DD Porter/Siemens

# UCLH, BIRKBECK UNIVERSITY - MRI

## Calculation Package

UCL-WSP-ZZ-ZZ-SC-S-0001
JANUARY 2018

CONFIDENTIAL

DD Porter/**Siemens**

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## Calculation Package

**CONFIDENTIAL**

**PROJECT NO. 70038590**
**OUR REF. NO. UCL-WSP-ZZ-ZZ-SC-S-0001**

**DATE: JANUARY 2018**

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# QUALITY CONTROL

| Issue/revision | First issue | Revision 1 | Revision 2 | Revision 3 |
|---|---|---|---|---|
| Remarks | INFORMATION | | | |
| Date | 12th February 2018 | | | |
| Prepared by | Patrick Gittings | | | |
| Signature | PG | | | |
| Checked by | Nathan Pentelow | | | |
| Signature | NP | | | |
| Authorised by | Mark Bundy | | | |
| Signature | MRB | | | |
| Project number | 70038590 | | | |
| Report number | UCL-WSP-ZZ-ZZ-SC-S-0001 | | | |
| File reference | | | | |

# CONTENTS

# 1 INTRODUCTION

The following document details the various structural calculations that have been carried out by WSP on behalf of DD Porter for the project at Birkbeck University, 26 Bedford Way, London. The calculations refer to the following structural works, which will facilitate the installation of a new Siemens 3T MRI scanner:

- A new 350mm thick RC Slab (with stainless steel bars) to support the MRI scanner.
- RC stub columns to support the slab, in addition to foundations.
- A new internal steel frame to support required RF shielding.
- Structural steel columns and beams to provide an opening in the existing facade to facilitate the delivery of the MRI scanner.

Additional information referring to the properties of the materials used and the structural philosophy can be found in WSP document UCL-WSP-ZZ-ZZ-RP-S-0001.

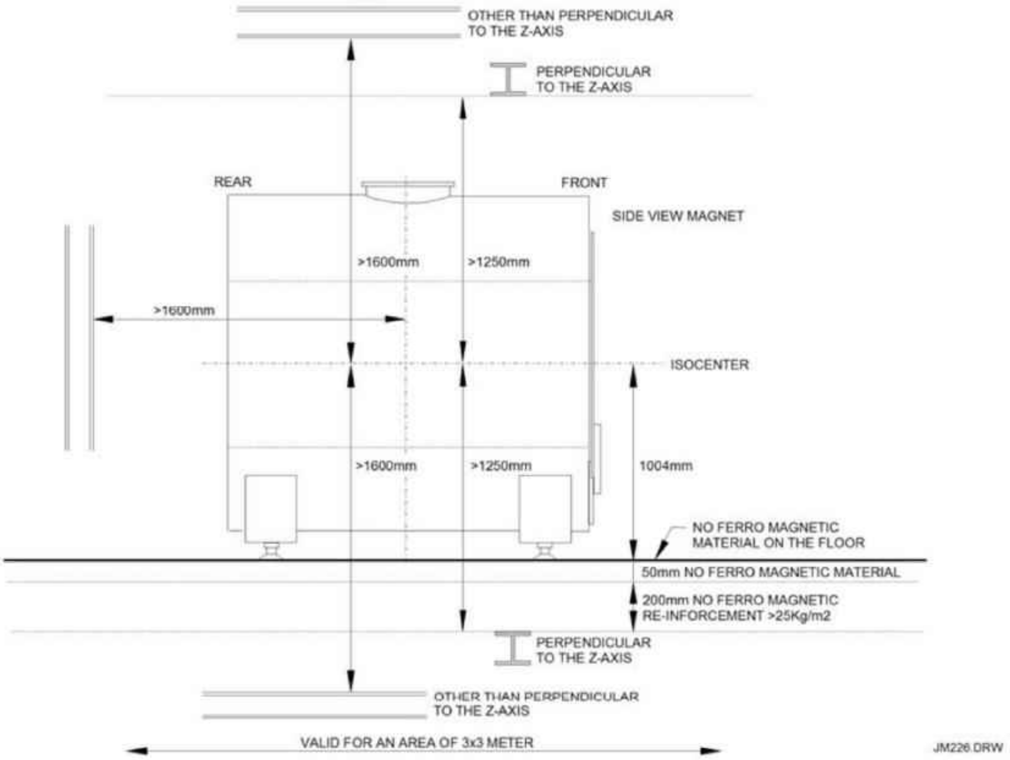
# 2 MRI SUPPORT SLAB & SUPPORTS

## 2.1 RC SLAB DESIGN

The MRI support slab has been designed using the following loadings:

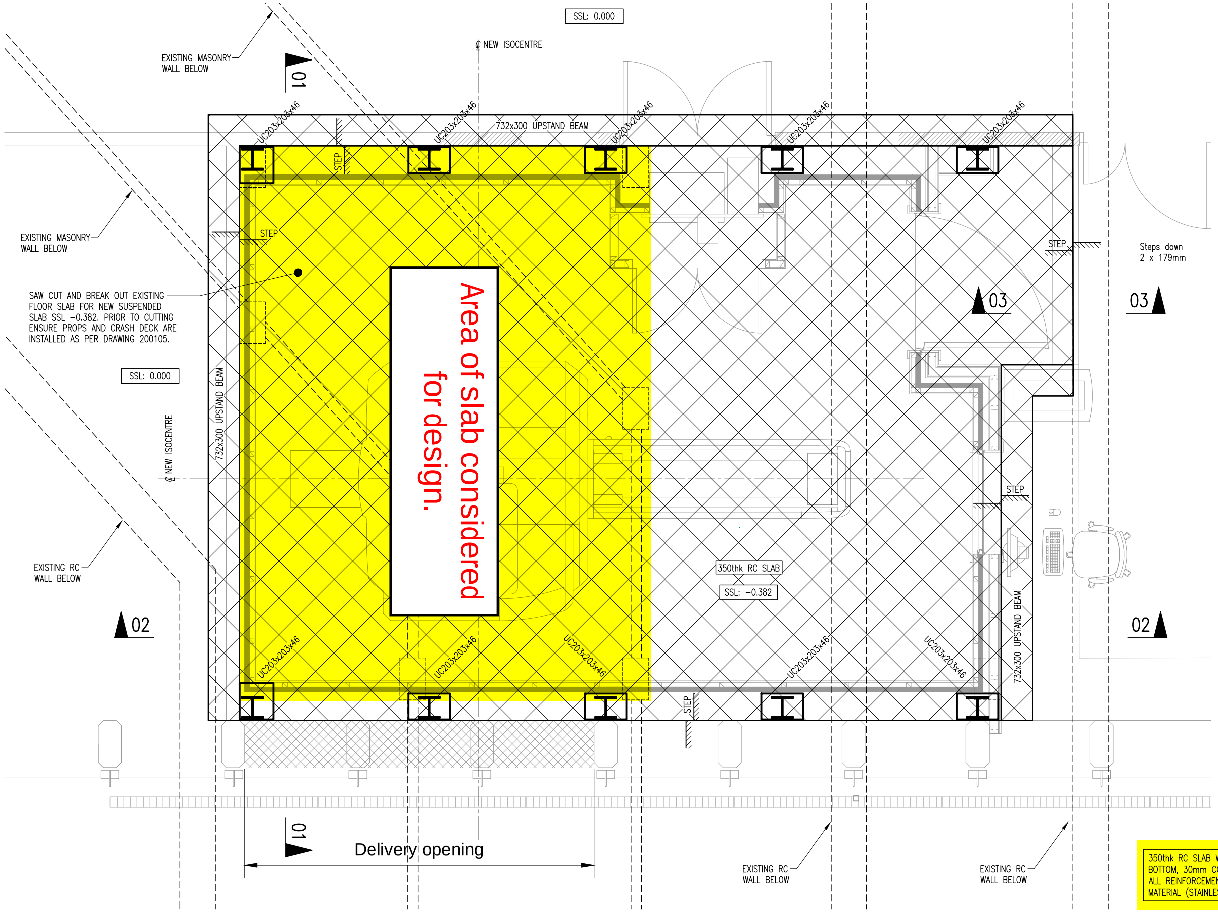
- Dead Load of 8.4 kN/m$^2$ for the 350mm thick slab
- Super Imposed Dead Load of 2.25 kN/m$^2$ for the RF cage and partitions
- Services Load of 0.25 kN/m$^2$
- Imposed Load of 25 kN/m$^2$, this value is based on the weight of the 12000kg MRI scanner being distributed over an area of 5m$^2$, plus an additional nominal allowance of 1.5 kN/m$^2$ for general imposed load.
- A load of 1.5 kN/m$^2$ has been used to allow for the weight of the shielding (based on 20mm thick steel plates).

Full design outputs for a section of the slab are shown below:



**CAUTION**

If beams closer than 1.25m to the iso centre plane are needed for construction reasons, these must be made of non-ferromagnetic material e.g. stainless steel (AISA 316L, 304 or 321) or aluminum. Not all stainless steel is non-ferromagnetic. A bar magnet can be used to test if the material is non-ferromagnetic.



## GROUND FLOOR PLAN

1:25

350thk RC SLAB WITH B16@200 TOP AND B20@200 BOTTOM, 30mm COVER. CONCRETE GRADE TO BE C32/40. ALL REINFORCEMENT MUST BE A NON-FERROMAGNETIC MATERIAL (STAINLESS STEEL 316L, 304 OR 321).

## DO NOT SCALE

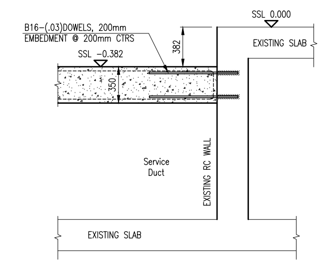
## GENERAL NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH CSM ARCHITECTS DRAWING 4443/15.
2. UNLESS NOTED OTHERWISE, MINIMUM COVER TO BE:
   - TOP = 30mm
   - BOTTOM & SIDES = 30mm
3. CONCRETE MIX: C32/40 (0.55/300) OR RC40
4. FOR BAR BENDING SCHEDULE REFER TO UCL-WSP-00-GF-SH-S-200101.
5. REINFORCEMENT IS SCHEDULED IN ACCORDANCE WITH B.S 8666:2005
6. UNLESS OTHERWISE STATED ALL LAPS SHOULD BE AS FOLLOWS: (MINIMUM)
   - H10 = 400mm
   - H12 = 500mm
   - H16 = 650mm
   - H20 = 800mm
   - H25 = 1000mm
7. WHERE STARTER BARS AND CONTINUITY BARS PROJECT FROM THE CONCRETE, THERE IS A RISK OF INJURY. THE REINFORCEMENT HAS BEEN DETAILED ASSUMING THAT THE CONTRACTOR SHALL TAKE APPROPRIATE MEASURES TO MITIGATE THIS RISK.

▨ DENOTES SAW CUT AND BREAK OUT EXISTING FLOOR SLAB

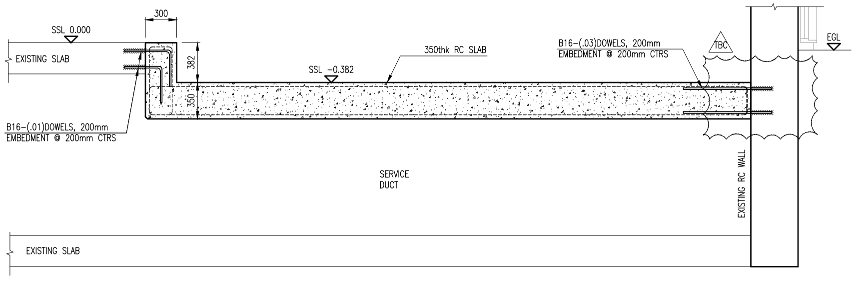
## KEY TO HEALTH & SAFETY SYMBOLS

- ⚠ WARNING RISK INDICATES A RESIDUAL RISK AS A WARNING.
- ● COMPULSORY RISK INDICATES A RESIDUAL RISK REQUIRING A COMPULSORY ACTION.
- ⊘ PROHIBITIVE RISK INDICATES A RESIDUAL RISK REQUIRING A PROHIBITIVE ACTION.
- ⓘ INFORMATION RISK INDICATES A RESIDUAL RISK FOR INFORMATION.



