

Specifying Bolt Length for High-Strength Bolts

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INTRODUCTION

Two tables that are useful in determining the proper bolt length for high-strength bolts are provided in the AISC *Manual of Steel Construction*.¹ Table 8-2, which includes constants to be added to the grip and washer thickness (RCSC Specification Table C2² is the basis for these constants) and a table in Figure 8-3, which indicates the outer-ply thickness required to exclude the threads from the faying surface of the connection. While it is a simple operation to select bolt lengths using these tables, the repetitive calculation becomes somewhat tedious and could be simplified.

In this paper, a design aid is presented for the selection of high-strength bolt lengths for bearing (snug-tightened and fully tensioned) and slip-critical connections. Nominal bolt lengths are tabulated based upon the grip for $\frac{3}{4}$ -in., $\frac{7}{8}$ -in., 1-in., and $1\frac{1}{8}$ -in. diameter ASTM A325 and A490 bolts with zero, one, or two $\frac{5}{32}$ -in.-thick ASTM F436 flat washer(s) and an ASTM A563 nut; bevelled washers are not considered in this paper. Additionally, the outer-ply thickness required when it is desired to exclude the threads from the shear plane is tabulated. Example problems are included to illustrate use of the table. The following topics are also briefly addressed in this paper: (1) tolerances on bolt length, nut thickness, and washer thickness; (2) thread run-out, stick-through requirements, and risk of jamming the nut; (3) washer requirements; and, (4) excluding threads from the shear plane of the connection.

MINIMUM BOLT LENGTH

The minimum possible length of high strength bolts is calculated by summing the nominal grip, the nominal thickness of washer(s), and the appropriate value from Table C2 of the *Specification for Structural Joints Using ASTM A325 or A490 Bolts*.² Values in RCSC Specification Table C2 provide for the nominal thickness of the heavy hex nut and the following tolerances: (1) the minus tolerance on bolt length; (2) the plus tolerance on washer thickness; and (3) the plus tolerance on nut thickness. By one order of magnitude, the tolerance on bolt length is the most significant; see Appendix. Taking the worst case accumulation of these three tolerances, Table 1 illustrates that the values in RCSC Specification Table C2 are

conservative for all bolts less than or equal to 6-in. long. For bolts longer than 6 inches, the values are conservative for $1\frac{1}{8}$ -in. diameter bolts and negligibly unconservative (within $\frac{3}{64}$ -in.) for $\frac{3}{4}$ -in., $\frac{7}{8}$ -in., and 1-in. diameter bolts assuming. This is considered to be negligible because the worst-case accumulation of tolerances assumed is a statistical improbability. The nominal bolt length is then selected as the next larger increment based on the minimum possible length. As is general industry practice, for bolt lengths less than 5 inches, a nominal length increment of $\frac{1}{4}$ -in. is used; otherwise, a nominal length increment of $\frac{1}{2}$ -in. is used.

In the installed condition, even if the nominal length is exactly equal to the minimum possible length, the end of the bolt will be at least flush with the end of the nut. Some project specifications include a stick-through requirement (minimum protrusion of the bolt point beyond the nut). However, because the threaded length for any given bolt diameter is constant regardless of the bolt length, a stick-through requirement may require a longer bolt and thereby increases the risk of jamming the nut on the thread run-out. Because a stick-through requirement does not improve the performance of the bolt, its specification is discouraged.

In Table 2, bolt lengths L have been tabulated for $\frac{3}{4}$ -in., $\frac{7}{8}$ -in., 1-in., and $1\frac{1}{8}$ -in. diameter ASTM A325 and A490 bolts with zero, one, or two $\frac{5}{32}$ -in.-thick ASTM F436 washer(s). Because 8 inches is generally the maximum stock bolt length available except by special order, tabulated values for combinations requiring longer lengths have been omitted. The tabulated values are valid for conventional high-strength bolts and alternative design fasteners, such as tension-control or twist-off bolts. If direct tension indicator devices are to be used, the tabulated values remain useful if the thickness of such devices is considered to be part of the grip.

In many cases when one washer is used, the minimum possible bolt length exceeds a nominal length increment by $\frac{1}{32}$ -in. For example, a $\frac{3}{4}$ -in. diameter bolt with one $\frac{5}{32}$ -in.-thick washer and a $\frac{7}{8}$ -in. grip would require a length of

$$\frac{7}{8} + \frac{5}{32} + 1 = 2\frac{1}{32} \text{ in.}$$

where 1 inch is the value from RCSC Specification Table C2. In this and other such cases, the tabulated minimum bolt length has been rounded down to the shorter nominal length increment because $\frac{1}{32}$ -in. is negligible. In all other cases, the tabulated minimum bolt length is rounded to the next longer nominal length increment.

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Shading in the table indicates that the combination of grip, bolt length, and number of washers is such that the nut may jamb on the thread run-out; this occurs only for bolts longer than 5 inches (i.e., when $\frac{1}{2}$ -in. length increments are used). The use of additional washers, which may also require a longer bolt, is a common solution. Jamming may occur when the bolt length minus the threaded length exceeds the grip plus the minimum thickness of washer(s) minus an allowance for the elongation of the bolt during tensioning. For most bolts, a nut rotation of one-half to two-thirds from snug-tight is required to achieve full tensioning; longer bolts may require one full turn. Conservatively assuming one full turn, and because the nut surface is countersunk by approximately one third of one thread pitch, the appropriate allowance (see Appendix) for elongation of the bolt during tensioning is two-thirds of one thread pitch;³ this will be conservative for snug-tightened bolts, which may have significantly less elongation.

WASHER REQUIREMENTS

RCSC Specification Section 7(c) indicates the cases in which $\frac{5}{32}$ -in.-thick ASTM F436 washers must be used with ASTM A325 and A490 bolts. Such washers are not required for these high-strength bolts in standard, oversized, and short-slotted holes except:

1. under the turned element when the bolt is fully tensioned by the calibrated wrench method.
2. under the head and nut when ASTM A490 bolts are used in combination with material with a specified yield point below 40 ksi.
3. to cover an oversized or short-slotted hole in an outer ply. For ASTM A490 bolts over 1 inch in diameter through an oversized or short-slotted hole in an outer ply, the washer must be $\frac{5}{16}$ -in.-thick; two $\frac{5}{32}$ -in.-thick washers do not meet this requirement.

