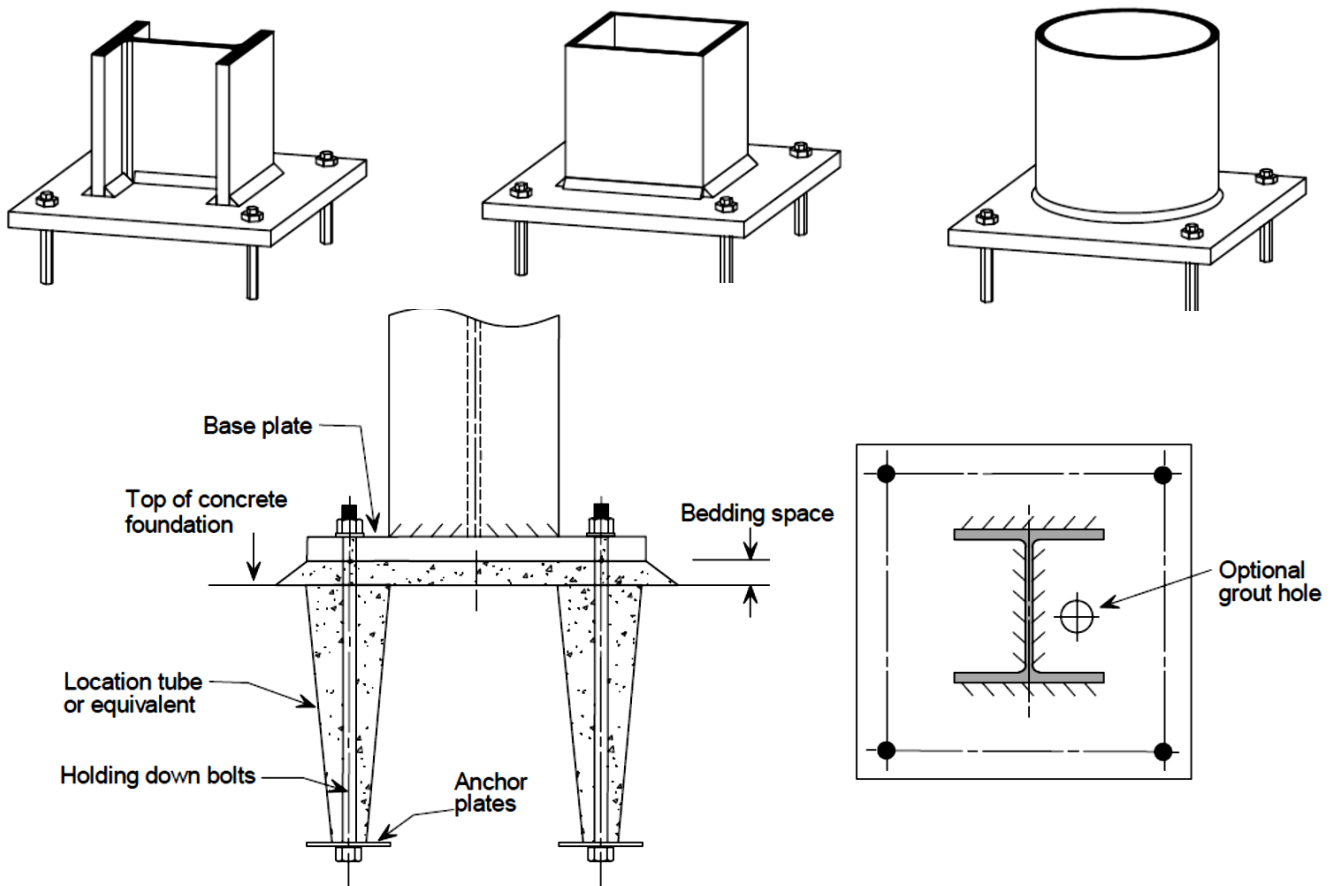


Design of Column Base Plates

Typical column bases, as shown below, consist of a single plate fillet welded to the end of the column and attached to the foundation with four holding down bolts. The bolts are cast into the concrete base in location tubes or cones and are fitted with anchor plates to prevent pull-out. High strength grout is poured into the space below the plate.



Such column bases are usually assumed to be subject to axial compression and shear only. The base plate should be of sufficient size, stiffness and strength to transmit the axial compressive force from the column to the foundation through the bedding material, without exceeding the local bearing resistance of the foundation.

