Fast Check for Block Shear

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Block shear is a fracture type failure in which fracture may occur either along the shear plane or along the tension plane (see Fig. 1). The first plane to reach its fracture strength will not fail (separate) but is restrained by the stronger plane until the fracture strength of the second is reached. Just before fracture along the stronger plane the total strength will be the sum of the fracture strength along the stronger plane plus the yield strength of the weaker plane.

Tables are provided in the AISC LRFD Manual which give values of C_1 and C_2 for two modes of failure. One mode is tension fracture, shear yield. The other is shear fracture, tension yield. The strength of the connection is given by the equation

$$R_{BS} = t_w (C_1 + C_2)$$

where t_w is the thickness of the element being considered.

The method described in the LRFD Manual uses the larger value of R_{BS} calculated for each failure mode as the strength of the connection. The value thus calculated does not always agree with the phenomenon described in the first paragraph above.

A convenient method is offered herein for accurately and quickly determining which mode of failure to use. R_{BS} is determined for that mode by using the values of C_1 and C_2 in the tables for that particular mode of failure.

This method is limited to the following conditions:

1. There is one row of bolts (same as for Manual tables).
2. Bolt spacing is three inches (same as for Manual tables).
3. Bolt hole dimensions are bolt diameter plus 1/16-in. for shear fracture and bolt diameter plus 1/8-in. for tension fracture.
4. Vertical edge distance, l_v, is equal to or greater than 1.5 times the bolt diameter.
5. No less than two bolts are used.

These conditions are shown in Fig. 2.

Equations for fracture are:

Tension fracture (Eq. J5-2)

$$R_{TF} = \phi F_u A_{nt}$$
$$= \phi F_u t_w \left(l_h - \frac{d_{ht}}{2} \right)$$

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Shear fracture (Eq. J4-1)

$$R_{SF} = \phi F_u A_{ns}$$
$$= \phi 0.6 F_u t_w \left[N(3 - d_{hs}) + \frac{d_{hs}}{2} - 3 + l_v \right]$$

where

ϕ = resistance factor, 0.75
F_u = specified minimum tensile strength, ksi
t_w = thickness of element (web), in.
l_h = distance from center of hole to edge along tension plane, in.
l_v = distance from center of hole to edge along shear plane, in.
d_{ht} = diameter of hole (bolt diameter + 1/8-in.)
d_{hs} = diameter of hole (hole diameter + 1/16-in.)
d = bolt diameter
N = number of bolts

Let $l_v = 1.5d$ (lower bound), set $R_{TF} = R_{SF}$ and solve for l_h.

$$l_h = 2.375 - 0.4d$$

For this value of l_h both planes have the same fracture strength. Since this is a special value of l_h it will be called l_h*. For a value of l_h less than l_h* it is obvious that shear fracture will be the stronger fracture strength and the table in the Manual for "shear fracture, tension yield" is used for selecting values for C_1 and C_2. If the number of bolts is increased shear fracture strength will increase (shear area increases) and will continue to be the failure mode to use. If l_h exceeds l_h* tension fracture will be the stronger and the table for "tension fracture, shear yield" is used for determining C_1 and C_2.

For different bolt sizes and number of bolts the values of l_h* have been calculated and are tabulated below (Table A). If l_h is less than the value tabulated the "shear fracture, tension yield" table should be used. For the designer's convenience, values of $l_v = 1.5d$ are included in the table.

An examination of Table A indicates that, for most beam end connection situations, "shear fracture, tension yield" will govern the strength of the connection. For instance, if three or more bolts of 1½-in. or less in diameter are used "shear fracture will govern if l_h is less than 3⅜-in. This is also the governing case for two bolts if l_h is less than 2³⁄₃₂-in.

Example:

For the connection shown in Fig. 3, determine R using Table A.

$l_v = 3\frac{1}{2} - 2 = 1\frac{1}{2} > (1.5d = 1\frac{5}{16}\text{-in.})$

$l_h = 1\frac{1}{4} < (l_h{}^* = 4\frac{23}{32}\text{-in., for } \frac{7}{8}\text{-in. bolt})$

Use shear fracture, tension yield table.