Some alternative design fasteners provide a bearing circle on the bolt head and/or nut of diameter equal to or greater than the diameter of an ASTM F436 washer. When such fasteners are used, the need for washers in cases 1 and 2 above is eliminated.

When high-strength bolts are used through long-slotted holes in an outer ply, a plate washer with standard holes that completely covers the slot must be provided; the plate washer must be made from structural grade material with a minimum thickness of $\frac{5}{16}$ -in., but need not be hardened. For ASTM A490 bolts over 1 inch in diameter through long-slotted holes in an outer ply, single $\frac{5}{16}$ -in.-thick ASTM F436 washers must be used; two $\frac{5}{32}$ -in.-thick washers do not meet this requirement.

EXCLUDING THREADS FOR BEARING X CONNECTIONS

The minimum thickness t of the outer connected ply closest to the nut to exclude threads from the shear plane of the

connection has been tabulated in Table 2. It is calculated as the grip plus the threaded length minus the bolt length. A dash indicates that, for the given grip, the threads will be excluded regardless of the actual thickness of the ply closest to the nut (i.e., $t \leq 0$). A common solution when it is desired to exclude the threads but the minimum thickness is not present is to use a longer bolt with additional washer(s) under the nut. Nominal dimensions are used in this calculation for two reasons: (1) RCSC Specification Commentary Section C2 permits thread run-out into the shear plane; and, (2) the control dimension in bolt threading is the distance from the underside of the bolt head to the first useable thread; i.e., the bolt underlength tolerance is absorbed in the threaded length. In calculating the tabulated values of t , washers (if used) are assumed to be installed under the nut. If washer(s) are present under the bolt head, their thickness must be added to the tabulated value of t . When a dash is shown and washer(s) are to be placed under the bolt head, the value of t can be determined as indicated above; alternatively, the washer thickness may be considered as part of the grip.

A common rule of thumb² can be generalized from the tabulated values for minimum outer-ply thickness. With no washers, the threads will always be excluded from the shear plane (regardless of the grip) for $\frac{3}{4}$ -in. and $\frac{7}{8}$ -in. diameter bolts if the outer ply thickness is not less than $\frac{3}{8}$ -in.; the same is true for 1-in. and $1\frac{1}{8}$ -in. diameter bolts if the outer ply thickness is not less than $\frac{1}{2}$ -in. With one washer under the nut, these values may be reduced by $\frac{1}{8}$ -in. Because this rule of thumb is based upon the worst case combination of grip and bolt length, reference to the tabulated values for lesser outer-ply thicknesses will often be beneficial.

A supplementary provision has been added to ASTM A325 for full-length threading (ASTM A325T). This provision may be specified for ASTM A325 bolts of length less than or equal to four times the bolt diameter only; there is no similar provision in ASTM A490. Note that if ASTM A325T bolts are specified, it is impossible to exclude the threads from the shear plane. Thus, for these bolts, the tabulated values of t are meaningless.

ILLUSTRATIVE EXAMPLES

The following examples illustrate the use of Table 2.

Example 1

Given:

Select the bolt length for $\frac{3}{4}$ -in. diameter ASTM A325-N bolts in standard holes in a $\frac{3}{8}$ -in. single-plate connection supporting a W21×50 beam (nominal $t_w = \frac{3}{8}$ -in.).

Solution:

The grip is $\frac{3}{8} + \frac{3}{8} = \frac{3}{4}$ -in. From Table 2, for $\frac{3}{4}$ -in. diameter bolts with zero washers, use $1\frac{3}{4}$ -in. bolt length.

Example 2

Given:

Select the bolt length for $\frac{3}{4}$ -in. diameter ASTM A325-X bolts in standard holes in a double-angle connection with $2L5 \times 3 \times \frac{5}{16}$ supporting a $W27 \times 84$ beam (nominal $t_w = \frac{7}{16}$ -in.).

Solution:

The grip is $\frac{5}{16} + \frac{7}{16} + \frac{5}{16} = 1\frac{1}{16}$ in. From Table 2, for $\frac{3}{4}$ -in. diameter bolts with zero washers, try $2\frac{1}{4}$ -in. bolt length. Also from Table 2, the minimum thickness of the ply closest to the nut to exclude the threads is $\frac{3}{16}$ -in. Since this is less than the $\frac{5}{16}$ -in. angle thickness, use $2\frac{1}{4}$ -in. bolt length.

Example 3

Given:

Select the bolt length for fully tensioned $\frac{3}{4}$ -in. diameter ASTM A325-N bolts connecting a $\frac{1}{2}$ -in.-thick angle to a $W14 \times 500$ column flange (nominal $t_w = 3\frac{1}{2}$ in.). The calibrated wrench method will be used to tension the bolts requiring one washer under the turned element.

Solution:

The grip is $\frac{1}{2} + 3\frac{1}{2} = 4$ in. From Table 2, for $\frac{3}{4}$ -in. diameter bolts with one washer, the table cell is shaded, indicating that this combination or grip, number of washers, and bolt length is such that the nut may jamb on the thread run-out. Therefore, try two washers. From Table 2, for $\frac{3}{4}$ -in. diameter bolts with two washers, use $5\frac{1}{2}$ -in. bolt length.

Example 4

Given:

Select the bolt length for $\frac{7}{8}$ -in. diameter ASTM A490-N bolts in standard holes in an extended end-plate moment connection (1-in. thick) to a $W14 \times 132$ column flange (nominal $t_f = 1$ in.). The column and end-plate material are ASTM A572 grade 50 material. Bolts will be tension-control-type alternative design fasteners.

Solution:

The grip is $1 + 1 = 2$ in. From Table 2, for $\frac{7}{8}$ -in. diameter bolts with zero washers, use $3\frac{1}{4}$ -in. bolt length.

REFERENCES

1. American Institute of Steel Construction, *Manual of Steel Construction—Load and Resistance Factor Design, Volume II—Connections*, p. 8-11 and 8-18, Chicago, IL, 1994.
2. Research Council on Structural Connections, *Load and Resistance Factor Design Specification for Structural Joints Using ASTM A325 or A490 Bolts*, AISC, Chicago, IL, 1988.
3. Industrial Fasteners Institute, *Fastener Standards*, Sixth Ed., IFI, Cleveland, OH, 1988.

APPENDIX

The following table is from the RCSC Specification.²

Table C2.	
Nominal Bolt Size, inches	To Determine Required Bolt Length Add to Grip, in inches
$\frac{1}{2}$	$1\frac{1}{16}$
$\frac{5}{8}$	$\frac{7}{8}$
$\frac{3}{4}$	1
$\frac{7}{8}$	$1\frac{1}{8}$
1	$1\frac{1}{4}$
$1\frac{1}{8}$	$1\frac{1}{2}$
$1\frac{1}{4}$	$1\frac{5}{8}$
$1\frac{3}{8}$	$1\frac{3}{4}$
$1\frac{1}{2}$	$1\frac{7}{8}$

The following tables are summarized from *Fastener Standards*.³

Bolt length tolerance		
Dia., in.	Bolt length, in.	
	6 or less	over 6
$\frac{3}{4}$	-0.19	-0.25
$\frac{7}{8}$	-0.19	-0.25
1	-0.19	-0.25
$1\frac{1}{8}$	-0.25	-0.25

Washer thickness tolerances			
Dia., in.	Washer thickness, in.		
	Max.	Nom.	Min.
$\frac{3}{4}$	0.177	$\frac{5}{32}$ (0.156)	0.122
$\frac{7}{8}$	0.177	$\frac{5}{32}$ (0.156)	0.136
1	0.177	$\frac{5}{32}$ (0.156)	0.136
$1\frac{1}{8}$	0.177	$\frac{5}{32}$ (0.156)	0.136

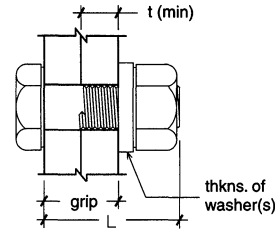
Nut thickness tolerances			
Dia., in.	Nut thickness, in.		
	Max.	Nom.	Min.
$\frac{3}{4}$	0.758	$\frac{47}{64}$ (0.734)	0.710
$\frac{7}{8}$	0.885	$\frac{55}{64}$ (0.859)	0.833
1	1.012	$\frac{63}{64}$ (0.984)	0.956
$1\frac{1}{8}$	1.139	$1\frac{7}{64}$ (1.109)	1.079

Allowance for elongation due to full tensioning			
Dia., in.	Threads per inch	Thread pitch, p , in.	$2p/3$
$\frac{3}{4}$	10	0.100	0.067
$\frac{7}{8}$	9	0.111	0.074
1	8	0.125	0.084
$1\frac{1}{8}$	7	0.143	0.096

Table 1.
Bolt, Nut, and Washer Tolerances vs. RCSC Specification Table C2 Allowance
(all values in inches)

Bolts less than or equal to 6-in. long								
Bolt Diameter	RCSC Spec. Table C2 Allowance	Nut Thickness	Tolerances from Appendix			RCSC Spec. Table C2 conservative by:		
			Bolt Underlength	Nut Overthick	Washer Overthick	Number of washers		
						Zero	One	Two
3/4	1	47/64	0.19	0.024	0.021	3/64	1/32	1/64
7/8	1 1/8	55/64	0.19	0.026	0.021	3/64	1/32	1/64
1	1 1/4	63/64	0.19	0.028	0.021	3/64	1/32	0
1 1/8	1 1/2	17/64	0.25	0.030	0.021	7/64	3/32	1/16
Bolts over 6-in. long								
Bolt Diameter	RCSC Table C2	Nut Thickness	Tolerances from Appendix			RCSC Spec. Table C2 conservative by:		
			Bolt Underlength	Nut Overthick	Washer Overthick	Number of washers		
						Zero	One	Two
3/4	1	47/64	0.25	0.024	0.021	-1/64	-1/32	-3/64
7/8	1 1/8	55/64	0.25	0.026	0.021	-1/64	-1/32	-3/64
1	1 1/4	63/64	0.25	0.028	0.021	-1/64	-1/32	-3/64
1 1/8	1 1/2	17/64	0.25	0.030	0.021	7/64	3/32	1/16
Shading indicates that RCSC Specification Table C2 values result in negligibly unconservative bolt lengths.								

Table 2.
ASTM A325 and A490 Bolts with
zero, one, or two 5/32-in.-thick washer(s)

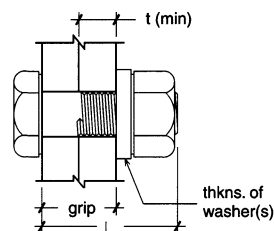


Grip	3/4-in. dia.						7/8-in. dia.					
	no washers		1 washer		2 washers		no washers		1 washer		2 washers	
	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.
1/2	1 1/2	3/8	1 3/4	1/8	2	—	1 3/4	1/4	1 3/4	1/4	2	—
9/16	1 3/4	3/16	1 3/4	3/16	2	—	1 3/4	5/16	2	1/16	2	1/16
5/8	1 3/4	1/4	1 3/4	1/4	2	—	1 3/4	3/8	2	1/8	2 1/4	—
1 1/16	1 3/4	5/16	2	1/16	2	1/16	2	3/16	2	3/16	2 1/4	—
3/4	1 3/4	3/8	2	1/8	2 1/4	—	2	1/4	2	1/4	2 1/4	—
13/16	2	3/16	2	3/16	2 1/4	—	2	5/16	2 1/4	1/16	2 1/4	1/16
7/8	2	1/4	2	1/4	2 1/4	—	2	3/8	2 1/4	1/8	2 1/2	—
15/16	2	5/16	2 1/4	1/16	2 1/4	1/16	2 1/4	3/16	2 1/4	3/16	2 1/2	—
1	2	3/8	2 1/4	1/8	2 1/2	—	2 1/4	1/4	2 1/4	1/4	2 1/2	—
1 1/16	2 1/4	3/16	2 1/4	3/16	2 1/2	—	2 1/4	5/16	2 1/2	1/16	2 1/2	1/16
1 1/8	2 1/4	1/4	2 1/4	1/4	2 1/2	—	2 1/4	3/8	2 1/2	1/8	2 3/4	—
1 3/16	2 1/4	5/16	2 1/2	1/16	2 1/2	1/16	2 1/2	3/16	2 1/2	3/16	2 3/4	—
1 1/4	2 1/4	3/8	2 1/2	1/8	2 3/4	—	2 1/2	1/4	2 1/2	1/4	2 3/4	—
1 5/16	2 1/2	3/16	2 1/2	3/16	2 3/4	—	2 1/2	5/16	2 3/4	1/16	2 3/4	1/16
1 3/8	2 1/2	1/4	2 1/2	1/4	2 3/4	—	2 1/2	3/8	2 3/4	1/8	3	—
1 7/16	2 1/2	5/16	2 3/4	1/16	2 3/4	1/16	2 3/4	3/16	2 3/4	3/16	3	—
1 1/2	2 1/2	3/8	2 3/4	1/8	3	—	2 3/4	1/4	2 3/4	1/4	3	—
1 9/16	2 3/4	3/16	2 3/4	3/16	3	—	2 3/4	5/16	3	1/16	3	1/16
1 5/8	2 3/4	1/4	2 3/4	1/4	3	—	2 3/4	3/8	3	1/8	3 1/4	—
1 11/16	2 3/4	5/16	3	1/16	3	1/16	3	3/16	3	3/16	3 1/4	—
1 3/4	2 3/4	3/8	3	1/8	3 1/4	—	3	1/4	3	1/4	3 1/4	—
1 13/16	3	3/16	3	3/16	3 1/4	—	3	5/16	3 1/4	1/16	3 1/4	1/16
1 7/8	3	1/4	3	1/4	3 1/4	—	3	3/8	3 1/4	1/8	3 1/2	—
1 15/16	3	5/16	3 1/4	1/16	3 1/4	1/16	3 1/4	3/16	3 1/4	3/16	3 1/2	—
2	3	3/8	3 1/4	1/8	3 1/2	—	3 1/4	1/4	3 1/4	1/4	3 1/2	—
2 1/16	3 1/4	3/16	3 1/4	3/16	3 1/2	—	3 1/4	5/16	3 1/2	1/16	3 1/2	1/16
2 1/8	3 1/4	1/4	3 1/4	1/4	3 1/2	—	3 1/4	3/8	3 1/2	1/8	3 3/4	—
2 3/16	3 1/4	5/16	3 1/2	1/16	3 1/2	1/16	3 1/2	3/16	3 1/2	3/16	3 3/4	—

Notes:

1. Minimum bolt length calculated per RCSC Specification Table C2
2. Below 5-in. bolt length, minimum length increment is 1/4-in.; otherwise, 1/2-in.
3. When washer(s) are under bolt head, increase t by thickness of washer(s)
4. Shaded cells indicate longer bolt and additional washers may be required to prevent nut from jamming on the thread run-out
5. "—" indicates that threads are excluded regardless of ply thickness

Table 2.
ASTM A325 and A490 Bolts
with zero, one, or two 5/32-in.-thick washer(s)

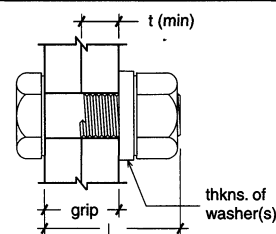


Grip	1-in. dia.						1 1/8-in. dia.					
	no washers		1 washer		2 washers		no washers		1 washer		2 washers	
	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.
1/2	1 3/4	1/2	2	1/4	2 1/4	—	2	1/2	2 1/4	1/4	2 1/2	—
9/16	2	5/16	2	5/16	2 1/4	1/16	2 1/4	5/16	2 1/4	5/16	2 1/2	1/16
5/8	2	3/8	2	3/8	2 1/4	1/8	2 1/4	3/8	2 1/4	3/8	2 1/2	1/8
1 1/16	2	7/16	2 1/4	3/16	2 1/4	3/16	2 1/4	7/16	2 1/2	3/16	2 1/2	3/16
3/4	2	1/2	2 1/4	1/4	2 1/2	—	2 1/4	1/2	2 1/2	1/4	2 3/4	—
13/16	2 1/4	5/16	2 1/4	5/16	2 1/2	1/16	2 1/2	5/16	2 1/2	5/16	2 3/4	1/16
7/8	2 1/4	3/8	2 1/4	3/8	2 1/2	1/8	2 1/2	3/8	2 1/2	3/8	2 3/4	1/8
15/16	2 1/4	7/16	2 1/2	3/16	2 1/2	3/16	2 1/2	7/16	2 3/4	3/16	2 3/4	3/16
1	2 1/4	1/2	2 1/2	1/4	2 3/4	—	2 1/2	1/2	2 3/4	1/4	3	—
1 1/16	2 1/2	5/16	2 1/2	5/16	2 3/4	1/16	2 3/4	5/16	2 3/4	5/16	3	1/16
1 1/8	2 1/2	3/8	2 1/2	3/8	2 3/4	1/8	2 3/4	3/8	2 3/4	3/8	3	1/8
1 3/16	2 1/2	7/16	2 3/4	3/16	2 3/4	3/16	2 3/4	7/16	3	3/16	3	3/16
1 1/4	2 1/2	1/2	2 3/4	1/4	3	—	2 3/4	1/2	3	1/4	3 1/4	—
1 5/16	2 3/4	5/16	2 3/4	5/16	3	1/16	3	5/16	3	5/16	3 1/4	1/16
1 3/8	2 3/4	3/8	2 3/4	3/8	3	1/8	3	3/8	3	3/8	3 1/4	1/8
1 7/16	2 3/4	7/16	3	3/16	3	3/16	3	7/16	3 1/4	3/16	3 1/4	3/16
1 1/2	2 3/4	1/2	3	1/4	3 1/4	—	3	1/2	3 1/4	1/4	3 1/2	—
1 9/16	3	5/16	3	5/16	3 1/4	1/16	3 1/4	5/16	3 1/4	5/16	3 1/2	1/16
1 5/8	3	3/8	3	3/8	3 1/4	1/8	3 1/4	3/8	3 1/4	3/8	3 1/2	1/8
1 11/16	3	7/16	3 1/4	3/16	3 1/4	3/16	3 1/4	7/16	3 1/2	3/16	3 1/2	3/16
1 3/4	3	1/2	3 1/4	1/4	3 1/2	—	3 1/4	1/2	3 1/2	1/4	3 3/4	—
1 13/16	3 1/4	5/16	3 1/4	5/16	3 1/2	1/16	3 1/2	5/16	3 1/2	5/16	3 3/4	1/16
1 7/8	3 1/4	3/8	3 1/4	3/8	3 1/2	1/8	3 1/2	3/8	3 1/2	3/8	3 3/4	1/8
1 15/16	3 1/4	7/16	3 1/2	3/16	3 1/2	3/16	3 1/2	7/16	3 3/4	3/16	3 3/4	3/16
2	3 1/4	1/2	3 1/2	1/4	3 3/4	—	3 1/2	1/2	3 3/4	1/4	4	—
2 1/16	3 1/2	5/16	3 1/2	5/16	3 3/4	1/16	3 3/4	5/16	3 3/4	5/16	4	1/16
2 1/8	3 1/2	3/8	3 1/2	3/8	3 3/4	1/8	3 3/4	3/8	3 3/4	3/8	4	1/8
2 3/16	3 1/2	7/16	3 3/4	3/16	3 3/4	3/16	3 3/4	7/16	4	3/16	4	3/16

Notes:

1. Minimum bolt length calculated per RCSC Specification Table C2
2. Below 5-in. bolt length, minimum length increment is 1/4-in.; otherwise, 1/2-in.
3. When washer(s) are under bolt head, increase t by thickness of washer(s)
4. Shaded cells indicate longer bolt and additional washers may be required to prevent nut from jamming on the thread run-out
5. "—" indicates that threads are excluded regardless of ply thickness

Table 2.
ASTM A325 and A490 Bolts
with zero, one, or two 5/32-in.-thick washer(s)

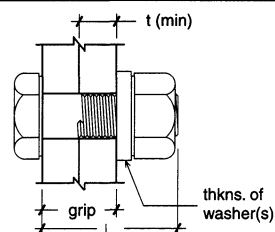


Grip	3/4-in. dia.						7/8-in. dia.					
	no washers		1 washer		2 washers		no washers		1 washer		2 washers	
	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.
2 1/4	3 1/4	3/8	3 1/2	1/8	3 3/4	—	3 1/2	1/4	3 1/2	1/4	3 3/4	—
2 5/16	3 1/2	3/16	3 1/2	3/16	3 3/4	—	3 1/2	5/16	3 3/4	1/16	3 3/4	1/16
2 3/8	3 1/2	1/4	3 1/2	1/4	3 3/4	—	3 1/2	3/8	3 3/4	1/8	4	—
2 7/16	3 1/2	5/16	3 3/4	1/16	3 3/4	1/16	3 3/4	3/16	3 3/4	3/16	4	—
2 1/2	3 1/2	3/8	3 3/4	1/8	4	—	3 3/4	1/4	3 3/4	1/4	4	—
2 9/16	3 3/4	3/16	3 3/4	3/16	4	—	3 3/4	5/16	4	1/16	4	1/16
2 5/8	3 3/4	1/4	3 3/4	1/4	4	—	3 3/4	3/8	4	1/8	4 1/4	—
2 11/16	3 3/4	5/16	4	1/16	4	1/16	4	3/16	4	3/16	4 1/4	—
2 3/4	3 3/4	3/8	4	1/8	4 1/4	—	4	1/4	4	1/4	4 1/4	—
2 13/16	4	3/16	4	3/16	4 1/4	—	4	5/16	4 1/4	1/16	4 1/4	1/16
2 7/8	4	1/4	4	1/4	4 1/4	—	4	3/8	4 1/4	1/8	4 1/2	—
2 15/16	4	5/16	4 1/4	1/16	4 1/4	1/16	4 1/4	3/16	4 1/4	3/16	4 1/2	—
3	4	3/8	4 1/4	1/8	4 1/2	—	4 1/4	1/4	4 1/4	1/4	4 1/2	—
3 1/16	4 1/4	3/16	4 1/4	3/16	4 1/2	—	4 1/4	5/16	4 1/2	1/16	4 1/2	1/16
3 1/8	4 1/4	1/4	4 1/4	1/4	4 1/2	—	4 1/4	3/8	4 1/2	1/8	4 3/4	—
3 3/16	4 1/4	5/16	4 1/2	1/16	4 1/2	1/16	4 1/2	3/16	4 1/2	3/16	4 3/4	—
3 1/4	4 1/4	3/8	4 1/2	1/8	4 3/4	—	4 1/2	1/4	4 1/2	1/4	4 3/4	—
3 5/16	4 1/2	3/16	4 1/2	3/16	4 3/4	—	4 1/2	5/16	4 3/4	1/16	4 3/4	1/16
3 3/8	4 1/2	1/4	4 1/2	1/4	4 3/4	—	4 1/2	3/8	4 3/4	1/8	5	—
3 7/16	4 1/2	5/16	4 3/4	1/16	4 3/4	1/16	4 3/4	3/16	4 3/4	3/16	5	—
3 1/2	4 1/2	3/8	4 3/4	1/8	5	—	4 3/4	1/4	4 3/4	1/4	5	—
3 9/16	4 3/4	3/16	4 3/4	3/16	5	—	4 3/4	5/16	5	1/16	5	1/16
3 5/8	4 3/4	1/4	4 3/4	1/4	5	—	4 3/4	3/8	5	1/8	5 1/2	—
3 11/16	4 3/4	5/16	5	1/16	5	1/16	5	3/16	5	3/16	5 1/2	—
3 3/4	4 3/4	3/8	5	1/8	5 1/2	—	5	1/4	5	1/4	5 1/2	—
3 13/16	5	3/16	5	3/16	5 1/2	—	5	5/16	5 1/2	—	5 1/2	—
3 7/8	5	1/4	5	1/4	5 1/2	—	5	3/8	5 1/2	—	5 1/2	—
3 15/16	5	5/16	5 1/2	—	5 1/2	—	5 1/2	—	5 1/2	—	5 1/2	—

Notes:

1. Minimum bolt length calculated per RCSC Specification Table C2
2. Below 5-in. bolt length, minimum length increment is 1/4-in.; otherwise, 1/2-in.
3. When washer(s) are under bolt head, increase *t* by thickness of washer(s)
4. Shaded cells indicate longer bolt and additional washers may be required to prevent nut from jamming on the thread run-out
5. "—" indicates that threads are excluded regardless of ply thickness

Table 2.
ASTM A325 and A490 Bolts
with zero, one, or two 5/32-in.-thick washer(s)

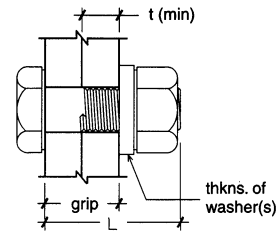


Grip	1-in. dia.						1 1/8-in. dia.					
	no washers		1 washer		2 washers		no washers		1 washer		2 washers	
	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.
2 1/4	3 1/2	1/2	3 3/4	1/4	4	—	3 3/4	1/2	4	1/4	4 1/4	—
2 5/16	3 3/4	5/16	3 3/4	5/16	4	1/16	4	5/16	4	5/16	4 1/4	1/16
2 3/8	3 3/4	3/8	3 3/4	3/8	4	1/8	4	3/8	4	3/8	4 1/4	1/8
2 7/16	3 3/4	7/16	4	3/16	4	3/16	4	7/16	4 1/4	3/16	4 1/4	3/16
2 1/2	3 3/4	1/2	4	1/4	4 1/4	—	4	1/2	4 1/4	1/4	4 1/2	—
2 9/16	4	5/16	4	5/16	4 1/4	1/16	4 1/4	5/16	4 1/4	5/16	4 1/2	1/16
2 5/8	4	3/8	4	3/8	4 1/4	1/8	4 1/4	3/8	4 1/4	3/8	4 1/2	1/8
2 11/16	4	7/16	4 1/4	3/16	4 1/4	3/16	4 1/4	7/16	4 1/2	3/16	4 1/2	3/16
2 3/4	4	1/2	4 1/4	1/4	4 1/2	—	4 1/4	1/2	4 1/2	1/4	4 3/4	—
2 13/16	4 1/4	5/16	4 1/4	5/16	4 1/2	1/16	4 1/2	5/16	4 1/2	5/16	4 3/4	1/16
2 7/8	4 1/4	3/8	4 1/4	3/8	4 1/2	1/8	4 1/2	3/8	4 1/2	3/8	4 3/4	1/8
2 15/16	4 1/4	7/16	4 1/2	3/16	4 1/2	3/16	4 1/2	7/16	4 3/4	3/16	4 3/4	3/16
3	4 1/4	1/2	4 1/2	1/4	4 3/4	—	4 1/2	1/2	4 3/4	1/4	5	—
3 1/16	4 1/2	5/16	4 1/2	5/16	4 3/4	1/16	4 3/4	5/16	4 3/4	5/16	5	1/16
3 1/8	4 1/2	3/8	4 1/2	3/8	4 3/4	1/8	4 3/4	3/8	4 3/4	3/8	5	1/8
3 3/16	4 1/2	7/16	4 3/4	3/16	4 3/4	3/16	4 3/4	7/16	5	3/16	5	3/16
3 1/4	4 1/2	1/2	4 3/4	1/4	5	—	4 3/4	1/2	5	1/4	5 1/2	—
3 5/16	4 3/4	5/16	4 3/4	5/16	5	1/16	5	5/16	5	5/16	5 1/2	—
3 3/8	4 3/4	3/8	4 3/4	3/8	5	1/8	5	3/8	5	3/8	5 1/2	—
3 7/16	4 3/4	7/16	5	3/16	5	3/16	5	7/16	5 1/2	—	5 1/2	—
3 1/2	4 3/4	1/2	5	1/4	5 1/2	—	5	1/2	5 1/2	—	5 1/2	—
3 9/16	5	5/16	5	5/16	5 1/2	—	5 1/2	1/16	5 1/2	1/16	5 1/2	1/16
3 5/8	5	3/8	5	3/8	5 1/2	—	5 1/2	1/8	5 1/2	1/8	5 1/2	1/8
3 11/16	5	7/16	5 1/2	—	5 1/2	—	5 1/2	3/16	5 1/2	3/16	5 1/2	3/16
3 3/4	5	1/2	5 1/2	—	5 1/2	—	5 1/2	1/4	5 1/2	1/4	6	—
3 13/16	5 1/2	1/16	5 1/2	1/16	5 1/2	1/16	5 1/2	5/16	5 1/2	5/16	6	—
3 7/8	5 1/2	1/8	5 1/2	1/8	5 1/2	1/8	5 1/2	3/8	5 1/2	3/8	6	—
3 15/16	5 1/2	3/16	5 1/2	3/16	5 1/2	3/16	5 1/2	7/16	6	—	6	—

Notes:

1. Minimum bolt length calculated per RCSC Specification Table C2
2. Below 5-in. bolt length, minimum length increment is 1/4-in.; otherwise, 1/2-in.
3. When washer(s) are under bolt head, increase *t* by thickness of washer(s)
4. Shaded cells indicate longer bolt and additional washers may be required to prevent nut from jamming on the thread run-out
5. "—" indicates that threads are excluded regardless of ply thickness

Table 2.
ASTM A325 and A490 Bolts
with zero, one, or two 5/32-in.-thick washer(s)

