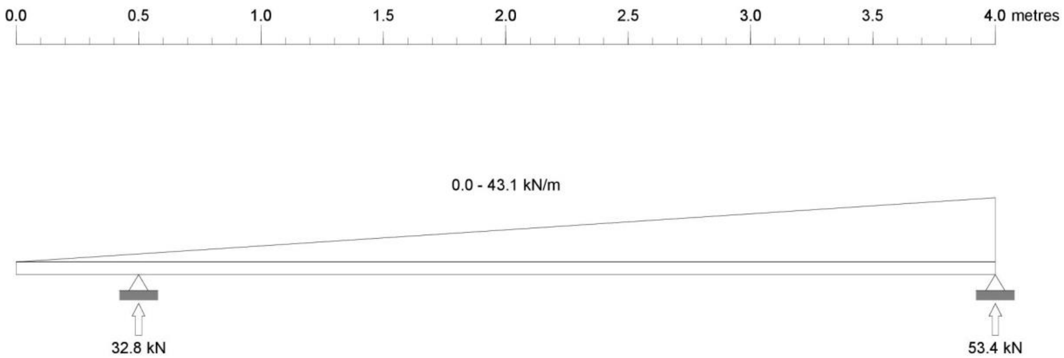
## Prop Reactions

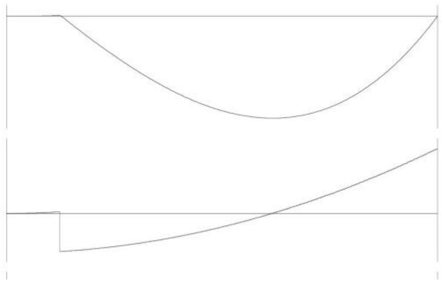



Section : 152x152x37UC

Bending Stiffness, EI = 4420 kNm² Shear Stiffness, GA = (Not Included) Self-Weight, w = 0.370 kN/m

Self-Weight of the beam is not included in the analysis

## Bending Moment Diagram



Bending Moment :
- Largest Positive = +37.6 kNm
- Largest Negative = -0.2 kNm

Shear Force :
- Largest Positive = +31.5 kN
- Largest Negative = -53.4 kN

From analysis using computer software (Pallett Temporary Works), the horizontal force at $R_B$ is 53.4KN/base.

The vertical beams will be placed in every underpinning base, which are at 1.2 c/c.

Design moment = 37.6 x 1.45 = **54.5 KNm (ULS)**

Try 152 x 152 x 37 UKC grade S355 restrained at 3.5m

From Steelwork Design Guide to BS5950-1:2000 “Blue Book”, p. D-78;
$M_C$ for grade S355 steel, for 152UC37, with Le = 3.5m = 88.4 KNm > 54.5 KNm, therefore OK.

