Maximum A325 Bolt Loads at a Glance

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SOME DESIGNERS AND DETAILERS have voiced a need for a method that enables a more rapid and clearer determination of the most efficient load capacity for high strength bolts used for single and double shear connections on thin supporting webs and similar material where bearing may control. In friction-type connections, load capacities are not affected by thickness of material or by shear planes intersecting bolt threads; therefore, the bolt capacities are constant. This paper suggests a technique that is advantageous in building-type structures where both friction- and bearing-type connections can be used. Too often, sight is lost of the most efficient, economical solution. The problem is centered on a rather narrow range of supporting material thicknesses (webs, etc.) where the several limitations on bolt capacities seemingly converge.

Current specifications governing usage of high strength bolts contain four determinants of bolt capacity, exclusive of applied tension. First is an allowable "frictional" shear where the concept of a friction-type joint is employed. The other three determinants, pertaining to bearing-type connections, are (1) an allowable shear on the nominal cross-sectional area of the bolt when threads are in a shear plane, (2) a higher allowable shear on the nominal cross-sectional area of the bolt when threads are excluded from shear planes, and (3) an allowable bearing on the projected bolt area of the supporting member or connections detail material.

When high strength bolts were introduced in the early 1950's, they were designed using the "friction" concept. It was about ten years later before the second concept of "bearing" came into being. The latter concept is the most advantageous, since it develops more of the inherent strength of A325 bolts, except where bearing on thin base material of the connected parts severely limits bolt capacity. Then the "friction" concept becomes more favorable strengthwise. This suggests a merger whereby the best of each concept is utilized.

It should always be borne in mind that regardless of joint concept, be it friction or bearing, all A325 bolts are not only physically alike but are also installed and tightened to the same minimum tension requirements. As someone once facetiously remarked, "The bolt does not know how the connection is to behave". All properly installed A325 bolts transmit their loads by friction until slip into bearing occurs. In unpainted joints, whether friction-type or bearing-type, slip would not occur until the loads exceeded the calculated working load. In painted joints, permissible for the bearing-type, slippage into bearing is anticipated.

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Obviously, if the designer and fabricator both seek efficiency and economy, A325 bolts should be used to their largest allowable capacity, independently of the concept of joint behavior. This objective is attainable for bolts subject to single or double shear. However, the special case of combined shear and tension must be designed as provided in Sect. 1.6.3 of the AISC Specification.

The "load capacity" concept in this paper in no way subverts the requirements of the Specification, which differentiates between connection types. It simply reduces the mental acrobatics in choosing between friction- and bearing-type connections, and results in a simpler and more convenient procedure. It is accomplished by observing the following three conditions:

(a) Maximum allowable bolt load prevails.
(b) Joint contact surfaces are free of paint, where applicable.
(c) Bolt threads are eliminated from shear planes, where applicable.

MAXIMUM BOLT VALUES

The maximum allowable load on a bolt is determined by the applicable single shear or double shear values. Thus, for a ¾-in. diameter bolt these values are 9.72 and 19.44 kips, respectively. An upper load boundary is established where these shear loads are equal to the allowable bearing loads on the enclosed area of the supporting material. Beyond this point, i.e., in the direction of thicker supporting webs, the bolt capacity is a constant and the maximum.

A lower boundary is similarly established where the bearing load is equal to that permitted for frictional shear.

Thus, for the ¾-in. diameter bolt, these lower boundary values are 6.63 and 13.25 kips, respectively. These values are the maximum for lesser thicknesses of the supporting material and remain constant, since they are based on friction type connections in each case. Between these two boundaries the load capacities are a variable dependent upon the yield stress, F_y, of the lowest strength material in the connection, the corresponding bearing stress, F_p, and the thickness of the material. Condition (a) simply establishes the selection of the maximum bolt value.

CONTACT SURFACES

Condition (b) recognizes the Specification requirement that paint be omitted on the contact surfaces of friction type joints. Attention to this detail is necessary only where the material thickness is below the lower boundary and the bolt capacity for friction type connection is selected. In this regard it should be noted that the current AISC Specification does not require shop paint on many types of structures unless it is specified on the contract drawings or specifications.

