**Chapter 18 Installation Requirements for Seismic Protection**

18.1\* Protection of Piping Against Damage Where Subject to Earthquakes

18.1.1

Where water-based fire protection systems are required to be protected against damage from earthquakes, the requirements of Chapter 18 shall apply, unless the requirements of 18.1.2 are met.

18.1.2

Alternative methods of providing earthquake protection of sprinkler systems based on a seismic analysis certified by a registered professional engineer such that system performance will be at least equal to that of the building structure under expected seismic forces shall be permitted.

18.1.3 Obstructions to Sprinklers

Braces and restraints shall not obstruct sprinklers and shall comply with the obstruction rules of Chapters 10 through 14.

18.2\* Flexible Couplings

18.2.1

Flexible couplings joining grooved end pipe shall be provided as flexure joints to allow individual sections of piping 21/2 in. (65 mm) or larger to move differentially with the individual sections of the building to which it is attached.

18.2.2

Flexible couplings shall be arranged to coincide with structural separations within a building.

18.2.3

Systems having more flexible couplings than required by this section shall be provided with additional sway bracing as required in 18.5.5.9.

18.2.3.1

The flexible couplings shall be installed as follows:

\* Within 24 in. (600 mm) of the top and bottom of all risers, unless the following provisions are met:

In risers less than 3 ft (900 mm) in length, flexible couplings shall be permitted to be omitted.

In risers 3 ft to 7 ft (900 mm to 2100 mm) in length, one flexible coupling shall be adequate.

Within 12 in. (300 mm) above and within 24 in. (600 mm) below the floor in multistory buildings, unless the following provision is met:

\* In risers up to 7 ft (2.1 m) in length terminating above the roof assembly or top landing, the flexible coupling shall not be required above the landing or roof assembly.

On both sides of concrete or masonry walls within 1 ft (300 mm) of the wall surface, unless clearance is provided in accordance with Section 18.4

\* Within 24 in. (600 mm) of building expansion joints

Within 24 in. (600 mm) of the top of drops exceeding 15 ft (4.6 m) in length to portions of systems supplying more than one sprinkler, regardless of pipe size

Within 24 in. (600 mm) above and 24 in. (600 mm) below any intermediate points of support for a riser or other vertical pipe

18.2.3.2

When the flexible coupling below the floor is above the tie-in main to the main supplying that floor, a flexible coupling shall be provided in accordance with one of the following:

\* On the horizontal portion within 24 in. (600 mm) of the tie-in where the tie-in is horizontal

\* On the vertical portion of the tie-in where the tie-in incorporates a riser

18.2.4\* Flexible Couplings for Drops

Flexible couplings for drops to hose lines, rack sprinklers, mezzanines, and freestanding structures shall be installed regardless of pipe sizes as follows:

Within 24 in. (600 mm) of the top of the drop

Within 24 in. (600 mm) above the uppermost drop support attachment, where drop supports are provided to the structure, rack, or mezzanine

Within 24 in. (600 mm) above the bottom of the drop where no additional drop support is provided

18.3\* Seismic Separation Assembly

18.3.1

An approved seismic separation assembly shall be installed where sprinkler piping, regardless of size, crosses building seismic separation joints at ground level and above.

18.3.2

Seismic separation assemblies shall consist of flexible fittings or flexible piping so as to allow movement sufficient to accommodate closing of the separation, opening of the separation to twice its normal size, and movement relative to the separation in the other two dimensions in an amount equal to the separation distance.

18.3.3\*

The seismic separation assembly shall include a four-way brace upstream and downstream within 6 ft (1.8 m) of the seismic separation assembly.

18.3.4

Bracing shall not be attached to the seismic separation assembly.

18.4\* Clearance

18.4.1\*

Clearance shall be provided around all piping extending through walls, floors, platforms, and foundations, including drains, fire department connections, and other auxiliary piping.

18.4.2

Unless any of the requirements of 18.4.3 through 18.4.7 or 18.4.10 are met, where pipe passes through holes in platforms, foundations, walls, or floors, the holes shall be sized such that the diameter of the holes is nominally 2 in. (50 mm) larger than the pipe for pipe 1 in. (25 mm) nominal to 31/2 in. (90 mm) nominal and 4 in. (100 mm) larger than the pipe for pipe 4 in. (100 mm) nominal and larger.

18.4.3

Where clearance is provided by a pipe sleeve, a nominal diameter 2 in. (50 mm) larger than the nominal diameter of the pipe shall be acceptable for pipe sizes 1 in. (25 mm) through 31/2 in. (90 mm), and the clearance provided by a pipe sleeve of nominal diameter 4 in. (100 mm) larger than the nominal diameter of the pipe shall be acceptable for pipe sizes 4 in. (100 mm) and larger.

18.4.4

No clearance shall be required for piping passing through gypsum board or equally frangible construction.

18.4.5

No clearance shall be required if flexible couplings are located within 1 ft (300 mm) of each side of a wall or if the requirements of 18.2.3.1 (2) are met.

18.4.6

No clearance shall be required where horizontal piping passes perpendicularly through successive studs or joists that form a wall or floor/ceiling assembly.

18.4.7

No clearance shall be required where nonmetallic pipe has been demonstrated to have inherent flexibility equal to or greater than the minimum provided by flexible couplings located within 1 ft (300 mm) of each side of a wall, floor, platform, or foundation.

18.4.8

Where required, the clearance shall be filled with a flexible material that is compatible with the piping material.

18.4.9

The installed horizontal and upward vertical clearance between horizontal sprinkler piping and structural members not penetrated or used, collectively or independently, to support the piping shall be at least 2 in. (50 mm).

18.4.10\*

No clearance shall be required where piping is supported by holes through structural members as permitted by 17.1.7.3.

18.4.11\*

The installed clearance between a sprinkler and structural elements not used collectively or independently to support the sprinklers shall be at least 3 in. (75 mm).

18.4.11.1

Where sprinklers are installed using flexible sprinkler hose, clearance for the sprinkler shall not be required.

18.4.12

Clearance shall not be required for piping that is vertically supported by the bottom edge of holes through structural members as permitted by 17.1.7.3.

18.4.13

No horizontal clearance (tight fit) shall be provided for piping that is laterally supported by the side edges of holes through structural members.

18.4.13.1

Clearance shall be permitted where piping is secured to the structural member with an approved hanger or restraint.

18.5\* Sway Bracing

18.5.1 General

18.5.1.1

The system piping shall be braced to resist both lateral and longitudinal horizontal seismic loads and to prevent vertical motion resulting from seismic loads.

18.5.1.2

The structural components to which bracing is attached shall be determined to be capable of resisting the added applied seismic loads.

18.5.1.3\*

Horizontal loads on system piping shall be determined in accordance with 18.5.9.

18.5.1.4\*

A shared support structure shall be permitted to support both the gravity loads addressed in 17.1.4.1 and the seismic loads addressed in 18.5.9.

18.5.1.4.1

When a shared support structure is used to support gravity and seismic loads, the structure shall be designed to support these loads for all pipe and distribution systems on the structure using either 18.5.9.3 or 18.5.9.4 with an importance factor, Ip, of 1.5 being applied to all of the distribution systems.

18.5.1.5\*

If a shared support structure is used to support sprinkler pipe and other distribution systems per 17.1.4.1 and that structure does not provide seismic resistance as required in 18.5.1.4, the following shall be met:

The sprinkler pipe shall be braced using the method in 18.5.6 with the zone of influence including the water-filled sprinkler pipe and all other distribution systems that are not independently equipped with seismic protection and attached to the shared support structure.

The sprinkler sway bracing attachment shall be connected to the same building or structure as the shared support structure.

18.5.1.6

Bracing requirements of Section 18.5 shall not apply to drain piping downstream of the drain valve.

18.5.2 Listing

18.5.2.1

Sway bracing assemblies shall be listed for a maximum load rating, unless the requirements of 18.5.2.2 are met.

18.5.2.2

Where sway bracing utilizing pipe, angles, flats, or rods as shown in Table 18.5.11.8(a) through Table 18.5.11.8(f) is used, the components shall not require listing.

18.5.2.2.1

Bracing fittings and connections used with those specific materials shall be listed.

18.5.2.3\*

The listed load rating shall be reduced as shown in Table 18.5.2.3 to determine the allowable load for installations where the brace is less than 90 degrees from vertical.

Table 18.5.2.3 Listed Horizontal Load Adjustment

Brace Angle Degrees from Vertical Allowable Horizontal Load

30 to 44 Listed load rating divided by 2.000

45 to 59 Listed load rating divided by 1.414

60 to 89 Listed load rating divided by 1.155

90 Listed load rating

18.5.2.3.1\*

Maximum allowable horizontal loads shall be determined by testing at angles of 30, 45, 60, and 90 degrees from vertical and confirmed to be equal to or greater than those calculated using 18.5.2.3.

18.5.2.3.2

For attachments to structures, additional tests shall be performed at 0 degrees.

18.5.3 Component Material

18.5.3.1

Unless permitted by 18.5.3.2, components of sway brace assemblies shall be ferrous.

18.5.3.2

Nonferrous components that have been proven by fire tests to be adequate for the hazard application, that are listed for this purpose, and that are in compliance with the other requirements of this section shall be acceptable.

18.5.4 Sway Bracing Design

18.5.4.1

Sway braces shall be designed to withstand forces in tension and compression, unless the requirements of 18.5.4.2 are met.

18.5.4.2\*

Tension-only bracing systems shall be permitted for use where listed for this service and where installed in accordance with their listing limitations, including installation instructions.

18.5.4.3

For all braces, whether or not listed, the maximum allowable load shall be based on the weakest component of the brace with safety factors.

18.5.5 Lateral Sway Bracing

18.5.5.1\*

Lateral sway bracing shall be provided on all feed and cross mains regardless of size and all branch lines and other piping with a diameter of 21/2 in. (65 mm) and larger.

18.5.5.1.1

Where branch lines are not provided with lateral sway bracing, they shall be provided with restraint in accordance with Section 18.6.

18.5.5.2\*

The spacing between lateral sway braces shall be in accordance with either Table 18.5.5.2(a) through Table 18.5.5.2(l) or 18.5.5.3, based on the piping material of the sprinkler system.

Table 18.5.5.2(a) Maximum Load (Fpw) in Zone of Influence (lb), (Fy = 30 ksi) Schedule 10 Steel Pipe

Diameter of Pipe (in.) Being Braced Lateral Sway Brace Spacing (ft)

20 25 30 35 40

1 111 89 73 63 52

11/4 176 141 116 99 83

11/2 241 193 158 136 114

2 390 312 256 219 183

21/2 641 513 420 360 301

3 966 773 633 543 454

31/2 1281 1025 840 720 603

4 1634 1307 1071 918 769

5 2814 2251 1844 1581 1324

6 and larger\* 4039 3231 2647 2269 1900

Note: ASTM A106 Grade B or ASTM A53 Grade B has an Fy = 35 ksi. An Fy = 30 ksi was used as a conservative value to account for differences in material properties as well as other operational stresses.

\*Larger diameter pipe can be used when justified by engineering analysis.

Table 18.5.5.2(b) Maximum Load (Fpw) in Zone of Influence (kg), (Fy = 207 N/mm2) Schedule 10 Steel Pipe

Diameter of Pipe (mm) Being Braced Lateral Sway Brace Spacing (m)

6.1 7.6 9.1 11 12

25 50 40 33 29 24

32 80 64 53 45 38

40 109 88 72 62 52

50 177 142 116 99 83

65 291 233 191 163 137

80 438 351 287 246 206

90 581 465 381 327 273

100 741 593 486 416 349

125 1276 1021 836 717 601

150\* 1832 1466 1201 1029 862

Note: ASTM A106 Grade B or ASTM A53 Grade B has an Fy = 241 N/mm2. An Fy = 207 N/mm2 was used also as a conservative value to account for differences in material properties as well as other operational stresses.

\*Larger diameter pipe can be used when justified by engineering analysis.

Table 18.5.5.2(c) Maximum Load (Fpw) in Zone of Influence (lb), (Fy = 30 ksi) Schedule 40 Steel Pipe

Diameter of Pipe (in.) Being Braced Lateral Sway Brace Spacing (ft)

20 25 30 35 40

1 121 97 79 68 57

11/4 214 171 140 120 100

11/2 306 245 201 172 144

2 520 416 341 292 245

21/2 984 787 645 553 463

3 1597 1278 1047 897 751

31/2 2219 1775 1455 1247 1044

4 2981 2385 1954 1675 1402

5 5061 4049 3317 2843 2381

6 and larger\* 7893 6314 5173 4434 3713

Note: ASTM A106 Grade B or ASTM A53 Grade B has an Fy = 35 ksi. An Fy = 30 ksi was used as a conservative value to account for differences in material properties as well as other operational stresses.

\*Larger diameter pipe can be used when justified by engineering analysis.

Table 18.5.5.2(d) Maximum Load (Fpw) in Zone of Influence (kg), (Fy = 207 N/mm2) Schedule 40 Steel Pipe

Diameter of Pipe (in.) Being Braced Lateral Sway Brace Spacing (m)

6.1 7.6 9.1 11 12

25 55 44 36 31 26

32 97 78 63 54 45

40 139 111 91 78 65

50 236 189 155 132 111

65 446 357 293 251 210

80 724 580 475 407 341

90 1007 805 660 566 474

100 1352 1082 886 760 636

125 2296 1837 1505 1290 1080

150\* 3580 2864 2346 2011 1684

Note: ASTM A106 Grade B or ASTM A53 Grade B has an Fy = 241 N/mm2. An Fy = 207 N/mm2 was used also as a conservative value to account for differences in material properties as well as other operational stresses.

\*Larger diameter pipe can be used when justified by engineering analysis.

Table 18.5.5.2(e) Maximum Load (Fpw) in Zone of Influence (lb), (Fy = 30 ksi) Schedule 5 Steel Pipe

Diameter of Pipe (in.) Being Braced Lateral Sway Brace Spacing (ft)

20 25 30 35 40

1 71 56 46 40 33

11/4 116 93 76 65 55

11/2 154 124 101 87 73

2 246 197 161 138 116

21/2 459 367 301 258 216

3 691 552 453 388 325

31/2 910 728 597 511 428

4\* 1160 928 760 652 546

Note: ASTM A106 Grade B or ASTM A53 Grade B has an Fy = 35 ksi. An Fy = 30 ksi was used as a conservative value to account for differences in material properties as well as other operational stresses.

\*Larger diameter pipe can be used when justified by engineering analysis.

Table 18.5.5.2(f) Maximum Load (Fpw) in Zone of Influence (kg), (Fy = 207 N/mm2) Schedule 5 Steel Pipe

Diameter of Pipe (mm) Being Braced Lateral Sway Brace Spacing (m)

6.1 7.6 9.1 11 12

25 32 25 21 18 15

32 53 42 34 29 25

40 70 56 46 39 33

50 112 89 73 63 53

65 208 166 137 117 98

80 313 250 205 176 147

90 413 330 271 232 194

100\* 526 421 345 296 248

Note: ASTM A106 Grade B or ASTM A53 Grade B has an Fy = 241 N/mm2. An Fy = 207 N/mm2 was used also as a conservative value to account for differences in material properties as well as other operational stresses.

\*Larger diameter pipe can be used when justified by engineering analysis.

Table 18.5.5.2(g) Maximum Load (Fpw) in Zone of Influence (lb), (Fy = 8 ksi) CPVC Pipe

Diameter of Pipe (in.) Being Braced Lateral Sway Brace Spacing (ft)

20 25 30 35 40

3/4 15 12 10 8 7

1 28 22 18 15 13

11/4 56 45 37 30 26

11/2 83 67 55 45 39

2 161 129 105 87 76

21/2 286 229 188 154 135

3 516 413 338 278 243

Table 18.5.5.2(h) Maximum Load (Fpw) in Zone of Influence (kg), (Fy = 55 N/mm2) CPVC Pipe

Diameter of Pipe (in.) Being Braced Lateral Sway Brace Spacing (m)

6.1 7.6 9.1 11 12

20 7 5 5 4 3

25 13 10 8 7 6

32 25 20 17 14 12

40 38 30 25 20 18

50 73 59 48 39 34

65 130 104 85 70 61

80 234 187 153 126 110

Table 18.5.5.2(i) Maximum Load (Fpw) in Zone of Influence (lb), (Fy = 30 ksi) Type M Copper Tube (with Soldered Joints)

Diameter of Pipe (in.) Being Braced Lateral Sway Brace Spacing (ft)

20 25 30 35 40

3/4 16 13 10 9 8

1 29 24 19 16 14

11/4 53 42 35 28 25

11/2 86 69 56 46 41

2\* 180 144 118 97 85

\*Larger diameter pipe can be used when justified by engineering analysis.

Table 18.5.5.2(j) Maximum Load (Fpw) in Zone of Influence (kg), (Fy = 3207 N/mm2) Type M Copper Tube (with Soldered Joints)

Diameter of Pipe (in.) Being Braced Lateral Sway Brace Spacing (m)

6.1 7.6 9.1 11 12

20 7.3 5.9 5 4.1 3.6

25 13.2 10.9 8.6 7.3 6.4

32 24 19.1 15.9 12.7 11.3

40 39 31.3 25.4 20.9 18.6

50\* 81.6 65.3 53 44 38.6

\*Larger diameter pipe can be used when justified by engineering analysis.

Table 18.5.5.2(k) Maximum Load (Fpw) in Zone of Influence (lb), (Fy = 9 ksi) Type M Copper Tube (with Brazed Joints)

Diameter of Pipe (in.) Being Braced Lateral Sway Spacing (ft)

20 25 30 35 40

3/4 6 5 4 3 3

1 11 9 7 6 5

11/4 20 16 13 12 10

11/2 33 27 22 19 16

2\* 70 56 46 39 33

\*Larger diameter pipe can be used when justified by engineering analysis.

Table 18.5.5.2(l) Maximum Load (Fpw) in Zone of Influence (lb), (Fy = 9 ksi) Red Brass Pipe (with Brazed Joints)

Diameter of Pipe (in.) Being Braced Lateral Sway Spacing (ft)

20 25 30 35 40

3/4 34 27 22 19 16

1 61 49 40 35 29

11/4 116 93 76 65 55

11/2 161 129 105 90 76

2\* 272 218 178 153 128

\*Larger diameter pipe can be used when justified by engineering analysis.

18.5.5.2.1

Specially listed nonstandard pipe shall be permitted using the values in Table 18.5.5.2(e) and Table 18.5.5.2(f) or with values provided by the manufacturer.

18.5.5.2.2

Spacing shall not exceed a maximum interval of 40 ft (12 m) on center.

18.5.5.2.3

The maximum permissible load in the zone of influence of a sway brace shall not exceed the values given in Table 18.5.5.2(a) through Table 18.5.5.2(1) or the values calculated in accordance with 18.5.5.3.

18.5.5.2.4

When determining permissible loads in accordance with 18.5.5.2 or 18.5.5.2.1 on a main with varying sizes, the allowable load shall be based on the smallest pipe size within the zone of influence.

18.5.5.3

The maximum load (Fpw) in the zone of influence for specially listed pipe shall be calculated. (See Annex E.)

18.5.5.4

The requirements of 18.5.5.1 shall not apply to 21/2 in. (65 mm) starter pieces that do not exceed 12 ft (3.7 m) in length.

18.5.5.5

The distance between the last brace and the end of the pipe shall not exceed 6 ft (1.8 m).

18.5.5.6

Where there is a change in direction of the piping, the cumulative distance between consecutive lateral sway braces shall not exceed the maximum permitted distance in accordance with 18.5.5.2.2.

18.5.5.7

The last length of pipe at the end of a feed or cross main shall be provided with a lateral brace.

18.5.5.8

Lateral braces shall be allowed to act as longitudinal braces if they are within 24 in. (600 mm) of the centerline of the piping braced longitudinally and the lateral brace is on a pipe of equal or greater size than the pipe being braced longitudinally.

18.5.5.9

Where flexible couplings are installed on mains other than as required in Section 18.2, a lateral brace shall be provided within 24 in. (600 mm) of every other coupling, including flexible couplings at grooved fittings, but not more than 40 ft (12 m) on center.

18.5.5.10\*

The lateral sway bracing required by 18.5.5 shall be permitted to be omitted when 18.5.5.10.1 for branch lines or 18.5.5.10.2 for mains is met.

18.5.5.10.1

Branch lines shall comply with the following:

\* The branch lines shall be individually supported within 6 in. (150 mm) of the structure, measured between the top of the pipe and the point of attachment to the building structure.

At least 75 percent of all the hangers on the branch line shall meet the requirements of 18.5.5.10.1(1).

Consecutive hangers on the branch line shall not be permitted to exceed the limitation in 18.5.5.10.1(1).

18.5.5.10.2

Mains shall comply with all the following:

\* The main piping shall be individually supported within 6 in. (150 mm) of the structure, measured between the top of the pipe and the point of attachment to the building structure.

At least 75 percent of all the hangers on the main shall meet the requirements of 18.5.5.10.2(1).

Consecutive hangers on the main shall not be permitted to exceed the limitation in 18.5.5.10.2(1)

The seismic coefficient (Cp) shall not exceed 0.5.

The nominal pipe diameter shall not exceed 6 in. (150 mm) for feed mains and 4 in. (100 mm) for cross mains.

Hangers shall not be omitted in accordance with 17.4.4.3, 17.4.4.4, or 17.4.4.5.

18.5.5.10.3

Branch lines permitted to omit lateral sway bracing by 18.5.5.10 shall not be omitted from load calculations for the mains serving them in 18.5.9.6.

18.5.5.11

The lateral sway bracing required by 18.5.5 shall be permitted to be omitted when 18.5.5.11.1 for branch lines or 18.5.5.11.2 for mains is met.

18.5.5.11.1

Branch lines shall comply with the following:

The branch lines shall be individually supported by wraparound u-hooks or u-hooks arranged to keep pipe tight to the structural element provided the legs are bent out at least 30 degrees from the vertical and the maximum length of each leg and the rod size satisfies the conditions of Table 18.5.11.8(a) through Table 18.5.11.8(f), or the length of the rod shall be calculated.

At least 75 percent of all the hangers on the branch line shall meet the requirements of 18.5.5.11.2(1).

Consecutive hangers on the branch line shall not be permitted to exceed the limitation in 18.5.5.11.2(1).

18.5.5.11.2

Mains shall comply with all the following:

The main piping shall be individually supported by wraparound u-hooks or u-hooks arranged to keep pipe tight to the structural element provided the legs are bent out at least 30 degrees from the vertical and the maximum length of each leg and rod size satisfies the conditions of Table 18.5.11.8(a) through Table 18.5.11.8(f).

At least 75 percent of all the hangers on the main shall meet the requirements of 18.5.5.11.2(1).

Consecutive hangers on the main shall not be permitted to exceed the limitation in 18.5.5.11.2(1).

The seismic coefficient (Cp) shall not exceed 0.5.

The nominal pipe diameter shall not exceed 6 in. (150 mm) for feed mains and 4 in. (100 mm) for cross mains.

Hangers shall not be omitted in accordance with 17.4.4.3, 17.4.4.4, or 17.4.4.5.

18.5.6 Longitudinal Sway Bracing

18.5.6.1

Longitudinal sway bracing spaced at a maximum of 80 ft (24 m) on center shall be provided for feed and cross mains.

18.5.6.2

Longitudinal braces shall be allowed to act as lateral braces if they are within 24 in. (600 mm) of the centerline of the piping braced laterally.

18.5.6.3

The distance between the last brace and the end of the pipe or a change in direction shall not exceed 40 ft (12 m).

18.5.7 Pipe With Change(s) in Direction

18.5.7.1

Each run of pipe between changes in direction shall be provided with both lateral and longitudinal bracing, unless the requirements of 18.5.7.2 are met.

18.5.7.2\*

Pipe runs less than 12 ft (3.7 m) in length shall be permitted to be supported by the braces on adjacent runs of pipe.

18.5.8 Sway Bracing of Risers

18.5.8.1\*

Tops of risers exceeding 3 ft (900 mm) in length shall be provided with a four-way brace.

18.5.8.1.1\*

The four-way brace shall not be required for risers up to 7 ft (2.1 m) in length that terminate above the roof assembly or top landing.

18.5.8.2

Riser nipples shall be permitted to omit the four-way brace required by 18.5.8.1.

18.5.8.3

When a four-way brace at the top of a riser is attached on the horizontal piping, it shall be within 24 in. (600 mm) of the centerline of the riser and the loads for that brace shall include both the vertical and horizontal pipe.

18.5.8.4

Distance between four-way braces for risers shall not exceed 25 ft (7.6 m).

18.5.8.5

Four-way bracing shall not be required where risers penetrate intermediate floors in multistory buildings where the clearance does not exceed the limits of Section 18.4.

18.5.9\* Horizontal Seismic Loads

18.5.9.1\*

The horizontal seismic load for the braces shall be as determined in 18.5.9.6 or 18.5.9.7, or as required by the authority having jurisdiction.

18.5.9.2

The weight of the system being braced (Wp) shall be taken as 1.15 times the weight of the water-filled piping. (See A.18.5.9.1.)

18.5.9.3

The horizontal force, Fpw, acting on the brace shall be taken as Fpw = CpWp, where Cp is the seismic coefficient selected in Table 18.5.9.3 utilizing the short period response parameter, Ss.

Table 18.5.9.3 Seismic Coefficient Table

Ss Cp Sp Cp

0.33 or less 0.35 2.2 1.03

0.4 0.38 2.3 1.07

0.5 0.4 2.4 1.12

0.6 0.42 2.5 1.17

0.7 0.42 2.6 1.21

0.8 0.44 2.7 1.26

0.9 0.48 2.8 1.31

1 0.51 2.9 1.35

1.1 0.54 3 1.4

1.2 0.57 3.1 1.45

1.3 0.61 3.2 1.49

1.4 0.65 3.3 1.54

1.5 0.7 3.4 1.59

1.6 0.75 3.5 1.63

1.7 0.79 3.6 1.68

1.8 0.84 3.7 1.73

1.9 0.89 3.8 1.77

2 0.93 3.9 1.82

2.1 0.98 4 1.87

18.5.9.3.1

The value of Ss used in Table 18.5.9.3 shall be obtained from the authority having jurisdiction or from seismic hazard maps.

18.5.9.3.2\*

Linear interpolation shall be permitted to be used for intermediate values of Ss.

18.5.9.4\*

The horizontal force, Fpw, acting on the brace shall be permitted to be determined in accordance with 13.3.1 of ASCE/SEI 7, Minimum Design Loads for Buildings and Other Structures, multiplied by 0.7 to convert to allowable stress design (ASD).

18.5.9.5\*

Where data for determining Cp are not available, the horizontal seismic force acting on the braces shall be determined as specified in 18.5.9.3 with Cp = 0.5.

18.5.9.6\*

The zone of influence for lateral braces shall include all branch lines, drops, sprigs, and mains tributary to the brace, except branch lines that are provided with longitudinal bracing or as prohibited by 18.5.9.6.1.

18.5.9.6.1\*

When riser nipples are provided in systems requiring seismic protection, they shall satisfy the following equation, unless one of the following conditions is met:

Where riser nipples are 4 ft (1.2 m) or less in length and Cp is 0.50 or less

Where riser nipples are 3 ft (900 mm) or less in length and Cp is less than 0.67

Where riser nipples are 2 ft (600 mm) in length or less and Cp is less than is 1.0

[18.5.9.6.1]

where:

Hr = length of riser nipple piping (in inches)

Wp = tributary weight (in pounds) for the branch line or portion of branch line within the zone of influence including the riser nipple

Cp = seismic coefficient

S = sectional modulus of the riser nipple pipe

Fy = allowable yield strength of 30,000 psi (2070 bar) for steel, 30,000 psi for copper (soldered), 8000 psi (550 bar) for CPVC

18.5.9.6.2

If the calculated value is equal to or greater than the yield strength of the riser nipple, the longitudinal seismic load of each line shall be evaluated individually, and branch lines shall be provided with longitudinal sway bracing per 18.5.6.

18.5.9.7

The zone of influence for longitudinal braces shall include all mains tributary to the brace.

18.5.10 Net Vertical Reaction Forces

Where the horizontal seismic loads used exceed 0.5 Wp and the brace angle is less than 45 degrees from vertical or where the horizontal seismic load exceeds 1.0 Wp and the brace angle is less than 60 degrees from vertical, the braces shall be arranged to resist the net vertical reaction produced by the horizontal load.

18.5.11\* Sway Brace Installation

18.5.11.1\*

Bracing shall be attached directly to the system pipe.

18.5.11.2

Sway bracing shall be tight.

18.5.11.3

For individual braces, the slenderness ratio (l/r) shall not exceed 300, where l is the length of the brace and r is the least radius of gyration.

18.5.11.4

Where threaded pipe is used as part of a sway brace assembly, it shall not be less than Schedule 30.

18.5.11.5

All parts and fittings of a brace shall lie in a straight line to avoid eccentric loadings on fittings and fasteners.

18.5.11.6

For longitudinal braces only, the brace shall be permitted to be connected to a tab welded to the pipe in conformance to 7.5.2.

18.5.11.7

For tension-only braces, two tension-only brace components opposing each other must be installed at each lateral or longitudinal brace location.

18.5.11.8

The loads determined in 18.5.9 shall not exceed the lesser of the maximum allowable loads provided in Table 18.5.11.8(a) through Table 18.5.11.8(f), and the manufacturer's certified maximum allowable horizontal loads for brace angles of 30 to 44 degrees, 45 to 59 degrees, 60 to 89 degrees, or 90 degrees.

Table 18.5.11.8(a) Maximum Horizontal Loads for Sway Braces with l/r = 100 for Steel Braces with Fy = 36 ksi

Brace Shape and Size (in.) Area (in.2) Least Radius

of Gyration (r) (in.) Maximum Length for

l/r= 100 Maximum Horizontal Load (lb)

Brace Angle

ft in. 30° to 44°Angle from Vertical 45° to 59°Angle from Vertical 60° to 90°Angle from Vertical

Pipe Schedule 40 1 0.494 0.421 3 6 3,150 4,455 5,456

11/4 0.669 0.540 4 6 4,266 6,033 7,389

11/2 0.799 0.623 5 2 5,095 7,206 8,825

2 1.07 0.787 6 6 6,823 9,650 11,818

Angles 11/2 × 11/2 × 1/4 0.688 0.292 2 5 4,387 6,205 7,599

2 × 2 × 1/4 0.938 0.391 3 3 5,982 8,459 10,360

21/2 × 2 × 1/4 1.06 0.424 3 6 6,760 9,560 11,708

21/2 × 21/2 × 1/4 1.19 0.491 4 1 7,589 10,732 13,144

3 × 21/2 × 1/4 1.31 0.528 4 4 8,354 11,814 14,469

3 × 3 × 1/4 1.44 0.592 4 11 9,183 12,987 15,905

Rods (all thread) 3/8 0.07 0.075 0 7 446 631 773

1/2 0.129 0.101 0 10 823 1,163 1,425

5/8 0.207 0.128 1 0 1,320 1,867 2,286

3/4 0.309 0.157 1 3 1,970 2,787 3,413

7/8 0.429 0.185 1 6 2,736 3,869 4,738

Rods (threaded at ends only) 3/8 0.11 0.094 0 9 701 992 1,215

1/2 0.196 0.125 1 0 1,250 1,768 2,165

5/8 0.307 0.156 1 3 1,958 2,769 3,391

3/4 0.442 0.188 1 6 2,819 3,986 4,882

7/8 0.601 0.219 1 9 3,833 5,420 6,638

Flats 11/2 × 1/4 0.375 0.0722 0 7 2,391 3,382 4,142

2 × 1/4 0.5 0.0722 0 7 3,189 4,509 5,523

2 × 3/8 0.75 0.1082 0 10 4,783 6,764 8,284

Table 18.5.11.8(b) Maximum Horizontal Loads for Sway Braces with l/r = 200 for Steel Braces with Fy = 36 ksi

Brace Shape and Size (in.) Area (in.2) Least Radius

of Gyration

(r) (in.) Maximum Length for

l/r= 200 Maximum Horizontal Load (lb)

Brace Angle

ft in. 30° to 44°

Angle from Vertical 45° to 59°

Angle

from Vertical 60° to 90°

Angle

from Vertical

Pipe Schedule 40 1 0.494 0.421 7 0 926 1310 1604

11/4 0.669 0.540 9 0 1254 1774 2173

11/2 0.799 0.623 10 4 1498 2119 2595

2 1.07 0.787 13 1 2006 2837 3475

Angles 11/2 × 11/2 × 1/4 0.688 0.292 4 10 1290 1824 2234

2 × 2 × 1/4 0.938 0.391 6 6 1759 2487 3046

21/2 × 2 × 1/4 1.06 0.424 7 0 1988 2811 3442

21/2 × 21/2 × 1/4 1.19 0.491 8 2 2231 3155 3865

3 × 21/2 × 1/4 1.31 0.528 8 9 2456 3474 4254

3 × 3 × 1/4 1.44 0.592 9 10 2700 3818 4677

Rods (all thread) 3/8 0.07 0.075 1 2 131 186 227

1/2 0.129 0.101 1 8 242 342 419

5/8 0.207 0.128 2 1 388 549 672

3/4 0.309 0.157 2 7 579 819 1004

7/8 0.429 0.185 3 0 804 1138 1393

Rods (threaded at ends only) 3/8 0.11 0.094 1 6 206 292 357

1/2 0.196 0.125 2 0 368 520 637

5/8 0.307 0.156 2 7 576 814 997

3/4 0.442 0.188 3 1 829 1172 1435

7/8 0.601 0.219 3 7 1127 1594 1952

Flats 11/2 × 1/4 0.375 0.0722 1 2 703 994 1218

2 × 1/4 0.5 0.0722 1 2 938 1326 1624

2 × 3/8 0.75 0.1082 1 9 1406 1989 2436

Table 18.5.11.8(c) Maximum Horizontal Loads for Sway Braces with l/r = 300 for Steel Braces with Fy = 36 ksi

Brace Shape and Size (in.) Area (in.2) Least Radius

of Gyration (r) (in.) Maximum Length for

l/r = 300 Maximum Horizontal Load (lb)

Brace Angle

ft in. 30° to 44°Angle from Vertical 45° to 59°Angle from Vertical 60° to 90°Angle from Vertical

Pipe Schedule 40 1 0.494 0.421 10 6 412 582 713

11/2 0.669 0.540 13 6 558 788 966

11/2 0.799 0.623 15 6 666 942 1153

2 1.07 0.787 19 8 892 1261 1544

Angles 11/2 × 11/2 × 1/4 0.688 0.292 7 3 573 811 993

2 × 2 × 1/4 0.938 0.391 9 9 782 1105 1354

21/2 × 2 × 1/4 1.06 0.424 10 7 883 1249 1530

21/2 × 21/2 × 1/4 1.19 0.491 12 3 992 1402 1718

3 × 21/2 × 1/4 1.31 0.528 13 2 1092 1544 1891

3 × 3 × 1/2 1.44 0.592 14 9 1200 1697 2078

Rods (all thread) 3/8 0.07 0.075 1 10 58 82 101

1/2 0.129 0.101 2 6 108 152 186

5/8 0.207 0.128 3 2 173 244 299

3/4 0.309 0.157 3 11 258 364 446

7/8 0.429 0.185 4 7 358 506 619

Rods (threaded at ends only) 3/8 0.11 0.094 2 4 92 130 159

1/2 0.196 0.125 3 1 163 231 283

5/8 0.307 0.156 3 10 256 362 443

3/4 0.442 0.188 4 8 368 521 638

7/8 0.601 0.219 5 5 501 708 867

Flats 11/2 × 1/4 0.375 0.0722 1 9 313 442 541

2 × 1/4 0.5 0.0722 1 9 417 589 722

2 × 3/8 0.75 0.1082 2 8 625 884 1083

Table 18.5.11.8(d) Maximum Horizontal Loads for Sway Braces with l/r = 100 for Steel Braces with Fy = 248 N/mm2

Brace Shape and Size (mm) Area (mm2) Least Radius

of Gyration (r) (mm) Maximum Length for

l/r = 100 Maximum Horizontal Load (kg)

Brace Angle

meters mm 30° to 44°Angle from Vertical 45° to 59°Angle from Vertical 60° to 90°Angle from Vertical

Pipe Schedule 40 25 318.7 11 1.0 150 1,429 2,021 2,475

32 431.6 14 1.2 150 1,935 2,737 3,352

40 515.5 16 1.5 50 2,311 3,269 4,003

50 690.3 20 1.8 150 3,095 4,377 5,361

Angles 40 × 40 × 6 443.9 7 0.6 125 1,990 2,815 3,447

50 × 50 × 6 605.2 10 1.0 75 2,713 3,837 4,699

65 × 50 × 6 683.9 11 1.0 150 3,066 4,336 5,311

65 × 65 × 6 767.7 12 1.2 25 3,442 4,868 5,962

80 × 65 × 6 845.2 13 1.2 100 3,789 5,359 6,563

80 × 80 × 6 929.0 15 1.2 275 4,165 5,891 7,214

Rods (all thread) 10 45.2 2 0.0 175 202 286 351

15 83.2 3 0.0 250 373 528 646

16 133.5 3 0.3 0 599 847 1,037

20 199.4 4 0.3 75 894 1,264 1,548

22 276.8 5 0.3 150 1,241 1,755 2,149

Rods (threaded at ends only) 10 71.0 2 0.0 225 318 450 551

15 126.5 3 0.3 0 567 802 982

16 198.1 4 0.3 75 888 1,256 1,538

20 285.2 5 0.3 150 1,279 1,808 2,214

22 387.7 5 0.3 225 1,739 2,458 3,011

Flats 40 × 6 241.9 2 0.0 175 1,085 1,534 1,879

50 × 6 322.6 2 0.0 175 1,447 2,045 2,505

50 × 10 483.9 3 0.0 250 2,170 3,068 3,758

Table 18.5.11.8(e) Maximum Horizontal Loads for Sway Braces with l/r = 200 for Steel Braces with Fy= 248 N/mm2

Brace Shape and Size (mm) Area (mm2) Least Radius

of Gyration (r) (mm) Maximum Length for

l/r = 200 Maximum Horizontal Load (kg)

Brace Angle

meters mm 30° to 44°Angle from Vertical 45° to 59°Angle from Vertical 60° to 90°Angle from Vertical

Pipe Schedule 40 25 318.7 11 2.1 0 420 594 728

32 431.6 14 2.7 0 569 805 986

40 515.5 16 3 100 679 961 1177

50 690.3 20 4.0 25 910 1287 1576

Angles 40 × 40 × 6 443.9 7 1.2 250 585 827 1013

50 × 50 × 6 605.2 10 1.8 150 798 1128 1382

65 × 50 × 6 683.9 11 2.1 0 902 1275 1561

65 × 65 × 6 767.7 12 2.4 50 1012 1431 1753

80 × 65 × 6 845.2 13 2.4 225 1114 1576 1930

80 × 80 × 6 929.0 15 2.7 250 1225 1732 2121

Rods (all thread) 10 45.2 2 0.3 50 59 84 103

15 83.2 3 0.3 200 110 155 190

16 133.5 3 0.6 25 176 249 305

20 199.4 4 0.6 175 263 371 455

22 276.8 5 0.9 0 365 516 632

Rods (threaded at ends only) 10 71.0 2 0.3 150 93 132 162

15 126.5 3 0.6 0 167 236 289

16 198.1 4 0.6 175 261 369 452

20 285.2 5 0.9 25 376 532 651

22 387.7 5 0.9 175 511 723 885

Flats 40 × 6 241.9 2 0.3 50 319 451 552

50 × 6 322.6 2 0.3 50 425 601 737

50 × 10 483.9 3 0.3 225 638 902 1105

Table 18.5.11.8(f) Maximum Horizontal Loads for Sway Braces with l/r = 300 for Steel Braces with Fy = 248 N/mm2

Brace Shape and Size (mm) Area (mm2) Least Radius

of Gyration (r) (mm) Maximum Length for

l/r = 300 Maximum Horizontal Load (kg)

Brace Angle

meters mm 30° to 44°Angle from Vertical 45° to 59°Angle from Vertical 60° to 90°Angle from Vertical

Pipe Schedule 40 25 318.7 10.5 3 150 187 264 323

32 431.6 13.5 4 150 253 357 438

40 515.5 15.6 4.6 150 302 427 523

50 690.3 19.7 5.8 200 405 572 700

Angles 40 × 40 × 6 443.9 7.3 2.1 75 260 368 450

50 × 50 × 6 605.2 9.8 2.7 225 355 501 614

65 × 50 × 6 683.9 10.6 3 175 401 567 694

65 × 65 × 6 767.7 12.3 3.7 75 450 636 779

80 × 65 × 6 845.2 13.2 4 50 495 700 858

80 × 80 × 6 929.0 14.8 4.3 225 544 770 943

Rods (all thread) 10 45.2 1.9 0.3 250 26 37 46

15 83.2 2.5 0.6 150 49 69 84

16 133.5 3.2 0.9 50 79 111 136

20 199.4 3.9 0.9 275 117 165 202

22 276.8 4.6 1.2 175 162 230 281

Rods (threaded at ends only) 10 71.0 2.4 0.6 100 42 59 72

15 126.5 3.1 0.9 25 74 105 128

16 198.1 3.9 0.9 250 116 164 201

20 285.2 4.7 1.2 200 167 236 289

22 387.7 5.5 1.5 125 227 321 393

Flats 40 × 6 241.9 1.8 0.3 225 142 200 245

50 × 6 322.6 1.8 0.3 225 189 267 327

50 × 10 483.9 2.7 0.6 200 283 401 491

18.5.11.9\*

Other pipe schedules and materials not specifically included in Table 18.5.11.8(a) through Table 18.5.11.8(f) shall be permitted to be used if certified by a registered professional engineer to support the loads determined in accordance with the criteria in the tables.

18.5.11.9.1

Calculations shall be submitted where required by the authority having jurisdiction.

18.5.11.10

C-type clamps including beam and large flange clamps, with or without restraining straps, shall not be used to attach braces to the building structure.

18.5.11.11

Powder-driven fasteners shall not be used to attach braces to the building structure, unless they are specifically listed for service in resisting lateral loads in areas subject to earthquakes.

18.5.12\* Fasteners

18.5.12.1

The designated angle category for the fastener(s) used in the sway brace installation shall be determined in accordance with Figure 18.5.12.1.

FIGURE 18.5.12.1 Designation of Angle Category Based on Angle of Sway Brace and Fastener Orientation.

18.5.12.2\*

For individual fasteners, unless alternative allowable loads are determined and certified by a registered professional engineer, the loads determined in 18.5.9 shall not exceed the allowable loads provided in Table 18.5.12.2(a) through Table 18.5.12.2(m) or 18.5.12.7.

Table 18.5.12.2(a) Maximum Load for Wedge Anchors in 3000 psi (207 bar) Lightweight Cracked Concrete on Metal Deck

Wedge Anchors in 3000 psi Sand Lightweight Cracked Concrete on 41/2 in. Flute Width Metal Deck (lb)

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Max. Flute Center Offset

(in.) A B C D E F G H I

Pr ≤2.0 Pr ≤1.1 Pr ≤0.7 Pr ≤1.2 Pr ≤1.1 Pr ≤1.1 Pr ≤1.4 Pr ≤0.9 Pr ≤0.8

3/8 2.375 6.25 1 123 183 233 — — — — — —

1/2 3.750 6.25 1 147 231 310 — — — — — —

5/8 3.875 6.25 1 188 292 387 — — — — — —

3/4 4.500 6.25 1 255 380 486

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Max. Flute Center Offset

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 2.375 6.25 1 79 133 193 — — — — — —

1/2 3.750 6.25 1 86 160 247 — — — — — —

5/8 3.875 6.25 1 113 204 311 — — — — — —

3/4 4.500 6.25 1 165 275 402 — — — — — —

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Max. Flute Center Offset

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 2.375 6.25 1 56 104 165 — — — — — —

1/2 3.750 6.25 1 60 121 205 — — — — — —

5/8 3.875 6.25 1 79 157 260 — — — — — —

3/4 4.500 6.25 1 116 216 343 — — — — — —

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Max. Flute Center Offset

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 2.375 6.25 1 43 85 144 — — — — — —

1/2 3.750 6.25 1 46 94 175 — — — — — —

5/8 3.875 6.25 1 60 124 224 — — — — — —

3/4 4.500 6.25 1 89 177 299 — — — — — —

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(b) Maximum Load for Wedge Anchors in 3000 psi (207 bar) Lightweight Cracked Concrete

Wedge Anchors in 3000 psi Lightweight Cracked Concrete (lb)

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr ≤2.0 Pr ≤1.1 Pr ≤0.7 Pr ≤1.2 Pr ≤1.1 Pr ≤1.1 Pr ≤1.4 Pr ≤0.9 Pr ≤0.8

3/8 2.375 5 4 142 216 280 162 216 256 139 208 244

1/2 3.750 6 6 200 314 419 243 314 362 209 312 365

5/8 3.875 6 6 259 394 512 297 394 467 255 380 446

3/4 4.500 7 8 356 552 731 424 552 641 365 544 636

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 2.375 5 4 89 154 229 133 154 157 117 170 204

1/2 3.750 6 6 119 218 335 195 218 209 172 250 299

5/8 3.875 6 6 163 281 418 244 281 286 215 311 373

3/4 4.500 7 8 214 386 588 343 386 376 303 438 525

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 2.375 5 4 62 119 194 113 119 108 101 144 175

1/2 3.750 6 6 83 167 279 163 167 144 147 208 254

5/8 3.875 6 6 113 218 354 207 218 197 186 263 320

3/4 4.500 7 8 150 297 492 288 297 259 259 367 447

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 2.375 5 4 47 97 168 98 97 82 89 125 154

1/2 3.750 6 6 63 130 239 140 130 109 128 178 220

5/8 3.875 6 6 87 178 306 179 178 150 163 228 281

3/4 4.500 7 8 115 234 422 248 234 197 226 315 389

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(c) Maximum Load for Wedge Anchors in 3000 psi (207 bar) Normal Weight Cracked Concrete

Wedge Anchors in 3000 psi Normal Weight Cracked Concrete (lb)

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr <2.0 Pr <1.1 Pr <0.7 Pr <1.2 Pr <1.1 Pr <1.1 Pr <1.4 Pr <0.9 Pr <0.8

3/8 2.375 5 4 189 274 342 197 274 340 170 251 297

1/2 3.750 6 6 272 423 563 326 423 490 281 419 490

5/8 3.875 6 6 407 623 814 472 623 733 406 605 709

3/4 4.500 7 8 613 940 1232 715 940 1104 615 916 1073

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 2.375 5 4 125 203 288 167 203 219 147 212 256

1/2 3.750 6 6 162 295 451 263 295 285 233 337 403

5/8 3.875 6 6 252 441 662 386 441 442 341 492 590

3/4 4.500 7 8 378 665 999 583 665 662 515 744 892

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 2.375 5 4 92 162 249 145 162 159 130 184 225

1/2 3.750 6 6 113 226 377 220 226 196 199 281 342

5/8 3.875 6 6 176 341 557 326 341 304 293 415 506

3/4 4.500 7 8 264 514 841 493 514 456 443 627 763

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 2.375 5 4 70 134 220 128 134 121 116 162 200

1/2 3.750 6 6 87 178 323 190 178 149 173 241 298

5/8 3.875 6 6 135 276 481 283 276 232 258 359 442

3/4 4.500 7 8 203 413 725 426 413 348 389 541 667

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(d) Maximum Load for Wedge Anchors in 4000 psi (276 bar) Normal Weight Cracked Concrete

Wedge Anchors in 4000 psi Normal Weight Cracked Concrete (lb)

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr ≤2.0 Pr ≤1.1 Pr ≤0.7 Pr ≤1.2 Pr ≤1.1 Pr ≤1.1 Pr ≤1.4 Pr ≤0.9 Pr ≤0.8

3/8 2.375 5 4 206 293 360 208 293 370 179 264 313

1/2 3.750 6 6 304 466 610 353 466 548 304 453 531

5/8 3.875 6 6 469 716 935 542 716 844 467 694 814

3/4 4.500 7 8 657 997 1293 750 997 1182 646 959 1125

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 2.375 5 4 138 221 307 178 221 242 157 226 272

1/2 3.750 6 6 188 330 495 289 330 330 255 368 442

5/8 3.875 6 6 291 508 761 444 508 511 392 566 678

3/4 4.500 7 8 414 711 1057 617 711 725 544 786 942

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 2.375 5 4 103 177 268 156 177 179 139 197 241

1/2 3.750 6 6 131 255 417 244 255 227 219 310 378

5/8 3.875 6 6 203 393 641 375 393 352 337 477 582

3/4 4.500 7 8 289 553 894 524 553 500 470 665 810

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 2.375 5 4 80 148 237 139 148 138 125 175 216

1/2 3.750 6 6 100 205 360 211 205 173 192 268 330

5/8 3.875 6 6 156 319 554 325 319 268 296 413 509

3/4 4.500 7 8 222 452 774 455 452 381 414 577 711

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(e) Maximum Load for Wedge Anchors in 6000 psi (414 bar) Normal Weight Cracked Concrete

Wedge Anchors in 6000 psi Normal Weight Cracked Concrete (lb)

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr ≤2.0 Pr ≤1.1 Pr ≤0.7 Pr ≤1.2 Pr ≤1.1 Pr ≤1.1 Pr ≤1.4 Pr ≤0.9 Pr ≤0.8

3/8 2.375 5 4 225 313 379 219 313 402 189 277 329

1/2 3.750 6 6 354 529 676 392 529 637 337 500 589

5/8 3.875 6 6 546 812 1036 601 812 981 517 766 902

3/4 4.500 7 8 763 1127 1429 829 1127 1370 714 1055 1243

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 2.375 5 4 153 240 327 190 240 267 167 240 289

1/2 3.750 6 6 228 382 559 326 382 400 287 414 498

5/8 3.875 6 6 353 589 859 500 589 617 441 636 764

3/4 4.500 7 8 496 822 1190 693 822 868 611 881 1058

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 2.375 5 4 115 194 288 168 194 200 149 211 258

1/2 3.750 6 6 161 299 477 279 299 278 250 354 431

5/8 3.875 6 6 249 462 733 429 462 431 384 544 663

3/4 4.500 7 8 354 647 1019 596 647 612 534 756 921

Diameter

(in.) Min. Nom. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 2.375 5 4 91 163 257 150 163 157 135 189 233

1/2 3.750 6 6 123 246 415 243 246 212 221 308 380

5/8 3.875 6 6 192 380 639 375 380 329 341 475 585

3/4 4.500 7 8 272 533 891 523 533 467 475 662 815

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(f) Maximum Load for Metal Deck Inserts in 3000 psi (207 bar) Lightweight Cracked Concrete on Metal Deck

Metal Deck Inserts in 3000 psi Sand Lightweight Cracked Concrete on 41/2 in. Flute Width Metal Deck (lb)

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Max. Flute Center Offset

(in.) A B C D E F G H I

Pr ≤2.0 Pr ≤1.1 Pr ≤0.7 Pr ≤1.2 Pr ≤1.1 Pr ≤1.1 Pr ≤1.4 Pr ≤0.9 Pr ≤0.8

3/8 1.750 6.25 1 135 192 236 — — — — — —

1/2 1.750 6.25 1 138 199 247 — — — — — —

5/8 1.750 6.25 1 138 199 247 — — — — — —

3/4 1.750 6.25 1 164 257 344

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Max. Flute Center Offset

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 1.750 6.25 1 90 144 201 — — — — — —

1/2 1.750 6.25 1 91 148 209 — — — — — —

5/8 1.750 6.25 1 91 148 209 — — — — — —

3/4 1.750 6.25 1 97 178 275 — — — — — —

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Max. Flute Center Offset

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 1.750 6.25 1 67 115 175 — — — — — —

1/2 1.750 6.25 1 67 118 181 — — — — — —

5/8 1.750 6.25 1 67 118 181 — — — — — —

3/4 1.750 6.25 1 67 136 229 — — — — — —

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Max. Flute Center Offset

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 1.750 6.25 1 52 96 155 — — — — — —

1/2 1.750 6.25 1 52 98 160 — — — — — —

5/8 1.750 6.25 1 52 98 160 — — — — — —

3/4 1.750 6.25 1 52 106 196 — — — — — —

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(g) Maximum Load for Wood Form Inserts in 3000 psi (207 bar) Lightweight Cracked Concrete

Wood Form Inserts in 3000 psi Lightweight Cracked Concrete (lb)

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr ≤2.0 Pr ≤1.1 Pr ≤0.7 Pr ≤1.2 Pr ≤1.1 Pr ≤1.1 Pr ≤1.4 Pr ≤0.9 Pr ≤0.8

3/8 1.100 4 6 224 316 387 223 316 401 193 283 336

1/2 1.690 4 6 252 376 480 278 376 454 239 355 418

5/8 1.750 4 8 252 376 480 278 376 454 239 355 418

3/4 1.750 4 8 252 376 480 278 376 454 239 355 418

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 1.100 4 6 150 239 331 192 239 264 169 243 293

1/2 1.690 4 6 163 272 398 231 272 286 204 294 354

5/8 1.750 4 8 163 272 398 231 272 286 204 294 354

3/4 1.750 4 8 163 272 398 231 272 286 204 294 354

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 1.100 4 6 113 193 290 169 193 196 150 213 260

1/2 1.690 4 6 115 213 339 198 213 199 178 251 307

5/8 1.750 4 8 115 213 339 198 213 199 178 251 307

3/4 1.750 4 8 115 213 339 198 213 199 178 251 307

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 1.100 4 6 88 161 257 150 161 152 135 190 234

1/2 1.690 4 6 88 175 296 173 175 152 157 219 271

5/8 1.750 4 8 88 175 296 173 175 152 157 219 271

3/4 1.750 4 8 88 175 296 173 175 152 157 219 271

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(h) Maximum Load for Wood Form Inserts in 3000 psi (207 bar) Normal Weight Cracked Concrete

Wood Form Inserts in 3000 psi Normal Weight Cracked Concrete (lb)

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr ≤2.0 Pr ≤1.1 Pr ≤0.7 Pr ≤1.2 Pr ≤1.1 Pr ≤1.1 Pr ≤1.4 Pr ≤0.9 Pr ≤0.8

3/8 1.100 4 6 248 342 411 237 342 444 205 300 357

1/2 1.690 4 6 297 443 565 327 443 535 282 418 492

5/8 1.750 4 8 297 443 565 327 443 535 282 418 492

3/4 1.750 4 8 297 443 565 327 443 535 282 418 492

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 1.100 4 6 170 264 357 207 264 298 182 261 315

1/2 1.690 4 6 192 321 468 272 321 336 240 347 416

5/8 1.750 4 8 192 321 468 272 321 336 240 347 416

3/4 1.750 4 8 192 321 468 272 321 336 240 347 416

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 1.100 4 6 129 215 315 184 215 224 163 231 282

1/2 1.690 4 6 135 251 399 233 251 235 209 296 361

5/8 1.750 4 8 135 251 399 233 251 235 209 296 361

3/4 1.750 4 8 135 251 399 233 251 235 209 296 361

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 1.100 4 6 104 181 282 165 181 179 148 208 256

1/2 1.690 4 6 104 207 348 204 207 179 185 258 319

5/8 1.750 4 8 104 207 348 204 207 179 185 258 319

3/4 1.750 4 8 104 207 348 204 207 179 185 258 319

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(i) Maximum Load for Wood Form Inserts in 4000 psi (276 bar) Normal Weight Cracked Concrete

Wood Form Inserts in 4000 psi Normal Weight Cracked Concrete (lb)

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr ≤2.0 Pr ≤1.1 Pr ≤0.7 Pr ≤1.2 Pr ≤1.1 Pr ≤1.1 Pr ≤1.4 Pr ≤0.9 Pr ≤0.8

3/8 1.100 4 6 270 364 431 249 364 482 215 313 374

1/2 1.690 4 6 335 493 623 361 493 602 311 459 541

5/8 1.750 4 8 344 511 653 378 511 618 326 482 568

3/4 1.750 4 8 344 511 653 378 511 618 326 482 568

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 1.100 4 6 188 287 379 220 287 330 193 277 334

1/2 1.690 4 6 218 361 520 303 361 382 266 384 462

5/8 1.750 4 8 222 371 541 315 371 389 278 400 481

3/4 1.750 4 8 222 371 541 315 371 389 278 400 481

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 1.100 4 6 145 236 338 197 236 251 175 247 302

1/2 1.690 4 6 157 284 446 261 284 271 233 330 403

5/8 1.750 4 8 157 290 461 270 290 271 242 342 417

3/4 1.750 4 8 157 290 461 270 290 271 242 342 417

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 1.100 4 6 117 201 305 178 201 202 160 224 275

1/2 1.690 4 6 120 234 390 229 234 207 207 290 357

5/8 1.750 4 8 120 239 402 236 239 207 214 299 368

3/4 1.750 4 8 120 239 402 236 239 207 214 299 368

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(j) Maximum Load for Wood Form Inserts in 6000 psi (414 bar) Normal Weight Cracked Concrete

Wood Form Inserts in 6000 psi Normal Weight Cracked Concrete (lb)

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr ≤ 2.0 Pr ≤ 1.1 Pr ≤ 0.7 Pr ≤ 1.2 Pr ≤ 1.1 Pr ≤ 1.1 Pr ≤ 1.4 Pr ≤ 0.9 Pr ≤ 0.8

3/8 1.100 4 6 302 395 458 264 395 537 228 332 397

1/2 1.690 4 6 385 551 680 394 551 690 339 499 591

5/8 1.750 4 8 421 627 800 463 627 756 399 591 696

3/4 1.750 4 8 421 627 800 463 627 756 399 591 696

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 2.1—3.5 Pr 1.2—1.8 Pr 0.8—1.0 Pr 1.3—1.7 Pr 1.2—1.8 Pr 1.2—2.0 Pr 1.5—1.9 Pr 1.0—1.3 Pr 0.9—1.1

3/8 1.100 4 6 216 319 409 237 319 379 207 297 360

1/2 1.690 4 6 256 413 578 336 413 449 296 426 512

5/8 1.750 4 8 272 454 662 386 454 476 340 491 589

3/4 1.750 4 8 272 454 662 386 454 476 340 491 589

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 3.6—5.0 Pr 1.9—2.5 Pr 1.1—1.3 Pr 1.8—2.2 Pr 1.9—2.5 Pr 2.1—2.9 Pr 2.0—2.4 Pr 1.4—1.7 Pr 1.2—1.4

3/8 1.100 4 6 169 267 370 215 267 292 190 270 329

1/2 1.690 4 6 192 330 503 293 330 332 262 371 452

5/8 1.750 4 8 192 356 565 331 356 332 296 419 511

3/4 1.750 4 8 192 356 565 331 356 332 296 419 511

Diameter

(in.) Min. Effect. Embedment

(in.) Min. Slab Thickness

(in.) Min. Edge Distance

(in.) A B C D E F G H I

Pr 5.1—6.5 Pr 2.6—3.2 Pr 1.4—1.6 Pr 2.3—2.7 Pr 2.6—3.2 Pr 3.0—3.8 Pr 2.5—2.9 Pr 1.8—2.1 Pr 1.5—1.7

3/8 1.100 4 6 138 229 337 196 229 238 176 246 303

1/2 1.690 4 6 147 275 445 260 275 253 235 328 405

5/8 1.750 4 8 147 293 493 289 293 253 263 366 451

3/4 1.750 4 8 147 293 493 289 293 253 263 366 451

\*Pr = Prying factor range. (Refer to A.18.5.12.2 for additional information.)

Table 18.5.12.2(k) Maximum Load for Connections to Steel Using Unfinished Steel Bolts

Connections to Steel (Values Assume Bolt Perpendicular to Mounting Surface)

Diameter of Unfinished Steel Bolt (in.)

1/4 3/8

A B C D E F G H I A B C D E F G H I

400 500 600 300 500 650 325 458 565 900 1200 1400 800 1200 1550 735 1035 1278

Diameter of Unfinished Steel Bolt (in.)

1/2 5/8

A B C D E F G H I A B C D E F G H I

1600 2050 2550 1450 2050 2850 1300 1830 2260 2500 3300 3950 2250 3300 4400 2045 2880 3557

Table 18.5.12.2(l) Maximum Load for Through-Bolts in Sawn Lumber or Glue-Laminated Timbers

Through-Bolts in Sawn Lumber or Glue-Laminated Timbers (Load Perpendicular to Grain)

Length of Bolt in Timber (in.) Bolt Diameter (in.)

1/2 5/8 3/4

A B C D E F G H I A B C D E F G H I A B C D E F G H I

11/2 115 165 200 135 230 395 130 215 310 135 190 235 155 270 460 155 255 380 155 220 270 180 310 530 170 300 450

21/2 140 200 240 160 280 480 165 275 410 160 225 280 185 320 550 190 320 495 180 255 310 205 360 615 215 365 575

31/2 175 250 305 200 350 600 200 330 485 200 285 345 230 400 685 235 405 635 220 310 380 255 440 755 260 455 730

51/2 — — — — — — — — — 280 395 485 325 560 960 315 515 735 310 440 535 360 620 1065 360 610 925

Note: Wood fastener maximum capacity values are based on the 2001 National Design Specifications (NDS) for wood with a specific gravity of 0.35. Values for other types of wood can be obtained by multiplying the above values by the factors in Table 18.5.12.2(n).

Table 18.5.12.2(m) Maximum Load for Lag Screws and Lag Bolts in Wood

Lag Screws and Lag Bolts in Wood (Load Perpendicular to Grain — Holes Predrilled Using Good Practice)

Length of Bolt in Timber (in.) Lag Bolt Diameter (in.)

1/2 5/8 3/4

A B C D E F G H I A B C D E F G H I A B C D E F G H I

31/2 165 190 200 170 220 310 80 120 170 — — — — — — — — — — — — — — — — — —

41/2 180 200 200 175 235 350 80 120 170 300 355 380 315 400 550 145 230 325 — — — — — — — — —

51/2 190 200 200 175 245 380 80 120 170 320 370 380 320 420 610 145 230 325 435 525 555 425 550 775 195 320 460

61/2 195 205 200 175 250 400 80 120 170 340 375 380 325 435 650 145 230 325 465 540 555 430 570 840 195 320 460

Note: Wood fastener maximum capacity values are based on the 2001 National Design Specifications (NDS) for wood with a specific gravity of 0.35. Values for other types of wood can be obtained by multiplying the above values by the factors in Table 18.5.12.2(n).

Table 18.5.12.2(n) Factors for Wood Based on Specific Gravity

Specific Gravity of Wood Multiplier

0.36 thru 0.49 1.17

0.50 thru 0.65 1.25

0.66 thru 0.73 1.50

18.5.12.3\*

The type of fasteners used to secure the bracing assembly to the structure shall be limited to those shown in Table 18.5.12.2(a) through Table 18.5.12.2(m) or to listed devices.