Holding down systems are designed to stabilize the column during construction, and resist any uplift in braced bays. In some cases it is assumed that horizontal shear is also carried by the holding down bolts

Practical Considerations

- 1- Base plates will usually be flame cut or sawn from S275 or S355 plate. Most plates have a sufficiently flat bearing surface without machining or cold pressing.
- 2- The main function of the weld is to hold the column shaft securely in position on the base plate and to ensure the column is stable in any temporary condition.
- 3- Fillet welds are generally provided, 6 mm or 8 mm leg length, usually along the outside of the flanges and for a short distance either side of the web. Full profile welds will usually only be used if additional resistance is needed during erection or as an anti-corrosion measure.
- 4- The embedded length of the holding down bolt in the concrete will usually be in the region of 16 to 18 bolt diameters. The thread length must allow for tolerances and should be 100 mm plus the bolt diameter.
- 5- Holding down bolts are usually property class 8.8 (property class 4.6 is not commonly used). M20 bolts are often used, although M24 bolts are recommended for bases up to 50 mm thick, increasing to M36 for plates over 50 mm thick.
- 6- **Hole sizes:** Clearance holes in the base plate should be 6 mm larger than the bolt diameter, to allow for adjustment; for bases thicker than 60 mm, this figure may need to be increased.
- 7- **Concrete strength:** Typical concrete strengths are shown in Table 7.1, taken from BS EN 1992-1-1.

$$\text{The design compressive strength } f_{cd} = \frac{\alpha_{cc} f_{ck}}{\gamma_c}$$

which $\alpha_{cc} = 0.85$ and $\gamma_c = 1.5$. Thus $f_{cd} = 0.56f_{ck}$. It may be assumed that, for initial design, the design bearing strength f_{jd} is equal to the design compressive strength.

For design purposes, the lowest strength of either the grout or the concrete in the foundation should be used. In most situations, the design will be based on the strength of the concrete in the foundation, and non-shrink cementitious grout will be specified to be at least as strong. Other bedding materials may be specified.

Concrete strengths

Concrete class	Cylinder strength (N/mm ²)	Cube strength (N/mm ²)	Design compressive strength (N/mm ²)
	f_{ck}	$f_{ck,cube}$	f_{cd}
C25/30	25	30	14.2
C30/37	30	37	16.8
C35/45	30	45	17.0
C40/50	40	50	22.7

8- **Clearance under the baseplate:** A space between the top of the foundation and the baseplate of between 25 mm and 50 mm is the normal allowance when using grout. This gives reasonable access for grouting the bolt pockets, which is necessary to prevent corrosion, and for thoroughly filling the space under the base plate. It also makes a reasonable allowance for tolerances.

9- Normal practice is for the base plate to be at least 100 mm larger all round than the column, with a thickness greater than or equal to that of the column flange and with four holding down bolts positioned outside the section. Baseplate dimensions are generally rounded up to the nearest 50 mm.

DESIGN

The design procedure for column bases is taken from BS EN 1993-1-8 and follows an ***effective area approach***. The procedure covers the design of bases under axial compression only. The process is to:

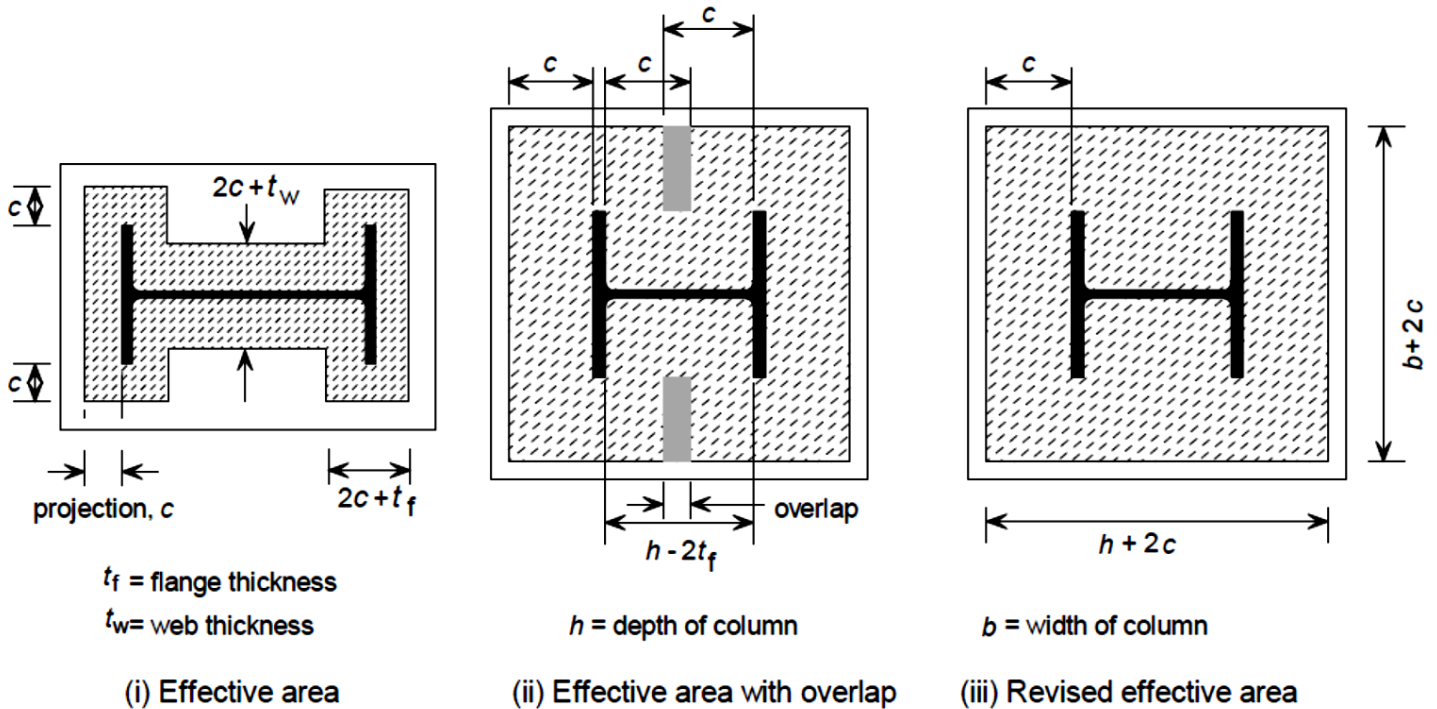
1. Find the required area, A_{req} .
2. Determine the effective area, A_{eff} , in terms of the projection width from the steel profile, c .
3. By equating A_{req} and A_{eff} , calculate c .
4. Calculate the required plate thickness.

Assuming that the projection width c is a uniformly loaded cantilever. Column bases subject to both axial load and an overturning moment have to take into account the effect of tension on one side of the base.

Effective area method

It is assumed that the bearing pressure on the effective area is uniform and that the plate acts as a simple cantilever around the perimeter of the section.

The effective area is a constant width c either side of each flange and web, as shown below in with respect to a rolled I section.



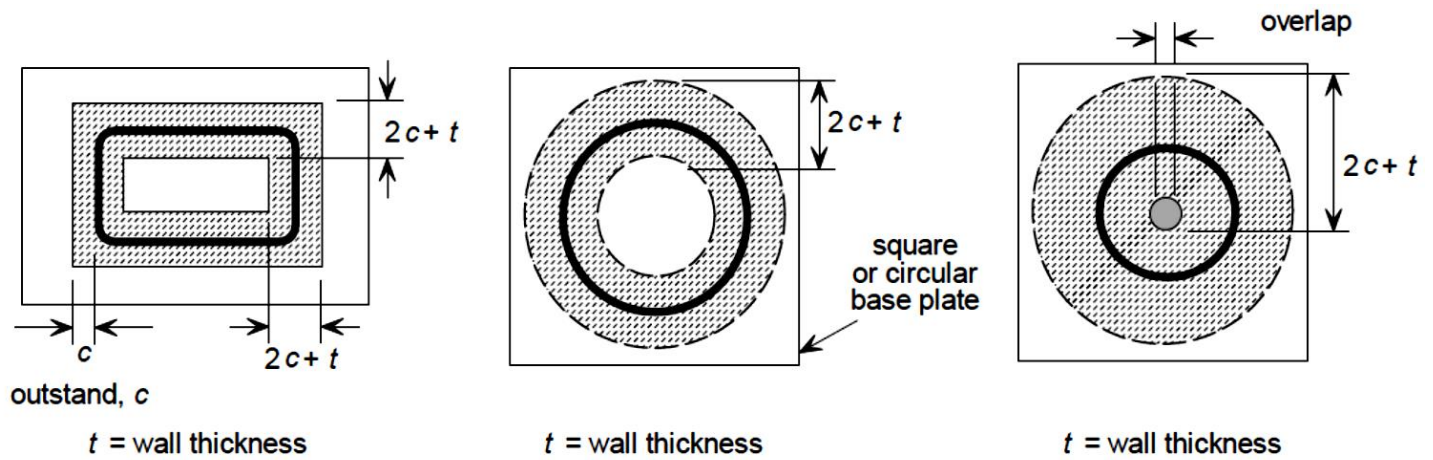
Calculated effective area for a rolled section