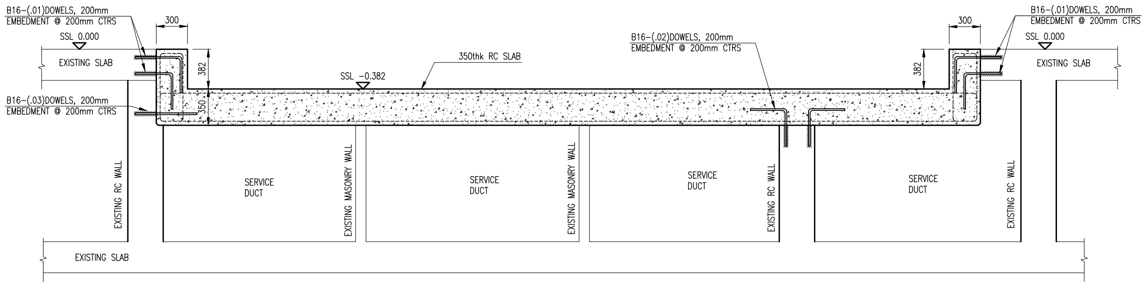
## SECTION 03–03

1:25



## SECTION 01–01

1:25

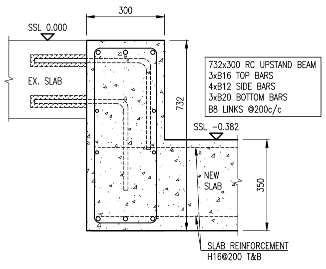


## SECTION 02–02

1:25

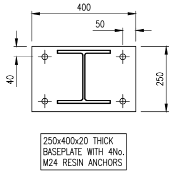
SITE MEASUREMENTS REQUIRED TO CONFIRM SETTING OUT OF EXISTING STRUCTURE

⚠ EXISTING STRUCTURAL DETAILS/CONSTRUCTION TO BE CONFIRMED ON SITE PRIOR TO COMMENCING WORKS



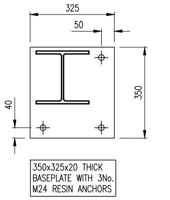
## 732x300 UPSTAND BEAM TYPICAL DETAIL

1:10



## 203x203UC BASEPLATE

1:10



## 203x203UC BASEPLATE CORNER

1:10

| REV | DATE | BY | DESCRIPTION | CHK | APP |
|---|---|---|---|---|---|
| 01 | 18-01-18 | NP | ISSUED FOR INFORMATION | NP | MRB |

DRAWING STATUS: INFORMATION

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CLIENT: DD PORTER / SIEMENS

ARCHITECT: CSM ARCHITECTS LTD

SITE/PROJECT: UCLH, BIRKBECK UNIVERSITY
MRI

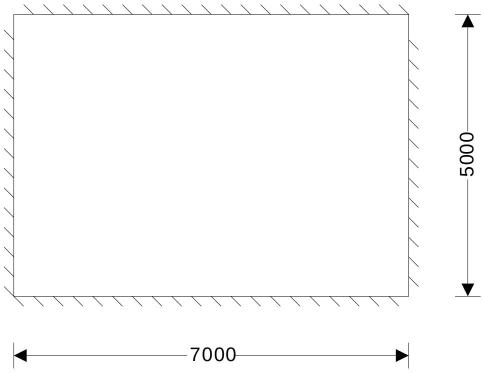
TITLE: STRUCTURAL
GROUND FLOOR
SECTION AND DETAILS

SCALE @ A1: 1:25
CHECKED: MRB
APPROVED: MRB
PROJECT NO: 70038590
DESIGNED: NP
DRAWN: HD
DATE: JAN 2018
DRAWING No: UCL-WSP-00-GF-DR-S-200101
REV: 01

## RC SLAB DESIGN

**In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex**

Tedds calculation version 1.0.12



### Slab definition

| | |
|---|---|
| Slab reference name | **MRI Slab 350mm** |
| Type of slab | **Two way spanning with restrained edges** |
| Overall slab depth | $h$ = **350** mm |
| Shorter effective span of panel | $l_x$ = **5000** mm |
| Longer effective span of panel | $l_y$ = **7000** mm |
| Support conditions | **Four edges discontinuous** |
| Bottom outer layer of reinforcement | **Short span direction** |

### Loading

| | |
|---|---|
| Characteristic permanent action | $G_k$ = **10.9** kN/m$^2$ |
| Characteristic variable action | $Q_k$ = **25.0** kN/m$^2$ |
| Partial factor for permanent action | $\gamma_G$ = **1.35** |
| Partial factor for variable action | $\gamma_Q$ = **1.50** |
| Quasi-permanent value of variable action | $\psi_2$ = **0.30** |
| Design ultimate load | $q = \gamma_G \times G_k + \gamma_Q \times Q_k$ = **52.2** kN/m$^2$ |
| Quasi-permanent load | $q_{SLS} = 1.0 \times G_k + \psi_2 \times Q_k$ = **18.4** kN/m$^2$ |

### Concrete properties

| | |
|---|---|
| Concrete strength class | C32/40 |
| Characteristic cylinder strength | $f_{ck}$ = **32** N/mm$^2$ |
| Partial factor (Table 2.1N) | $\gamma_C$ = **1.50** |
| Compressive strength factor (cl. 3.1.6) | $\alpha_{cc}$ = **0.85** |
| Design compressive strength (cl. 3.1.6) | $f_{cd}$ = **18.1** N/mm$^2$ |
| Mean axial tensile strength (Table 3.1) | $f_{ctm} = 0.30 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3}$ = **3.0** N/mm$^2$ |
| Maximum aggregate size | $d_g$ = **20** mm |

### Reinforcement properties

| | |
|---|---|
| Characteristic yield strength | $f_{yk}$ = **314** N/mm$^2$ |
| Partial factor (Table 2.1N) | $\gamma_S$ = **1.15** |
| Design yield strength (fig. 3.8) | $f_{yd} = f_{yk} / \gamma_S$ = **273.0** N/mm$^2$ |

**Concrete cover to reinforcement**

| | |
|---|---|
| Nominal cover to outer bottom reinforcement | $c_{nom\_b}$ = **30** mm |
| Fire resistance period to bottom of slab | $R_{btm}$ = **60** min |
| Axia distance to bottom reinft (Table 5.8) | $a_{fi\_b}$ = **10** mm |
| Min. btm cover requirement with regard to bond | $c_{min,b\_b}$ = **20** mm |
| Reinforcement fabrication | **Not subject to QA system** |
| Cover allowance for deviation | $\Delta c_{dev}$ = **10** mm |
| Min. required nominal cover to bottom reinft | $c_{nom\_b\_min}$ = **30.0** mm |
| | ***PASS - There is sufficient cover to the bottom reinforcement*** |

**Reinforcement design at midspan in short span direction (cl.6.1)**

| | |
|---|---|
| Bending moment coefficient | $\beta_{sx\_p}$ = **0.0870** |
| Design bending moment | $M_{x\_p} = \beta_{sx\_p} \times q \times l_x^2$ = **113.6** kNm/m |
| Reinforcement provided | 20 mm dia. bars at 200 mm centres |
| Area provided | $A_{sx\_p}$ = 1571 mm$^2$/m |
| Effective depth to tension reinforcement | $d_{x\_p} = h - c_{nom\_b} - \phi_{x\_p} / 2$ = **310.0** mm |
| K factor | $K = M_{x\_p} / (b \times d_{x\_p}^2 \times f_{ck})$ = **0.037** |
| Redistribution ratio | $\delta = 1.0$ |
| K' factor | $K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208** |
| | ***K < K' - Compression reinforcement is not required*** |
| Lever arm | $z = \min(0.95 \times d_{x\_p}, d_{x\_p}/2 \times (1 + (1 - 3.53 \times K)^{0.5}))$ = **294.5** mm |
| Area of reinforcement required for bending | $A_{sx\_p\_m} = M_{x\_p} / (f_{yd} \times z)$ = **1413** mm$^2$/m |
| Minimum area of reinforcement required | $A_{sx\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{x\_p}, 0.0013 \times b \times d_{x\_p})$ = **770** mm$^2$/m |
| Area of reinforcement required | $A_{sx\_p\_req} = \max(A_{sx\_p\_m}, A_{sx\_p\_min})$ = **1413** mm$^2$/m |
| | ***PASS - Area of reinforcement provided exceeds area required*** |

**Check reinforcement spacing**

| | |
|---|---|
| Reinforcement service stress | $\sigma_{sx\_p} = (f_{yk} / \gamma_S) \times \min((A_{sx\_p\_m}/A_{sx\_p}), 1.0) \times q_{SLS} / q$ = **86.6** N/mm$^2$ |
| Maximum allowable spacing (Table 7.3N) | $s_{max\_x\_p}$ = **300** mm |
| Actual bar spacing | $s_{x\_p}$ = **200** mm |
| | ***PASS - The reinforcement spacing is acceptable*** |

**Reinforcement design at midspan in long span direction (cl.6.1)**

| | |
|---|---|
| Bending moment coefficient | $\beta_{sy\_p}$ = **0.0560** |
| Design bending moment | $M_{y\_p} = \beta_{sy\_p} \times q \times l_x^2$ = **73.1** kNm/m |
| Reinforcement provided | 20 mm dia. bars at 200 mm centres |
| Area provided | $A_{sy\_p}$ = 1571 mm$^2$/m |
| Effective depth to tension reinforcement | $d_{y\_p} = h - c_{nom\_b} - \phi_{x\_p} - \phi_{y\_p} / 2$ = **290.0** mm |
| K factor | $K = M_{y\_p} / (b \times d_{y\_p}^2 \times f_{ck})$ = **0.027** |
| Redistribution ratio | $\delta = 1.0$ |
| K' factor | $K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21$ = **0.208** |
| | ***K < K' - Compression reinforcement is not required*** |
| Lever arm | $z = \min(0.95 \times d_{y\_p}, d_{y\_p}/2 \times (1 + (1 - 3.53 \times K)^{0.5}))$ = **275.5** mm |
| Area of reinforcement required for bending | $A_{sy\_p\_m} = M_{y\_p} / (f_{yd} \times z)$ = **972** mm$^2$/m |
| Minimum area of reinforcement required | $A_{sy\_p\_min} = \max(0.26 \times (f_{ctm}/f_{yk}) \times b \times d_{y\_p}, 0.0013 \times b \times d_{y\_p})$ = **720** mm$^2$/m |
| Area of reinforcement required | $A_{sy\_p\_req} = \max(A_{sy\_p\_m}, A_{sy\_p\_min})$ = **972** mm$^2$/m |
| | ***PASS - Area of reinforcement provided exceeds area required*** |

**Check reinforcement spacing**

Reinforcement service stress $\sigma_{sy\_p} = (f_{yk} / \gamma_S) \times \min((A_{sy\_p\_m}/A_{sy\_p}), 1.0) \times q_{SLS} / q = \mathbf{59.5}$ N/mm$^2$

Maximum allowable spacing (Table 7.3N) $s_{max\_y\_p} = \mathbf{300}$ mm

Actual bar spacing $s_{y\_p} = \mathbf{200}$ mm

***PASS - The reinforcement spacing is acceptable***

**Shear capacity check at short span discontinuous support**

Shear force $V_{x\_d} = q \times l_x / 2 = \mathbf{130.5}$ kN/m

Reinforcement provided **20 mm dia. bars at 200 mm centres**

Area provided $A_{sx\_d} = \mathbf{1571}$ mm$^2$/m

Effective depth $d_{x\_d} = d_{x\_p} = \mathbf{310.0}$ mm

Effective depth factor $k = \min(2.0, 1 + (200 \text{ mm} / d_{x\_d})^{0.5}) = \mathbf{1.803}$

Reinforcement ratio $\rho_l = \min(0.02, A_{sx\_d} / (b \times d_{x\_d})) = \mathbf{0.0051}$

Minimum shear resistance $V_{Rd,c\_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{x\_d}$

$V_{Rd,c\_min} = \mathbf{148.6}$ kN/m

Shear resistance $V_{Rd,c\_x\_d} = \max(V_{Rd,c\_min}, 0.18 \text{ N/mm}^2 / \gamma_C \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{x\_d})$

$V_{Rd,c\_x\_d} = \mathbf{169.6}$ kN/m

***PASS - Shear capacity is adequate (0.770)***

**Shear capacity check at long span discontinuous support**

Shear force $V_{y\_d} = q \times l_x / 2 = \mathbf{130.5}$ kN/m

Reinforcement provided **20 mm dia. bars at 200 mm centres**

Area provided $A_{sy\_d} = \mathbf{1571}$ mm$^2$/m

Effective depth $d_{y\_d} = d_{y\_p} = \mathbf{290.0}$ mm

Effective depth factor $k = \min(2.0, 1 + (200 \text{ mm} / d_{y\_d})^{0.5}) = \mathbf{1.830}$

Reinforcement ratio $\rho_l = \min(0.02, A_{sy\_d} / (b \times d_{y\_d})) = \mathbf{0.0054}$

Minimum shear resistance $V_{Rd,c\_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{y\_d}$

$V_{Rd,c\_min} = \mathbf{142.2}$ kN/m

Shear resistance $V_{Rd,c\_y\_d} = \max(V_{Rd,c\_min}, 0.18 \text{ N/mm}^2 / \gamma_C \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{y\_d})$

$V_{Rd,c\_y\_d} = \mathbf{164.7}$ kN/m

***PASS - Shear capacity is adequate (0.793)***

**Basic span-to-depth deflection ratio check (cl. 7.4.2)**

Reference reinforcement ratio $\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000 = \mathbf{0.0057}$

Required tension reinforcement ratio $\rho = \max(0.0035, A_{sx\_p\_req} / (b \times d_{x\_p})) = \mathbf{0.0036}$

Required compression reinforcement ratio $\rho' = A_{scx\_p\_req} / (b \times d_{x\_p}) = \mathbf{0.0000}$

Stuctural system factor (Table 7.4N) $K_\delta = \mathbf{1.0}$

Basic limit span-to-depth ratio $\text{ratio}_{lim\_x\_bas} = K_\delta \times [11 + 1.5 \times (f_{ck}/1 \text{ N/mm}^2)^{0.5} \times \rho_0/\rho + 3.2 \times (f_{ck}/1 \text{ N/mm}^2)^{0.5} \times (\rho_0/\rho - 1)^{1.5}]$

(Exp. 7.16) $\text{ratio}_{lim\_x\_bas} = \mathbf{32.45}$

Mod span-to-depth ratio limit $\text{ratio}_{lim\_x} = \min(40 \times K_\delta, \min(1.5, (500 \text{ N/mm}^2/f_{yk}) \times (A_{sx\_p}/A_{sx\_p\_m})) \times \text{ratio}_{lim\_x\_bas}) = \mathbf{40.00}$

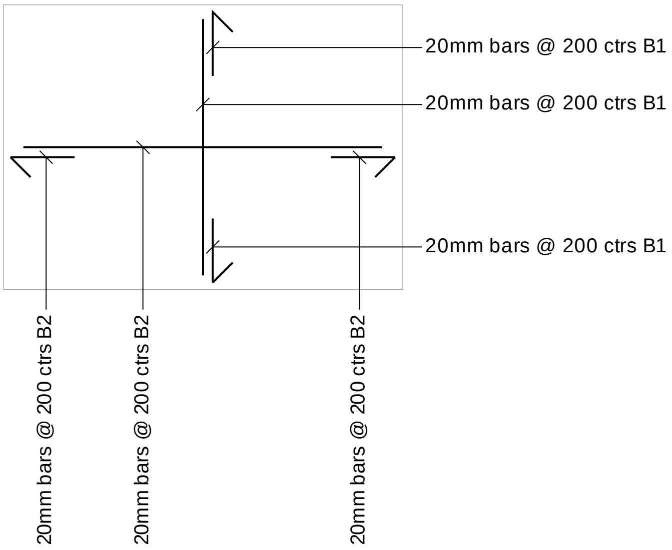
Actual span-to-eff. depth ratio $\text{ratio}_{act\_x} = l_x / d_{x\_p} = \mathbf{16.13}$

***PASS - Actual span-to-effective depth ratio is acceptable***

**Reinforcement sketch**

The following sketch is indicative only. Note that additional reinforcement may be required in accordance with clauses 9.2.1.2, 9.2.1.4 and 9.2.1.5 of EN 1992-1-1:2004 to meet detailing rules.

| WSP<br>One Queens Drive<br>Birmingham<br>B5 4PJ | Project<br>UCLH, Birkbeck University - MRI | | | | Job no.<br>70038590 | |
|---|---|---|---|---|---|---|
| | Calcs for<br>MRI Support Slab | | | | Start page no./Revision<br>p 4 01 | |
| | Calcs by<br>PG | Calcs date<br>18/01/2018 | Checked by<br>NP | Checked date<br>18/01/2018 | Approved by<br>MB | Approved date<br>18/01/2018 |



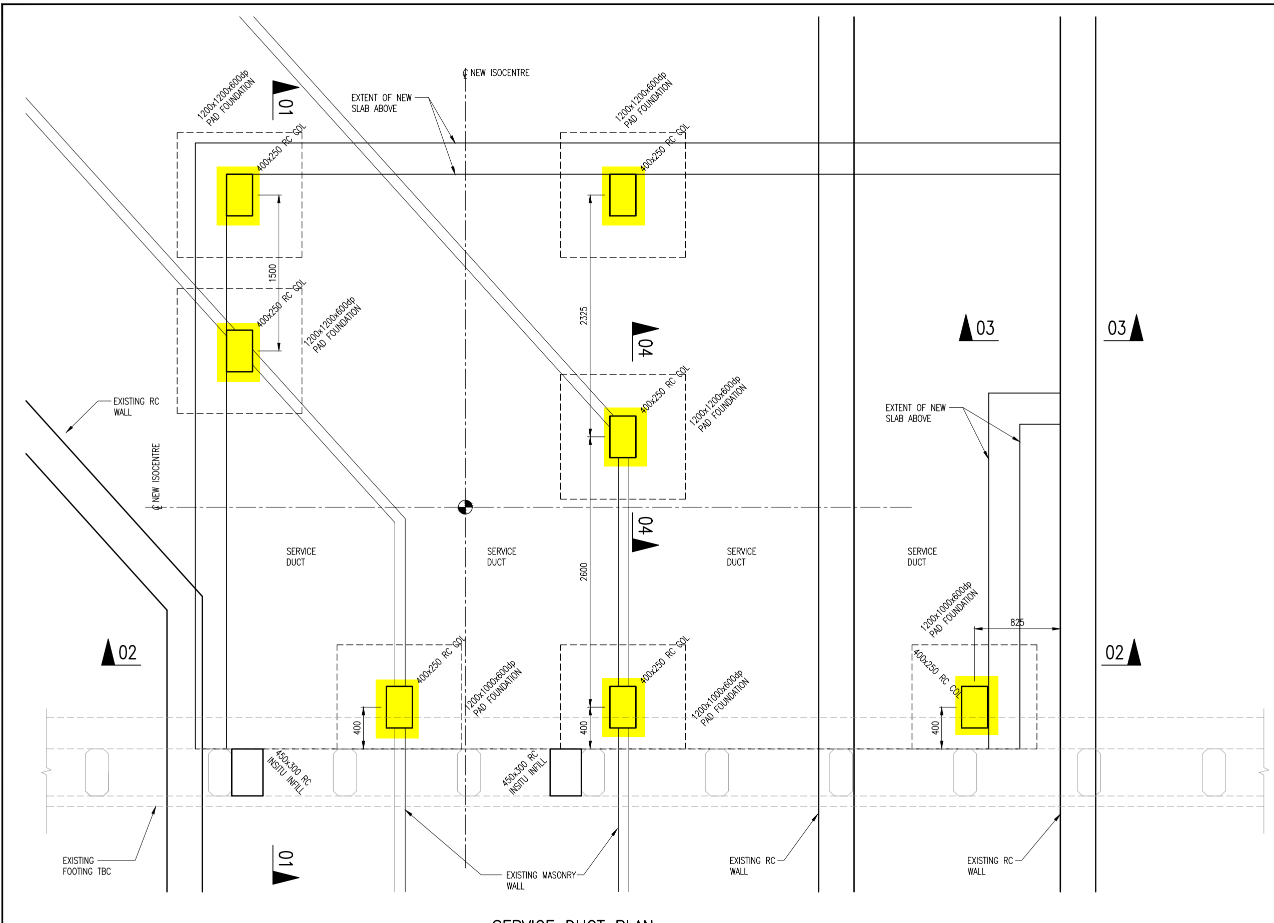
Provide:

Top Bars B16@200mm c-c

Bottom Bars B20@200mm c-c

## 2.2 RC STUB COLUMN DESIGN

Full design outputs for a typical RC stub column are shown below:



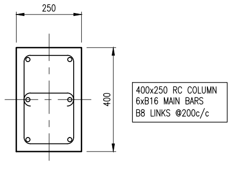
## SERVICE DUCT PLAN

1:25

SITE MEASUREMENTS REQUIRED TO CONFIRM SETTING OUT OF EXISTING STRUCTURE

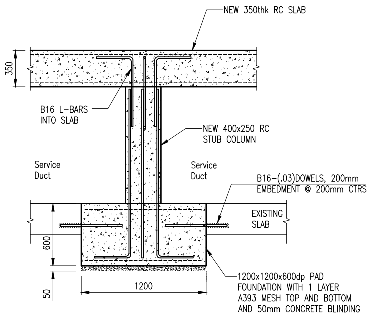
⚠ EXISTING STRUCTURAL DETAILS/CONSTRUCTION TO BE CONFIRMED ON SITE PRIOR TO COMMENCING WORKS

⚠ RECORD INFORMATION SHOWS AREA TO CONTAIN EXISTING "LIVE" SERVICES. FURTHER INVESTIGATION REQUIRED PRIOR TO COMMENCING WORKS ON SITE.



## RC STUB COLUMN

1:10



## SECTION 04–04

1:25

DO NOT SCALE

## GENERAL NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH CSM ARCHITECTS DRAWING 4443/15.
2. UNLESS NOTED OTHERWISE, MINIMUM COVER TO BE:
   - –TOP = 30mm
   - –BOTTOM & SIDES = 30mm
3. CONCRETE MIX: C32/40 (0.55/300) OR RC40
4. FOR BAR BENDING SCHEDULE REFER TO UCL-WSP-00-GF-SH-S-200101.
5. REINFORCEMENT IS SCHEDULED IN ACCORDANCE WITH B.S 8666:2005
6. UNLESS OTHERWISE STATED ALL LAPS SHOULD BE AS FOLLOWS: (MINIMUM)
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   - H12 = 500mm
   - H16 = 650mm
   - H20 = 800mm
   - H25 = 1000mm
7. WHERE STARTER BARS AND CONTINUITY BARS PROJECT FROM THE CONCRETE, THERE IS A RISK OF INJURY. THE REINFORCEMENT HAS BEEN DETAILED ASSUMING THAT THE CONTRACTOR SHALL TAKE APPROPRIATE MEASURES TO MITIGATE THIS RISK.
8. FOUNDATIONS ARE TO BE SET OUT SYMMETRICALLY ABOUT COLUMNS AND CAVITY WALL/CENTRE LINES UNLESS OTHERWISE NOTED.
9. FOUNDATIONS HAVE BEEN DESIGNED TO A BEARING CAPACITY OF 100kN/m².
10. ALL FOUNDATIONS TO HAVE 50mm CONCRETE BLINDING TO THE UNDERSIDE.

## KEY TO HEALTH & SAFETY SYMBOLS

⚠ WARNING RISK
INDICATES A RESIDUAL RISK AS A WARNING.

● COMPULSORY RISK
INDICATES A RESIDUAL RISK REQUIRING A COMPULSORY ACTION.

⊘ PROHIBITIVE RISK
INDICATES A RESIDUAL RISK REQUIRING A PROHIBITIVE ACTION.

ℹ INFORMATION RISK
INDICATES A RESIDUAL RISK FOR INFORMATION.

| REV | DATE | BY | DESCRIPTION | CHK | APP |
|---|---|---|---|---|---|
| 01 | 18-01-18 | NP | ISSUED FOR INFORMATION | NP | MRB |

DRAWING STATUS:
INFORMATION

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CLIENT:
DD PORTER / SIEMENS

ARCHITECT:
CSM ARCHITECTS LTD

SITE/PROJECT:
UCLH, BIRKBECK UNIVERSITY
MRI

TITLE:
STRUCTURAL
FOUNDATION
SECTION AND DETAILS

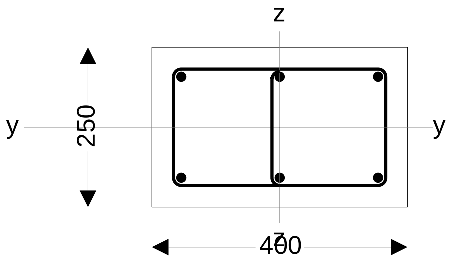
SCALE @ A1: 1:25
CHECKED: MRB
APPROVED: MRB
PROJECT NO: 70038590
DESIGNED: NP
DRAWN: HD
DATE: JAN 2018
DRAWING No: UCL-WSP-00-GF-DR-S-200102
REV: 01

File name \\UK.WSPGROUP.COM\CENTRAL DATA\PROJECTS\700385XX\70038590 - UCL 26 BEDFORD WAY\02 WIP\BS BUILDING STRUCTURE\02 DRAWING\WSP\UCL-WSP-00-GF-DR-S-200101.DWG, printed on 22 January 2018 11:12:39, by Pentelow, Nathan

## RC COLUMN DESIGN

**In accordance with EN1992-1-1:2004 incorporating Corrigendum January 2008 and the UK national annex**

Tedds calculation version 1.2.14



6 no. 16 mm diameter longitudinal bars

8 mm diameter links

Max link spacing 250 mm generally, 150 mm for

250 mm above and below slab/beam and at laps

### Column input details

**Column geometry**

| | |
|---|---|
| Overall depth (perpendicular to y axis) | h = **250** mm |
| Overall breadth (perpendicular to z axis) | b = **400** mm |
| Stability in the z direction | **Unbraced** |
| Stability in the y direction | **Unbraced** |

**Concrete details**

| | |
|---|---|
| Concrete strength class | **C32/40** |
| Partial safety factor for concrete (2.4.2.4(1)) | $\gamma_C$ = **1.50** |
| Coefficient $\alpha_{cc}$ (3.1.6(1)) | $\alpha_{cc}$ = **0.85** |
| Maximum aggregate size | $d_g$ = **20** mm |

**Reinforcement details**

| | |
|---|---|
| Nominal cover to links | $c_{nom}$ = **30** mm |
| Longitudinal bar diameter | $\phi$ = **16** mm |
| Link diameter | $\phi_v$ = **8** mm |
| Total number of longitudinal bars | N = **6** |
| No. of bars per face parallel to y axis | $N_y$ = **3** |
| No. of bars per face parallel to z axis | $N_z$ = **2** |
| Area of longitudinal reinforcement | $A_s = N \times \pi \times \phi^2 / 4$ = **1206** mm$^2$ |
| Characteristic yield strength | $f_{yk}$ = **500** N/mm$^2$ |
| Partial safety factor for reinft (2.4.2.4(1)) | $\gamma_S$ = **1.15** |
| Modulus of elasticity of reinft (3.2.7(4)) | $E_s$ = **200** kN/mm$^2$ |

**Fire resistance details**

| | |
|---|---|
| Fire resistance period | R = **60** min |
| Exposure to fire | **Exposed on more than one side** |
| Ratio of fire design axial load to design resistance | $\mu_{fi}$ = **0.70** |

**Axial load and bending moments from frame analysis**

| | |
|---|---|
| Design axial load | $N_{Ed}$ = **48.0** kN |
| Moment about y axis at top | $M_{topy}$ = **0.0** kNm |
| Moment about y axis at bottom | $M_{btmy}$ = **0.0** kNm |
| Moment about z axis at top | $M_{topz}$ = **0.0** kNm |
| Moment about z axis at bottom | $M_{btmz}$ = **0.0** kNm |

**Column effective lengths**

| | |
|---|---|
| Effective length for buckling about y axis | $l_{0y}$ = **1500** mm |
| Effective length for buckling about z axis | $l_{0z}$ = **1500** mm |

## Calculated column properties

**Concrete properties**

| | |
|---|---|
| Area of concrete | $A_c = h \times b =$ **100000** mm$^2$ |
| Characteristic compression cylinder strength | $f_{ck} =$ **32** N/mm$^2$ |
| Design compressive strength (3.1.6(1)) | $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C =$ **18.1** N/mm$^2$ |
| Mean value of cylinder strength (Table 3.1) | $f_{cm} = f_{ck}$ + 8 MPa = **40.0** N/mm$^2$ |
| Secant modulus of elasticity (Table 3.1) | $E_{cm}$ = 22000 MPa × ($f_{cm}$ / 10 MPa)$^{0.3}$ = **33.3** kN/mm$^2$ |

**Rectangular stress block factors**

| | |
|---|---|
| Depth factor (3.1.7(3)) | $\lambda_{sb} = 0.8$ |
| Stress factor (3.1.7(3)) | $\eta = 1.0$ |

**Strain limits**

| | |
|---|---|
| Compression strain limit (Table 3.1) | $\varepsilon_{cu3} =$ **0.00350** |
| Pure compression strain limit (Table 3.1) | $\varepsilon_{c3} =$ **0.00175** |

**Design yield strength of reinforcement**

| | |
|---|---|
| Design yield strength (3.2.7(2)) | $f_{yd} = f_{yk} / \gamma_S =$ **434.8** N/mm$^2$ |

**Check nominal cover for fire and bond requirements**

| | |
|---|---|
| Min. cover reqd for bond (to links) (4.4.1.2(3)) | $c_{min,b} = \max(\phi_v, \phi - \phi_v) =$ **8** mm |
| Min axis distance for fire (EN1992-1-2 T 5.2a) | $a_{fi}$ = **46** mm |
| Allowance for deviations from min cover (4.4.1.3) | $\Delta c_{dev}$ = **10** mm |
| Min allowable nominal cover | $c_{nom\_min} = \max(a_{fi} - \phi / 2 - \phi_v, c_{min,b} + \Delta c_{dev}) =$ **30.0** mm |

***PASS - the nominal cover equals the minimum required***

**Effective depths of bars for bending about y axis**

| | |
|---|---|
| Area per bar | $A_{bar} = \pi \times \phi^2 / 4 =$ **201** mm$^2$ |
| Spacing of bars in faces parallel to z axis (c/c) | $s_z = (h - 2 \times (c_{nom} + \phi_v) - \phi) / (N_z - 1) =$ **158** mm |
| Layer 1 (in tension face) | $d_{y1} = h - c_{nom} - \phi_v - \phi / 2 =$ **204** mm |
| Layer 2 | $d_{y2} = d_{y1} - s_z =$ **46** mm |
| Effective depth about y axis | $d_y = d_{y1} =$ **204** mm |

**Effective depths of bars for bending about z axis**

| | |
|---|---|
| Area of per bar | $A_{bar} = \pi \times \phi^2 / 4 =$ **201** mm$^2$ |
| Spacing of bars in faces parallel to y axis (c/c) | $s_y = (b - 2 \times (c_{nom} + \phi_v) - \phi) / (N_y - 1) =$ **154** mm |
| Layer 1 (in tension face) | $d_{z1} = b - c_{nom} - \phi_v - \phi / 2 =$ **354** mm |
| Layer 2 | $d_{z2} = d_{z1} - s_y =$ **200** mm |
| Layer 3 | $d_{z3} = d_{z2} - s_y =$ **46** mm |
| 2nd moment of area of reinft about z axis | $I_{sz} = 2 \times A_{bar} \times N_z \times (d_{z1}-b/2)^2 =$ **1907** cm$^4$ |
| Radius of gyration of reinft about z axis | $i_{sz} = \sqrt{(I_{sz} / A_s)} =$ **126** mm |
| Effective depth about z axis (5.8.8.3(2)) | $d_z = b / 2 + i_{sz} =$ **326** mm |

**Column slenderness about y axis**

| | |
|---|---|
| Radius of gyration | $i_y = h / \sqrt{(12)} =$ **7.2** cm |
| Slenderness ratio (5.8.3.2(1)) | $\lambda_y = l_{0y} / i_y =$ **20.8** |

**Column slenderness about z axis**

Radius of gyration $i_z = b / \sqrt{(12)} =$ **11.5** cm

Slenderness ratio (5.8.3.2(1)) $\lambda_z = l_{0z} / i_z =$ **13.0**

## Design bending moments

**Frame analysis moments about y axis combined with moments due to imperfections (cl. 5.2 & 6.1(4))**

Ecc. due to geometric imperfections (y axis) $e_{iy} = l_{0y} /400 =$ **3.8** mm

Min end moment about y axis $M_{01y} = \min(\text{abs}(M_{topy}), \text{abs}(M_{btmy})) + e_{iy} \times N_{Ed} =$ **0.2** kNm

Max end moment about y axis $M_{02y} = \max(\text{abs}(M_{topy}), \text{abs}(M_{btmy})) + e_{iy} \times N_{Ed} =$ **0.2** kNm

**Slenderness limit for buckling about y axis (cl. 5.8.3.1)**

Factor A $A =$ **0.7**

Mechanical reinforcement ratio $\omega = A_s \times f_{yd} / (A_c \times f_{cd}) =$ **0.289**

Factor B $B = \sqrt{(1 + 2 \times \omega)} =$ **1.256**

Moment ratio $r_{my} =$ **1.000**

Factor C $C_y = 1.7 - r_{my} =$ **0.700**

Relative normal force $n = N_{Ed} / (A_c \times f_{cd}) =$ **0.026**

Slenderness limit $\lambda_{limy} = 20 \times A \times B \times C_y / \sqrt{(n)} =$ **75.7**

***$\lambda_y < \lambda_{limy}$ - Second order effects may be ignored***

**Frame analysis moments about z axis combined with moments due to imperfections (cl. 5.2 & 6.1(4))**

Ecc. due to geometric imperfections (z axis) $e_{iz} = l_{0z} /400 =$ **3.8** mm

Min end moment about z axis $M_{01z} = \min(\text{abs}(M_{topz}), \text{abs}(M_{btmz})) + e_{iz} \times N_{Ed} =$ **0.2** kNm

Max end moment about z axis $M_{02z} = \max(\text{abs}(M_{topz}), \text{abs}(M_{btmz})) + e_{iz} \times N_{Ed} =$ **0.2** kNm

Slenderness limit for buckling about y axis (cl. 5.8.3.1)

Factor A $A =$ **0.7**

Mechanical reinforcement ratio $\omega = A_s \times f_{yd} / (A_c \times f_{cd}) =$ **0.289**

Factor B $B = \sqrt{(1 + 2 \times \omega)} =$ **1.256**

Moment ratio $r_{mz} =$ **1.000**

Factor C $C_z = 1.7 - r_{mz} =$ **0.700**

Relative normal force $n = N_{Ed} / (A_c \times f_{cd}) =$ **0.026**

Slenderness limit $\lambda_{limz} = 20 \times A \times B \times C_z / \sqrt{(n)} =$ **75.7**

***$\lambda_z < \lambda_{limz}$ - Second order effects may be ignored***

**Design bending moments (cl. 6.1(4))**

Design moment about y axis $M_{Edy} = \max(M_{02y}, N_{Ed} \times \max(h/30, 20\text{ mm})) =$ **1.0** kNm

Design moment about z axis $M_{Edz} = \max(M_{02z}, N_{Ed} \times \max(b/30, 20\text{ mm})) =$ **1.0** kNm

## Moment capacity about y axis with axial load $N_{Ed}$

**Moment of resistance of concrete**

By iteration:-

Position of neutral axis $y =$ **49.0** mm

Concrete compression force (3.1.7(3)) $F_{yc} = \eta \times f_{cd} \times \min(\lambda_{sb} \times y , h) \times b =$ **284.3** kN

Moment of resistance $M_{Rdyc} = F_{yc} \times [h / 2 - (\min(\lambda_{sb} \times y , h)) / 2] =$ **30.0** kNm

**Moment of resistance of reinforcement**

Strain in layer 1 $\varepsilon_{y1} = \varepsilon_{cu3} \times (1 - d_{y1} / y) =$ **-0.01107**

Stress in layer 1 $\sigma_{y1} = \max(-1 \times f_{yd}, E_s \times \varepsilon_{y1}) =$ **-434.8** N/mm$^2$

| | |
|---|---|
| Force in layer 1 | $F_{y1} = N_y \times A_{bar} \times \sigma_{y1} = \mathbf{-262.3}$ kN |
| Moment of resistance of layer 1 | $M_{Rdy1} = F_{y1} \times (h / 2 - d_{y1}) = \mathbf{20.7}$ kNm |
| Strain in layer 2 | $\varepsilon_{y2} = \varepsilon_{cu3} \times (1 - d_{y2} / y) = \mathbf{0.00021}$ |
| Stress in layer 2 | $\sigma_{y2} = \min(f_{yd}, E_s \times \varepsilon_{y2}) = \mathbf{42.7}$ N/mm$^2$ |
| Force in layer 2 | $F_{y2} = N_y \times A_{bar} \times \sigma_{y2} = \mathbf{25.8}$ kN |
| Moment of resistance of layer 2 | $M_{Rdy2} = F_{y2} \times (h / 2 - d_{y2}) = \mathbf{2.0}$ kNm |
| Resultant concrete/steel force | $F_y = \mathbf{47.8}$ kN |

***PASS - This is within half of one percent of the applied axial load***

**Combined moment of resistance**

| | |
|---|---|
| Moment of resistance about y axis | $M_{Rdy} = \mathbf{52.7}$ kNm |

***PASS - The moment capacity about the y axis exceeds the design bending moment***

### Moment capacity about z axis with axial load $N_{Ed}$

**Moment of resistance of concrete**

By iteration:-

| | |
|---|---|
| Position of neutral axis | $z = \mathbf{79.1}$ mm |
| Concrete compression force (3.1.7(3)) | $F_{zc} = \eta \times f_{cd} \times \min(\lambda_{sb} \times z , b) \times h = \mathbf{287.0}$ kN |
| Moment of resistance | $M_{Rdzc} = F_{zc} \times [b / 2 - (\min(\lambda_{sb} \times z , b)) / 2] = \mathbf{48.3}$ kNm |

**Moment of resistance of reinforcement**

| | |
|---|---|
| Strain in layer 1 | $\varepsilon_{z1} = \varepsilon_{cu3} \times (1 - d_{z1} / z) = \mathbf{-0.01216}$ |
| Stress in layer 1 | $\sigma_{z1} = \max(-1 \times f_{yd}, E_s \times \varepsilon_{z1}) = \mathbf{-434.8}$ N/mm$^2$ |
| Force in layer 1 | $F_{z1} = N_z \times A_{bar} \times \sigma_{z1} = \mathbf{-174.8}$ kN |
| Moment of resistance of layer 1 | $M_{Rdz1} = F_{z1} \times (b / 2 - d_{z1}) = \mathbf{26.9}$ kNm |
| Strain in layer 2 | $\varepsilon_{z2} = \varepsilon_{cu3} \times (1 - d_{z2} / z) = \mathbf{-0.00535}$ |
| Stress in layer 2 | $\sigma_{z2} = \max(-1 \times f_{yd}, E_s \times \varepsilon_{z2}) = \mathbf{-434.8}$ N/mm$^2$ |
| Force in layer 2 | $F_{z2} = 2 \times A_{bar} \times \sigma_{z2} = \mathbf{-174.8}$ kN |
| Moment of resistance of layer 2 | $M_{Rdz2} = F_{z2} \times (b / 2 - d_{z2}) = \mathbf{0.0}$ kNm |
| Strain in layer 3 | $\varepsilon_{z3} = \varepsilon_{cu3} \times (1 - d_{z3} / z) = \mathbf{0.00147}$ |
| Stress in layer 3 | $\sigma_{z3} = \min(f_{yd}, E_s \times \varepsilon_{z3}) - \eta \times f_{cd} = \mathbf{274.9}$ N/mm$^2$ |
| Force in layer 3 | $F_{z3} = N_z \times A_{bar} \times \sigma_{z3} = \mathbf{110.6}$ kN |
| Moment of resistance of layer 3 | $M_{Rdz3} = F_{z3} \times (b / 2 - d_{z3}) = \mathbf{17.0}$ kNm |
| Resultant concrete/steel force | $F_z = \mathbf{47.8}$ kN |

***PASS - This is within half of one percent of the applied axial load***

**Combined moment of resistance**

| | |
|---|---|
| Moment of resistance about z axis | $M_{Rdz} = \mathbf{92.3}$ kNm |

***PASS - The moment capacity about the z axis exceeds the design bending moment***

### Biaxial bending

**Determine if a biaxial bending check is required (5.8.9(3))**

| | |
|---|---|
| Ratio of column slenderness ratios | $ratio_{\lambda} = \max(\lambda_y, \lambda_z) / \min(\lambda_y, \lambda_z) = \mathbf{1.60}$ |
| Eccentricity in direction of y axis | $e_y = M_{Edz} / N_{Ed} = \mathbf{20.0}$ mm |
| Eccentricity in direction of z axis | $e_z = M_{Edy} / N_{Ed} = \mathbf{20.0}$ mm |
| Equivalent depth | $h_{eq} = i_y \times \sqrt{(12)} = \mathbf{250}$ mm |
| Equivalent width | $b_{eq} = i_z \times \sqrt{(12)} = \mathbf{400}$ mm |
| Relative eccentricity in direction of y axis | $e_{rel\_y} = e_y / b_{eq} = \mathbf{0.050}$ |
| Relative eccentricity in direction of z axis | $e_{rel\_z} = e_z / h_{eq} = \mathbf{0.080}$ |

| | |
|---|---|
| Ratio of relative eccentricities | $\text{ratio}_e = \min(e_{rel\_y}, e_{rel\_z}) / \max(e_{rel\_y}, e_{rel\_z}) = \mathbf{0.625}$ |
| | ***$\text{ratio}_e$ > 0.2 - Biaxial bending check is required*** |

**Biaxial bending (5.8.9(4))**

| | |
|---|---|
| Design axial resistance of section | $N_{Rd} = (A_c \times f_{cd}) + (A_s \times f_{yd}) = \mathbf{2337.8}$ kN |
| Ratio of applied to resistance axial loads | $\text{ratio}_N = N_{Ed} / N_{Rd} = \mathbf{0.021}$ |
| Exponent a | $a = \mathbf{1.00}$ |
| Biaxial bending utilisation | $UF = (M_{Edy} / M_{Rdy})^a + (M_{Edz} / M_{Rdz})^a = \mathbf{0.029}$ |
| | ***PASS - The biaxial bending capacity is adequate*** |

## 2.3 RC FOUNDATION DESIGN

Full design outputs for a typical pad foundation for the stub columns are shown below:

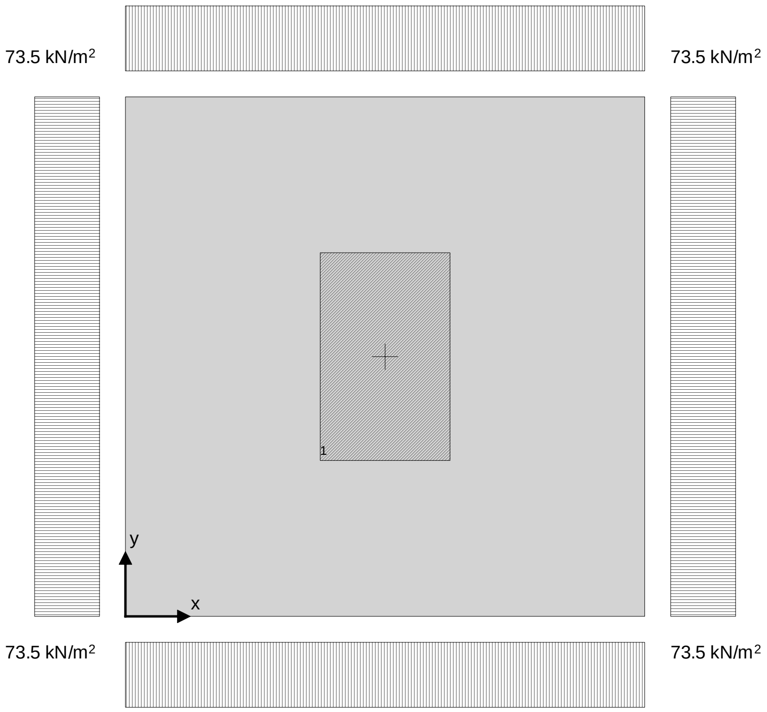
## FOUNDATION ANALYSIS (EN1997-1:2004)

**In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1**

TEDDS calculation version 3.2.11

### Pad foundation details

| | |
|---|---|
| Length of foundation | $L_x$ = **1000** mm |
| Width of foundation | $L_y$ = **1000** mm |
| Foundation area | $A = L_x \times L_y$ = **1.000** $m^2$ |
| Depth of foundation | h = **600** mm |
| Depth of soil over foundation | $h_{soil}$ = **600** mm |
| Level of water | $h_{water}$ = **0** mm |
| Density of water | $\gamma_{water}$ = **9.8** $kN/m^3$ |
| Density of concrete | $\gamma_{conc}$ = **24.5** $kN/m^3$ |



### Column no.1 details

| | |
|---|---|
| Length of column | $l_{x1}$ = **250** mm |
| Width of column | $l_{y1}$ = **400** mm |
| position in x-axis | $x_1$ = **500** mm |
| position in y-axis | $y_1$ = **500** mm |

### Soil properties

| | |
|---|---|
| Density of soil | $\gamma_{soil}$ = **18.0** $kN/m^3$ |
| Characteristic cohesion | $c'_k$ = **0** $kN/m^2$ |
| Characteristic effective shear resistance angle | $\phi'_k$ = **30** deg |
| Characteristic friction angle | $\delta_k$ = **20** deg |

**Foundation loads**

Self weight $F_{swt} = h \times \gamma_{conc} =$ **14.7** kN/m$^2$

Soil weight $F_{soil} = h_{soil} \times \gamma_{soil} =$ **10.8** kN/m$^2$

**Column no.1 loads**

Permanent load in z $F_{Gz1} =$ **16.5** kN

Variable load in z $F_{Qz1} =$ **31.5** kN

**Bearing resistance (Section 6.5.2)**

**Forces on foundation**

Force in z-axis $F_{dz} = A \times (F_{swt} + F_{soil}) + F_{Gz1} + F_{Qz1} =$ **73.5** kN

**Moments on foundation**

Moment in x-axis $M_{dx} = A \times (F_{swt} + F_{soil}) \times L_x / 2 + F_{Gz1} \times x_1 + F_{Qz1} \times x_1 =$ **36.8** kNm