$C_1 = 72.9 \qquad C_2 = 149$

$R_{SF} = t_w\,(C_1 + C_2)$

$= 0.4(72.9 + 149) = 88.76$ kips

ALLOWABLE STRESS DESIGN (ASD)

The ninth edition of the ASD Manual does not have tables similar to those in the LRFD Manual for checking block shear

Table A.
$l_h{}^*$

	Bolt Size							
N	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2
2	2 1/8	2 3/16	2 1/4	2 5/16	2 3/8	2 1/4	2 1/2	2 9/16
3	3 1/2	3 1/2	3 15/32	3 15/32	3 15/32	3 1/4	3 7/16	3 13/32
4	4 29/32	4 13/16	4 23/32	4 5/8	4 17/32	4 9/32	4 3/8	4 9/32
5	6 9/32	6 1/8	5 31/32	5 25/32	5 5/8	5 9/32	5 5/16	5 5/32
$l_v = 1.5d$	15/16	1 1/8	1 5/16	1 1/2	1 11/16	1 7/8	2 1/16	2 1/4

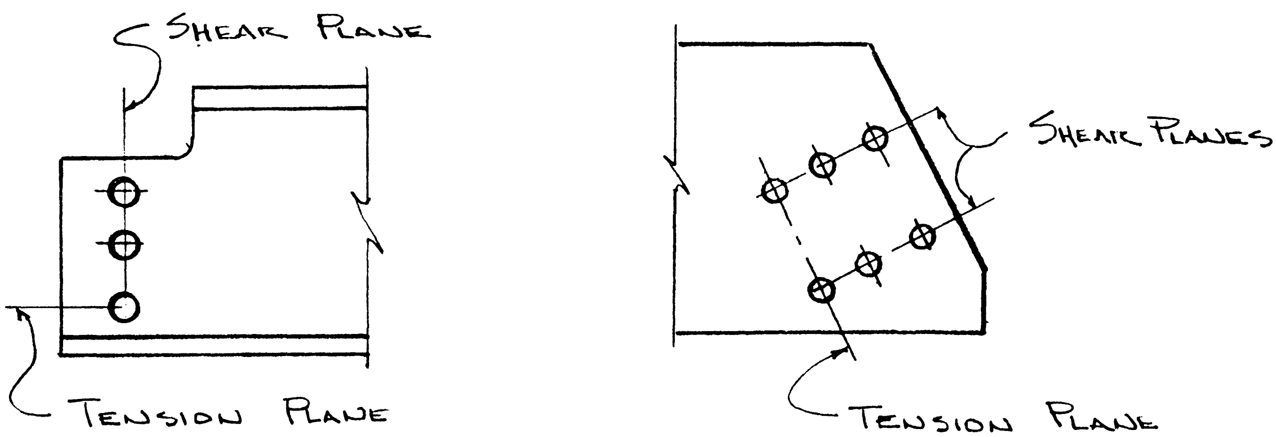

Figure 1

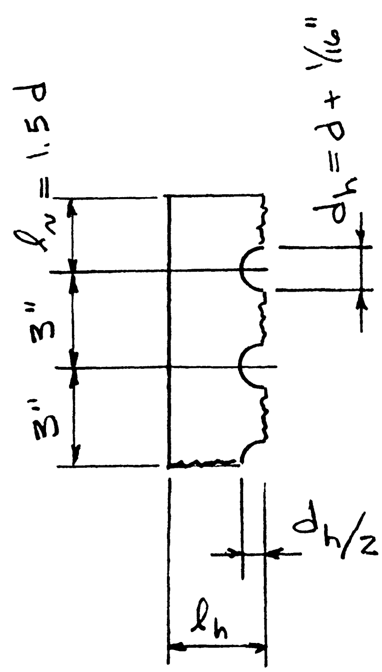

Figure 2

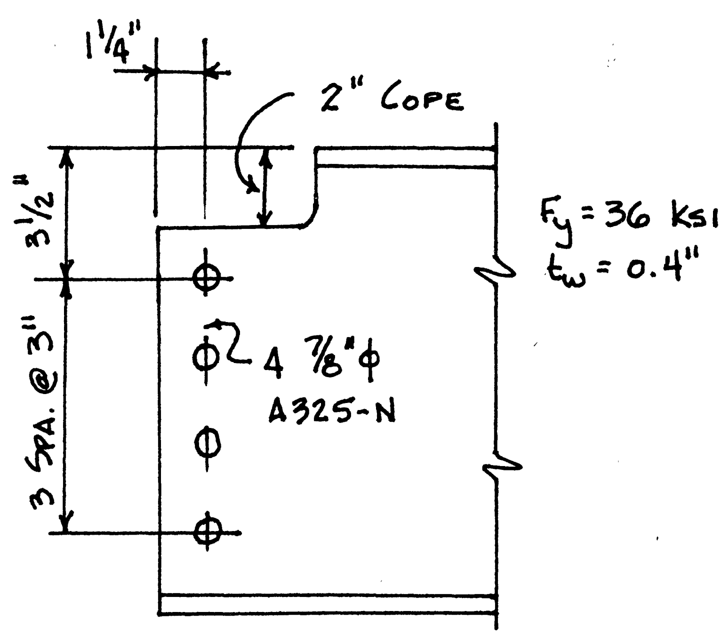

Figure 3

based on the assumption of fracture of one plane plus yielding on the perpendicular plane. Since the ratio of shear fracture strength to tension fracture strength is the same for ASD as it is for LRFD, i.e.

$$\frac{\phi\,(0.6F_u A_{ns})}{\phi F_u A_{nt}} = \frac{0.3F_u A_{nw}}{0.5F_u A_{nt}} = 0.6\left(\frac{A_{ns}}{A_{nt}}\right)$$

Table A is applicable to ASD as well as LRFD.

