The factored resistance of the steel section can be determined by:

Flexural resistance:

$$M_r = \phi_a Z_s f_y \geq M_f = V_f a + \frac{0.5V_f^2}{(\alpha_1 \phi_c f'_c\, b)}$$

Shear resistance:

$$V_r = \phi_a 0.66 f_y h t \geq V_f$$

where:

- Z_s = plastic section modulus of the steel section (see Fig. 4.13.3)
- f_y = yield strength of the steel section
- h, t = depth and thickness of steel web, respectively
- ϕ_a = 0.90

It is recommended that hollow structural steel sections be filled with concrete in order to improve the bearing condition.

For steel shapes projecting equally from each side of the element, with approximately symmetrical loading, the factored shear resistance on each side as governed by the capacity of the concrete can be calculated by:

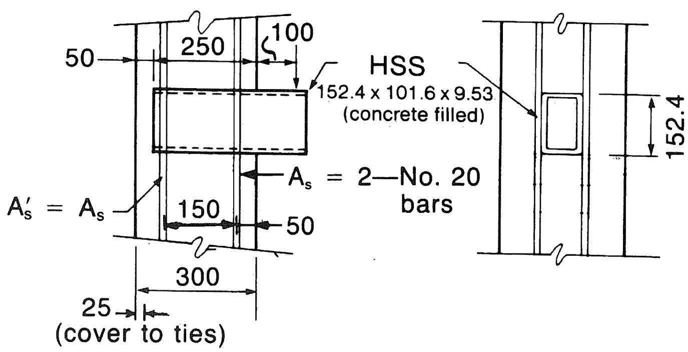
$$V_r = \frac{\alpha_1 \phi_c f'_c b h}{2}$$

Horizontal forces, N_f, are resisted by bond on the perimeter of the section. If the bond stress resulting from factored loads exceeds 1.7 MPa, headed studs or reinforcing bars can be welded to the section.

Example - Design of structural steel haunch

Given:

The structural steel haunch shown.



$e = 100 + 250/2 = 225$

$b = 2.5\,w = 254$

$b_{max} = 300 - (2)(25) = 250$

$s = 150$

Effective $A_s = 2\,A_s = (2)(600) = 1200\ mm^2$

f'_c = 35 MPa

f_y(reinforcement) = 400 MPa (weldable)

f_y(structural steel) = 350 MPa

Problem:

Find the factored resistance of the connection.

Solution:

$$V_c = \frac{\alpha_1 \phi_c f'_c b \ell_e}{1 + 3.6\, e/\ell_e}$$

$$= \frac{(0.80)(0.65)(35)(250)(250)/10^3}{1 + (3.6)(225/250)}$$

$$= 268\ kN$$

$$V_s = \frac{2\phi_s A_s f_y}{1 + \frac{6e/\ell_e}{4.8s/\ell_e - 1}}$$

$$= \frac{(2)(1200)(0.85)(400)(10^{-3})}{1 + \frac{(6)(225/250)}{(4.8)(150/250) - 1}}$$

$$= 211\,kN$$

$$V_r = 268 + 211 = 479\ kN$$

Plastic section modulus of HSS[R4.13.2]:

$$Z_a = 205 \times 10^3\ mm^3$$

Flexural resistance of HSS (neglect concrete fill):

$$M_r = \phi_a Z_s f_y = (0.9)(205 \times 10^3)(350)/10^6$$

$$= 64.6\ kN\cdot m$$

$$M_r = V_r a + \frac{0.5V_r^2}{\alpha_1 \phi_c f'_c b}$$

$$\therefore V_r = 438\ kN < 479\,kN$$

Shear resistance of HSS:

$$V_r = \phi_a 0.66 f_y h t$$

$$= (0.9)(0.66)(350)(152.4)(2)(9.53)/10^6$$

$$= 604\ kN > 438\,kN$$

Therefore, flexural resistance of the HSS controls and $V_r = 443$ kN.

4.14 CONNECTION ANGLES

Angles used to support light precast elements can be designed by statics as shown in Fig. 4.14.1.

In addition to the applied vertical and horizontal loads, the design should include all loads induced by restraint of relative movement between the precast element and the supporting element. The minimum thickness of non-gusseted angles loaded in shear as shown in Fig. 4.14.2 can be determined by:

Fig. 4.14.1 Design relationships for connection angles

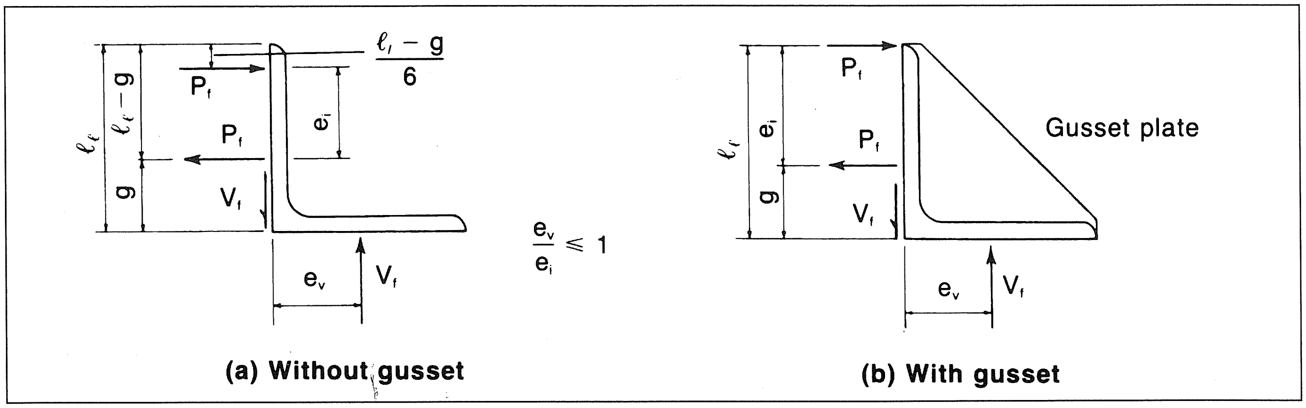


Fig. 4.14.2 Vertical loads on connection angle

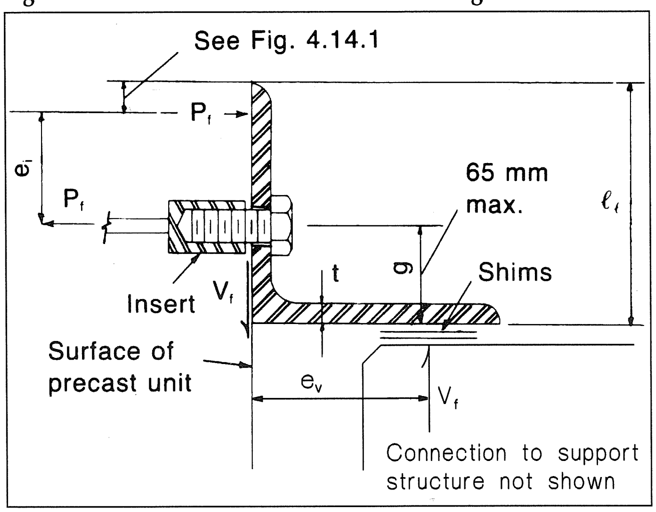
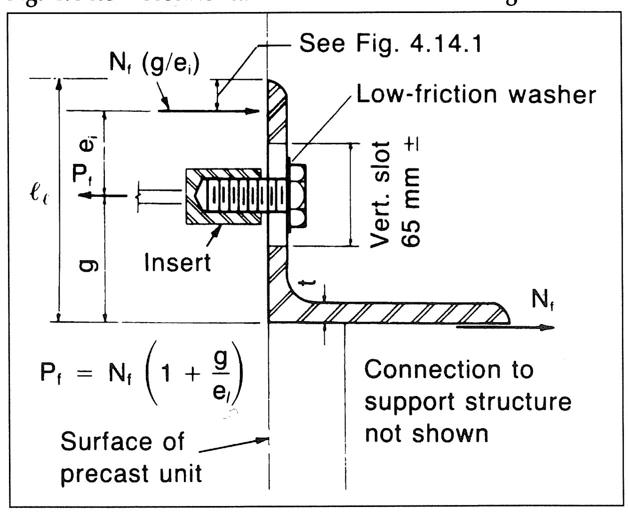


Fig. 4.14.3 Horizontal loads on connection angle



$$t = \sqrt{\frac{4V_f e_v}{\phi_a f_y b}}$$

where:

ϕ_a = 0.9

b = width of angle

Design e_v = specified e_v + 20 mm

The tension on the bolt can be calculated by:

$$P_f = V_f \frac{e_v}{e_i}$$

For angles loaded axially (Fig. 4.14.3) either in tension or compression, the minimum thickness of non-gusseted angles can be calculated by:

$$t = \sqrt{\frac{4N_f g}{\phi_a f_y b}}$$

where:

ϕ_a = 0.9

g = gauge of angle (see Fig. 4.14.3)

b = width of angle

4.15 COLUMN BASE PLATES

Column bases must be designed for both erection loads and loads which occur in service, the former often being critical. Two commonly used base plate details are shown in Fig. 4.15.1, although other details are also frequently used.

If in the analysis for erection loads or temporary construction loads before grout is placed under the plate, all anchor bolts are in compression, the base plate thickness required to satisfy bending is determined from:

$$t = \sqrt{\frac{(\Sigma F)4x_c}{\phi_a f_y b}}$$

where:

ϕ_a = 0.9

x_c, b from Fig. 4.15.1.

f_y = yield strength of the base plate

ΣF = greatest sum of anchor bolt factored forces on one side of the column

If the analysis indicates that the anchor bolts on one or both of the column faces are in tension, the base plate thickness is determined by: