R.J. AUSTIN
Chartered Structural Engineer
C.Eng., M.I. Struct.E.

57 Fernie Fields
High Wycombe
Bucks HP12 4SN

Tel: 01494 531756
Fax: 01494 531366
Mobile: 07976 529 289

C/08/193

# STRUCTURAL CALCULATIONS

FOR

PROPOSED OPENING

AT

THE NATIONAL HOSPITAL

ALBANY WING

THIRD FLOOR

DECEMBER 2008

**INDEX**



## 1.00 DESIGN DATA

Steelwork to be grade 43.

Brickwork to be 20N/mm3 in 1. 1. 6. mortar unless noted otherwise.

## NOTES

1. All steelwork to be shot blasted and painted.
2. All steels supporting existing walls to be wedged up at 1.0Mc/c to predeflect new beam prior to pinning up with 1-3 dry-pack incorporating 'Combex 100' expanding agent.
3. All beam ends to be built in solid each end.
4. Existing walls and floor over to be properly pinned propped and supported during construction.

## 2.0 LOADINGS

### ROOF (PITCHED)

| | | | | |
|---|---|---|---|---|
| Tiles | | = | 0.65 | KN/m2 |
| Battens Felt & Insulation | | = | 0.05 | = |
| Rafters | | = | 0.10 | = |
| Ceiling | | = | 0.20 | = |
| | | = | 1.00 | = |
| Superimposed. | (40 Degree Pitch) | = | 0.60 | = |
| Superimposed on ceiling | | = | 0.25 | = |
| | | = | 1.85 | KN/m2 |

### UPPER FLOORS ALBANY WING

| | | | | |
|---|---|---|---|---|
| Screed | | = | 1.80 | KN/m2 |
| Infill | | = | 6.00 | = |
| Ceiling | | = | 0.20 | = |
| | | = | 8.00 | = |
| Superimposed. | | = | 5.00 | = |
| | | = | 13.00 | KN/m2 |

### WALLS (ELEVATION AREA)

| | | | |
|---|---|---|---|
| 105mm Brick | = | 2.50 | KN/m2 |
| 215mm Brick | = | 5.00 | = |

**Analysis for a simply-supported single-span beam to BS 5950 (with LTB)**

**Span length & partial factors for loading**

| Span (mm) | Factors for moments & forces | | | Factors for deflection | | |
|---|---|---|---|---|---|---|
| | $\gamma_{fd}$ | $\gamma_{fi}$ | $\gamma_{fw}$ | $\gamma_{dd}$ | $\gamma_{di}$ | $\gamma_{dw}$ |
| **4500** | **1.40** | **1.60** | **0.00** | **1.00** | **1.00** | **1.00** |

**Load descriptions**

Loads are applied normal to the major principal axis (x-axis) of the member.

| Ref. | Category | Description |
|---|---|---|
| 1 | **"Dead"** | **"ROOF"** |
| 2 | **"Imposed"** | **"ROOF"** |
| 3 | **"Dead"** | **"WALL"** |
| 4 | **"Dead"** | **"FLOORS"** |
| 5 | **"Imposed"** | **"FLOORS"** |

**Loading data (unfactored)**

| Ref. | Category | Type | Load kN/m | Position mm | Load kN/m | Position mm |
|---|---|---|---|---|---|---|
| **1** | **"Dead"** | UDL | **5.0** | **0** | - | **4500** |
| **2** | **"Imposed"** | UDL | **4.0** | **0** | - | **4500** |
| **3** | **"Dead"** | UDL | **18.0** | **0** | - | **4500** |
| **4** | **"Dead"** | UDL | **32.0** | **0** | - | **4500** |
| **5** | **"Imposed"** | UDL | **23.0** | **0** | - | **4500** |

**Analysis results - entire span**

| $R_a$ | $R_b$ | $F_{vy}$ | $M_x$ | | Deflection: $\delta EI_x$ | |
|---|---|---|---|---|---|---|
| kN (fac) | kN (fac) | kN (fac) | kNm (fac) | Sense | $kNm^3$ | Direction |
| **270.5** | **270.5** | **270.5** | **304.3** | **"Sagging"** | **437.83** | **"Down"** |

