Material Properties

- Characteristic strength of concrete, $f_{cu}$ (≤ 60 N/mm$^2$; HSC N/A): 35 N/mm$^2$  ▼ OK
- Yield strength of longitudinal steel, $f_y$: 460 N/mm$^2$  ▼
- Yield strength of shear link steel, $f_{yv}$: 460 N/mm$^2$  ▼
- Elastic modulus of steel, $E_s$: 205000 N/mm$^2$
- Ultimate strain of concrete, $\varepsilon_{cc}$: 0.0035

Dimensions

- Width, $b$: 1000 mm
- Dimension, $a_1$: 450 mm
- Dimension, $a_2$: 450 mm
- Dimension, $a_3$: 300 mm
- Distance of centreline of applied load from face of column, $a_v$: 300 mm  ▼ 425 mm  cl.5.2.7.1 BS8110
  (Note $a_v$ should be taken as $a_3$ for stiff bearing and $a_3/2$ for flexible bearing)
  (Note cl.6.2.3(8) EC2 which states that $a_v$ should be taken as greater than 0.5d is nevertheless considered even as that clause presumably applies to vertical shear reinforcement)
- Effective depth to tensile steel, $d = a_1 + a_2 - \phi_t/2$: 849 mm
- Shear span to depth ratio, $a_v/d$: OK 0.50

Reinforcement

- Cover to all reinforcement, cover (usually 35 (C35) or 30 (C40) internal; 40 external): 35 mm
- Tension steel reinforcement diameter, $\phi_t$ (> = 10 mm): 32 mm  ▼ OK
- Tension steel reinforcement number, $n_t$: 10
- Tension steel area provided, $A_{s,prov,t} = n_t.\pi.\phi_t^2/4$: 8042 mm$^2$
- Horizontal shear link diameter, $\phi_{link}$: 25 mm  ▼
- Number of horizontal links in a cross section, i.e. number of legs, $n_{leg}$: 4
- Number of cross sections of horizontal links within $d$, $n_{sec}$: 4
  (Note horizontal links to be provided within upper 2/3 of effective depth as per cl.5.2.7.2.3 BS8110)
- Area provided by all horizontal links within $d$, $A_{sv,prov} = \pi.\phi_{link}^2/4.\phi_{leg}.\phi_{sec}$: 7854 mm$^2$

Loading

- ULS applied load, $N$: 1800 kN
**Executive Summary**

<table>
<thead>
<tr>
<th>Item</th>
<th>UT</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing stress utilisation</td>
<td>49%</td>
<td>OK</td>
</tr>
<tr>
<td>Tension reinforcement utilisation</td>
<td>30%</td>
<td>OK</td>
</tr>
<tr>
<td>Ultimate shear stress utilisation</td>
<td>45%</td>
<td>OK</td>
</tr>
<tr>
<td>Design shear resistance utilisation</td>
<td>28%</td>
<td>OK</td>
</tr>
<tr>
<td>Min tension steel reinforcement pitch utilisation</td>
<td>80%</td>
<td>OK</td>
</tr>
<tr>
<td>% Min tension reinforcement utilisation</td>
<td>42%</td>
<td>OK</td>
</tr>
<tr>
<td>% Max tension reinforcement utilisation</td>
<td>73%</td>
<td>OK</td>
</tr>
<tr>
<td>% Min shear reinforcement utilisation</td>
<td>11%</td>
<td>OK</td>
</tr>
<tr>
<td>% Min combined tension and shear reinforcement utilisation</td>
<td>38%</td>
<td>OK</td>
</tr>
<tr>
<td>% Max combined tension and shear reinforcement utilisation</td>
<td>94%</td>
<td>OK</td>
</tr>
<tr>
<td><strong>Total utilisation</strong></td>
<td>94%</td>
<td>OK</td>
</tr>
</tbody>
</table>
Member Design - Reinforced Concrete Column BS8110

### Bearing Stress Limit

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bearing area, ( A = b \cdot (a_3 - r) )</td>
<td>265000 mm²</td>
</tr>
<tr>
<td>Red. of dimension ( a_3 ), due to chamfer &amp; gap, ( r )</td>
<td>35 mm</td>
</tr>
<tr>
<td>Bearing stress, ( \sigma = \frac{N}{A} )</td>
<td>7 N/mm²</td>
</tr>
<tr>
<td>Bearing stress limit, ( \sigma_{\text{lim}} = 0.4f_{\text{cu}} )</td>
<td>14 N/mm²</td>
</tr>
<tr>
<td>Bearing stress utilisation, ( \sigma/\sigma_{\text{lim}} )</td>
<td>49% OK</td>
</tr>
</tbody>
</table>

### Tension Reinforcement Design

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter, ( k = \frac{N}{(0.9f_{\text{cu}} \cdot b \cdot a_v)} )</td>
<td>0.13</td>
</tr>
<tr>
<td>Lever arm, ( z = d \cdot (0.5+\sqrt{0.25-(1+k) \cdot k \cdot a_v^2/d^2}) ) / (1+k)</td>
<td>719 mm</td>
</tr>
<tr>
<td>Depth to neutral axis, ( x = (d-z) / 0.45 )</td>
<td>290 mm</td>
</tr>
<tr>
<td>Ratio ( x/d )</td>
<td>0.342</td>
</tr>
<tr>
<td>Tension steel yielded or not ?</td>
<td>Yielded</td>
</tr>
<tr>
<td>( f_{\text{st}} )</td>
<td>437 N/mm²</td>
</tr>
<tr>
<td>(Note if ( x/d &gt; 0.615 ), tension steel not yielded; and vice versa)</td>
<td></td>
</tr>
<tr>
<td>Tension force, ( F_t = \frac{N \cdot a_v}{z} ) (( \geq 0.5N ))</td>
<td>1063 kN</td>
</tr>
<tr>
<td>Area of tension steel required, ( A_s = \frac{F_t}{f_{\text{st}}} )</td>
<td>2433 mm²</td>
</tr>
<tr>
<td>Area of tensile steel reinforcement provided, ( A_{s,\text{prov}} )</td>
<td>8042 mm²</td>
</tr>
<tr>
<td>Tension reinforcement utilisation, ( \frac{A_s}{A_{s,\text{prov}}} )</td>
<td>30% OK</td>
</tr>
</tbody>
</table>

\( \% \) Min tension reinforcement = 0.4%.bd
\( \% \) Min tension reinforcement utilisation
\( \% \) Max tension reinforcement = 1.3%.bd
\( \% \) Max tension reinforcement utilisation

\( T_t = (b - 2 \cdot \text{cover} - 2 \cdot \phi_{\text{link}} - \phi_t) / (n_t - 1) \) | 94 mm          |

Min tension steel reinforcement pitch utilisation (\( >75 \text{mm}, >100 \text{mm if T40} \)) | 80% OK         |

(Note no allowance has been made for laps in the min pitch as not deemed to be required)
**Shear Reinforcement Design**

| Ultimate shear stress, $v_u = N/bd$ ($< 0.8f_{cu}^{0.5} \& 5N/mm^2$) | 2.12 N/mm$^2$ |
| Design shear stress utilisation | 45% OK |

(Shear capacity enhancement by calculating $v_e$ at support and comparing against enhanced $v_c$ within 2d of the support as clause 3.4.5.8 BS8110 employed, that of clause 3.4.5.10 BS8110 not applicable;)

Area of tensile steel reinforcement provided, $A_{s,prov}$

$\rho_w = 100A_{s,prov}/bd$ = 0.95 %

$v_c = (0.79/1.25)(\rho_w f_{cu}/25)^{1/3}(400/d)^{1/4}; \rho_w<3; f_{cu}<40; (400/d)^{1/4}>0.67$ = 0.58 N/mm$^2$

Enhanced shear capacity, $2dv_p/a_v$ = 2.30 N/mm$^2$

Enhanced shear capacity, $2dv_c/a_v$ ($< 0.8f_{cu}^{0.5} \& 5N/mm^2$) = 2.30 N/mm$^2$

**Check $v_d < 0.5(2dv_c/a_v)$ for no horizontal links**

Concrete shear capacity $2dv_c/a_v$.(bd) = 1954 kN

**Check $v_d \geq 0.5(2dv_c/a_v)$ for design horizontal links**

Concrete and design horizontal links shear capacity $(A_{sv,prov})/(0.95f_{yv})$ = 6530 kN

Area provided by all horizontal links within $(2/3)d$, $A_{sv,prov}$ = 5236 mm$^2$

(Note cl.6.2.3(8) EC2 which states that only links within the central $0.75a_v$ effectively cross the inclined shear cracks is not considered as that clause presumably applies to vertical shear reinforcement)

Design shear resistance utilisation = 28% OK

Pitch of horizontal links, $s_{link} = d / (n_{sec} - 1)$ = 283 mm

% Min shear reinforcement = 0.2%.b.$s_{sec}$ = 566 mm$^2$

% Min shear reinforcement utilisation = 11% OK

% Min combined tension and shear reinforcement = 0.6%.bd = 5094 mm$^2$

% Min combined tension and shear reinforcement utilisation = 38% OK

% Max combined tension and shear reinforcement = 2.0%.bd = 16980 mm$^2$

% Max combined tension and shear reinforcement utilisation = 94% OK
CORBELS MCB1

Without welds.

This detail is suitable when using 13mm dia. bars or smaller for the main tensile reinforcement.

Nominal cover specified by designer.

Distance between edge of bearing and inside of bar to be a minimum of the bar diameter or 0.75 x cover, whichever is greater.

Two column links should be placed close to corbel top.

Main tensile reinforcement. Large radius of bend is required.

Secondary horizontal reinforcement. Total area of this should not be less than 0.5D of area of main tensile reinforcement.

Compression bars. Total area of this should not be less than 1000mm²/metre width of corbel.

Compressive anchorages

Outer compression bars angled to pass inside links.
CORBELS MCB2

With welds.

This detail is suitable when using 20mm dia. bars or greater for the main tensile reinforcement.

Nominal cover:
Specified by designer.

Distance between edge of bearing and outside of plate or bar should not be less than the vertical cover to the plate or bar.

Large radius of bend required.

Two column links should be placed close to corbel lap.

Main tensile bars welded to a cross bar, or plates, and to the vertical compression bars.

Horizontal links. Total area should not be less than 0.50 of area of the main tensile reinforcement.

Compression bars. Total area of which should not be less than 1000mm²/metre width of corbel.

A-A
9.2.7 Arrangement of Reinforcement

The arrangement of reinforcement is very closely related to the design of corbels, halfjoints and nubs, and the designer must ensure that the detail design is clearly specified. He should refer to the OAP Design Guidance Notes, Concrete Construction: 4, May 1976. Other references are given in section 2.5.

In general small bar diameters, i.e. not larger than 16mm, should be used when detailing such elements. If larger diameter bars are used, it is likely that welding will be required. However, the designer should be aware that welding on site is not encouraged and if specified, often causes the contractor to suggest alternatives.

9.2.7.1 Corbels (BS 8110, CI 5.2.7; EC2, CI 5.4.4)

The use of small bar diameters, horizontal 'U' bars or links with easy bends is preferred, as shown in Model Detail MCB1. However, where the loading is high and the geometry restrictive, large bar diameters may be necessary, in which case welding them to a cross bar or plate may be the only solution. The size of this may be governed by the strength of weld. This is shown in Model Detail MCB2.

It is essential that the main tensile reinforcement is extended to as close to the outer face of the corbel as possible, and that it extends beyond the load-bearing area by a minimum of the distance shown on the Model Details.

Where large horizontal forces are required to be transmitted into the corbel, a welded joint may be the only suitable solution. (See Park, R., and Paulay, T. Reinforced concrete structures.)

9.2.7.2 Half-Joints in Beams

The use of inclined bars in halfjoints provides better control of cracking than other arrangements of reinforcement (See Clark, L.A., and Thorogood P.: Serviceability behaviour of reinforced concrete halfjoints). However such bars are often difficult to fix correctly and can cause congestion of reinforcement. Great care is needed to ensure the use of practical details with inclined links or bent bars, especially when large bar diameters are required and a welded solution is adopted.

9.2.7.3 Continuous Nibs (BS 8110, CI 5.2.8)

The arrangement of reinforcement for continuous nibs may control the depth of nib. Vertical 'U' bars or links should be used wherever possible, as shown in Model Detail MN1. However, where a shallow nib is required, e.g. for supporting brickwork, horizontal 'U' bars should be used, as shown in Model Detail MN2. The vertical leg of the links in the supporting beam must be designed to carry the loads from the nibs. The designer should note that it is necessary to reduce the value of d as the concrete in the nib below the vertical link does not contribute to the resistance. See Structures Note 1992NSt 9, concerning Strut and Tie models.

![Diagram of a nib with a vertical link and an attached strut](image)

In situations where horizontal movement may occur between the nib and the supported member, the nib should be designed to allow for this movement. The position at which the slab is split may be critical to the design.
**HALF JOINTS MHJ**

**Note:**
Special design information must be given concerning the bearing pads.

**Nominal cover:**
Specified by designer. (Normally 40 to main steel).

- Full length links sufficient to resist total reaction equally spaced.
- Distance between edge of bearing and inside of bar to be a minimum of the bar diameter or 0.75 x cover, whichever is greater.
- Horizontal 'U' bar to be the same diameter as main bottom bars.
- Cranked bars III necessary for crack control.

**Nominal hangar links at 450:**

**Tension lap for cranked bar:**

**Horizontal 'U' bar with standard radius of bend:**

**Nominal links at 150:**
NIBS MN1

This detail is suitable for half joints in slabs.

Minimum nominal overlap of reinforcement in rib and reinforcement in supported member to be 60.

Nominal cover:
Specified by designer.

<table>
<thead>
<tr>
<th>Tension anchorage length if &quot;U&quot; bars are used.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Links to be specified by designer to take load on rib.</td>
</tr>
<tr>
<td>Closed links or &quot;U&quot; bars may be used.</td>
</tr>
<tr>
<td>Not less than bar diameter or 0.75 z nominal cover, whichever is greater.</td>
</tr>
<tr>
<td>Diameter of links to be not more than 12.</td>
</tr>
</tbody>
</table>
NIBS MN2

Shallow nibs not suitable for supporting brickwork.

Nominal cover:
Specified by designer.

Links to be specified by designer to take load on nib.

Horizontal 'U' bar. Diameter to be not more than 16.

Depth of nib to be not less than 140.

See also design notes 8.2.7.3 for strut & tie model

Lacer bar to be same diameter as 'U' bars.

Pitch of 'U' bars to be not more than 250.