Anchor Bolts: ASCE 7-10 Modifications

ASCE 7-10 Modification:
13.4.2.2 Non-structural components
14.4.5 Material specific design and detailing requirements
   IBC Section 1613 excludes Chapter 14 of ASCE 7
15.4.9.2 Non-building structures

Anchor Bolts Embedded in Grout.
Anchorage assemblies connecting masonry elements that are part of the
seismic force-resisting system to diaphragms and chords:

- Design so that anchor strength is governed by steel tensile or shear yielding.
- Alternatively, if governed by masonry breakout or anchor pullout, design to
  resist not less than 2.5 times the factored forces transmitted by the assembly.

ASCE 7-10 12.11.2:
Anchorage of Structural Walls and Transfer of Design Forces into Diaphragms.
Structural walls shall be designed to resist bending between anchors where the
anchor spacing exceeds 4 ft.

Example: Anchor Bolts
After 2009 NEHRP Recommended Seismic Provisions:
Design Examples FEMA P-751 / September 2012

Given: 8 in. normal weight (125 pcf) CMU wall; Grade 60 steel; Type S PCL mortar (special reinforced wall);
$f_m'=2000$psi; roof forces act at 7.32 in. eccentricity; $S_{DS}=1.43$,
$I=1.0$, bars at 24 in. ($w_w = 56$psf),

Required: Anchor bolts for out-of-plane loading

Solution: ASCE 7-10, 12.11.2.1 Wall Anchorage Forces

$$F_p = 0.4S_{DS}k_aI_eW_p > 0.2k_aI_eW_p$$

$$k_a = 1.0 + \frac{L_f}{100} \leq 2.0 \quad \text{L_f = 200 ft, so } k_a = 2$$

$$F_p = 0.4(1.43)(2.0)(1.0)(0.056ksf)(2 ft + 14 ft) = 1.02k / ft$$

Vertical Shear Load = 1.486D = 1.486(0.2k/ft) = 0.30k/ft
Example: Anchor Bolts

Try ¾ in. A 307 Anchor Bolt. Assume $f_y = 36$ ksi
- Max length of bolt in block
  - $7.62 - 1.25 - 0.5 = 5.88$ in. Use 5.75 in.
- Embedment length, $l_b$
  - $5.75 - 0.5 = 5.25$ in.

$$A_{pt} = \pi \ell_b^2 = \pi \left(5.25\text{in}\right)^2 = 86.6\text{in}^2$$

Tensile breakout of anchor: $\phi = 0.5$

$$\phi B_{amb} = \phi 4 A_{pt} \sqrt{f_m}$$

$$= 0.5(4)\left(86.6\text{in}^2\right)\sqrt{2000\text{psi}} = 7.74\text{kips}$$
Example: Anchor Bolts

Tensile yield of anchor: $\phi = 0.9$

$$\phi B_{ass} = \phi A_b f_y$$

$$= 0.9 \left(0.334 \text{in}^2 \right) (36 \text{ksi}) = 10.8 \text{kips}$$

- Tensile breakout controls
- Divide by 2.5 to meet ASCE 7
  - $7.74 / 2.5 = 3.10 \text{ kips}$

Use $\phi B_{tan} = 3.10 \text{ kips}$

Shear yield of anchor: $\phi = 0.9$

$$\phi B_{syp} = \phi 0.6 A_b f_y$$

$$= 0.9 \left(0.6 \right) \left(0.44 \text{in}^2 \right) (36 \text{ksi}) = 8.55 \text{kips}$$

Shear breakout of anchor: $\phi = 0.5$

$$\phi B_{vnb} = \phi 4 A_{pv} \sqrt{f_m}$$

Shear crushing of masonry: $\phi = 0.5$

$$\phi B_{vnc} = \phi 1050 \sqrt{f_m A_b}$$

$$= 0.5 (1050) \sqrt{(2000 \text{psi})(0.44 \text{in}^2)} = 2.86 \text{kips}$$

$$A_b = \frac{\pi}{4} \left( d_0 - \frac{0.9743}{n_t} \right)^2$$

$A_b =$ effective tensile stress area

$d_0 =$ nominal anchor diameter

$n_t =$ number of threads per inch

<table>
<thead>
<tr>
<th>Bolt</th>
<th>$A$ (in$^2$)</th>
<th>$A_b$ (in$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 - 13</td>
<td>0.196</td>
<td>0.142</td>
</tr>
<tr>
<td>5/8 - 11</td>
<td>0.307</td>
<td>0.266</td>
</tr>
<tr>
<td>3/4 - 10</td>
<td>0.442</td>
<td>0.334</td>
</tr>
<tr>
<td>7/8 - 9</td>
<td>0.601</td>
<td>0.462</td>
</tr>
<tr>
<td>1 - 8</td>
<td>0.785</td>
<td>0.606</td>
</tr>
</tbody>
</table>

Suitable approximation:

$A_b = 0.75$ (nominal area)

- Conservative to use $A_b =$ effective tensile area
- Reasonable to use nominal area if threads excluded from shear plane
- $A_b$ defined in TMS 402 as cross-sectional area of an anchor bolt
- Will not control since not near edge
- Often failure mode that controls in shear
Example: Anchor Bolts

Shear pryout of anchor: $\phi = 0.5$

$$\phi B_{vpy} = \phi 2.0 B_{anb} = 0.5 A_{pf} \sqrt{f_m}$$

$$= 0.5(8) \left( \frac{86.6 \text{ in}^2}{2000 \text{ psi}} \right) = 15.5 \text{kips}$$

Combined tension and shear
Determine required spacing of bolts, $s$

$$\frac{b_{af}}{\phi B_{an}} + \frac{b_{vf}}{\phi B_{vn}} \leq 1$$

$$\frac{1.02 \left( \frac{\text{k}}{\text{ft}} \right)s}{3.10 \text{k}} + \frac{0.30 \left( \frac{\text{k}}{\text{ft}} \right)s}{1.16 \text{k}} = 1$$

Shear crushing controls
- Divide by 2.5 to meet ASCE 7
  - $2.86/2.5 = 1.16 \text{kips}$

Use $\phi B_{vn} = 1.16 \text{kips}$

$$s = 1.70 \text{ ft} = 20.4 \text{ in.}$$

Use ¼ in. A307 bolt @ 16 in.