Anchor Bolt Design for Shear and Tension

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When column base plates are subject to both uplift and very large shear loads, two independent systems are normally used to resist tension in the anchor bolts and shear at the level of the base plate: (1) the length of embedment and the diameter of the anchor bolts are determined on the basis of uplift tension and (2) a shear key is welded to the column base plate to resist shear.

If very large shear loads do not accompany the uplift, the anchor bolts can be designed to resist both shear and tension, without using a shear key, as in the following example.

EXAMPLE

Given: Design anchor bolts for a column base plate for an uplift of 100 kips, and a shear load of 40 kips due to wind or seismic loading. Use 4 anchor bolts. (See Fig. 1.)

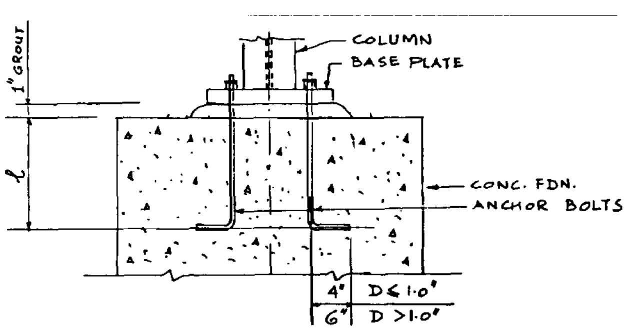

Figure 1

Design Data: Load per anchor bolt is as follows:

100/4 = 25 kips

40/4 = 10 kips

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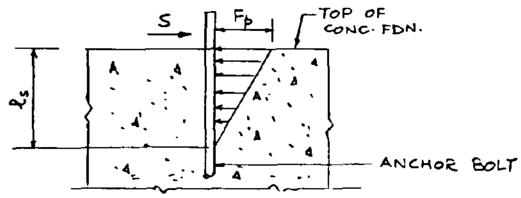

Figure 2

Solution:

Shear:

See Fig. 2.

f'_c = 3.0 ksi

F_p = $0.25f'_c = 0.75$ ksi

l_s = $12D$ (assumed)

A_c = $(l_sD) = 12D^2$

Concrete resistance for shear:

$S = ½F_pA_c = 6F_pD^2 = (6 \times 0.75)D^2$
$= 4.5D^2$

$$\therefore D = \left(\frac{S}{4.5}\right)^{1/2} = \left(\frac{10}{4.5}\right)^{1/2} = 49.1 \text{ in.}$$

Use D = 2 in.

$l_s = 12D$ = 24 in.

Tension:

For plain bars, $u = 4.75 \times 10^{-3/2}(f'_c)^{1/2}/D$

For D = 2:

$u = 4.75 \times 10^{-3/2}\,(3.0)^{1/2}/2 = 0.13$ ksi

$\therefore$use u = 0.13 ksi

$T = u(pD)\,l_t$

$$l_t = \frac{T}{u(pD)} = \frac{25}{0.13(p \times 2.0)} = 30.61 \text{ in.}$$

$l = (l_s + l_t) = (24 + 30.61) = 54.61$ in.

Use l = 4 ft-6 in.

Check Bolt Stresses:

(a) $A_g = \frac{pD^2}{4} = 3.141 \text{in.}^2$

$A_t = 0.75A_g = 2.356$ in.^{2} (AISC Spec. Sect. 1.5.2.1, with $n = 7$)

For A307 bolts, $F_y = 33$ ksi; $F_v = 0.3F_y = 10$ ksi

$Fnfnb = F_t = 0.6\ F_y = 20$ ksi

(b) $$f_v = \left(\frac{S}{A_g}\right) = \left(\frac{10}{3.141}\right) = 3.188 \text{ksi}$$

$$f_t = \left(\frac{T}{A_t}\right) = \left(\frac{25}{2.356}\right) = 10.16 \text{ksi}$$

$F_t = 28.0 - 1.6f_v = 22.90$ ksi ≤ 20 ksi (AISC Spec. Sect. 1.6.3)

$\therefore$ Use F_t or $F_b = 20$ ksi

(c) See Fig. 3.

Bending moment due to shear S at the level of top of grout = m.

$m = (S \times 1.0) = (10 \times 1.0) = 10$ kip-in.

$$f_b = \frac{m}{(p/32)D^3} = \frac{10.0}{(p/32) \times 2.0^3} = 12.73 \text{ksi}$$

$(1/1.33)\ (f_t + f_b) = (1/1.33)\ (10.61 + 12.73)$
$= 17.55$ ksi $< F_t = 20$ ksi **o.k.**

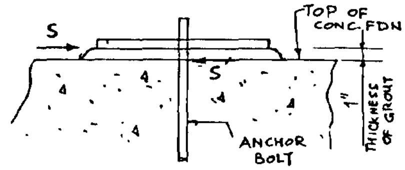

Figure 3

NOMENCLATURE

F_y = Yield stress of anchor bolt material, ksi
F_v = Allowable shear stress in anchor bolt, ksi
F_t = Allowable tensile stress in anchor bolt, ksi
F_b = Allowable bending stress in anchor bolt, ksi
A_c = Area of concrete in compression, in.^{2}
D = Diameter of anchor bolt, in.
A_g = Gross area of anchor bolt, in.^{2}
A_t = Tensile stress area of anchor bolt, in.^{2}
F_p = Allowable bearing stress on concrete, ksi
f'_c = Specified compressive strength of concrete at the end of 28 days, ksi
l_s = Length of anchor bolt required for resisting shear force on bolt, in.
l_t = Length of anchor bolt required for resisting tensile force on bolt, in.
l = Total length of embedment required, in.
u = Allowable bond stress of concrete, ksi
f_v = Actual shear stress in anchor bolt, ksi
f_t = Actual tensile stress in anchor bolt, ksi
n = Number of threads per inch for anchor bolt