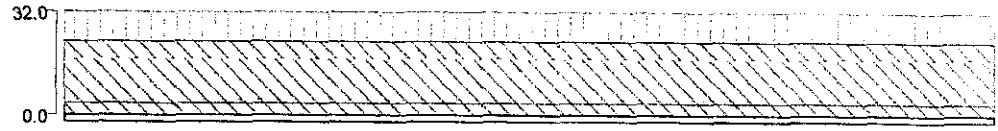
**Unfactored support reactions**

| | | | | | |
|---|---|---|---|---|---|
| Support A | Dead load | **-123.7** kN | Live load | **-60.7** kN | Wind load **0.0** kN |
| Support B | Dead load | **-123.7** kN | Live load | **-60.7** kN | Wind load **0.0** kN |

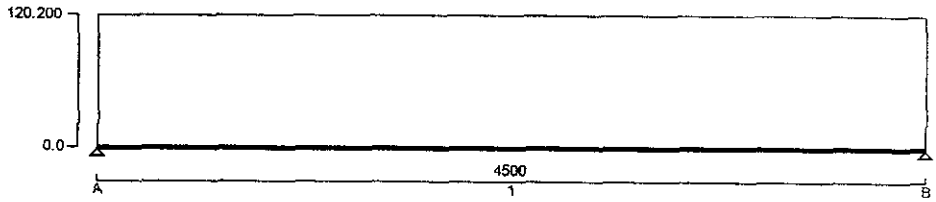
***LTB segment results***

| Seg. | $x_s$ mm | $x_e$ mm | $L_{LT}$ mm | $M_{LT}$ kNm (fac) | $M_{mLT2}$ kNm (fac) | $M_{mLT3}$ kNm (fac) | $M_{mLT4}$ kNm (fac) |
|---|---|---|---|---|---|---|---|
| 1 | **0** | **4500** | **4500** | **304.3** | **228.2** | **304.3** | **228.2** |

Beam Loads




Load Envelope - Combination 1




**Member design checks for a simply-supported single-span beam to BS 5950 (with LTB)**

**Summary of results**

| | | | |
|---|---|---|---|
| Material | Grade = **"S275"** | $p_y$ = **265** N/mm$^2$ | |
| Section | **"UC 254x254x107"** | Classification | **"Plastic"** |

| *Check* | *Load* | *Capacity* | *Notes* | *Result* |
|---|---|---|---|---|
| Deflection | $\delta_{y\_max}$ = **12.2** mm | $\delta_{lim}$ = **12.5** mm | **Span / 360 or 13.0 mm** | **Pass** |
| Shear | $F_{vy}$ = **270.5** kN | $P_{vy}$ = **542.8** kN | **Low shear** | **Pass** |
| Moment | $M_x$ = **304.3** kNm | $M_{cx}$ = **393.4** kNm | **Low shear** | **Pass** |
| LTB | $M_{LT}$ = **304.3** kNm | $M_b$ / $m_{LT}$ = **385.6** kNm | $L_{E\_LT}$ = **4.5** m<br>$m_{LT}$ = **0.93** | **Pass** |

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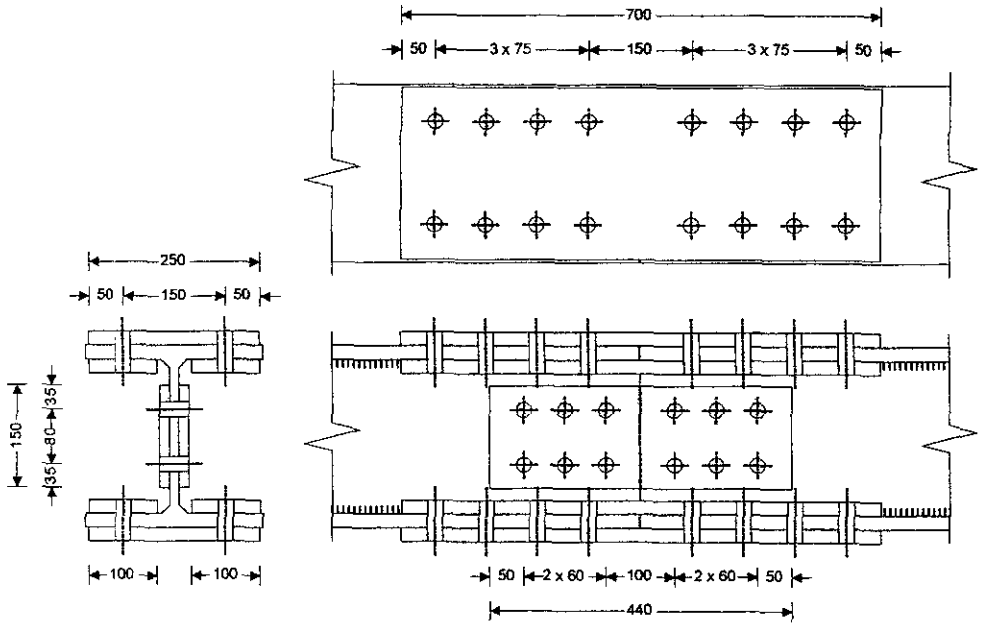
|---|---|---|---|---|---|
| | Section<br>SPLICE BEAM 1 | | | | Sheet no./rev.<br>3/ 3 |
| | Calc. by<br>RA | Date<br>30/11/2008 | Chk'd by | Date | App'd by | Date |

## BOLTED COVER PLATE SPLICE CONNECTION – BS5950-1:2000




**Connection loads**

| | |
|---|---|
| Design moment | M = **230** kNm |
| Axial force in the member (compression +ve) | N = **0** kN |
| Shear force in the member | V = **140** kN |

**Steel beam details**

| | |
|---|---|
| Beam section classification | **UC 254x254x107** |
| Grade of steel section | **S275** |
| Section bearing strength | $p_{bs\_s}$ = **460** N/mm$^2$ |

**General connection details**

| | |
|---|---|
| Grade of steel plate | **S275** |
| Plate bearing strength | $p_{bs\_p}$ = **460** N/mm$^2$ |
| Bolt classification | ***M20 (Torqued General Grade HSFG)*** |
| Hole diameter | $D_h$ = **22** mm |
| Bolt slip factor | $\mu$ = **0.50** |
| Hole type factor | $K_s$ = 1.0 |

**Flange plate details – plates bolted to both sides of each flange**

| | |
|---|---|
| Thickness of flange plates | $t_{fp}$ = **20** mm |
| Width of outer flange plates | $b_{fp}$ = **250** mm |
| Width of inner flange plates | $b_{fp\_i}$ = **100** mm |
| Length of flange plates | $l_{fp}$ = **700** mm |

**Flange bolting details**

| | |
|---|---|
| Rows of flange bolts on each side of joint | $n_{fb\_r}$ = **4** |
| Bolts per row | $n_{fb\_p}$ = **2** |
| Total number of flange bolts each side of joint | $n_{fb}$ = $n_{fb\_r}$ × $n_{fb\_p}$ = **8** |
| Spacing between rows of bolts | $S_f$ = **75** mm |

| | |
|---|---|
| Spacing between rows of bolts across joint | $S_{fc}$ = **150** mm |
| Spacing at end of flange plates | $S_{fe}$ = **50** mm |
| Lateral spacing between central bolts | $S_{flc}$ = **150** mm |
| Lateral spacing at edge of flange plates | $S_{fle}$ = **50** mm |

**Web plate details - plates bolted to both sides of the web**

| | |
|---|---|
| Thickness of web plates | $t_{wp}$ = **15** mm |
| Width of web plates | $b_{wp}$ = **440** mm |
| Length of web plates | $l_{wp}$ = **150** mm |

**Web bolting details**

| | |
|---|---|
| Rows of web bolts | $n_{wb\_r}$ = **2** |
| Bolts per row each side of joint | $n_{wb\_p}$ = **3** |
| Total number of web bolts each side of joint | $n_{wb} = n_{wb\_r} \times n_{wb\_p}$ = **6** |
| Spacing between rows of bolts | $S_w$ = **80** mm |
| Spacing at end of web plates | $S_{we}$ = **35** mm |
| *Lateral spacing between bolts* | $S_{wf}$ = ***60 mm*** |
| Lateral spacing between central bolts | $S_{wlc}$ = **100** mm |
| Lateral spacing at edge of web plates | $S_{wle}$ = **50** mm |

**Step 1 - Distribution of forces in member flanges**

| | |
|---|---|
| Forces in member tension flange | $T = [M / (D_b - T_b)] - N / 2$ = **934** kN |
| Forces in member compression flange | $C = [M / (D_b - T_b)] + N / 2$ = **934** kN |
| Force in the flange | $F_f = \max(T, C)$ = **934** kN |

**Step 2 - Calculate distribution of forces in member flanges**

**Check area of flange**

| | |
|---|---|
| Design strength of section | $p_{ys}$ = **265** N/mm$^2$ |
| Minimum required effective flange area | $F_f / p_{ys}$ = **3525** mm$^2$ |
| Effective net area coefficient | $K_e$ = **1.2** |
| Effective flange area | $A_{ef} = \min(K_e \times [B_b - (n_{fb\_p} \times D_h)] \times T_b, B_b \times T_b)$ = **5284** mm$^2$ |

***PASS - Effective flange area is adequate***

**Check area of flange plates**

| | |
|---|---|
| Design strength of plates | $p_{yp}$ = **265** N/mm$^2$ |
| *Minimum required effective flange plate area* | $F_f / p_{yp}$ = ***3525 mm***$^2$ |
| Effective flange plate area | $A_{ep} = \min(K_e \times [b_{fp} + 2 \times (b_{fp\_i} - (n_{fb\_p} \times D_h))] \times t_{fp}, (b_{fp} + 2 \times b_{fl\_i}) \times t_{fp})$ |
| | $A_{ep}$ = **8688** mm$^2$ |

***PASS - Effective flange plate area is adequate***

**Step 3 - Design of flange bolts**

| | |
|---|---|
| Slip resistance of the bolt per interface | $S_{fb} = 1.1 \times K_s \times \mu \times P_p$ = **79.2** kN |
| Bearing capacity of the bolt in the flange | $P_{bg\_s} = 1.5 \times d \times T_b \times p_{bs\_s}$ = **282.9** kN |
| Bearing capacity of the bolt in the plate | $P_{bg\_p} = 3 \times d \times t_{fp} \times p_{bs\_p}$ = **552.0** kN |
| Average flange bolt end distance | $S_{fe\_ave} = S_{fe} + (n_{fb\_r} - 1) \times S_f / 2$ = **162** mm |
| Bearing capacity limit of the bolt in the plate | $P_{bg\_p\_lim} = S_{fe\_ave} \times t_{fp} \times p_{bs\_p}$ = **1495.0** kN |
| Bolt capacity | $P_s = \min(2 \times S_{fb}, P_{bg\_s}, P_{bg\_p}, P_{bg\_p\_lim})$ = **158.4** kN |
| Number of bolts required | $n_{fb\_req} = F_f / P_s$ = **5.9** |
| Number of bolts provided | $n_{fb}$ = **8** |

***PASS - Flange plate bolting is adequate***

**Step 4 - Design of web plates and bolts**

**Check web plate in shear**

| | |
|---|---|
| Shear force in web plates | $V$ = **140** kN |
| Gross shear area | $A_v = n_{wp} \times l_{wp} \times t_{wp}$ = **4500** mm$^2$ |
| *Net shear area (allowing for bolt holes)* | $A_{v\_net} = n_{wp} \times (l_{wp} - n_{wb\_r} \times D_h) \times t_{wp}$ = **3180** mm$^2$ |
| Net shear area limit | $0.85 \times A_v / K_e$ = **3188** mm$^2$ |
| Net shear capacity of web plates | $p_{v\_net} = 0.7 \times K_e \times A_{v\_net} \times p_{yp}$ = **708** kN |
| Gross shear capacity of web plates | $p_{v\_gross} = 0.6 \times A_v \times p_{yp}$ = **716** kN |
| Length of block shear face | $L_v = S_{we} + (n_{wb\_r} - 1) \times S_w$ = **115** mm |
| Length of block tension face | $L_t = S_{wle} + (n_{wb\_p} - 1) \times S_{wl}$ = **170** mm |
| Block shear coefficient | $k = if(n_{wb\_p} > 1, 2.5, 0.5)$ = **2.5** |
| Block shear capacity of web plates | $p_{v\_block} = 0.6 \times p_{yp} \times t_{wp} \times n_{wp} \times [L_v + K_e \times (L_t - k \times D_h)]$ = **1207** kN |
| *Shear capacity of web plates* | $p_v = min(p_{v\_net}, p_{v\_gross}, p_{v\_block})$ = **708** kN |

***PASS - Effective web plate area is adequate in shear***

**Check web plate in bending**

| | |
|---|---|
| Second moment of area of web plate | $I = (t_{wp} \times l_{wp}^3 / 12) - (n_{wb\_r} \times t_{wp} \times D_h^3 / 12) - (t_{wp} \times D_h \times K \times S_w^2)$<br>$I$ = **3136130** mm$^4$ |
| Distance from joint to centroid of bolt group | $a = [((n_{wb\_p} - 1) \times S_{wl}) + S_{wlc}] / 2$ = **110** mm |
| Moment in web plate | $M_{wp} = V \times a$ = **15.4** kNm |
| Moment capacity of web plates | $M_{cap} = p_{yp} \times n_{wp} \times I / (l_{wp} / 2)$ = **22.2** kNm |

***PASS - Effective web plate area is adequate in bending***

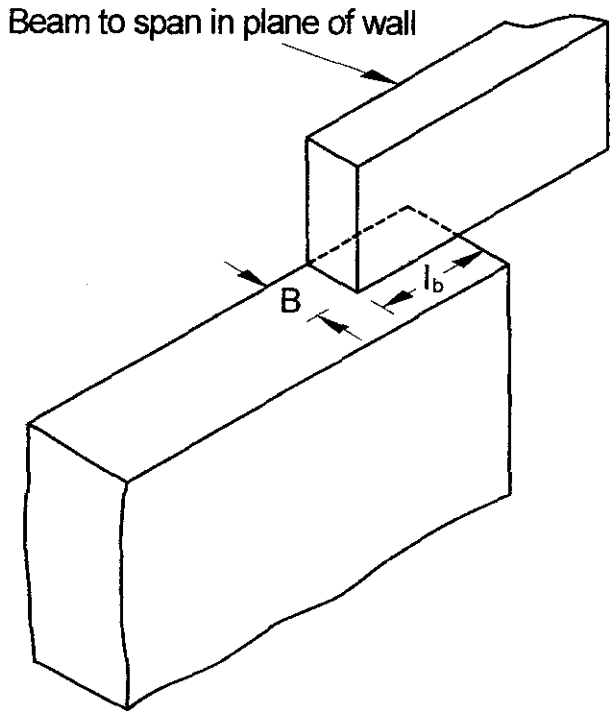
**Check web plate bolts**

| | |
|---|---|
| Moment of inertia of bolt group | $I_{bg}$ = **24000** mm$^2$ |
| Force on bolt due to direct shear | $F_v = V / n_{wb}$ = **23.3** kN |
| Vertical force on bolt due to moment | $F_{mv} = M_{wp} \times x / I_{bg}$ = **38.5** kN |
| Horizontal force on bolt due to moment | $F_{mh} = M_{wp} \times y / I_{bg}$ = **25.7** kN |
| Resultant bolt load | $F_r = \sqrt{((F_v + F_{mv})^2 + F_{mh}^2)}$ = **66.9** kN |
| Angle of the resultant bolt load | $\theta = atan(F_{mh} / (F_v + F_{mv}))$ = **22.5** deg |
| *Minimum edge distance* | $e_r = min(S_{we} / cos(\theta), S_{wle} / cos(90 - \theta))$ = **38** mm |
| Edge distance factor for web plate bearing | $K_{edge} = min(e_r / (3 \times d), 1)$ = **0.6** |
| Slip resistance of the bolt per interface | $S_{fb} = 1.1 \times K_s \times \mu \times P_p$ = **79.2** kN |
| Bearing capacity of the bolt in the web | $P_{bg\_s} = 1.5 \times d \times t_b \times p_{bs\_s}$ = **176.6** kN |
| Bearing capacity of the bolt in the plate | $P_{bg\_p} = 1.5 \times K_{edge} \times d \times t_{wp} \times n_{wp} \times p_{bs\_p}$ = **261.5** kN |
| Bolt capacity | $P_s = min(n_{wp} \times S_{fb}, P_{bg\_s}, P_{bg\_p})$ = **158.4** kN |

***PASS - Web plate bolting is adequate***

***Connection summary***

| | |
|---|---|
| Beam classification | **UC 254x254x107** |
| Bolt classification | **M20 (Torqued General Grade HSFG)** |
| Flange plates | **700 mm x 250 mm x 20 mm to the outside of each flange** |
| | **2 No. 700 mm x 100 mm x 20 mm to the inside of each flange** |
| Flange bolting | **16 No. total per flange - 4 No. rows of 2 No. bolts on each side of the joint** |
| Web plates | **150 mm x 440 mm x 15 mm on each side of the web** |
| Web bolting | **12 No. total - 2 No. rows of 3 No. bolts on each side of the joint** |




## MASONRY BEARING DESIGN TO BS5628-1:2005

**Masonry details**

| | |
|---|---|
| Masonry type | **Clay or calcium silicate bricks** |
| Compressive strength of unit | $p_{unit}$ = **50.0** N/mm$^2$ |
| Mortar designation | **i** |
| Category of masonry units | **Category I** |
| Category of construction control | **Normal** |
| Partial safety factor for material strength | $\gamma_m$ = **3.1** |
| *Thickness of load bearing leaf* | *t* = **220** *mm* |
| Effective thickness of masonry wall | $t_{ef}$ = **220** mm |
| Height of masonry wall | h = **3000** mm |
| Effective height of masonry wall | $h_{ef}$ = **2250** mm |

**Bearing details**

| | |
|---|---|
| Beam spanning in plane of wall | |
| Width of bearing | B = **220** mm |
| Length of bearing | $l_b$ = **450** mm |

**Compressive strength from Table 2 BS5628:Part 1 - Clay or calcium silicate bricks**

| | |
|---|---|
| Mortar designation | Mortar = **"i"** |
| Brick compressive strength | $p_{unit}$ = **50.0** N/mm$^2$ |
| Characteristic compressive strength | $f_k$ = **11.60** N/mm$^2$ |

**Loading details**

| | |
|---|---|
| Characteristic dead load | $G_k$ = **124** kN |

| | |
|---|---|
| Characteristic imposed load | $Q_k$ = **61** kN |
| Design load on bearing | $F = (G_k \times 1.4) + (Q_k \times 1.6)$ = **271.2** kN |

**Masonry bearing type**

| | |
|---|---|
| Bearing type | **Type 1** |
| Bearing safety factor | $\gamma_{bear}$ = **1.25** |

**Check design bearing without a spreader**

| | |
|---|---|
| Design bearing stress | $f_{ca} = F / (B \times l_b)$ = **2.739** N/mm$^2$ |
| Allowable bearing stress | $f_{cp} = \gamma_{bear} \times f_k / \gamma_m$ = **4.677** N/mm$^2$ |

***PASS - Allowable bearing stress exceeds design bearing stress***

**Check design bearing at 0.4 × h below the bearing level**

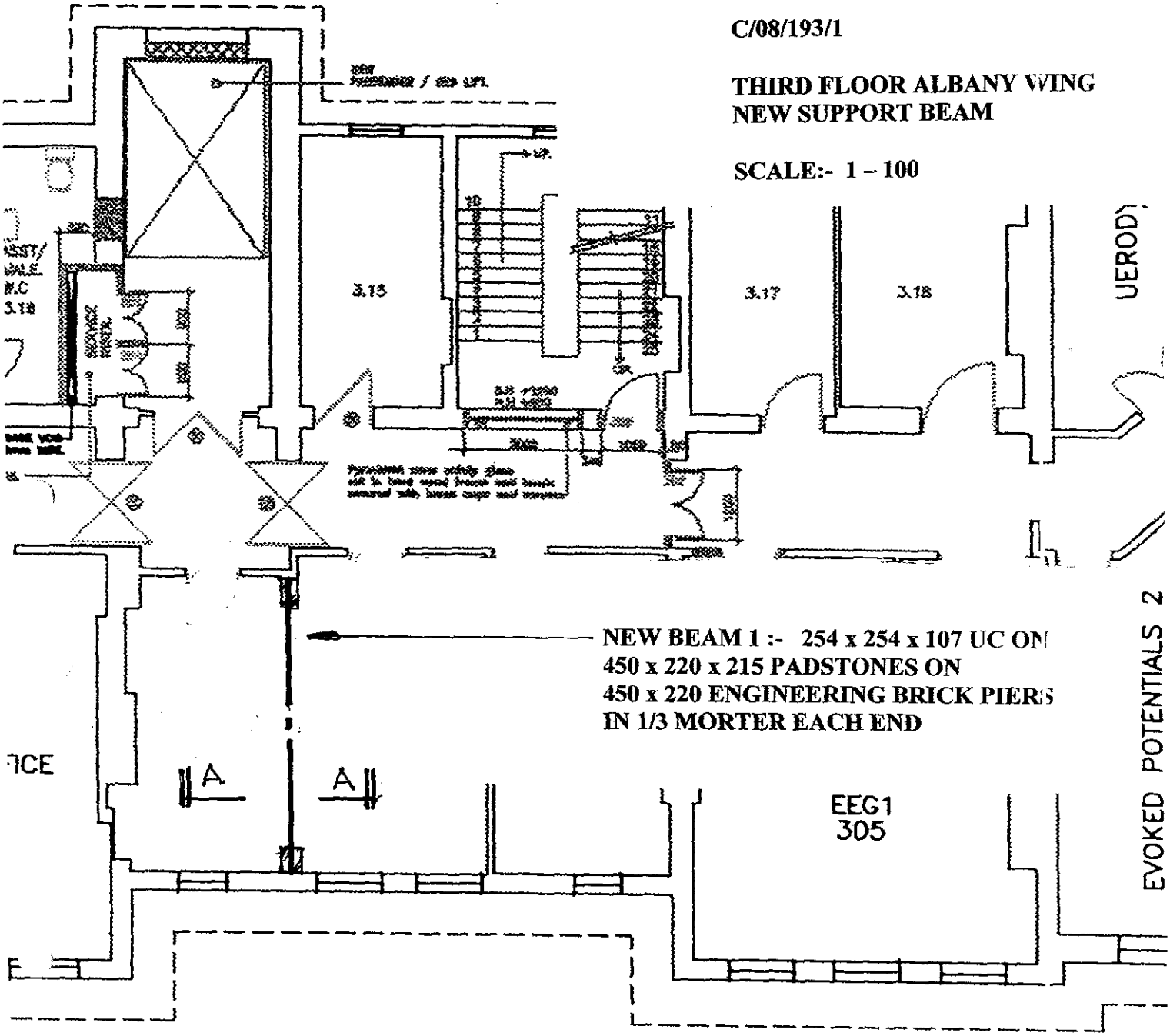
| | |
|---|---|
| Slenderness ratio | $h_{ef} / t_{ef}$ = **10.23** |
| Eccentricity at top of wall | $e_x$ = **0** mm |
| **From BS5268:1 Table 7** | |
| Capacity reduction factor | $\beta$ = **0.99** |
| Length of bearing distributed at 0.4 × h | $l_d$ = **1650** mm |
| Maximum bearing stress | $f_{ca} = F / (l_d \times t)$ = **0.747** N/mm$^2$ |
| Allowable bearing stress | $f_{cp} = \beta \times f_k / \gamma_m$ = **3.705** N/mm$^2$ |

***PASS - Allowable bearing stress at 0.4 × h below bearing level exceeds design bearing stress***

C/08/193/1

**THIRD FLOOR ALBANY WING**
**NEW SUPPORT BEAM**

**SCALE:- 1 – 100**




ATIONAL HOSPITAL FOR

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ENABILITATION AND THERAPY SERVICES