**Provide 152 x 152 x 37 UKC, grade S355 vertical posts to all underpin bases.**

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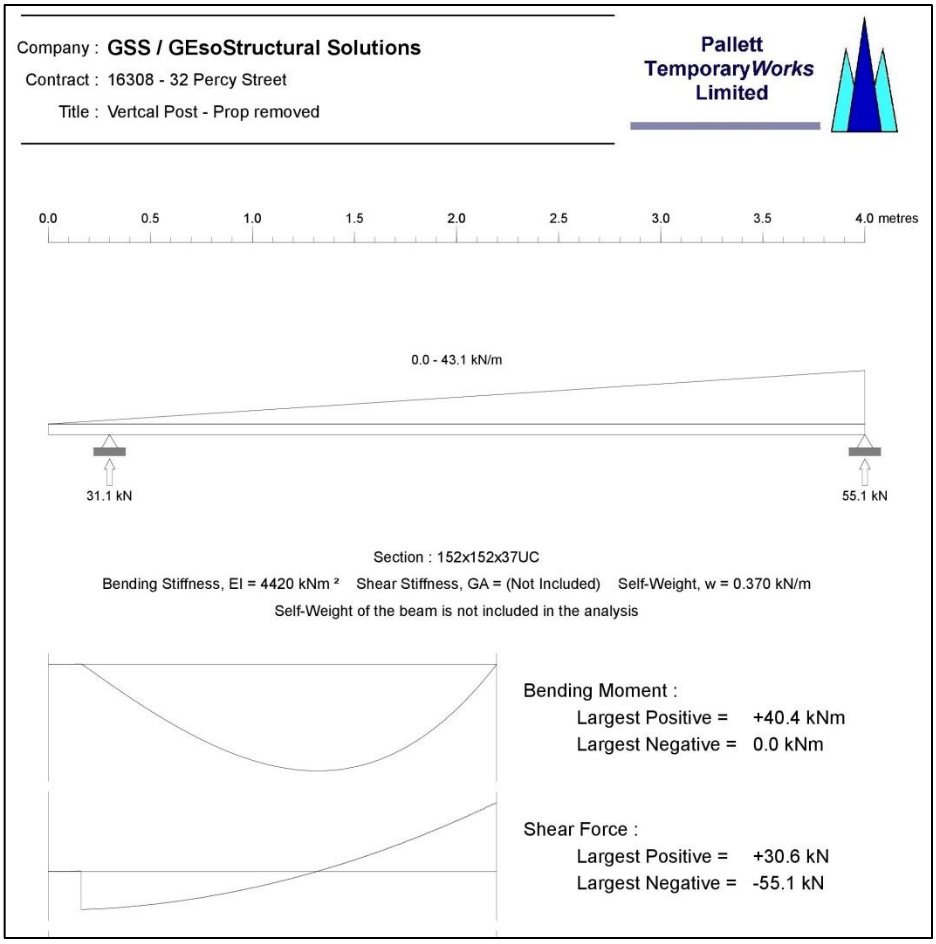
## Removal of Flying Prop

Once the ground floor slab has been cast, the horizontal flying prop can be removed. At this stage, the vertical columns will span from the soffit of the ground floor slab to the toe of the underpinning.

The clear span between the support = 3.7m

At the permanent case, the bending moment will increase to 40.4 KNm/m, which is still lower than the capacity of the section; hence the same section is sufficient.

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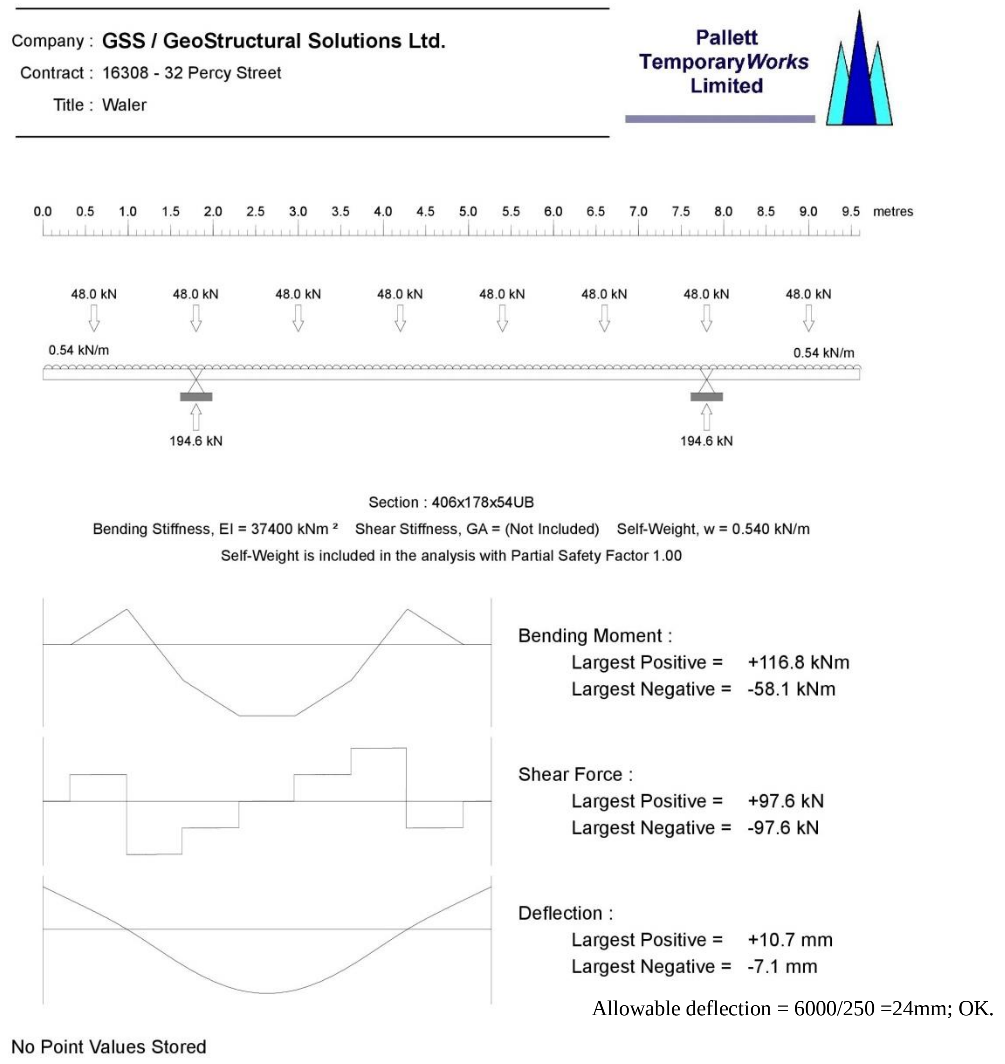
## Top Waler

Point loads = 32.8 x 1.45 = 48KN (ULS) – Point load will be applied at 1.2m c/c. 2No flying props will be used to transfer the load across to the opposite underpinning bases.




$M_{Rd}$ = 138 KNm @ 7.0m > Med = 116.8KNm, therefore OK.

**<u>Provide 406x178x54UB S355 Waler, fix to the vertical posts using 4M16 (8.8) Bolts.</u>**

**<u>Waler centerline to be at 0.2m below the slab soffit, flying props to be installed in line with underpinning bay 2 and 7.</u>**

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**Design Cover Sheet**

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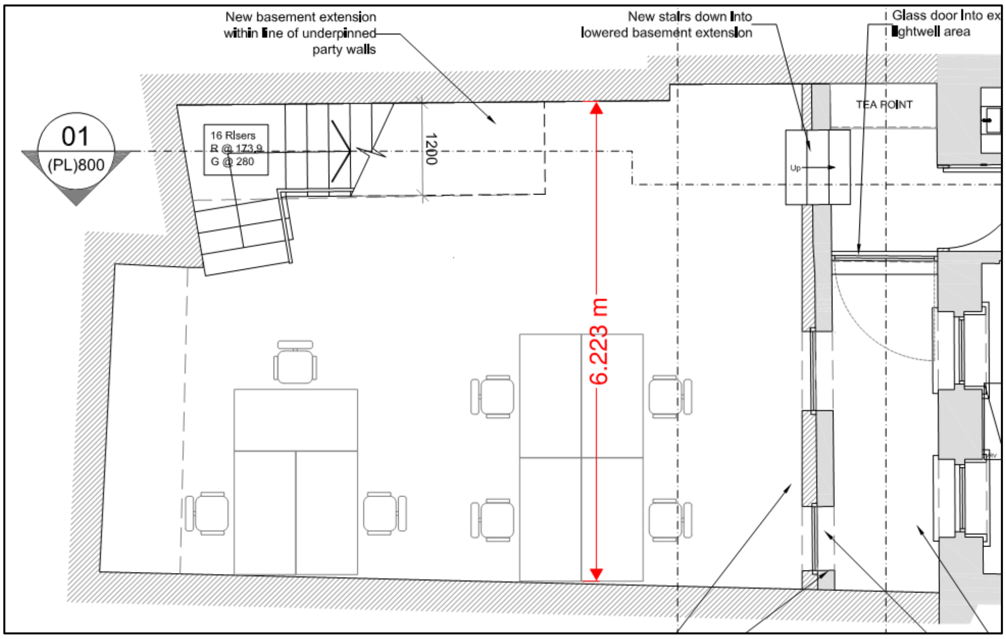
## Flying Props

Axial Loads = Ned = 194.6KN (ULS)

Assume 50mm eccentricity = Med = 194.6 x 0.05 = 9.73KNm

Prop length not exceeding 7.0m




*Section drawings above were extracted from Garnett+Partners drawings 806-(PL)600 rev -.*

Try 152 x 152 x 30 UKC S355

$N_{Rd(z-z)}$ = 545 KN @ 7.0m
$M_{Rd(z-z)}$ = 39.6 KNm

Compression + Bending Check = (194.6/545) + (9.73/39.6) = 0.60, therefore 152x152x30UKC S355 is suitable.

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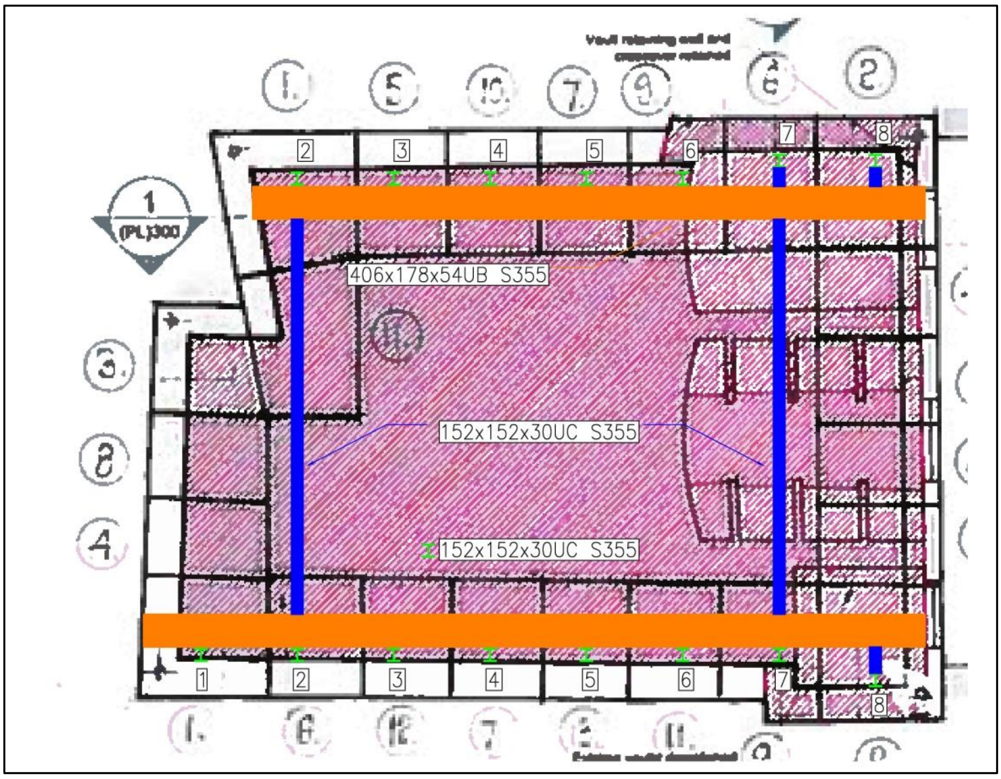
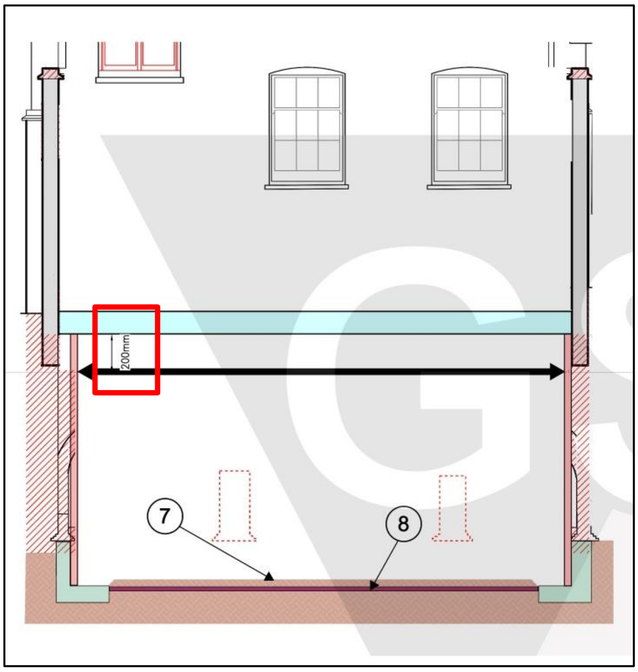



*Plan View – Propping arrangement*




*Section View – Propping arrangement*

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## Lateral Restrain to the Underpinning Toe

Underpinning toes are to be restrained at each every single bay, 1.2m c/c as the excavation progresses in strips, beginning from the existing property and moving forwards towards the rear of the site.