Moment in y-axis $M_{dy} = A \times (F_{swt} + F_{soil}) \times L_y / 2 + F_{Gz1} \times y_1 + F_{Qz1} \times y_1 =$ **36.8** kNm

**Eccentricity of base reaction**

Eccentricity of base reaction in x-axis $e_x = M_{dx} / F_{dz} - L_x / 2 =$ **0** mm

Eccentricity of base reaction in y-axis $e_y = M_{dy} / F_{dz} - L_y / 2 =$ **0** mm

**Pad base pressures**

$q_1 = F_{dz} \times (1 - 6 \times e_x / L_x - 6 \times e_y / L_y) / (L_x \times L_y) =$ **73.5** kN/m$^2$

$q_2 = F_{dz} \times (1 - 6 \times e_x / L_x + 6 \times e_y / L_y) / (L_x \times L_y) =$ **73.5** kN/m$^2$

$q_3 = F_{dz} \times (1 + 6 \times e_x / L_x - 6 \times e_y / L_y) / (L_x \times L_y) =$ **73.5** kN/m$^2$

$q_4 = F_{dz} \times (1 + 6 \times e_x / L_x + 6 \times e_y / L_y) / (L_x \times L_y) =$ **73.5** kN/m$^2$

Minimum base pressure $q_{min} = \min(q_1, q_2, q_3, q_4) =$ **73.5** kN/m$^2$

Maximum base pressure $q_{max} = \max(q_1, q_2, q_3, q_4) =$ **73.5** kN/m$^2$

**Presumed bearing capacity**

Presumed bearing capacity $P_{bearing} =$ **100.0** kN/m$^2$

***PASS - Presumed bearing capacity exceeds design base pressure***

**Partial factors on actions - Combination1**

Permanent unfavourable action - Table A.3 $\gamma_G =$ **1.35**

Permanent favourable action - Table A.3 $\gamma_{Gf} =$ **1.00**

Variable unfavourable action - Table A.3 $\gamma_Q =$ **1.50**

Variable favourable action - Table A.3 $\gamma_{Qf} =$ **0.00**

**Partial factors for spread foundations - Combination1**

Bearing - Table A.5 $\gamma_{R.v} =$ **1.00**

Sliding - Table A.5 $\gamma_{R.h} =$ **1.00**

**Forces on foundation**

Force in z-axis $F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) + \gamma_Q \times F_{Qz1} =$ **104.0** kN

**Moments on foundation**

Moment in x-axis $M_{dx} = \gamma_G \times (A \times (F_{swt} + F_{soil}) \times L_x / 2 + F_{Gz1} \times x_1) + \gamma_Q \times F_{Qz1} \times x_1 =$ **52.0** kNm

Moment in y-axis $M_{dy} = \gamma_G \times (A \times (F_{swt} + F_{soil}) \times L_y / 2 + F_{Gz1} \times y_1) + \gamma_Q \times F_{Qz1} \times y_1 =$ **52.0** kNm

**Eccentricity of base reaction**

Eccentricity of base reaction in x-axis $e_x = M_{dx} / F_{dz} - L_x / 2 =$ **0** mm

Eccentricity of base reaction in y-axis $e_y = M_{dy} / F_{dz} - L_y / 2 =$ **0** mm

**Effective area of base**

Effective length $L'_x = L_x - 2 \times e_x = \mathbf{1000}$ mm

Effective width $L'_y = L_y - 2 \times e_y = \mathbf{1000}$ mm

Effective area $A' = L'_x \times L'_y = \mathbf{1.000}\ m^2$

**Pad base pressure**

Design base pressure $f_{dz} = F_{dz} / A' = \mathbf{104}\ kN/m^2$

**Partial factors on actions - Combination2**

Permanent unfavourable action - Table A.3 $\gamma_G = \mathbf{1.00}$

Permanent favourable action - Table A.3 $\gamma_{Gf} = \mathbf{1.00}$

Variable unfavourable action - Table A.3 $\gamma_Q = \mathbf{1.30}$

Variable favourable action - Table A.3 $\gamma_{Qf} = \mathbf{0.00}$

**Partial factors for spread foundations - Combination2**

Bearing - Table A.5 $\gamma_{R.v} = \mathbf{1.00}$

Sliding - Table A.5 $\gamma_{R.h} = \mathbf{1.00}$

**Forces on foundation**

Force in z-axis $F_{dz} = \gamma_G \times (A \times (F_{swt} + F_{soil}) + F_{Gz1}) + \gamma_Q \times F_{Qz1} = \mathbf{83.0}$ kN

**Moments on foundation**

Moment in x-axis $M_{dx} = \gamma_G \times (A \times (F_{swt} + F_{soil}) \times L_x / 2 + F_{Gz1} \times x_1) + \gamma_Q \times F_{Qz1} \times x_1 = \mathbf{41.5}$ kNm

Moment in y-axis $M_{dy} = \gamma_G \times (A \times (F_{swt} + F_{soil}) \times L_y / 2 + F_{Gz1} \times y_1) + \gamma_Q \times F_{Qz1} \times y_1 = \mathbf{41.5}$ kNm

**Eccentricity of base reaction**

Eccentricity of base reaction in x-axis $e_x = M_{dx} / F_{dz} - L_x / 2 = \mathbf{0}$ mm

Eccentricity of base reaction in y-axis $e_y = M_{dy} / F_{dz} - L_y / 2 = \mathbf{0}$ mm

**Effective area of base**

Effective length $L'_x = L_x - 2 \times e_x = \mathbf{1000}$ mm

Effective width $L'_y = L_y - 2 \times e_y = \mathbf{1000}$ mm

Effective area $A' = L'_x \times L'_y = \mathbf{1.000}\ m^2$

**Pad base pressure**

Design base pressure $f_{dz} = F_{dz} / A' = \mathbf{83}\ kN/m^2$

## FOUNDATION DESIGN (EN1992-1-1:2004)

**In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1**

TEDDS calculation version 3.2.11

**Concrete details (Table 3.1 - Strength and deformation characteristics for concrete)**

Concrete strength class C32/40

Characteristic compressive cylinder strength $f_{ck} = \mathbf{32}\ N/mm^2$

Characteristic compressive cube strength $f_{ck,cube} = \mathbf{40}\ N/mm^2$

Mean value of compressive cylinder strength $f_{cm} = f_{ck} + 8\ N/mm^2 = \mathbf{40}\ N/mm^2$

Mean value of axial tensile strength $f_{ctm} = 0.3\ N/mm^2 \times (f_{ck}/\ 1\ N/mm^2)^{2/3} = \mathbf{3.0}\ N/mm^2$

5% fractile of axial tensile strength $f_{ctk,0.05} = 0.7 \times f_{ctm} = \mathbf{2.1}\ N/mm^2$

Secant modulus of elasticity of concrete $E_{cm} = 22\ kN/mm^2 \times [f_{cm}/10\ N/mm^2]^{0.3} = \mathbf{33346}\ N/mm^2$

Partial factor for concrete (Table 2.1N) $\gamma_C = \mathbf{1.50}$

| | |
|---|---|
| Compressive strength coefficient (cl.3.1.6(1)) | $\alpha_{cc}$ = **0.85** |
| Design compressive concrete strength (exp.3.15) | $f_{cd} = \alpha_{cc} \times f_{ck} / \gamma_C$ = **18.1** N/mm$^2$ |
| Tens.strength coeff.for plain concrete (cl.12.3.1(1)) | $\alpha_{ct,pl}$ = **0.80** |
| Des.tens.strength for plain concrete (exp.12.1) | $f_{ctd,pl} = \alpha_{ct,pl} \times f_{ctk,0.05} / \gamma_C$ = **1.1** N/mm$^2$ |
| Maximum aggregate size | $h_{agg}$ = **20** mm |

**Reinforcement details**

| | |
|---|---|
| Characteristic yield strength of reinforcement | $f_{yk}$ = **500** N/mm$^2$ |
| Modulus of elasticity of reinforcement | $E_s$ = **210000** N/mm$^2$ |
| Partial factor for reinforcing steel (Table 2.1N) | $\gamma_S$ = **1.15** |
| Design yield strength of reinforcement | $f_{yd} = f_{yk} / \gamma_S$ = **435** N/mm$^2$ |
| Nominal cover to reinforcement | $c_{nom}$ = **30** mm |

**Strip and pad footings (Section 12.9.3)**

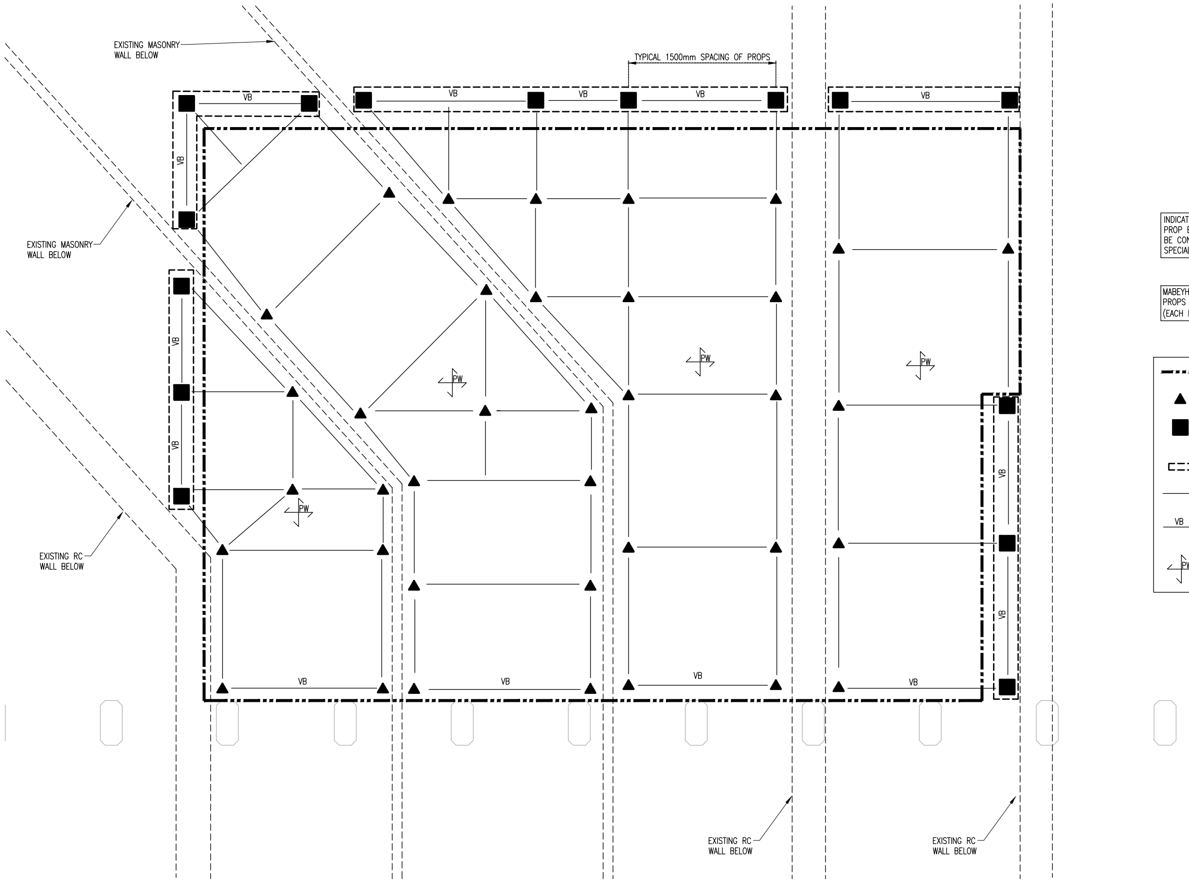
| | |
|---|---|
| Design base pressure | $f_{dz}$ = **104** kN/m$^2$ |
| Projection from column face | a = **375** mm |
| Max.projection from column face - (exp.12.13) | $a_{max} = 0.85 \times h / \sqrt{[3 \times f_{dz} / f_{ctd,pl}]}$ = **970** mm |