The projection width c , shown figure (i) is the minimum that is needed to ensure that the base pressure does not exceed the design bearing strength.

In some circumstances, it can be found that the projection c becomes so large that the strips overlap between the column flanges, as shown in Figure (ii), i.e.

$$c > (h - 2t_f) / 2$$

The overlapping area cannot be double counted, so the effective area must be recalculated on the basis shown in Figure (iii). For hollow section columns, the design procedure is similar and is illustrated for RHS and CHS columns in Figure below. If the internal projection overlaps in the centre of the section, a readjusted effective area must be recalculated in a similar manner to that for the open section.



Calculated effective area for RHS and CHS sections

Although the shaded area represents the size of the base plate theoretically required, the overall size of the plate can be made larger, to utilize rounded dimensions and to accommodate the holding down bolts.

The design process of the column base plate requires four checks:

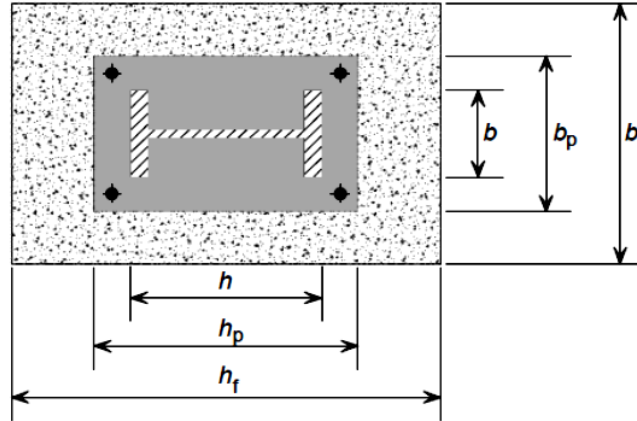
Check 1 – Required area

Check 2 – Effective area

Check 3 – Plate thickness

Check 4 – Welds

Check 1 – Required area



Basic requirement:

$$A_p \geq A_{req}$$

A_p is the area of base plate
 $= h_p b_p$ for rectangular plates

$$= \frac{\pi d_p^2}{4} \quad \text{for circular plates}$$

A_{req} is the required area of base plate

$$= \frac{N_{Ed}}{f_{jd}}$$

where:

$$f_{jd} = \beta_1 \alpha f_{cd}$$

β_1 may be taken as $\frac{2}{3}$ (see note 1)

α is a coefficient which accounts for diffusion of the concentrated force within the foundation. α depends on the foundation depth and the distance between the plate and the edge(s) of the foundation.

Where the foundation's dimensions are unknown, but will be orthodox (i.e. not narrow or shallow) it is reasonable to assume $\alpha = 1.5$, and hence

$$f_{jd} = f_{cd} = 0.85 \frac{f_{ck}}{\gamma_c} \quad \text{(see note 2)}$$

$$f_{cd} = \alpha_{cc} \frac{f_{ck}}{\gamma_c}$$

$\alpha_{cc} = 0.85$ (National Annex to BS EN 1992-1-1)

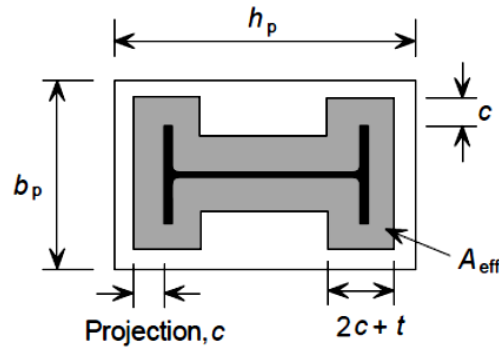
γ_c is the material factor for concrete ($\gamma_c = 1.5$ as given in the UK NA)

Concrete class	C20/25	C25/30	C30/37	C35/45
Cylinder strength, f_{ck} (N/mm ²)	20	25	30	35
Cube strength, $f_{ck,cube}$, (N/mm ²)	25	30	37	45

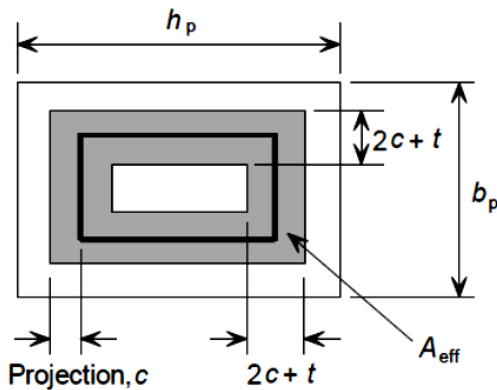
Notes:

- (1) In accordance with clause 6.2.5(7) of BS EN 1993-1-8, the use of $\beta_1 = 2/3$ requires that:
 - a. The grout has a compressive strength at least equal to $0.2 f_{cd}$, and:
 - i. the grout is less than 50 mm thickness
 - ii. the thickness of grout is less than $0.2 h_p$ and $0.2 b_p$
 - b. The grout has a compressive strength at least equal to f_{cd} if over 50 mm thick
- (2) If $\alpha = 1.5$ is assumed, the foundation depth should be at least 50% of the larger base plate dimension, and all edge distances between the plate and the edge of the foundation should be at least 25% of the larger base plate dimension. If precision is required, $\alpha = \sqrt{A_{c1}/A_{c0}}$ as given in BS EN 1992-1-1 clause 6.7

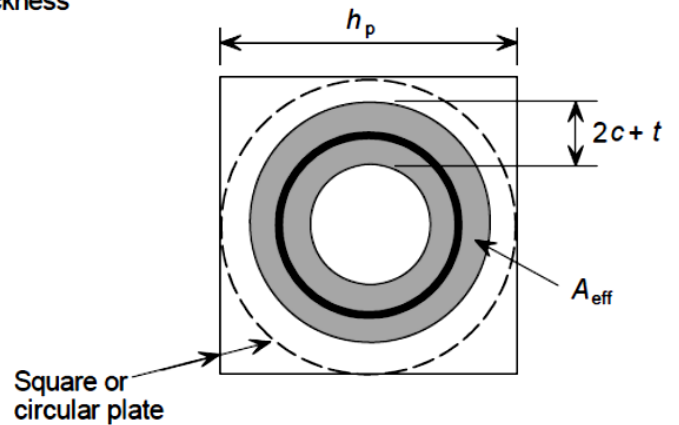
Check 2 – Effective area



t_f = flange thickness
 t_w = web thickness



t = wall thickness



t = wall thickness

Basic requirement:

$$A_{req} \leq A_{eff}$$

Provided there is no overlap, c may be calculated from the following equations:

For UKB, UKC $A_{eff} = 4c^2 + P_{col} c + A_{col}$

For SHS or RHS column $A_{eff} = P_{col} (t + 2c)$

For CHS column $A_{eff} = \pi (d - t) (t + 2c)$

If there is an overlap, c may be calculated from the following equations:

For UKB, UKC, when $c \geq \frac{h - 2t_f}{2}$:

$$A_{eff} = 4c^2 + 2(h + b)c + h b$$

For SHS and RHS column, when $c \geq \frac{b - 2t}{2}$:

$$A_{eff} = 4c^2 + 2(h + b)c + h b$$

For CHS column, when $c \geq \frac{d - 2t}{2}$:

$$A_{eff} = 0.25 \pi (d + 2c)^2$$

where:

A_{req} is the required area of base plate (from Check 1)

A_{col} is the cross sectional area of the column

h is the depth of the column

b is the width of the column

d is the diameter of the CHS column

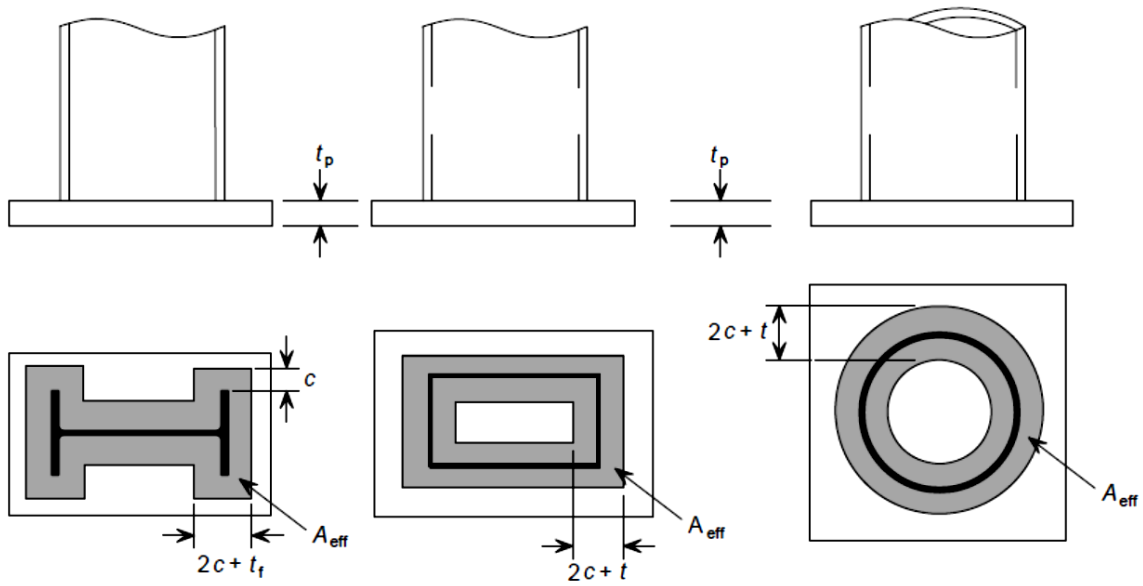
For a universal beam or column section:

P_{col} is the column perimeter

For a square or rectangular hollow section:

P_{col} is the perimeter of the centre line of the section wall of the hollow section

Check 3 – Plate thickness



Basic requirement:

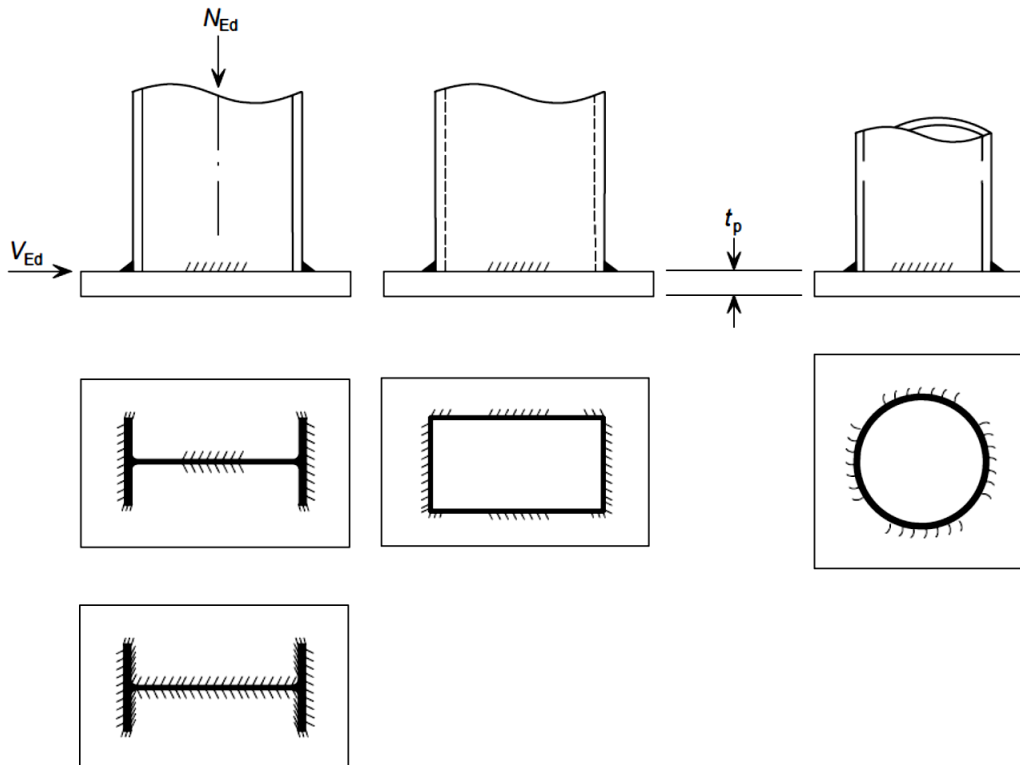
$$t_p \geq t_{p,min}$$

$$t_{p,min} = c \sqrt{\frac{3f_{jd} \gamma_{M0}}{f_{yp}}}$$

where:

- f_{yp} is the yield strength of the base plate
- f_{jd} is from Check 1
- c is from Check 2

Check 4 – Welds



Basic requirement:

For shear:

$$V_{Ed} \leq F_{w,Rd} \ell_{w,eff}$$

$F_{w,Rd}$ is the resistance of fillet weld per unit length

$$= f_{vw,d} a$$

$$f_{vw,d} = \frac{f_u / \sqrt{3}}{\beta_w \gamma_{M2}}$$

where:

a is the weld throat
 $= 0.7s$

s is the weld leg length

$\beta_w = 0.85$ for S275 steel
 $= 0.9$ for S355 steel

γ_{M2} is the partial factor for resistance of welds
($\gamma_{M2} = 1.25$ as given in the National Annex)

$\ell_{w,eff}$ is the total effective length of the welds in direction of shear

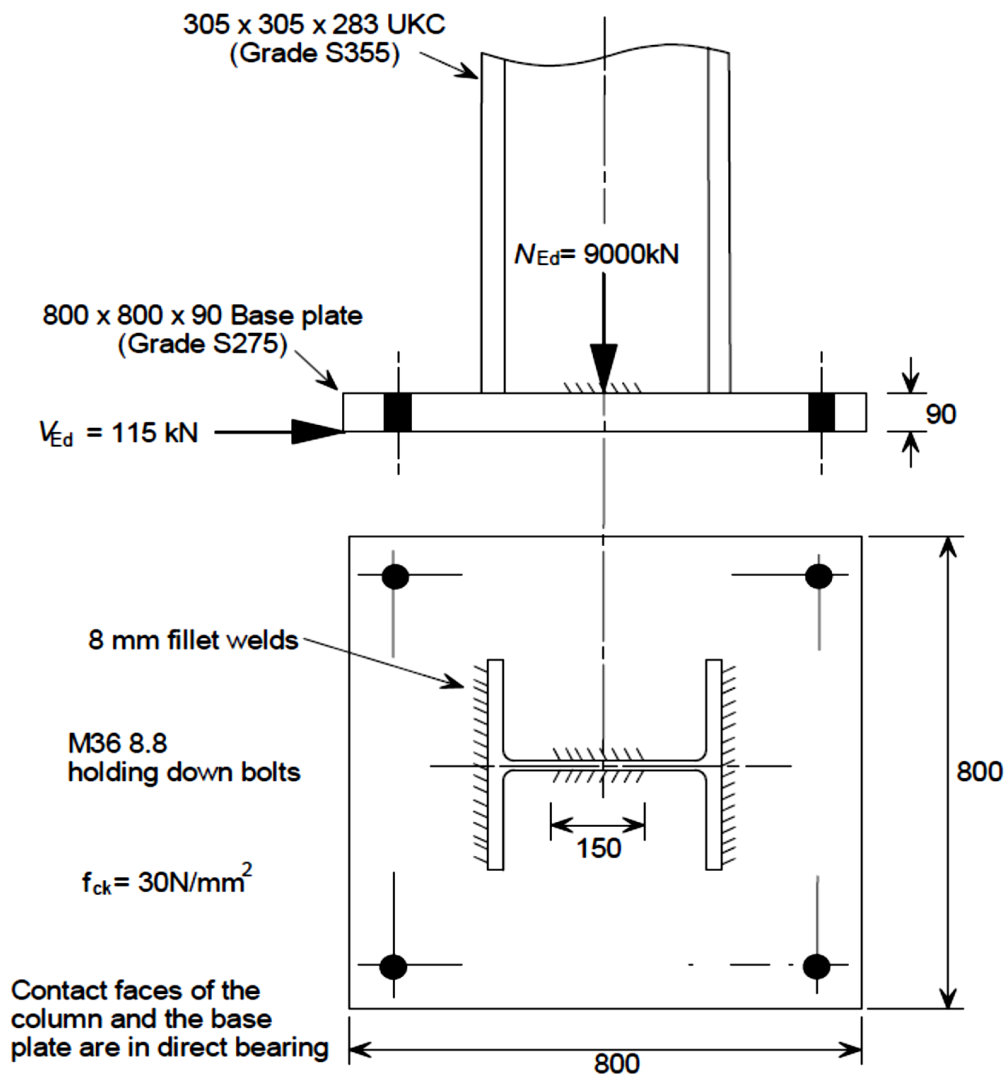
f_u is the ultimate strength of the weaker part joined

$= 410 \text{ N/mm}^2$ for S275 steel

$= 470 \text{ N/mm}^2$ for S355 steel

DESIGN EXAMPLE

Check the column base for the design forces shown.