Axial Loads = Ned = 55.1 x 1.45 = 80 KN (ULS)

Assume 50mm eccentricity = Med = 80 x 0.05 = 4KNm

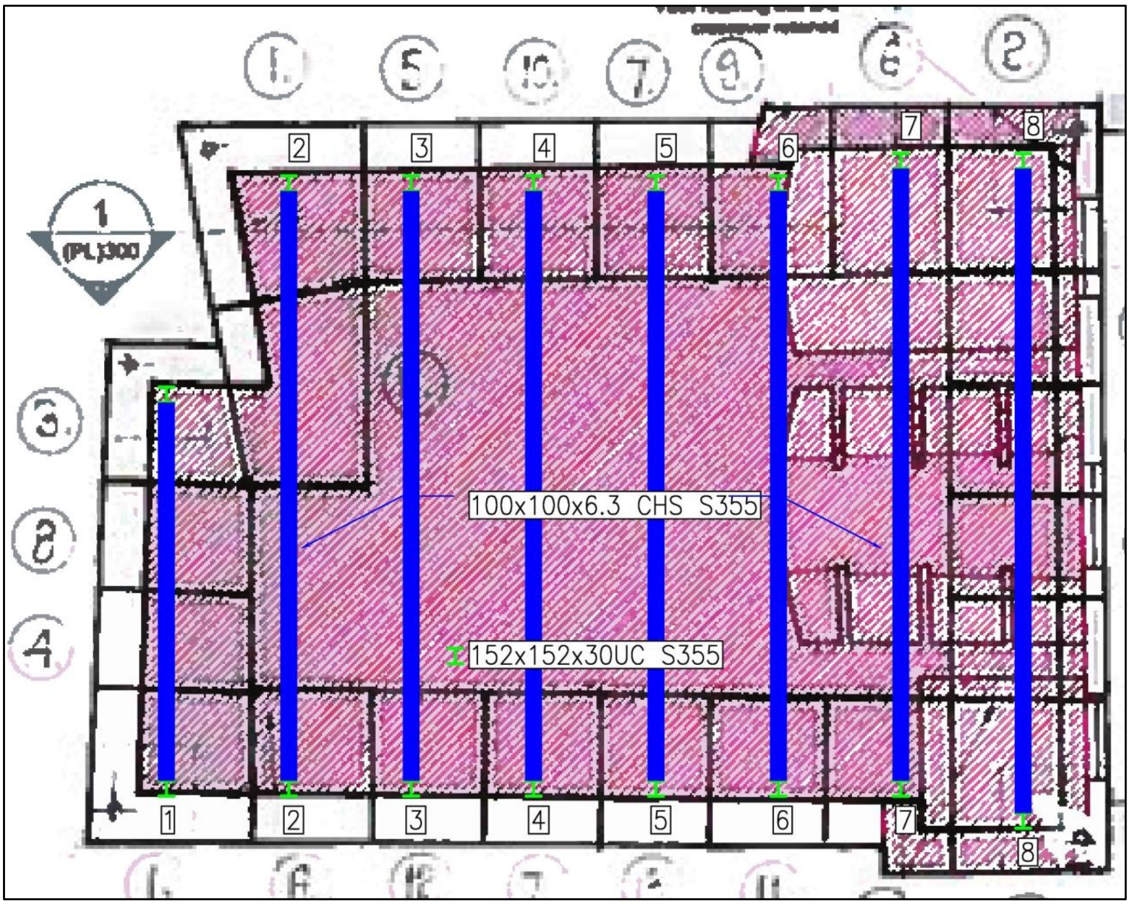
Prop length not exceeding = 7.0m

Try 100 x 100 x 6.3 CHS S355

$N_{Rd}$ = 129 KN @ 7.0m
$M_{Rd}$ = 28.7 KNm

Compression + Bending Check = (80/129) + (4/28.7) = 0.76, therefore 100x100x6.3CHS S355 is suitable.

**Provide 100x100x6.3 CHS S355 props, fix to the vertical posts using 4M16 (8.8) Bolts.**

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# 1st Stage Excavation

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## Design Brief

This is a temporary works design has been produced to check the stability of the underpinning bases during construction and to check the propping arrangement necessary to stabilised the bases excavation works.

**This calculations show the following:**

1) The level to which excavation can be carried out prior to the installation of props;
2) The size of the member to be used as a vertical beam against the underpin bases.
3) The size of the top props, top walers and bottom props.

**Data used in the calculation:**

a) ESD drawings from August 2016;

b) Site Investigation: Ref.: P9273J732, from August 2016, issued by Jomas.

c) A surcharge load of 10KN/m$^2$ has been allowed in this design.

| Soil Type | Bulk Density $\gamma_b$ (KN/m$^3$) | Undrained Shear Strength (Temporary Condition) | Long Term "Drained Condition" | |
|---|---|---|---|---|
| | | | C' | φ° |
| Made Ground | 18 | N/A | N/A | 28 |
| Silty Clay | 19 | N/A | N/A | 24 |
| Silty Gravel | 20 | N/A | N/A | 33 |
| Silty Clay | 19.5 | N/A | N/A | 24 |
| Sandy Clay | 20.5 | N/A | 0 | 24 |

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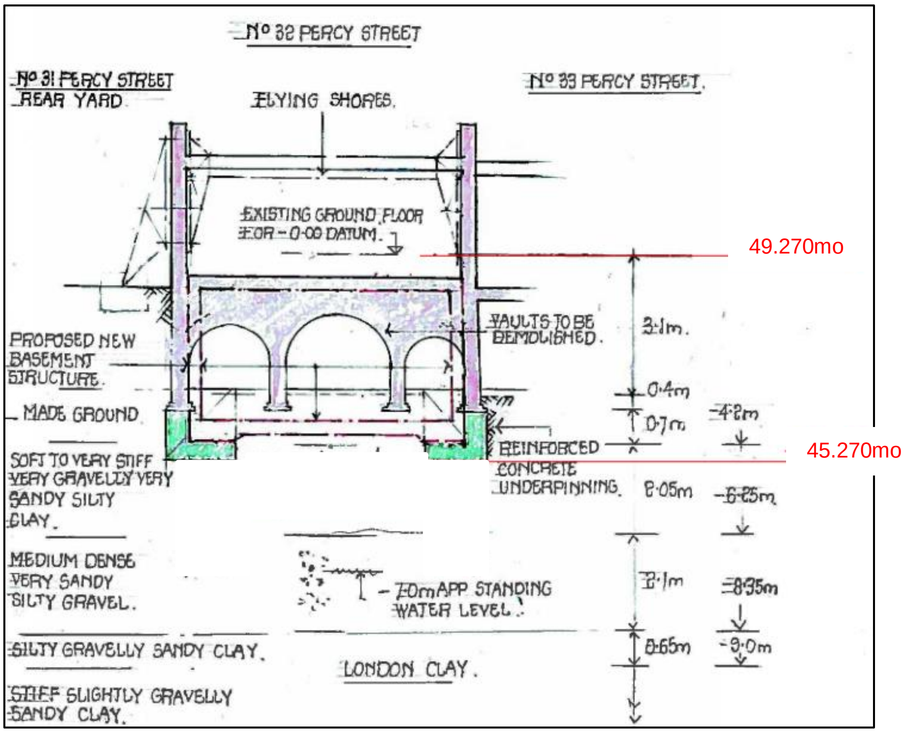
## Active Soil Pressure:

The soil pressures have been calculated using CADS Pile Wall Suite, according to soil data provided by the site investigation, a 10KPa surcharge has been allowed in the calculation.