Table B provides values of C_1 and C_2 for checking for block shear when using ASD.

REFERENCES

Manual of Steel Construction—Load and Resistance Factor Design, First Revised Edition, American Institute of Steel Construction, Inc., Chicago, 1991.

Manual of Steel Construction—Allowable Stress Design, Ninth Edition, American Institute of Steel Construction, Inc., 1989.

Table B.
ASD
Shear Fracture, Tension Yield
F_y = 36 F_u = 58

	C_1												
	l_h												
l_v	**1**	**1⅛**	**1¼**	**1⅜**	**1½**	**1⅝**	**1¾**	**1⅞**	**2**	**2¼**	**2½**	**2¾**	**3**
1¼	43.4	46.1	48.8	51.5	54.2	56.9	59.6	62.3	65.0	70.4	75.8	81.2	86.6
1⅜	45.5	48.2	50.9	53.6	56.3	59.0	61.7	64.4	67.1	72.5	77.9	83.3	88.7
1½	47.7	50.4	53.1	55.8	58.5	61.2	63.9	66.6	69.3	74.7	80.1	85.5	90.9
1⅝	49.9	52.6	55.3	58.0	60.7	63.4	66.1	68.8	71.5	76.9	82.3	87.7	93.1
1¾	52.1	54.8	57.5	60.2	62.9	65.6	68.3	71.0	73.7	79.1	84.5	89.9	95.3
1⅞	54.2	56.9	59.6	62.3	65.0	67.7	70.4	73.1	75.8	81.2	86.6	92.0	97.4
2	56.4	59.1	61.8	64.5	67.2	69.9	72.6	75.3	78.0	83.4	88.8	94.2	99.6
2¼	60.8	63.5	66.2	68.9	71.6	74.3	77.0	79.7	82.4	87.8	93.2	98.6	104.0
2½	65.1	67.8	70.5	73.2	75.9	78.6	81.3	84.0	86.7	92.1	97.5	103.0	108.0
2¾	69.5	72.2	74.9	77.6	80.3	83.0	85.7	88.4	91.1	96.5	102.0	107.0	113.0
3	73.8	76.5	79.2	81.9	84.6	87.3	90.0	92.7	95.4	101.0	106.0	112.0	117.0

C_2			
	Bolt Diameter		
n	¾	⅞	1
2	32.6	29.4	26.1
3	71.8	66.3	60.9
4	111.0	103.0	95.7
5	150.0	140.0	131.0
6	189.0	177.0	165.0
7	228.0	214.0	200.0
8	268.0	251.0	235.0
9	307.0	288.0	270.0
10	346.0	325.0	305.0

$R_{BS} = (C_1 + C_2)t$

Table B.
ASD
Tension Fracture, Shear Yield
F_y = 36 F_u = 58

	C_1												
	l_h												
l_v	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2¼	2½	2¾	3
1¼	47.0	50.6	54.2	57.9	61.5	65.1	68.7	72.4	76.0	83.2	90.5	97.7	105.0
1⅜	48.8	52.4	56.0	59.7	63.3	66.9	70.6	74.2	77.8	85.0	92.3	99.6	107.0
1½	50.6	54.2	57.8	61.5	65.1	68.7	72.3	76.0	79.6	86.8	94.1	101.0	109.0
1⅝	52.4	56.0	59.6	63.3	66.9	70.5	74.1	77.8	81.4	88.6	95.9	103.0	110.0
1¾	54.2	57.8	61.4	65.1	68.7	72.3	75.9	79.6	83.2	90.4	97.7	105.0	112.0
1⅞	56.0	59.6	63.2	66.9	70.5	74.1	77.7	81.4	85.0	92.2	99.5	107.0	114.0
2	57.8	61.4	65.0	68.7	72.3	75.9	79.5	83.2	86.8	94.0	101.0	109.0	116.0
2¼	61.4	65.0	68.6	72.3	75.9	79.5	83.1	86.8	90.4	97.6	105.0	112.0	119.0
2½	65.0	68.6	72.2	75.9	79.5	83.1	86.7	90.4	94.0	101.0	108.0	116.0	123.0
2¾	68.6	72.2	75.8	79.5	83.1	86.7	90.3	94.0	97.6	105.0	112.0	119.0	127.0
3	72.2	75.8	79.4	83.1	86.7	90.3	93.9	97.6	101.0	108.0	116.0	123.0	130.0