18.5.12.4\*

For connections to wood, through-bolts with washers on each end shall be used, unless the requirements of 18.5.12.5 are met.

18.5.12.5

Where it is not practical to install through-bolts due to the thickness of the wood member in excess of 12 in. (300 mm) or inaccessibility, lag screws shall be permitted and holes shall be pre-drilled 1/8 in. (3 mm) smaller than the maximum root diameter of the lag screw.

18.5.12.6

Holes for through-bolts and similar listed attachments shall be 1/16 in. (1.6 mm) greater than the diameter of the bolt.

18.5.12.6.1

The requirements of 18.5.12 shall not apply to other fastening methods, which shall be acceptable for use if certified by a registered professional engineer to support the loads determined in accordance with the criteria in 18.5.9.

18.5.12.6.2

Calculations shall be submitted where required by the authority having jurisdiction.

18.5.12.7 Concrete Anchors

18.5.12.7.1\*

Post-installed concrete anchors shall be prequalified for seismic applications in accordance with ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary, and installed in accordance with the manufacturer's instructions.

18.5.12.7.2

Unless the requirements of 18.5.12.7.3 are met, concrete anchors shall be based on concrete strength, anchor type, designated angle category A through I, prying factor (Pr) range, and allowable maximum load.

(A)

Sway brace manufacturers shall provide prying factors (Pr) based on geometry of the structure attachment fitting and the designated angle category A through I as shown in Figure 18.5.12.1.

(B)

Where the prying factor for the fitting is unknown, the largest prying factor range in Table 18.5.12.2(a) through Table 18.5.12.2(j) for the concrete strength and designated angle category A through I shall be used.

18.5.12.7.3

The allowable maximum load shall be permitted to be calculated.

(A)

Allowable concrete anchor loads shall be permitted to be determined using approved software that considers the effects of prying for concrete anchors.

(B)

Anchors shall be seismically prequalified per 18.5.12.7.1.

(C)

Allowable maximum loads shall be based on the anchor capacities given in approved evaluation service reports, where the calculation of ASD allowable shear and tension values are determined in accordance with Chapter 17 of ACI 318, Building Code Requirements for Structural Concrete and Commentary, and include the effects of prying, brace angle, and the over strength factor (Ω = 2.0).

(D)\*

The shear and tension values determined in 18.5.12.7.3(C) using Chapter 17 of ACI 318, Building Code Requirements for Structural Concrete and Commentary, shall be multiplied by 0.43.

18.5.12.7.4

Concrete anchors shall be acceptable for use where designed in accordance with the requirements of the building code and certified by a registered professional engineer.

18.5.12.7.5

Headed cast-in specialty inserts (concrete inserts) as prescribed in Table 18.5.12.2(a) through Table 18.5.12.2(j) shall be prequalified for seismic applications in accordance with ICC-ES AC446, Acceptance Criteria for Headed Cast-in Specialty Inserts in Concrete, and installed in accordance with the manufacturer's instructions.

18.5.13 Braces to Buildings With Differential Movement

A length of pipe shall not be braced to sections of the building that will move differentially.

18.6 Restraint of Branch Lines

18.6.1\*

Restraint is considered a lesser degree of resisting loads than bracing and shall be provided by use of one of the following:

Listed sway brace assembly

Wraparound U-hook satisfying the requirements of 18.5.5.11

No. 12, 440 lb (200 kg) wire installed at least 45 degrees from the vertical plane and anchored on both sides of the pipe

CPVC hangers listed to provide restraint

\* Hanger not less than 45 degrees from vertical installed within 6 in. (150 mm) of the vertical hanger arranged for restraint against upward movement, provided it is utilized such that l/r does not exceed 400, where the rod extends to the pipe or a surge clip has been installed

Other approved means

18.6.2 Wire Restraint

18.6.2.1

Wire used for restraint shall be located within 2 ft (600 mm) of a hanger.

18.6.2.2

The hanger closest to a wire restraint shall be of a type that resists upward movement of a branch line.

18.6.3

The end sprinkler on a branch line shall be restrained.

18.6.3.1

The location of the restraint from end of the line shall not be greater than 36 in. (900 mm) for 1 in. (25 mm) pipe, 48 in. (1200 mm) for 11/4 in. (32 mm) pipe, and 60 in. (1.5 m) for 11/2 in. (40 mm) or larger pipe.

18.6.4\*

Branch lines shall be laterally restrained at intervals not exceeding those specified in Table 18.6.4(a) or Table 18.6.4(b) based on branch line diameter and the value of Cp.

Table 18.6.4(a) Maximum Spacing [ft (m)] of Steel Pipe Restraints

Pipe [in. (mm)] Seismic Coefficient, Cp

Cp ≤ 0.50 0.5 < Cp ≤ 0.71 0.71 < CP ≤ 1.40 Cp> 1.40

1/2 (15) 34 (10.3) 29 (8.8) 20 (6.1) 18 (5.5)

3/4 (20) 38 (11.6) 32 (9.7) 23 (7.0) 20 (6.1)

1 (25) 43 (13.1) 36 (11.0) 26 (7.9) 22 (6.7)

11/4 (32) 46 (14.0) 39 (11.9) 27 (8.2) 24 (7.3)

11/2 (40) 49 (14.9) 41 (12.5) 29 (8.8) 25 (7.6)

2 (50) 53 (16.1) 45 (13.7) 31 (9.4) 27 (8.2)

Table 18.6.4(b) Maximum Spacing [ft (m)] of CPVC, Copper, and Red Brass Pipe Restraints

Pipe [in. (mm)] Seismic Coefficient, Cp

Cp ≤ 0.50 0.5 < Cp ≤ 0.71 0.71 < CP ≤ 1.40 Cp> 1.40

1/2 (15) 26 (7.9) 22 (6.7) 16 (4.9) 13 (4.0)

3/4 (20) 31 (9.4) 26 (7.9) 18 (5.5) 15 (4.6)

1 (25) 34 (10.3) 28 (8.5) 20 (6.1) 17 (5.2)

11/4 (32) 37 (11.3) 31 (9.4) 22 (6.7) 19 (5.8)

11/2 (40) 40 (12.2) 34 (10.3) 24 (7.3) 20 (6.1)

2 (50) 45 (13.7) 38 (11.6) 27 (8.2) 23 (7.0)

18.6.5

Where the branch lines are supported by rods less than 6 in. (150 mm) long measured between the top of the pipe and the point of attachment to the building structure, the requirements of 18.6.1 through 18.6.4 shall not apply and additional restraint shall not be required for the branch lines.

18.6.6\*

Sprigs 4 ft (1.2 m) or longer shall be restrained against lateral movement.

18.6.7

Drops and armovers shall not require restraint.

18.7 Hangers and Fasteners Subject to Earthquakes

18.7.1

Where seismic protection is provided, C-type clamps (including beam and large flange clamps) used to attach hangers to the building structure shall be equipped with a restraining strap unless the provisions of 18.7.1.1 are satisfied.

18.7.1.1

As an alternative to the installation of a required restraining strap, a device investigated and specifically listed to restrain the clamp to the structure is permitted where the intent of the device is to resist the worst-case expected horizontal load.

18.7.2

The restraining strap shall be listed for use with a C-type clamp or shall be a steel strap of not less than 16 gauge (1.57 mm) thickness and not less than 1 in. (25 mm) wide for pipe diameters 8 in. (200 mm) or less and 14 gauge (1.98 mm) thickness and not less than 11/4 in. (32 mm) wide for pipe diameters greater than 8 in. (200 mm).

18.7.3

The restraining strap shall wrap around the beam flange not less than 1 in. (25 mm).

18.7.4

A lock nut on a C-type clamp shall not be used as a method of restraint.

18.7.5

A lip on a "C" or "Z" purlin shall not be used as a method of restraint.

18.7.6

Where purlins or beams do not provide a secure lip to a restraining strap, the strap shall be through-bolted or secured by a self-tapping screw.

18.7.7

In areas where the horizontal force factor exceeds 0.50 Wp, powder-driven studs shall be permitted to attach hangers to the building structure where they are specifically listed for use in areas subject to earthquakes.

18.7.8\*

Where seismic protection is provided, concrete anchors used to secure hangers to the building structure shall be in accordance with ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary, and installed in accordance with manufacturer's instructions.

18.7.9

Where seismic protection is provided, cast-in-place anchors used to secure hangers to the building structure shall be in accordance with ICC-ES AC446, Acceptance Criteria for Headed Cast-in Specialty Inserts in Concrete, and installed in accordance with manufacturer's instructions.

18.8\* Pipe Stands Subject to Earthquakes

18.8.1

In areas where the horizontal force factor exceeds 0.5 Wp, pipe stands over 4 ft (1.2 m) in height shall be certified by a registered professional engineer to be adequate for the seismic forces.

18.8.2

Where seismic protection is provided, concrete anchors used to secure pipe stands to their bases shall be in accordance with ACI 355.2, Qualification of Post-Installed Mechanical Anchors in Concrete and Commentary, and shall be installed in accordance with manufacturer's instructions.