### Section A – A

Depth of underpinning = 49.270 – 45.270 = 4.0m
Max pressure at base of underpin (from CADS output for LL surcharge and soil only) = 35.9KN/m$^2$
Max horizontal load at base = (4.0/2 x 35.9) = 72 KN/m




*Section drawings above shows the proposed level in moD.*

### Section B – B

Depth of underpinning = 49.270 – 45.270 = 4.0m
Max pressure at base of underpin (from CADS output for LL surcharge and soil only) = 14.8KN/m$^2$
Max horizontal load at base = (4.0/2 x 14.8) = 30 KN/m

### Section 1 – 1

Depth of underpinning = 49.270 – 45.270 = 4.0m
Max pressure at base of underpin (from CADS output for LL surcharge and soil only) = 25.7KN/m$^2$
Max horizontal load at base = (4.0/2 x 14.8) = 51.4 KN/m

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## 1st Stage Excavation

## Section A-A

The excavation should be carried out to a level which the passive resistance is sufficient to provide a minimum safety factor of 2.0. From this excavation level trenches will be excavated at 1.2m c/c and the underpinning toes will be horizontally restrained using steel sections.

For practical purposes consider excavating the top 2.0m and then digging the trenches to install the horizontal props to the underpinning toes.

Determine the F.O.S at 2.0m below the initial excavation level.

## Active Force

Depth of excavation = 49.270 – 47.270 = 2.0m
Max pressure at base of underpin (from CADS output for LL surcharge and soil only) = 19.7 KN/$m^2$
Max horizontal load at base = (2.2/2 x 19.7) = 19.7 KN/m

## Passive Force

Depth of excavation = 47.270 – 42.270 = 2.0m

Passive resistance = $2^2$ x 0.5 x 19 x 2.38 = 90.4 KN/m/m.

$K_a = \frac{1-\sin 24°}{1+\sin 24°} = 0.42$

$K_p = \frac{1}{0.42} = 2.38$

Revised F.O.S. = $\frac{90.4}{19.7} = 4.6 > 2.0$, **passive resistance sufficient to allow excavation to this level. 2.0m below the ground floor slab level or to 47.270moD, over digging not allowed.**



7 Blenheim Court, Brownfields, Welwyn Garden City, Herts AL7 1AD
Tel: 01707 260022 Fax: 01707 260099

| | | | | |
|---|---|---|---|---|
| Contract No: | 16308 | Site Address: 32 Percy Street, London, W1T 2DE | | |
| Designed: WP | | Checked: DMB | *Design Category Check:* 2 | Page 20 |
| **Purpose of Design:** Underpinning Design | | | | |

## Section B – B

The excavation should be carried out to a level which the passive resistance is sufficient to provide a minimum safety factor of 2.0. From this excavation level trenches will be excavated at 1.2m c/c and the underpinning toes will be horizontally restrained using steel sections.

For practical purposes consider excavating the top 2.0m and then digging the trenches to install the horizontal props to the underpinning toes.

Determine the F.O.S at 2.0m below the initial excavation level (45.270mOD).

In this case the existing footing is found to be lower than the allowable 1$^{st}$ stage excavation. This would enable the site to be reduced all throughout before carrying out the underpinning bases.

| Rev | Description | Date |
|---|---|---|
| 0 | First Issue | 13/01/2017 |
| A | moD Levels revised. | 17/01/2017 |
| | | |

**7 Blenheim Court, Brownfields, Welwyn Garden City, Herts AL7 1AD**
**Tel: 01707 260022 Fax: 01707 260099**

## Section 1 – 1

The excavation should be carried out to a level which the passive resistance is sufficient to provide a minimum safety factor of 2.0. From this excavation level trenches will be excavated at 1.2m c/c and the underpinning toes will be horizontally restrained using steel sections.

For practical purposes consider excavating the top 2.0m and then digging the trenches to install the horizontal props to the underpinning toes.

Find the F.O.S at 2.0m below the initial excavation level.

## Active Force

Depth of excavation = 49.270 – 47.270 = 2.0m
Max pressure at base of underpin (from CADS output for LL surcharge and soil only) = 11.1KN/$m^2$
Max horizontal load at base = (2.0/2 x 11.1) = 11.1 KN/m/m

## Passive Force

Depth of excavation = 49.270 – 47.270 = 2.0m

Passive resistance = $2.0^2$ x 0.5 x 19 x 2.38 = 90.4 KN/m/m.

$K_a = \frac{1-\sin 24°}{1+\sin 24°} = 0.42$

$K_p = \frac{1}{0.42} = 2.38$

Revised F.O.S. = $\frac{90.4}{11.1} = 8.1 > 2.0$, **passive resistance sufficient to allow excavation to this level. 2.0m below the ground floor slab level or to 45.270moD, over digging not allowed.**



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