Check 1: Required area

Basic requirement: $A_p \geq A_{req}$

Area of base plate: $A_p = h_p \times b_p = 800 \times 800 = 640000 \text{ mm}^2$

Design compressive strength of the concrete: $f_{cd} = \alpha_{cc} \frac{f_{ck}}{\gamma_{M0}} = 0.85 \times \frac{30}{1.5} = 17 \text{ N/mm}^2$

$$f_{jd} = \alpha \beta_j f_{cd}$$

Assuming $\alpha = 1.5$, $\beta_j = 2/3$

$$f_{jd} = 1.5 \times 2/3 \times 17 = 17 \text{ N/mm}^2$$

Area required: $A_{req} = \frac{N_{Ed}}{f_{jd}} = \frac{9000 \times 10^3}{17} = 529000 \text{ mm}^2$

$$A_p = 640000 \text{ mm}^2 > 529000 \text{ mm}^2$$

Check 2: Effective area

Basic requirement: $A_{eff} = A_{req}$

To calculate the effective area, assume first that there is no overlap.

$$A_{eff} = 4c^2 + cP_{col} + A_{col}$$

$$\text{Column perimeter } P_{col} = 1940 \text{ mm}$$

$$\text{Area of column } A_{col} = 36000 \text{ mm}^2$$

$$A_{eff} = 4c^2 + 1940c + 36000 = 529000 \text{ mm}^2 = A_{req}$$

$$\therefore c = 184 \text{ mm}$$

To ensure that there is no overlap c has to be less than half the depth between flanges:

$$\frac{h - 2t_f}{2} = \frac{365.3 - 2 \times 44.1}{2} = 138.6 \text{ mm} < 184 \text{ mm}$$

Therefore assumption of no overlap is incorrect.

Recalculate c on the basis of a revised effective area as shown in Figure 7.3(iii)

$$A_{eff} = (h + 2c)(b + 2c) = 4c^2 + 2(h + b)c + hb$$

Equating the effective area, A_{eff} to the required area A_{req} (from Check 1) gives:

$$4c^2 + 2 \times (365.3 + 322.2)c + 365.3 \times 322.2 = 529000$$

$$\therefore c = 192 \text{ mm}$$

Also check that effective area fits on the base plate

$$h + 2c = 365.3 + (2 \times 192) = 749.3 \text{ mm} < h_p = 800 \text{ mm}$$

$$b + 2c = 322.3 + (2 \times 192) = 706.3 \text{ mm} < b_p = 800 \text{ mm}$$

Hence the new calculated value of c is valid

$$\therefore c = 192 \text{ mm}$$

Check 3: Plate thickness

$$t_{p,\min} = c \sqrt{\frac{3 f_{jd} \gamma_{M0}}{f_{yp}}}$$

Yield strength of the 90 mm plate, $f_{y,p} = 235 \text{ N/mm}^2$

$$t_{p,\min} = 192 \sqrt{\frac{3 \times 17 \times 1.0}{235}} = 89 \text{ mm}$$

$$\therefore t_p = 90 \text{ mm} > 89 \text{ mm}$$

Check 4: Welds

Basic requirement: $V_{Ed} \leq F_{w,Rd} \ell_{w,\text{eff}}$

$$F_{w,Rd} = f_{vw,d} a = \frac{f_u / \sqrt{3}}{\beta_w \gamma_{M2}} a = \frac{410 / \sqrt{3}}{0.85 \times 1.25} \times 0.7 \times 8 = 1248 \text{ N/mm}$$

$$\ell_{w,\text{eff}} = 2(\ell - 2s) = 2 \times (150 - 2 \times 8) = 268 \text{ mm}$$

$$F_{w,Rd} \ell_{w,\text{eff}} = 1248 \times 268 \times 10^{-3} = 334 \text{ kN}$$

$$\therefore V_{Ed} = 115 \text{ kN} < 334 \text{ kN}$$