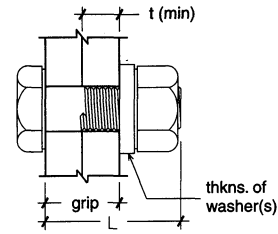


Grip	3/4-in. dia.						7/8-in. dia.					
	no washers		1 washer		2 washers		no washers		1 washer		2 washers	
	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.
4	5	3/8	5 1/2	—	5 1/2	—	5 1/2	—	5 1/2	—	5 1/2	—
4 1/16	5 1/2	—	5 1/2	—	5 1/2	—	5 1/2	1/16	5 1/2	1/16	5 1/2	1/16
4 1/8	5 1/2	—	5 1/2	—	5 1/2	—	5 1/2	1/8	5 1/2	1/8	6	—
4 3/16	5 1/2	1/16	5 1/2	1/16	5 1/2	1/16	5 1/2	3/16	5 1/2	3/16	6	—
4 1/4	5 1/2	1/8	5 1/2	1/8	6	—	5 1/2	1/4	5 1/2	1/4	6	—
4 5/16	5 1/2	3/16	5 1/2	3/16	6	—	5 1/2	5/16	6	—	6	—
4 3/8	5 1/2	1/4	5 1/2	1/4	6	—	5 1/2	3/8	6	—	6	—
4 7/16	5 1/2	5/16	6	—	6	—	6	—	6	—	6	—
4 1/2	5 1/2	3/8	6	—	6	—	6	—	6	—	6	—
4 9/16	6	—	6	—	6	—	6	1/16	6	1/16	6	1/16
4 5/8	6	—	6	—	6	—	6	1/8	6	1/8	6 1/2	—
4 11/16	6	1/16	6	1/16	6	1/16	6	3/16	6	3/16	6 1/2	—
4 3/4	6	1/8	6	1/8	6 1/2	—	6	1/4	6	1/4	6 1/2	—
4 13/16	6	3/16	6	3/16	6 1/2	—	6	5/16	6 1/2	—	6 1/2	—
4 7/8	6	1/4	6	1/4	6 1/2	—	6	3/8	6 1/2	—	6 1/2	—
4 15/16	6	5/16	6 1/2	—	6 1/2	—	6 1/2	—	6 1/2	—	6 1/2	—
5	6	3/8	6 1/2	—	6 1/2	—	6 1/2	—	6 1/2	—	6 1/2	—
5 1/16	6 1/2	—	6 1/2	—	6 1/2	—	6 1/2	1/16	6 1/2	1/16	6 1/2	1/16
5 1/8	6 1/2	—	6 1/2	—	6 1/2	—	6 1/2	1/8	6 1/2	1/8	7	—
5 3/16	6 1/2	1/16	6 1/2	1/16	6 1/2	1/16	6 1/2	3/16	6 1/2	3/16	7	—
5 1/4	6 1/2	1/8	6 1/2	1/8	7	—	6 1/2	1/4	6 1/2	1/4	7	—
5 5/16	6 1/2	3/16	6 1/2	3/16	7	—	6 1/2	5/16	7	—	7	—
5 3/8	6 1/2	1/4	6 1/2	1/4	7	—	6 1/2	3/8	7	—	7	—
5 7/16	6 1/2	5/16	7	—	7	—	7	—	7	—	7	—
5 1/2	6 1/2	3/8	7	—	7	—	7	—	7	—	7	—
5 9/16	7	—	7	—	7	—	7	1/16	7	1/16	7	1/16
5 5/8	7	—	7	—	7	—	7	1/8	7	1/8	7 1/2	—
5 11/16	7	1/16	7	1/16	7	1/16	7	3/16	7	3/16	7 1/2	—

Notes:

1. Minimum bolt length calculated per RCSC Specification Table C2
2. Below 5-in. bolt length, minimum length increment is 1/4-in.; otherwise, 1/2-in.
3. When washer(s) are under bolt head, increase *t* by thickness of washer(s)
4. Shaded cells indicate longer bolt and additional washers may be required to prevent nut from jamming on the thread run-out
5. "—" indicates that threads are excluded regardless of ply thickness

Table 2.
ASTM A325 and A490 Bolts
with zero, one, or two 5/32-in.-thick washer(s)

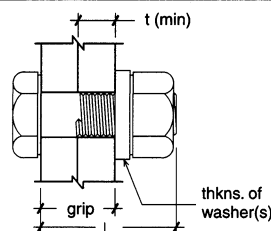


Grip	1-in. dia.						1 1/8-in. dia.					
	no washers		1 washer		2 washers		no washers		1 washer		2 washers	
	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.
4	5 1/2	1/4	5 1/2	1/4	6	—	5 1/2	1/2	6	—	6	—
4 1/16	5 1/2	5/16	5 1/2	5/16	6	—	6	1/16	6	1/16	6	1/16
4 1/8	5 1/2	3/8	5 1/2	3/8	6	—	6	1/8	6	1/8	6	1/8
4 3/16	5 1/2	7/16	6	—	6	—	6	3/16	6	3/16	6	3/16
4 1/4	5 1/2	1/2	6	—	6	—	6	1/4	6	1/4	6 1/2	—
4 5/16	6	1/16	6	1/16	6	1/16	6	5/16	6	5/16	6 1/2	—
4 3/8	6	1/8	6	1/8	6	1/8	6	3/8	6	3/8	6 1/2	—
4 7/16	6	3/16	6	3/16	6	3/16	6	7/16	6 1/2	—	6 1/2	—
4 1/2	6	1/4	6	1/4	6 1/2	—	6	1/2	6 1/2	—	6 1/2	—
4 9/16	6	5/16	6	5/16	6 1/2	—	6 1/2	1/16	6 1/2	1/16	6 1/2	1/16
4 5/8	6	3/8	6	3/8	6 1/2	—	6 1/2	1/8	6 1/2	1/8	6 1/2	1/8
4 11/16	6	7/16	6 1/2	—	6 1/2	—	6 1/2	3/16	6 1/2	3/16	6 1/2	3/16
4 3/4	6	1/2	6 1/2	—	6 1/2	—	6 1/2	1/4	6 1/2	1/4	7	—
4 13/16	6 1/2	1/16	6 1/2	1/16	6 1/2	1/16	6 1/2	5/16	6 1/2	5/16	7	—
4 7/8	6 1/2	1/8	6 1/2	1/8	6 1/2	1/8	6 1/2	3/8	6 1/2	3/8	7	—
4 15/16	6 1/2	3/16	6 1/2	3/16	6 1/2	3/16	6 1/2	7/16	7	—	7	—
5	6 1/2	1/4	6 1/2	1/4	7	—	6 1/2	1/2	7	—	7	—
5 1/16	6 1/2	5/16	6 1/2	5/16	7	—	7	1/16	7	1/16	7	1/16
5 1/8	6 1/2	3/8	6 1/2	3/8	7	—	7	1/8	7	1/8	7	1/8
5 3/16	6 1/2	7/16	7	—	7	—	7	3/16	7	3/16	7	3/16
5 1/4	6 1/2	1/2	7	—	7	—	7	1/4	7	1/4	7 1/2	—
5 5/16	7	1/16	7	1/16	7	1/16	7	5/16	7	5/16	7 1/2	—
5 3/8	7	1/8	7	1/8	7	1/8	7	3/8	7	3/8	7 1/2	—
5 7/16	7	3/16	7	3/16	7	3/16	7	7/16	7 1/2	—	7 1/2	—
5 1/2	7	1/4	7	1/4	7 1/2	—	7	1/2	7 1/2	—	7 1/2	—
5 9/16	7	5/16	7	5/16	7 1/2	—	7 1/2	1/16	7 1/2	1/16	7 1/2	1/16
5 5/8	7	3/8	7	3/8	7 1/2	—	7 1/2	1/8	7 1/2	1/8	7 1/2	1/8
5 11/16	7	7/16	7 1/2	—	7 1/2	—	7 1/2	3/16	7 1/2	3/16	7 1/2	3/16