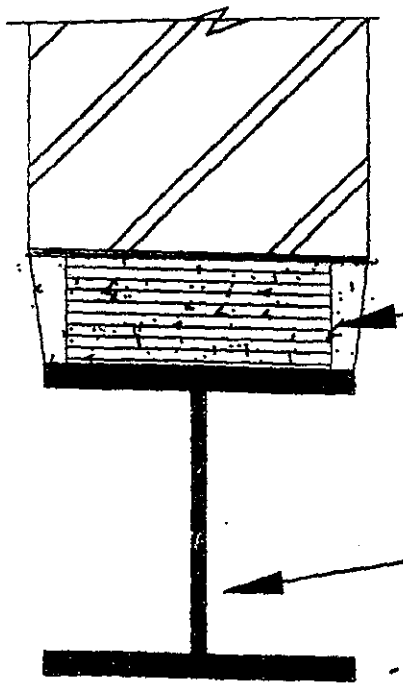
RD FLOOR – ALBANY WING

OPOSED FLOOR PLAN.

C/08/193/2

**THIRD FLOOR ALBANY WING**
**NEW SUPPORT BEAM**

**SECTION A - A**

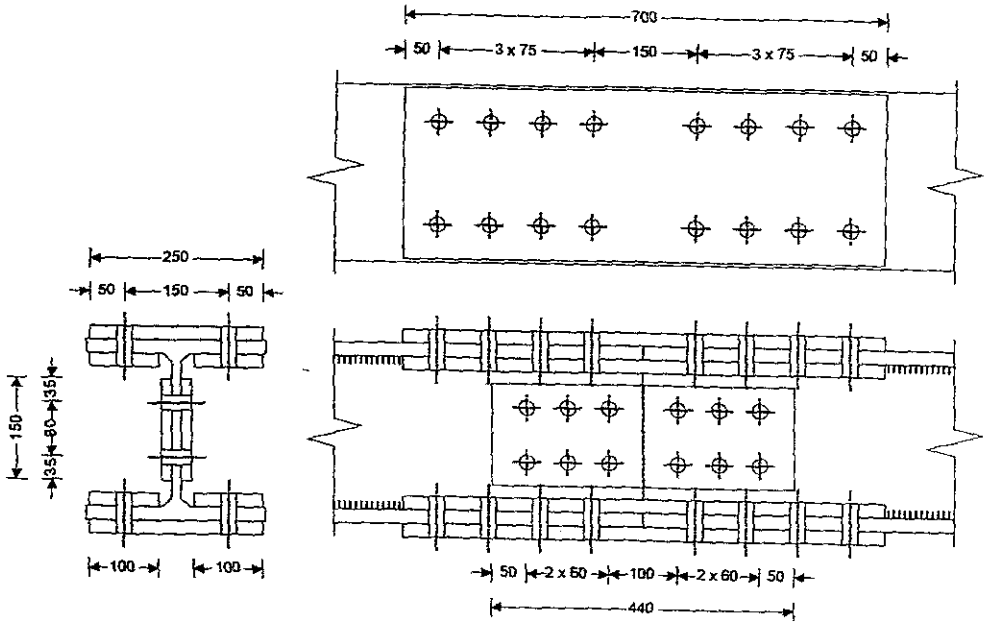


Robert Austin Associates
57 Fernie Fields
High Wycombe
HP12 4SN

| Project | | Job Ref. |
|---|---|---|
| NAT HOS ALBANY | | C/08/193 |
| Section | | Sheet no./rev. |
| SPLICE BEAM 1 | | 08/193/3 |

| Calc. by | Date | Chk'd by | Date | App'd by | Date |
|---|---|---|---|---|---|
| RA | 30/11/2008 | | | | |

## BOLTED COVER PLATE SPLICE CONNECTION – BS5950-1:2000




## SPLICE AT MAXIMUM 1.0M FROM FACE OF PIER EACH END

**Connection summary**

| | |
|---|---|
| Beam classification | **UC 254x254x107** |
| Bolt classification | **M20 (Torqued General Grade HSFG)** |
| Flange plates | **700 mm x 250 mm x 20 mm to the outside of each flange** |
| | **2 No. 700 mm x 100 mm x 20 mm to the inside of each flange** |
| Flange bolting | **16 No. total per flange - 4 No. rows of 2 No. bolts on each side of the joint** |
| Web plates | **150 mm x 440 mm x 15 mm on each side of the web** |
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