	C_2		
	Bolt Diameter		
n	¾	⅞	1
2	32.3	30.5	28.7
3	75.6	73.7	71.9
4	119.0	117.0	115.0
5	162.0	160.0	158.0
6	205.0	203.0	202.0
7	248.0	247.0	245.0
8	292.0	290.0	288.0
9	335.0	333.0	331.0
10	378.0	376.0	374.0

$$R_{BS} = (C_1 + C_2)t$$

Table B.
ASD
Shear Fracture, Tension Yield
F_y = 50 F_u = 65

	C_1												
	l_h												
l_v	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2¼	2½	2¾	3
1¼	54.4	58.1	61.9	65.6	69.4	73.1	76.9	80.6	84.4	91.9	99.4	107.0	114.0
1⅜	56.8	60.6	64.3	68.1	71.8	75.6	79.3	83.1	86.8	94.3	102.0	109.0	117.0
1½	59.3	63.0	66.8	70.5	74.3	78.0	81.8	85.5	89.3	96.8	104.0	112.0	119.0
1⅝	61.7	65.4	69.2	72.9	76.7	80.4	84.2	87.9	91.7	99.2	107.0	114.0	122.0
1¾	64.1	67.9	71.6	75.4	79.1	82.9	86.6	90.4	94.1	102.0	109.0	117.0	124.0
1⅞	66.6	70.3	74.1	77.8	81.6	85.3	89.1	92.8	96.6	104.0	112.0	119.0	127.0
2	69.0	72.8	76.5	80.3	84.0	87.8	91.5	95.3	99.0	107.0	114.0	122.0	129.0
2¼	73.9	77.6	81.4	85.1	88.9	92.6	96.4	100.0	104.0	111.0	119.0	126.0	134.0
2½	78.8	82.5	86.3	90.0	93.8	97.5	101.0	105.0	109.0	116.0	124.0	131.0	139.0
2¾	83.6	87.4	91.1	94.9	98.6	102.0	106.0	110.0	114.0	121.0	129.0	136.0	144.0
3	88.5	92.3	96.0	99.8	104.0	107.0	111.0	115.0	119.0	126.0	134.0	141.0	149.0

C_2			
	Bolt Diameter		
n	¾	⅞	1
2	36.6	32.9	29.3
3	80.4	74.3	68.3
4	124.0	116.0	107.0
5	168.0	157.0	146.0
6	212.0	199.0	185.0
7	256.0	240.0	224.0
8	300.0	282.0	263.0
9	344.0	323.0	302.0
10	388.0	364.0	341.0

$$R_{BS} = (C_1 + C_2)t$$

Table B.
ASD
Tension Fracture, Shear Yield
F_y = 50 F_u = 65

	C_1												
	l_h												
l_v	1	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2	2¼	2½	2¾	3
1¼	57.5	61.1	65.6	69.7	73.7	77.8	81.9	85.9	90.0	98.1	106.0	114.0	122.0
1⅜	60.0	64.1	68.1	72.2	76.2	80.3	84.4	88.4	92.5	101.0	109.0	117.0	125.0
1½	62.5	66.6	70.6	74.7	78.8	82.8	86.9	90.9	95.0	103.0	111.0	119.0	127.0
1⅝	65.0	69.1	73.1	77.2	81.2	85.3	89.4	93.4	97.5	106.0	114.0	122.0	130.0
1¾	67.5	71.6	75.6	79.7	83.7	87.8	91.9	95.9	100.0	108.0	116.0	124.0	132.0
1⅞	70.0	74.1	78.1	82.2	86.2	90.3	94.4	98.4	102.0	111.0	119.0	127.0	135.0
2	72.5	76.6	80.6	84.7	88.7	92.8	96.9	101.0	105.0	113.0	121.0	129.0	137.0
2¼	77.5	81.6	85.6	89.7	93.7	97.8	102.0	106.0	110.0	118.0	126.0	134.0	142.0
2½	82.5	86.6	90.6	94.7	98.7	103.0	107.0	111.0	115.0	123.0	131.0	139.0	147.0
2¾	87.5	91.6	95.6	99.7	104.0	108.0	112.0	116.0	120.0	128.0	136.0	144.0	152.0
3	92.5	96.6	101.0	105	109.0	113.0	117.0	121.0	125.0	133.0	141.0	149.0	157.0

C_2			
	Bolt Diameter		
n	¾	⅞	1
2	47.8	45.8	43.8
3	108.0	106.0	104.0
4	168.0	166.0	164.0
5	228.0	226.0	224.0
6	288.0	286.0	284.0
7	348.0	346.0	344.0
8	408.0	406.0	404.0
9	468.0	466.0	464.0
10	528.0	526.0	524.0

$$R_{BS} = (C_1 + C_2)t$$