Notes:

1. Minimum bolt length calculated per RCSC Specification Table C2
2. Below 5-in. bolt length, minimum length increment is 1/4-in.; otherwise, 1/2-in.
3. When washer(s) are under bolt head, increase *t* by thickness of washer(s)
4. Shaded cells indicate longer bolt and additional washers may be required to prevent nut from jamming on the thread run-out
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Table 2.
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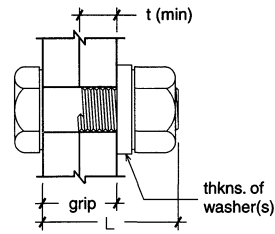
Grip	3/4-in. dia.						7/8-in. dia.					
	no washers		1 washer		2 washers		no washers		1 washer		2 washers	
	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.
5 3/4	7	1/8	7	1/8	7 1/2	—	7	1/4	7	1/4	7 1/2	—
5 13/16	7	3/16	7	3/16	7 1/2	—	7	5/16	7 1/2	—	7 1/2	—
5 7/8	7	1/4	7	1/4	7 1/2	—	7	3/8	7 1/2	—	7 1/2	—
5 15/16	7	5/16	7 1/2	—	7 1/2	—	7 1/2	—	7 1/2	—	7 1/2	—
6	7	3/8	7 1/2	—	7 1/2	—	7 1/2	—	7 1/2	—	7 1/2	—
6 1/16	7 1/2	—	7 1/2	—	7 1/2	—	7 1/2	1/16	7 1/2	1/16	7 1/2	1/16
6 1/8	7 1/2	—	7 1/2	—	7 1/2	—	7 1/2	1/8	7 1/2	1/8	8	—
6 3/16	7 1/2	1/16	7 1/2	1/16	7 1/2	1/16	7 1/2	3/16	7 1/2	3/16	8	—
6 1/4	7 1/2	1/8	7 1/2	1/8	8	—	7 1/2	1/4	7 1/2	1/4	8	—
6 5/16	7 1/2	3/16	7 1/2	3/16	8	—	7 1/2	5/16	8	—	8	—
6 3/8	7 1/2	1/4	7 1/2	1/4	8	—	7 1/2	3/8	8	—	8	—
6 7/16	7 1/2	5/16	8	—	8	—	8	—	8	—	8	—
6 1/2	7 1/2	3/8	8	—	8	—	8	—	8	—	8	—
6 9/16	8	—	8	—	8	—	8	1/16	8	1/16	8	1/16
6 5/8	8	—	8	—	8	—	8	1/8	8	1/8	8	—
6 11/16	8	1/16	8	1/16	8	1/16	8	3/16	8	3/16	8	—
6 3/4	8	1/8	8	1/8	8	—	8	1/4	8	1/4	8	—
6 13/16	8	3/16	8	3/16	8	—	8	5/16	8	—	8	—
6 7/8	8	1/4	8	1/4	8	—	8	3/8	8	—	8	—
6 15/16	8	5/16	8	—	8	—	8	—	8	—	8	—
7	8	3/8	8	—	8	—	8	—	8	—	8	—

Note: bolt lengths exceeding 8 inches are not generally available except by special order

Notes:

1. Minimum bolt length calculated per RCSC Specification Table C2
2. Below 5-in. bolt length, minimum length increment is 1/4-in.; otherwise, 1/2-in.
3. When washer(s) are under bolt head, increase *t* by thickness of washer(s)
4. Shaded cells indicate longer bolt and additional washers may be required to prevent nut from jamming on the thread run-out
5. "—" indicates that threads are excluded regardless of ply thickness

Table 2.
ASTM A325 and A490 Bolts
with zero, one, or two 5/32-in.-thick washer(s)



Grip	1-in. dia.						1 1/8-in. dia.					
	no washers		1 washer		2 washers		no washers		1 washer		2 washers	
	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.	L, in.	t, in.
5 3/4	7	1/2	7 1/2	—	7 1/2	—	7 1/2	1/4	7 1/2	1/4	8	—
5 13/16	7 1/2	1/16	7 1/2	1/16	7 1/2	1/16	7 1/2	5/16	7 1/2	5/16	8	—
5 7/8	7 1/2	1/8	7 1/2	1/8	7 1/2	1/8	7 1/2	3/8	7 1/2	3/8	8	—
5 15/16	7 1/2	3/16	7 1/2	3/16	7 1/2	3/16	7 1/2	7/16	8	—	8	—
6	7 1/2	1/4	7 1/2	1/4	8	—	7 1/2	1/2	8	—	8	—
6 1/16	7 1/2	5/16	7 1/2	5/16	8	—	8	1/16	8	1/16	8	1/16
6 1/8	7 1/2	3/8	7 1/2	3/8	8	—	8	1/8	8	1/8	8	1/8
6 3/16	7 1/2	7/16	8	—	8	—	8	3/16	8	3/16	8	3/16
6 1/4	7 1/2	1/2	8	—	8	—	8	1/4	8	1/4		
6 5/16	8	1/16	8	1/16	8	1/16	8	5/16	8	5/16		
6 3/8	8	1/8	8	1/8	8	1/8	8	3/8	8	3/8		
6 7/16	8	3/16	8	3/16	8	3/16	8	7/16				
6 1/2	8	1/4	8	1/4			8	1/2				
6 9/16	8	5/16	8	5/16								
6 5/8	8	3/8	8	3/8								
6 11/16	8	7/16										
6 3/4	8	1/2										

Note: bolt lengths exceeding 8 inches are not generally available except by special order

Notes:

1. Minimum bolt length calculated per RCSC Specification Table C2
2. Below 5-in. bolt length, minimum length increment is 1/4-in.; otherwise, 1/2-in.
3. When washer(s) are under bolt head, increase *t* by thickness of washer(s)
4. Shaded cells indicate longer bolt and additional washers may be required to prevent nut from jamming on the thread run-out
5. "—" indicates that threads are excluded regardless of ply thickness