THREADS IN SHEAR PLANES

The reduction in capacity caused by planes intersecting threads can be effectively eliminated by careful attention to bolt details. According to the Research Council's Commentary on the Specification for Structural Joints using ASTM A325 or A490 Bolts, the full thread may extend into the grip as much as ⅜-in. for ¾- and ⅞-in. diameter bolts. Thus, if the web or ply of material adjacent to the nut is ⅜-in. or less, it would ordinarily require a reduction in load capacity. This is an extreme case, since the bolt length usually contains an adjustment that increases the length for ordering in ¼-in. increments. Some designers, upon observing the possibility of threads extending into a shear plane, have eliminated any doubt by requiring a washer under the nut and increasing the bolt length accordingly. Thus, they avoid using the lower allowable shear load specified for the threaded end. Condition (c) simply makes the keeping of threads clear of shear planes a standard practice, thereby removing this determinant from further consideration.

TABLES OF BOLT CAPACITIES

Tables of bolt capacities (Tables I through IV) have been prepared for ¾- and ⅞-in. diameter A325 bolts in both single and double shear connections. Similar tables could be developed for larger A325 bolt sizes, as well as for A490 bolts. Load capacities are included for the several yield strengths of the recent (December 1966) ASTM standard for the columbium-vanadium steels,

Table I. Allowable Single Shear Loads in Kips for ¾-in. Dia. A325 Bolts

F_y, ksi	36	42	45	46	50	55	60	65
F_b, ksi	48.5	56.5	60.5	62.0	67.5	74.0	81.0	87.5
Material Thickness, In.								
0.27								
0.26	9.46							
0.250 (¼)	9.09							
0.24	8.73							
0.23	8.37							
0.22	8.00	9.32						
0.21	7.64	8.90	9.53					
0.20	7.28	8.48	9.08	9.30				
0.19	6.91	8.05	8.62	8.84	9.62			
0.1875 (3/16)	6.82	7.95	8.51	8.72	9.49			
0.18		7.63	8.17	8.37	9.11			
0.17		7.20	7.71	7.90	8.60	9.44		
0.16		6.78	7.26	7.44	8.10	8.88		
0.15			6.81	6.98	7.59	8.33	9.11	
0.14					7.09	7.77	8.51	9.19
0.13						7.21	7.90	8.53
0.125 (⅛)						6.94	7.59	8.20
0.12						6.66	7.29	7.88
0.11							6.68	7.22
0.10								
0.001	0.036	0.042	0.045	0.046	0.051	0.055	0.061	0.066

For all values in this shaded area, use 9.72 kips. (maximum value)

For all values in this shaded area, use 6.63 kips. (No paint on contact surfaces)

A572. Following the precedent established in the AISC Manual of Steel Construction, the allowable values in bearing, F_p, were conservatively rounded off to the lower whole or half kip.

Some detailers may prefer a separate table for each allowable bearing value F_p and for each size bolt. Then, capacity loads may also be given for bolt groups, perhaps from 2 to 18, in multiples of 2.

In Tables I through IV, the bolt load capacity is given for each 0.01 in. increment of thickness and also for each fraction of 1 in. In design practice, bearing on beam webs is based on the decimal thickness and bearing

Table II. Allowable Double Shear Loads in Kips for ¾-in. Dia. A325 Bolts

F_y, ksi	36	42	45	46	50	55	60	65
F_b, ksi	48.5	56.5	60.5	62.0	67.5	74.0	81.0	87.5
0.54								
0.53	19.28							
0.52	18.92							
0.51	18.55							
0.500 (½)	18.19							
0.49	17.83							
0.48	17.46							
0.47	17.10							
0.46	16.73							
0.45	16.37	19.07						
0.44	16.01	18.65						
0.4375 (7/16)	15.91	18.54						
0.43	15.64	18.22						
0.42	15.28	17.80	19.06					
0.41	14.92	17.38	18.60	19.07				
0.40	14.55	16.95	18.15	18.60				
0.39	14.18	16.53	17.70	18.14				
0.38	13.82	16.10	17.24	17.67	19.24			
0.375 (⅜)	13.64	15.89	17.01	17.44	18.98			
0.37	13.46	15.68	16.79	17.21	18.73			
0.36		15.25	16.33	16.74	18.23			
0.35		14.83	15.88	16.28	17.72			
0.34		14.41	15.43	15.81	17.21	18.87		
0.33		13.98	14.97	15.35	16.71	18.32		
0.32		13.56	14.52	14.88	16.20	17.76		
0.3125 (5/16)			14.18	14.53	15.82	17.34	18.98	
0.31			14.07	14.42	15.69	17.21	18.83	
0.30			13.61	13.95	15.19	16.65	18.23	
0.29				13.49	14.68	16.10	17.62	19.03
0.28					14.18	15.54	17.01	18.38
0.27					13.67	14.99	16.40	17.72
0.26						14.33	15.80	17.06
0.250 (¼)						13.88	15.19	16.41
0.24						13.32	14.58	15.75
0.23							13.97	15.09
0.22							13.37	14.44
0.21								13.78
0.20								
0.001	0.036	0.042	0.045	0.046	0.051	0.055	0.061	0.066

For all values in this shaded area, use 19.44 kips. (maximum value)

For all values in this shaded area, use 13.25 kips. (No paint on contact surfaces)

on plates and angles is based on fraction of 1 in. Generally, it will be sufficiently accurate to use the nearest 0.01 in. on the conservative side. Where greater refinement is desired, the load can be interpolated using the increment of load for 0.001 in. thickness given at the bottom of the tables. Similarly, the precise thickness of material at the boundaries may be readily determined if such information is of interest.

As with most engineering solutions, there are cases that require exercise of judgment. For example, the tables require that connections having material thinner than the lower load boundary of the table must have contact surfaces free of paint (since friction connections govern). If the steel is to be shop painted, and elimination of paint at the joints is undesirable, it may be preferable to use lower bolt capacities based on the bearing value of the supporting steel. In some cases, this would not require a larger number of bolts, since excess total bolt capacity is available in most joints. For example, if 7¼ bolts are computed to be needed, 8 bolts will be supplied. Thus, the same bolt group may satisfy the design loading even when lower load capacities are used.

EXAMPLES

Example A—Find the maximum load capacity for one ¾-in. diameter A325 bolt in double shear on ⅜-in. thick material of A36 steel.

Solution: Enter Table II at material thickness ⅜-in., and in column F_y = 36 ksi, use 13.64 kips.

Example B—Same as Example A, except connection is to web of 16WF36, A36 steel, shop painted.

Solution: From Manual, web thickness = 0.299 in. Enter Table II at material thickness 0.30 in., and in the column F_y = 36 ksi, use 13.25 kips. No paint may be on contact surfaces of joint.

Table III. Allowable Single Shear Loads in Kips for ⅞-in. Dia. A325 Bolts

F_y, ksi	36	42	45	46	50	55	60	65
F_b, ksi	48.5	56.5	60.5	62.0	67.5	74.0	81.0	87.5
Material thickness, In.								
0.32								
0.31	13.16							
0.30	12.73							
0.29	12.31							
0.28	11.88							
0.27	11.46							
0.26	11.03	12.85						
0.25 (¼)	10.61	12.36						
0.24	10.19	11.87	12.71	13.02				
0.23	9.76	11.37	12.18	12.48				
0.22	9.34	10.88	11.65	11.94	12.99			
0.21		10.38	11.12	11.39	12.40			
0 20		9.89	10.59	10.85	11.81	12.95		
0.19		9.39	9.96	10.31	11.22	12.30		
0 1875 (3/16)		9.27	9.93	10.17	11.07	12.14		
0.18			9.53	9.78	10.63	11.66	12.76	
0.17				9.22	10.04	11.01	12.05	13.02
0.16					9.45	10.36	11.34	12.25
0.15						9.71	10.63	11.48
0.14						9.07	9.92	10.72
0.13							9.21	9.95
0.125 (⅛)								9.57
0.12								9.19
0.11								
0.001	0.042	0.049	0.053	0.054	0.059	0.065	0.071	0.077

For all values in this shaded area, use 13.23 kips. (Maximum value)

For all values in this shaded area, use 9.02 kips. (No paint on contact surfaces)

Table IV. Allowable Double Shear Loads in Kips for 7/8-in. Dia. A325 Bolts

F_y, ksi	36	42	45	46	50	55	60	65
F_b, ksi	48.5	56.5	60.5	62.0	67.5	74.0	81.0	87.5
Material thickness, In.								
0.63								
0.62	26.31							
0.61	25.89							
0.60	25.46							
0.59	25.04							
0.58	24.62							
0.57	24.19							
0.5625 (9/16)	23.87							
0.56	23.77							
0.55	23.34							
0.54	22.92							
0.53	22.49	26.20						
0.52	22.07	25.71						
0.51	21.64	25.21						
0.500 (1/2)	21.22	24.72						
0.49	20.79	24.23	25.94					
0.48	20.37	23.73	25.41	26.04				
0.47	19.95	23.24	24.88	25.50				
0.46	19.52	22.74	24.35	24.95				
0.45	19.09	22.25	23.82	24.41				
0.44	18.67	21.75	23.29	23.87	25.99			
0.4375 (7/16)	18.57	21.63	23.16	23.73	25.84			
0.43	18.25	21.26	22.76	23.33	25.40			
0.42		20.76	22.23	22.79	24.81			
0.41		20.27	21.70	22.24	24.22			
0.40		19.78	21.17	21.70	23.62	25.90		
0.39		19.28	20.64	21.16	23.03	25.25		
0.38		18.79	20.12	20.61	22.44	24.61		
0.375 (3/8)		18.54	19.85	20.34	22.15	24.28		
0.37		18.29	19.58	20.07	21.85	23.96	26.22	
0.36			19.06	19.53	21.26	23.31	25.51	
0.35			18.53	18.99	20.67	22.66	24.81	
0.34				18.45	20.08	22.01	24.10	26.03
0.33					19.49	21.37	23.39	25.26
0.32					18.90	20.72	22.68	24.50
0.3125 (5/16)					18.46	20.23	22.15	23.93
0.31					18.31	20.07	21.97	23.73
0.30						19.43	21.26	22.97
0.29						18.78	20.55	22.20
0.28						18.13	19.85	21.44
0.27							19.14	20.67
0.26							18.43	19.91
0.250 (1/4)								19.14
0.24								18.37
0.23								
0.001	0.042	0.049	0.053	0.054	0.059	0.065	0.071	0.077

For all values in this shaded area, use 26.46 kips. (Maximum value)

For all values in this shaded area, use 18.04 kips. (No paint on contact surfaces)

Example C—Find the maximum load capacity of six A325 volts, 7/8-in. diameter, in double shear in web of 14WF38 of grade F_y = 50 ksi steel.

Solution: From Manual, web thickness = 0.331 in. Enter Table IV at material thickness 0.31 in., and in column F_y = 50 ksi, use 18.31 kips (the load for one bolt). Therefore, total load capacity = 6 × 18.31 = 109.86 kips.

Example D—Find the precise load capacity in Example C.

Solution: From Table IV, load capacity for 0.001 in. of material thickness is 0.059 kips. For 0.003 in., a value of 3 × 0.059 = 0.18 must be added to the value found in Example C:

$$18.31 + 0.18 = 18.49 \text{ kips}$$

Total load capacity = 6 × 18.49 = 110.94 kips.

Example E—Detail 3/4-in. diameter A325 bolts in a connection for two 10WF's framing opposite each other into a 14WF38, using 5/16-in. thick connection angles.

Solution: From Manual, web thickness of 14WF38 is 0.313 in. or 5/16-in.
Grip = 2 × 5/16 + 5/16 = 15/16-in.
From Table 6, "Specification for Structural Joints using ASTM A325 or A490 Bolts" (September 1, 1966), the length to be added to the grip for a 3/4-in. bolt is 1 in.*
Trial bolt length:
15/16 + 1 + 1/16 = 2 in.
From Table 5, in the above specifications, the threaded length for a 3/4-in. bolt is 1 3/8 in.*
Threads project into grip:
15/16 − (2 − 1 3/8) = 5/16-in.
Since connection angles are 5/16-in. thick, threads may be in shear planes.
Detail bolt length = 2 1/4 in.
Use 5/32-in. washer.

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* *Readers may place this information on the appropriate load capacity tables for ready reference.*