***PASS - Projection from the column face doesn't exceed permissible limit for plain concrete***

Provide 1000x1000x600 mm deep Foundation with A393 Mesh Top & Bottom

## 2.4 PROPPING REQUIREMENTS

The required propping arrangement for the slab is detailed below:



## GROUND FLOOR PROPPING PLAN

1:25

INDICATIVE LINE OF PROP BRACING, TO BE CONFIRMED BY SPECIALIST

MABEYHIRE, SYSTEM 160 SOLDIER PROPS OR SIMILAR TO BE USED. (EACH PROP LOAD APPROX. = 100kN)

| | |
|---|---|
| —·—·— | OUTLINE OF EXISTING SLAB TO BE CUT |
| ▲ | MAIN PROPS SUPPORTING CRASH DECK. TO BE REMOVED ONCE SLAB HAS BEEN CUT |
| ■ | MAIN PROPS SUPPORTING SLAB ALONG CUT EDGE. TO BE REMOVED ONCE FULL WORKS HAVE BEEN COMPLETED. |
| ⊏⊐ | 50mm RIGID PACKER TO UNDERSIDE OF SLAB TO PROVIDE CONTINUOUS SUPPORT |
| ——— | HORIZONTAL SOLDIER PROPS SET AT 50mm BELOW SLAB SOFFIT |
| VB | HORIZONTAL SOLDIER PROPS SET AT 50mm BELOW SLAB SOFFIT WITH A DIAGONAL SCAFFOLD TUBE BRACING. |
| PW | 2x18mm (MIN) PLYWOOD CRASH DECK ON SECONDARY SUPPORT SET AT 25mm BELOW SLAB SOFFIT. |

1. INSTALL PROPS, PROP BRACING AND PLYWOOD CRASH DECK AS INDICATIVELY SHOWN TO SUPPORT EXISTING CONCRETE SLAB. CRASH DECK TO BE INSTALLED 25mm BELOW SOFFIT OF EXISTING SLAB.
2. CORE DRILL AND REMOVE EXISTING SLAB
3. ONCE ALL CONCRETE HAS BEEN REMOVED THE INNER PROPS CAN BE REMOVED (DENOTED BY TRIANGLES). PROPS SUPPORTING THE EXISTING SLAB EDGE ARE TO REMAIN (DENOTED BY SQUARES).
4. DIG/CAST NEW RC STUB COLUMN FOUNDATIONS.
5. CAST RC STUB COLUMNS.
6. INSTALL REQUIRED DOWEL BARS FOR CONNECTION OF NEW SLAB BACK TO THE EXISTING SLAB. CAST NEW 350thk SLAB.
7. PROPS SUPPORTING THE EXISTING SLAB EDGE ARE TO REMAIN AFTER THE NEW SLAB HAS BEEN CAST FOR A MINIMUM OF 14 DAYS TO ALLOW CONCRETE TO GAIN STRENGTH.

SITE MEASUREMENTS REQUIRED TO CONFIRM SETTING OUT OF EXISTING STRUCTURE

⚠ EXISTING STRUCTURAL DETAILS/CONSTRUCTION TO BE CONFIRMED ON SITE PRIOR TO COMMENCING WORKS

DO NOT SCALE

## GENERAL NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH CSM ARCHITECTS DRAWING 4443/15.
2. FOR STRUCTURAL GENERAL ARRANGEMENT REFER TO UCL-WSP-00-GF-DR-S-200101.

### KEY TO HEALTH & SAFETY SYMBOLS

| | |
|---|---|
| ⚠ | WARNING RISK<br>INDICATES A RESIDUAL RISK AS A WARNING. |
| ● | COMPULSORY RISK<br>INDICATES A RESIDUAL RISK REQUIRING A COMPULSORY ACTION. |
| ⊘ | PROHIBITIVE RISK<br>INDICATES A RESIDUAL RISK REQUIRING A PROHIBITIVE ACTION. |
| ⓘ | INFORMATION RISK<br>INDICATES A RESIDUAL RISK FOR INFORMATION. |

| REV | DATE | BY | DESCRIPTION | CHK | APP |
|---|---|---|---|---|---|
| 01 | 18-01-18 | NP | ISSUED FOR INFORMATION | NP | MRB |

DRAWING STATUS:
INFORMATION

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CLIENT:
DD PORTER / SIEMENS

ARCHITECT:
CSM ARCHITECTS LTD

SITE/PROJECT:
UCLH, BIRKBECK UNIVERSITY
MRI

TITLE:
STRUCTURAL
GROUND FLOOR / FOUNDATION
PROPPING REQUIREMENTS

SCALE @ A1: 1:25
CHECKED: MRB
APPROVED: MRB
PROJECT NO: 70038590
DESIGNED: NP
DRAWN: HD
DATE: JAN 2018
DRAWING No: UCL-WSP-00-GF-DR-S-200105
REV: 01

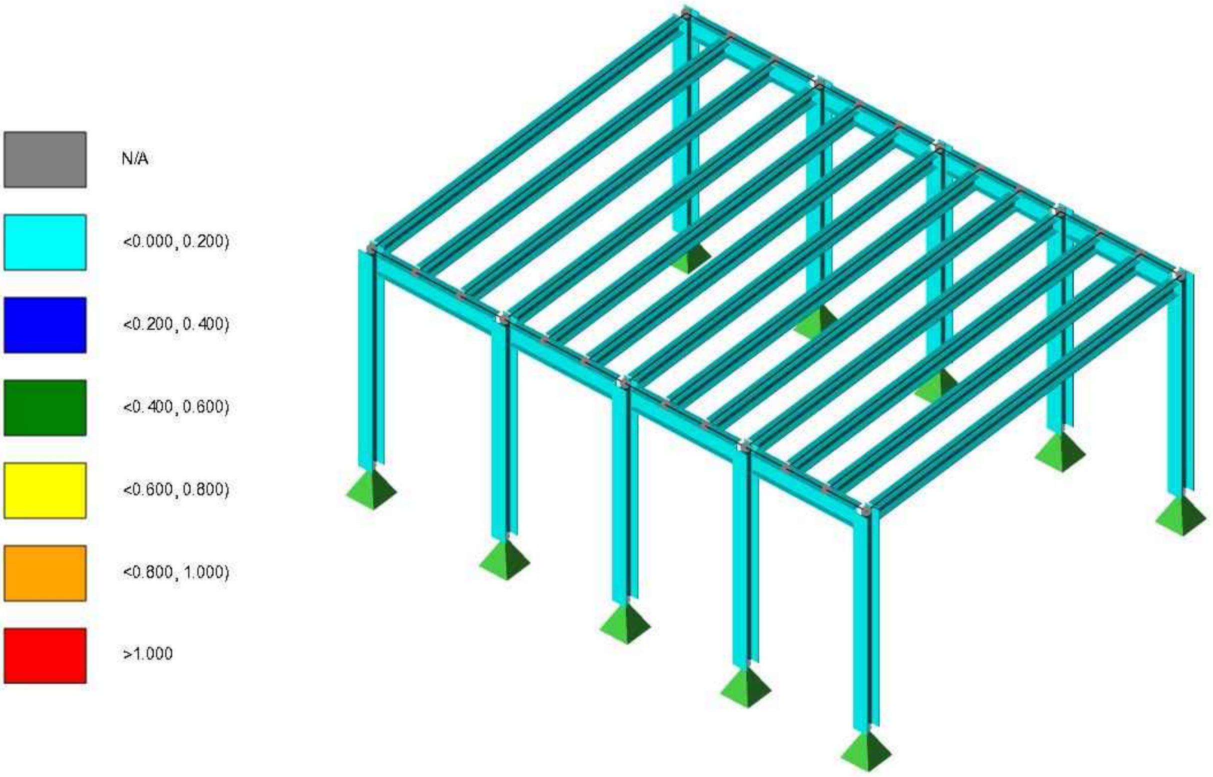
# 3 INTERNAL SHIELDING SUPPORT FRAME

## 3.1 STRUCTURAL STEELWORK

Considering the number of connections and proposed details, adequate stiffness will be provided to the frame without the requirement of additional bracing. Furthermore, with the frame being internal, it is considered that any lateral forces present will be nominal and will not have an adverse effect on the stability of the structure.

## 3.2 STEEL FRAME DESIGN

The frame has been modelled in Tekla Structural Designer, 3D view of the structure showing the utilisation ratio of structural elements. The frame has been designed assuming a super imposed dead load of 1.5kNm$^{-2}$ to account for the weight of the shielding. The member sizes have generally been selected to suit site restrictions and geometry requirements.



Beam Design

Beam Design Summary – Static

| Member Reference | Group Ref. | Span | Section | Grade | Length [m] | No. Connectors | Utilization | Status |
|---|---|---|---|---|---|---|---|---|
| SB 1/A/2-1/A/1 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.089 | ✓ Pass |
| SB 1/B/2-1/B/1 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.177 | ✓ Pass |
| SB 1/C/2-1/C/1 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.177 | ✓ Pass |
| SB 1/D/2-1/D/1 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.187 | ✓ Pass |
| SB 1/E/2-1/E/1 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.098 | ✓ Pass |
| SB 1/A/2-1/B/2 | SBR2 | 1 | UB 254x146x37 | S355 | 1.698 | 0 | 0.015 | ✓ Pass |
| SB 1/B/2-1/C/2 | SBR2 | 1 | UB 254x146x37 | S355 | 1.698 | 0 | 0.015 | ✓ Pass |
| SB 1/C/2-1/D/2 | SBR2 | 1 | UB 254x146x37 | S355 | 1.698 | 0 | 0.015 | ✓ Pass |
| SB 1/D/2-1/E/2 | SBR3 | 1 | UB 254x146x37 | S355 | 1.878 | 0 | 0.018 | ✓ Pass |
| SB 1/A/1-1/B/1 | SBR2 | 1 | UB 254x146x37 | S355 | 1.698 | 0 | 0.015 | ✓ Pass |

| Member Reference | Group Ref. | Span | Section | Grade | Length [m] | No. Connectors | Utilization | Status |
|---|---|---|---|---|---|---|---|---|
| SB 1/B/1-1/C/1 | SBR2 | 1 | UB 254x146x37 | S355 | 1.698 | 0 | 0.015 | ✓ Pass |
| SB 1/C/1-1/D/1 | SBR2 | 1 | UB 254x146x37 | S355 | 1.698 | 0 | 0.015 | ✓ Pass |
| SB 1/D/1-1/E/1 | SBR3 | 1 | UB 254x146x37 | S355 | 1.878 | 0 | 0.018 | ✓ Pass |
| SB 1/2/#5-1/1/#6 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.177 | ✓ Pass |
| SB 1/2/#7-1/1/#8 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.177 | ✓ Pass |
| SB 1/2/#9-1/1/#10 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.177 | ✓ Pass |
| SB 1/2/#11-1/1/#12 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.177 | ✓ Pass |
| SB 1/2/#13-1/1/#14 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.177 | ✓ Pass |
| SB 1/2/#15-1/1/#16 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.177 | ✓ Pass |
| SB 1/2/#17-1/1/#18 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.196 | ✓ Pass |
| SB 1/2/#19-1/1/#20 | SBR1 | 1 | UC 152x152x37 | S355 | 5.272 | 0 | 0.196 | ✓ Pass |

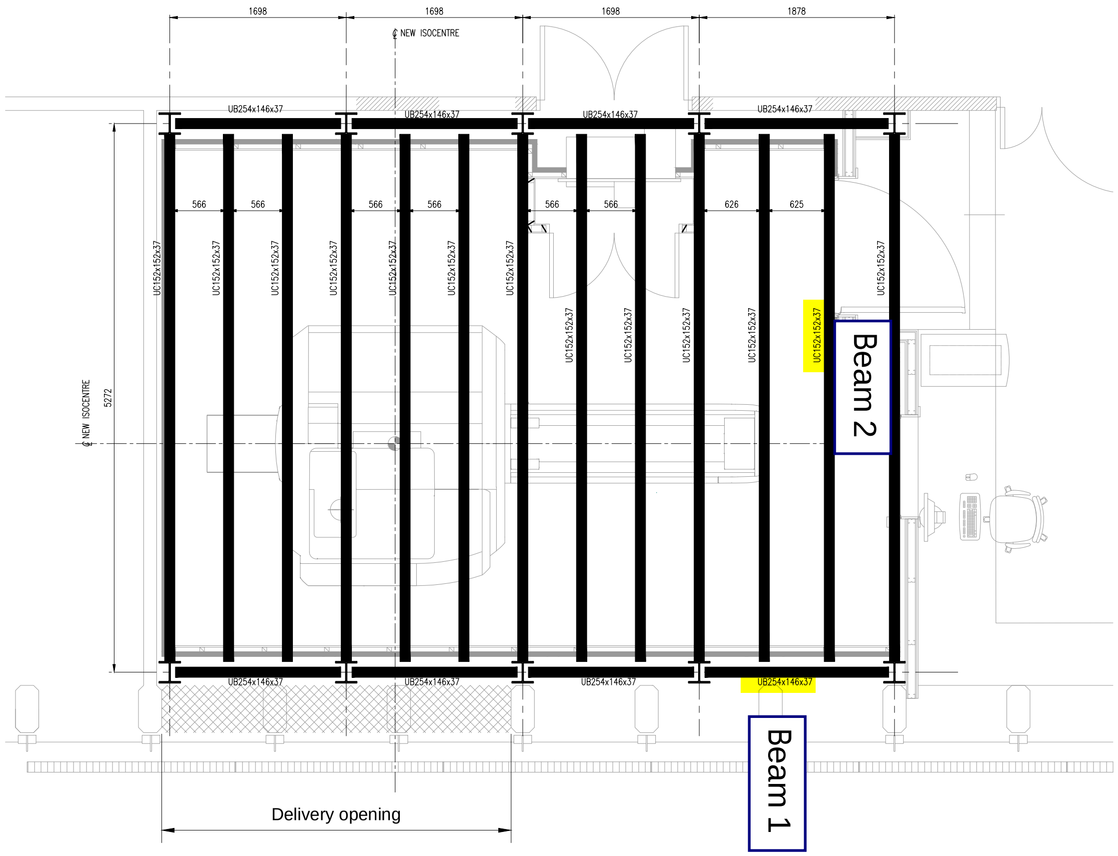
## Column Design

### Column Design Summary – Static

| Member Reference | Group Ref. | Stack | Section | Grade | Length [m] | Utilization | Status |
|---|---|---|---|---|---|---|---|
| SC A/2 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.013 | ✓ Pass |
| SC B/2 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.016 | ✓ Pass |
| SC C/2 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.016 | ✓ Pass |
| SC D/2 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.017 | ✓ Pass |
| SC E/2 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.014 | ✓ Pass |
| SC E/1 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.014 | ✓ Pass |
| SC D/1 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.017 | ✓ Pass |
| SC C/1 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.016 | ✓ Pass |
| SC B/1 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.016 | ✓ Pass |
| SC A/1 | SCR1 | 1 | UC 203x203x46 | S355 | 3.000 | 0.013 | ✓ Pass |

### 3.2.1 STEEL BEAMS

The full design outputs for selected steel beams are shown below:



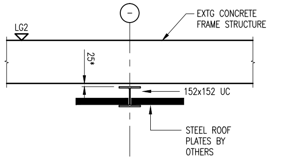
## MRI CEILING PLAN

1:25

SITE MEASUREMENTS REQUIRED TO CONFIRM SETTING OUT OF EXISTING STRUCTURE

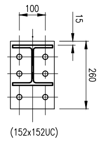
⚠ EXISTING STRUCTURAL DETAILS/CONSTRUCTION TO BE CONFIRMED ON SITE PRIOR TO COMMENCING WORKS

* DENOTES DIMENSION TBC ON SITE TO ENSURE NO OBSTRUCTIONS TO PROPOSED STEELWORK



## MRI CEILING SUPPORT BEAM DETAIL

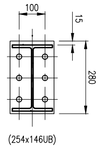
1:20



170x260x12 THK END PLATE 6No. M20 (8.8) BOLTS 8mm FW

## BEAM CONNECTION DETAIL 1

1:10



170x280x12 THK END PLATE 6No. M20 (8.8) BOLTS 8mm FW

## BEAM CONNECTION DETAIL 2

1:10

DO NOT SCALE

## GENERAL NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH CSM ARCHITECTS DRAWING 4443/15.

2. ALL STRUCTURAL STEELWORK TO COMPLY WITH BS.EN.1993

3. ALL STRUCTURAL STEELWORK TO BE GRADE S355 (U.N.O.) BRITISH MILD STEEL TO BS EN 10056–1:1999, BS.4–1:1993, BS EN 10210–2:1997 AND BS EN 10219–2:1997.

4. ALL STRUCTURAL STEELWORK TO BE BLAST CLEAN TO BS EN ISO 8501–1:2001, GRADE SA 2.5, FOLLOWED BY A HIGH BUILD ZINC PHOSPHATE PRIMER. TO 75 MICRON DRY FILM THICKNESS.

5. ALL BOLTS TO BE GRADE 8.8 ZINC PLATED

6. THE CONTRACTOR SHALL BE RESPONSIBLE FOR FOR ANY TEMPORARY BRACING DURING ERECTION, AND ALL SHOP DETAILS FABRICATION DRAWINGS. THE FABRICATION DRAWINGS SHALL BE SUBMITTED.

7. THE CONTRACTOR SHALL ALLOW FOR ANY AMENDMENTS OF FABRICATION DETAILS ARISING FROM ENGINEERS COMMENTS

8. DIMENSION LINES ARE NOT TO BE SCALED FORM THIS DRAWING

9. THE CONTRACTOR SHALL COMPLY WITH THE HEALTH AND SAFETY REQUIREMENTS AS SET BY THE CDM REGULATIONS, THE HEALTH AND SAFETY EXECUTIVE.

10. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE EXECUTION OF THE WORKS IN ACCORDANCE WITH THE DRAWINGS AND THE SPECIFICATION AND FOR THE ACCURACY OF ALL THE DIMENSIONS AND SETTING OUT ON SITE

11. UNLESS STATED CONNECTIONS SHOULD BE DESIGNED FOR 100KN (ULS) SHEAR LOADING.

12. FOR BUILDERS WORK FOR INCOMING SERVICES REFER TO ARCHITECT'S DRAWING FOR SETTING OUT.

KEY TO HEALTH & SAFETY SYMBOLS

| | |
|---|---|
| ⚠ | WARNING RISK<br>INDICATES A RESIDUAL RISK AS A WARNING. |
| ● | COMPULSORY RISK<br>INDICATES A RESIDUAL RISK REQUIRING A COMPULSORY ACTION. |
| ⊘ | PROHIBITIVE RISK<br>INDICATES A RESIDUAL RISK REQUIRING A PROHIBITIVE ACTION. |
| ⓘ | INFORMATION RISK<br>INDICATES A RESIDUAL RISK FOR INFORMATION. |

| REV | DATE | BY | DESCRIPTION | CHK | APP |
|---|---|---|---|---|---|
| 01 | 18–01–18 | NP | ISSUED FOR INFORMATION | NP | MRB |

DRAWING STATUS:
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CLIENT:
DD PORTER / SIEMENS

ARCHITECT:
CSM ARCHITECTS LTD

SITE/PROJECT:
UCLH, BIRKBECK UNIVERSITY
MRI

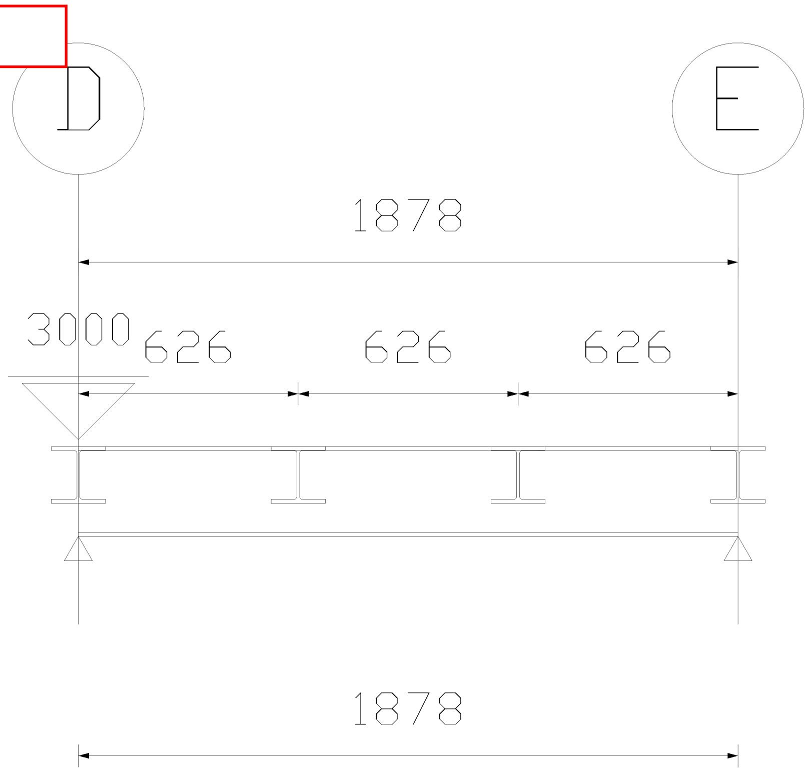
TITLE:
STRUCTURAL
MRI FRAME STEELWORK
SECTION AND DETAILS

| | | | |
|---|---|---|---|
| SCALE @ A1: 1:25 | CHECKED: MRB | | APPROVED: MRB |
| PROJECT NO: 70038590 | DESIGNED: NP | DRAWN: HD | DATE: JAN 2018 |

DRAWING No: UCL-WSP-00-GF-DR-S-200103
REV: 01

| | | | | | |
|---|---|---|---|---|---|
| WSP<br>One Queens drive<br>Birmingham<br>B5 4PJ | Project<br>UCLH, Birkbeck University - MRI | | | Job Ref.<br>70038590 | |
| | Structure<br>Internal Shielding Support Frame | | | Sheet no.<br>Page 1/2 | |
| | Calc. by<br>Patrick Gittings | Date<br>23/01/2018 | Chk'd by<br>Nathan Pentelow | Date<br>23/01/2018 | App'd by<br>Mark Bundy |
| | | | | | Date<br>23/01/2018 |

Beam 1



St. 1 (1): SB 1/D/1-1/E/1

UB 254x146x37 S355

**Restraints**

| Source | Distance / Length [m] | LTB Top / Sub-Beam | LTB Top Factor | LTB Btm / Sub-Beam | LTB Btm Factor | Strut Major / Sub-Beam | Strut Major Factor | Strut Minor / Sub-Beam | Strut Minor Factor |
|---|---|---|---|---|---|---|---|---|---|
| support | 0.000 | ● | | ● | | ● | | ● | |
| sub-beam | 0.626 | ● | 1.000 | | 1.000 | | 1.000 | | 1.000 |
| member | 0.626 | ● | | | | | | ● | |
| sub-beam | 0.626 | ● | 1.000 | | 1.000 | | 1.000 | | 1.000 |
| member | 1.252 | ● | | | | | | ● | |
| sub-beam | 0.626 | ● | 1.000 | | 1.000 | | 1.000 | | 1.000 |
| support | 1.878 | ● | | ● | | ● | | ● | |

**Static**

Summary UB 254x146x37(S355)

| Design Condition | # | Design Value | Design Capacity | Units | U.R. | Status |
|---|---|---|---|---|---|---|
| Classification | 1 | Class 1 | - | - | - | Pass |
| Shear Major | 1 | -5.1 | 360.6 | kN | 0.014 | Pass |