Fastener Loads for Plywood – Bolts

Number E825E

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Introduction

The integrity of a structure is frequently dependent upon the connections between its component elements. For maximum strength and stability, each joint requires a design based on the fastener type and the strength properties of the individual structural members. Included in the following tables are ultimate lateral loads for bolted plywood joints. These lateral-load values are based upon tests conducted by *APA – The Engineered Wood Association.* Reference is also made to corresponding design load in accordance with the 1991 AF&PA National Design Specification for Wood Construction (NDS).

End and edge distances are defined in Figure 1.

It should be noted that values given in this Technical Note were drawn from results of various test programs conducted for different purposes over a number of years. As new test programs require additional fastener data, results will be incorporated.

Test Results

Plywood-and-Metal Connections

Performance of plywood-and-metal connections is dependent upon the compressive strength properties of the plywood and the tensile yield strength of the metal fastener. As shown in Figure 2, once localized crushing of the wood has occurred, resistance to fastener-head or washer-nut embedment causes the bolt to be loaded in tension and joint behavior may become dependent upon the strength of the fastener. Plywood-critical joints are characterized by a shearing of plywood veneers oriented parallel to the direction of the applied force.

Tables 1 and 2 present ultimate lateral loads for single-shear and double-shear plywood-and-metal joints. The loaded plywood end distance was four times the diameter of the bolt.

All specimens were tested with a 3/16-inch-thick steel side plate, and values should not be applied when steel is thinner.

FIGURE 1

PLYWOOD END AND EDGE DISTANCE

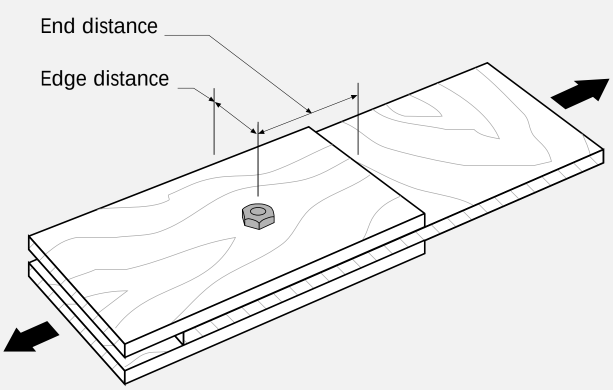
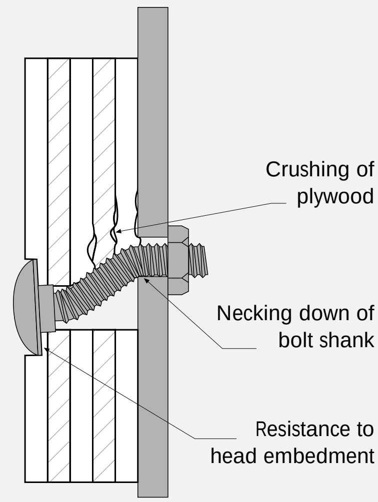


FIGURE 2

FAILURE OF A SINGLE-SHEAR PLYWOOD-AND-METAL CONNECTION



APA

The Engineered Wood Association

TABLE 1

CARRIAGE BOLTS: PLYWOOD-AND-METAL CONNECTIONS[a]

Bolt Diameter (in.)	Plywood Thickness (in.)	Plywood End Distance (in.)	Plywood Edge Distance (in.)	Design Load[b] (lb)	Ultimate Lateral Load (lb)[c]			
					Finger Tight		200 in.-lb Torque	
					Without Washer	With Washer	Without Washer	With Washer
3/8	1/2	1-1/2	3	205	1200	1480	1640	1830
	5/8	1-1/2	3	215	(1430)	(1710)	(1860)	(2230)
	3/4	1-1/2	3	235	1710	2520	2160	2700
1/2	1/2	2	3	270	1280	–	1560	–
	5/8	2	3	290	(1790)	–	(2320)	–
	3/4	2	3	310	1940	–	2710	–

(a) Plywood was C-D grade with exterior glue (all plies Group 1), face grain parallel to load. Side plate was 3/16"-thick steel. Bolts were No. 2 N.C. mild steel.

(b) The design load was estimated using equations published in the 1991 National Design Specification.

(c) Values in parentheses are estimates based on other tests.

Single shear
with carriage bolt

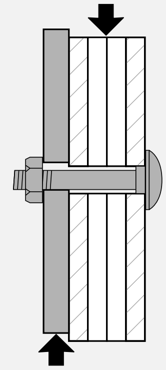


TABLE 2

MACHINE BOLTS: PLYWOOD-AND-METAL CONNECTIONS[a]

Bolt Diameter (in.)	Plywood Thick-ness (in.)	Plywood End Distance (in.)	Plywood Edge Distance (in.)	Single Shear			Double Shear		
				Design Load (lb)[b]	Ultimate Lateral Load (lb)[c]		Design Load (lb)[b]	Ultimate Lateral Load (lb)[c]	
					Finger Tight	200 in-lb Torque[d]		Finger Tight	200 in-lb Torque[d]
1/4	1/2	1	3	135	1180	(1410)	175	970	(1160)
	5/8	1	3	145	1200	(1430)	220	1130	(1350)
	3/4	1	3	155	1500	(1810)	265	1380	(1650)
5/16	1/2	1-1/4	3	170	1490	(1790)	220	1430	(1710)
	5/8	1-1/4	3	180	1370	(1640)	275	1260	(1510)
	3/4	1-1/4	3	195	2040	(2450)	330	1770	(2130)
3/8	1/2	1-1/2	3	205	1730	2030	265	1510	1820
	5/8	1-1/2	3	215	1680	(2010)	330	1650	(1980)
	3/4	1-1/2	3	235	2120	2560	395	2330	2790
1/2	1/2	2	3	270	1870	2240	–	–	–
	5/8	2	3	290	(2090)	(2510)	–	–	–
	3/4	2	3	310	2240	2960	–	–	–

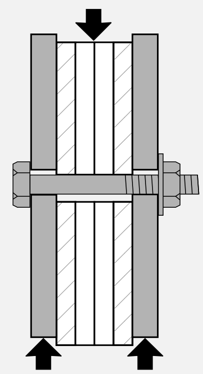
(a) Plywood was C-D grade with exterior glue (all plies Group 1), face grain parallel to load. Side plate was 3/16"-thick steel. Bolts were No. 2 N.C. mild steel, with washer.

(b) The design load was estimated using equations published in the 1991 National Design Specification.

(c) Values in parentheses are estimates based on other tests.

(d) Estimated values for 1/4" and 5/16" diameter bolts apply to torque level recommended by the bolt manufacturer.

Double shear
with machine bolt



Single shear
with machine bolt

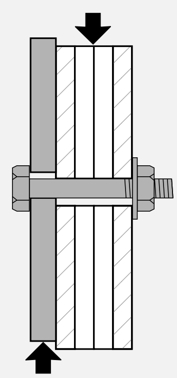


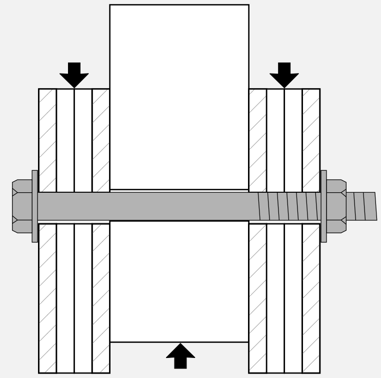
TABLE 3

BOLTS: PLYWOOD-TO-LUMBER CONNECTIONS[(a)]

Bolt Diameter (in.)	Plywood Thickness (in.)	Face Grain Direction	Plywood End Distance (in.)	Plywood Edge Distance (in.)	Design Load (lb)[(b)]	Ultimate Lateral Load (lb)
1/2	5/16	90°	4	2	440	2400
	1/2	0°	3	1	700	4750
		90°	3	1	700	4570
	5/8	0°	3	1-1/2	875	5400
		90°	3	1-1/2	875	4320
	3/4	0°	3	1-1/2	925	5280
		90°	3	3	925	5630
3/4	1/2	0°	4	2	1050	7800
		90°	4	1-3/4	1050	6900
	5/8	0°	4	1-1/2	1315	8070
		90°	4	1-1/2	1315	6900
	3/4	0°	6	1-1/2	1575	7920
		90°	6	1-1/2	1575	8650

(a) Plywood was all Group 1. Lumber was green stud-grade Douglas-fir 3 x 3. Bolt grade was unknown.

(b) The design load was estimated using equations published in the 1991 National Design Specification.



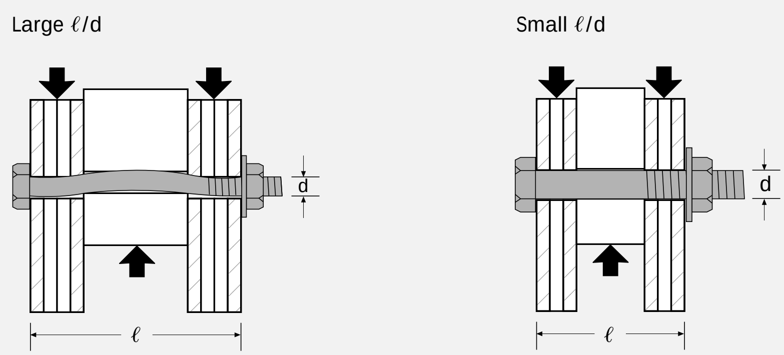
Plywood-to-Lumber Connections

Table 3 presents ultimate loads for plywood-to-lumber double-shear connections. Specimens consisted of gusset plates bolted to each side of a 2-1/2-inch x 2-1/2-inch green lumber central member. Table 3 shows the minimum plywood end and edge distances required to develop the plywood's full bolt-bearing strength. For lesser end and edge distances, with a minimum of 50 percent that tabulated, the ultimate load may be assumed to be directly proportional to the tabulated end or edge distance. For maximum strength, spacing between adjacent rows of bolts should be twice the tabulated edge distance.

In some cases bolt values for 1/2-inch-thick plywood are superior to those for 5/8-inch and 3/4-inch-thick plywood. This is probably accounted for by the fact that the ultimate bolt load was affected by the thickness of the lumber member. That is, the length-to-diameter ratio of the bolt was high enough to permit the bolt to bend, as shown in Figure 3.

FIGURE 3

INFLUENCE OF BOLT DIAMETER ON PLYWOOD-TO-LUMBER CONNECTIONS



Plywood-to-Plywood Connections

Bolts are not commonly used to join two plywood members. Such applications are usually limited to only the thicker plywood constructions. Table 4 presents ultimate loads for a single-shear joint comprised of two layers of plywood. Joints where the short loaded end distance was 1-1/2 inch were plywood-critical.

Estimating Allowable Design Loads

It is the responsibility of the designer to select a working load suitable for the particular application. The working load is typically based on the normal duration of load, which contemplates fully stressing the connection for approximately ten years, either continuously or cumulatively. There are two methods for estimating the working load. The first uses the

TABLE 4

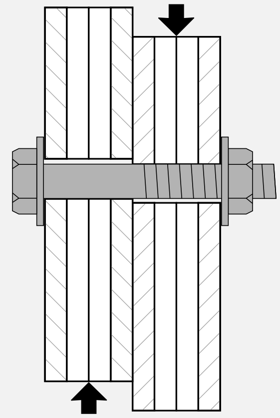
BOLTS: PLYWOOD-TO-PLYWOOD CONNECTIONS[a]

Bolt Diameter (in.)	Plywood Thickness (in.)	Face Grain Direction	Plywood Edge Distance (in.)	Plywood Edge Distance (in.)	Design Load (lb)[b]	Ultimate Lateral Load	
						Without Washer	With Washer
3/8	19/32	90°	4	3	145	–	2290
1/2	19/32	90°	4	3	190	–	2370
1/2	1-1/8	90°	1-1/2	1-1/2	360	2000	2710
3/4	1-1/8	90°	1-1/2	1-1/2	545	–	3840

(a) 19/32-inch plywood was C-D with exterior glue (all plies Group 1). 1-1/8-inch plywood was Sturd-I-Floor 48 oc (2-4-1). Bolt grade was unknown.

(b) The design load was estimated using equations published in the 1991 National Design Specification.

Single shear
with machine bolt



traditional means for estimating the normal duration working load by dividing the tabulated ultimate load by a factor of 5. The second uses the generalized equations published in the 1991 AF&PA National Design Specification for Wood Construction (NDS). The columns in Tables 1 through 4 labeled “Design Load” were estimated using these generalized equations. Several assumptions were made to calculate the design values:

1. The dowel bearing strength for the plywood was taken as $F_{e||}$ for Douglas fir-larch lumber regardless of the direction of the face grain (i.e., it was assumed that the plywood behaved similar to solid sawn lumber regardless of panel orientation).

2. The angle of load to grain for plywood (θ) was always assumed to be equal to zero.

The equations published in the 1991 NDS were based on generalized equations that assume the fasteners behave as perfect dowels with no end bearing. Although using washers and torquing the nut will improve the performance of the connection, the generalized design equations do not take these factors into account.

Adjustments for shorter or longer duration of load and for high moisture conditions apply to design values for mechanical fasteners when the strength of the wood (i.e., not the strength of the metal fastener) determines the load capacity. Adjustment of design values for varying duration and combinations of load, as well as for wet conditions, should be in accordance with the current NDS. The local building code is the final authority on the appropriate recognized load duration factor.

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