Practical Determination of Block Shear

Capacity in Structural Steel Tension Members

by

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Submitted in Partial Fulfillment of the Requirements

for the Degree of

Master of Science in Engineering

in the

Civil Engineering

Program

7/31/91

Advisor Date

August 5, 1991

Dean of the Graduate School Date

YOUNGSTOWN STATE UNIVERSITY

JULY, 1991

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ACKNOWLEDGEMENT

I would like to thank my advisor, Dr. J.D. Bakos, Jr., Chair of the Civil Engineering Department at Youngstown State University, for his guidance and helpful comments throughout the completion of this paper.

In addition, I would also like to thank the faculty and staff of the Department of Civil Engineering at Youngstown State University for their help and the use of their computer facilities.

This paper could not have been completed without the help and guidance of the above-mentioned people.

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ABSTRACT

The design approach for structural steel tension members consists of determining the controlling mode of failure to include consideration of: yielding of the gross member area, fracture of the effective net member area, and block shear failure.

The calculations for determining the block shear capacity of a tension member can be complex and time-consuming. Design aids to determine the block shear capacity of various tension members have been developed, and are presented. Many examples are used to demonstrate the ease of use and the accuracy of the developed design aids.

These design aids provide an accurate and time-saving method to determine the block shear capacity of structural steel tension members.

NOMENCLATURE

AISC	American Institute of Steel Construction
ASD	Allowable Stress Design
LLV	Long leg vertical
LRFD	Load and Resistance Factor Design
A_{tg}	Gross area of tension plane, sq. inch
A_{tn}	Net area of tension plane, sq. inch
A_{vg}	Gross area of shear plane, sq. inch
A_{vn}	Net area of shear plane, sq. inch
C, C_1, C_2, etc.	Block shear coefficient, kips/inch
F_u	Specified minimum tensile stress of steel, ksi
F_y	Specified minimum yield stress of steel, ksi
L_h	Distance from member edge to center of bolt hole, inch
L_1, L_2	Weld length parallel to load, inch
L_3	Weld length perpendicular to load, inch
P_{BS}, P_{BS1}, P_{BS2}	Block shear capacities, kips
b_f	Flange width, inch
d_b	Bolt diameter, inch
l_h	Distance from center of hole to beam (plate) end, inch. From AISC Specifications, Table 1-G

NOMENCLATURE
(Continued)

l_v	Distance from center of hole to edge of web (plate), inch. Fraom AISC Specifications, Table 1-G
m	Number of bolts perpendicular to load
n	Number of bolts parallel to load
t	Thickness of plate or member, inch
t_w	Web thickness, inch
ϕ	LRFD resistance factor; ϕ=0.75 for block shear

CHAPTER 1

INTRODUCTION

Classically, the method used to determine the size of a structural steel tension member consisted of determining the required area, then selecting a shape whose area was larger than that required. The required area was based on preventing yielding of the gross member area, or fracture across the effective net member area. These cases, however, are not the only modes of failure which need to be considered by the structural designer. It is important for the designer to compare the block shear mode of failure to the yielding and fracture cases in order to determine the critical mode of failure for the member.

The concept of block shear capacity is relatively easy to visualize. However, the equations which are used to determine the block shear capacity are often complex and lengthy. When analyzing a tension member, these equations are generally checked once since all of the controlling parameters are known. When designing a tension member, however, these equations must often be checked several times for differing conditions. This can become a very tedious and time-consuming effort.

The block shear capacity of structural steel tension members is based solely on the member geometry to include the connection details, and the strength properties of the material. Because the parameters involved are somewhat limited, block shear design aids can be easily developed for standard connections and materials. Block shear design aids are developed and presented in tabular form for welded members, bolted plates, and bolted angles. These design aids are based on both the AISC ASD Specification[2]* and the AISC LRFD Specification.[3] Numerous examples are used to demonstrate the use of the design aids as well as to verify their accuracy.

The design aids developed and presented in this paper provide the designer with a quick and accurate tool to determine the block shear capacity of a wide range of structural steel tension members.

* Numbers in parenthesis indicate the reference cited.

CHAPTER 2

THEORY AND DEVELOPMENT OF DESIGN AIDS

A significant type of failure in bolted beam connections, called a "block shear" failure, was observed and reported by Birkemoe and Gilmor.[4] This reported failure occurred in a coped-beam end connection, which is shown in Figure 2.1. The block shear failure occurred when the tension plane, which passes horizontally through the center of the bottom bolt, fractured. Following this fracture, the perpendicular plane, or the shear plane yielded along the vertical bolt line.

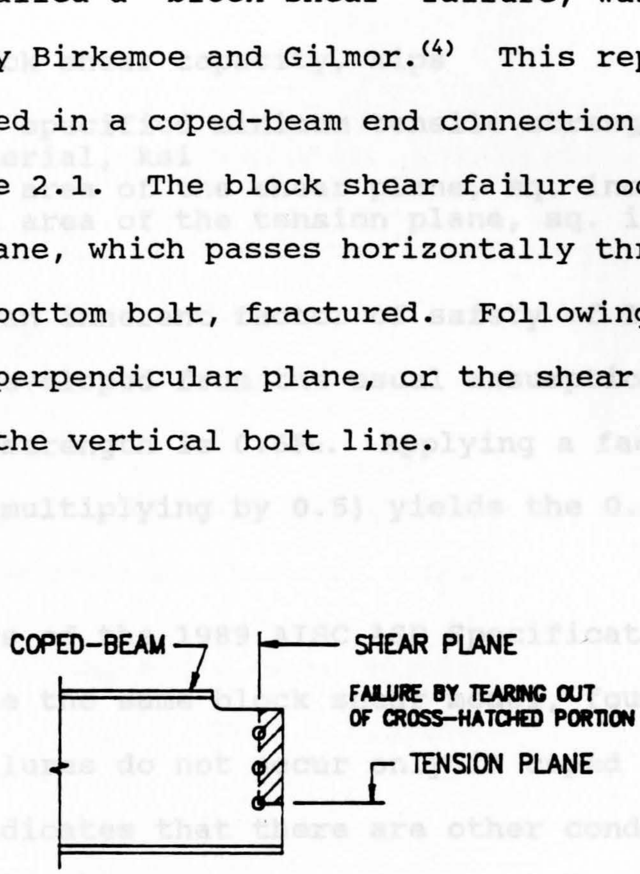


Figure 2.1

In order to anticipate this failure mode during the design process, the American Institute of Steel Construction adopted a block shear model which suggests simultaneous fracture along both the shear and tension planes. The model was incorporated in the 1978 AISC Specification[1] as follows:

$$P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn} \quad (1)$$

where

P_{BS} = block shear capacity, kips
F_u = the specified minimum tensile strength of the material, ksi
A_{vn} = net area of the shear plane, sq. inch
A_{tn} = net area of the tension plane, sq. inch

This model has an inherent factor of safety of 2.0.[6] The shear term is developed from the usual assumption that the ultimate shear strength is $0.6F_u$. Applying a factor of safety of 2.0 (multiplying by 0.5) yields the 0.3 factor in Equation (1).

The authors of the 1989 AISC ASD Specification,[2] which continues to use the same block shear model, found that block shear failures do not occur only in coped beam ends. The research indicates that there are other conditions in which block shear failure may control, and thus, should be verified. These are shown in Figure 2.2. All of these other conditions can be approached in a manner similar to that used for the coped-beam condition, i.e., by using Equation (1).

A more conservative model used to determine block shear strength was adopted by the 1989 AISC LRFD Specification.[3]

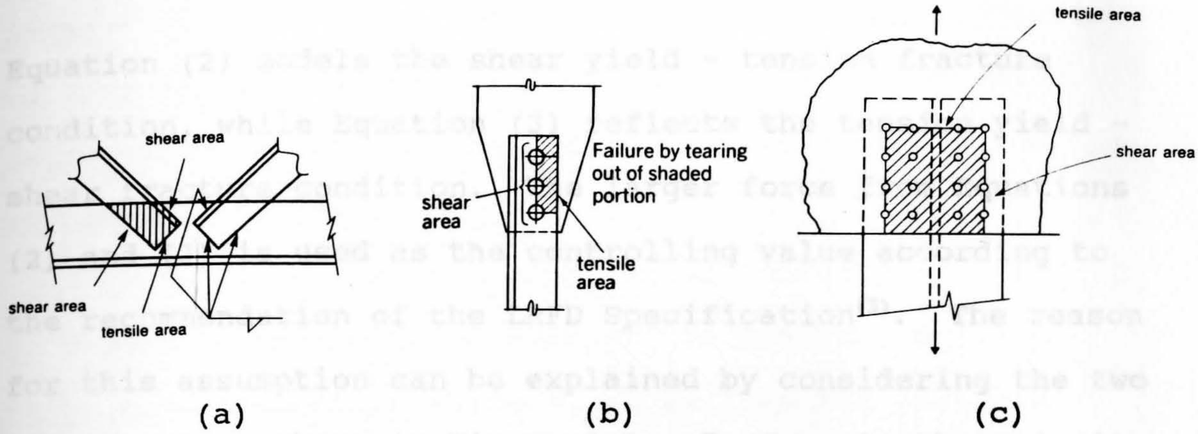


Figure 2.2: (a) Welded connections, (b) Bolted angles, (c) Bolted plates. (From Ref. 2)

Unlike the ASD model, which assumes simultaneous fracture of the shear and tension planes, the LRFD model assumes that one plane fractures, followed by yielding along the perpendicular plane.

The LRFD Specification[3] provides the following two equations to determine block shear capacity:

$$P_{BS} = \phi[0.6FyAvg + FuAtn] \quad (2)$$

$$P_{BS} = \phi[FyAtg + 0.6FuAvn] \quad (3)$$

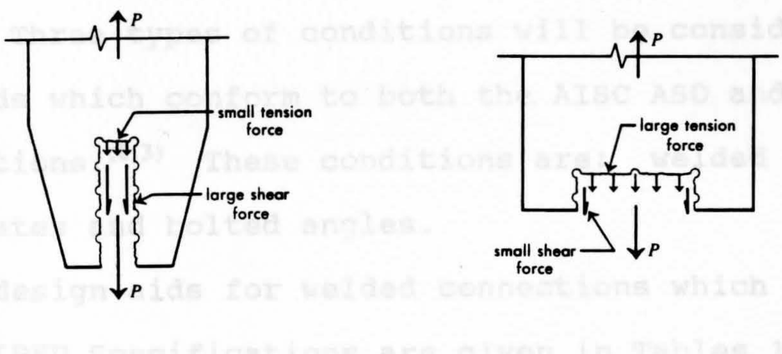
where

P_{BS} = block shear capacity, kips

Fu = minimum specified tensile strength of steel, ksi
Fy = minimum specified yield strength of steel, ksi
Atg = gross area of tension plane, sq. inch
Atn = net area of tension plane, sq. inch
Avg = gross area of shear plane, sq. inch
Avn = net area of shear plane, sq. inch
ϕ = LRFD resistance factor; ϕ=0.75 for block shear

Each of these equations represents a different model;

Equation (2) models the shear yield - tension fracture condition, while Equation (3) reflects the tension yield - shear fracture condition. The larger force from Equations (2) and (3) is used as the controlling value according to the recommendation of the LRFD Specification[3]. The reason for this assumption can be explained by considering the two extreme cases shown in Figure 2.3. In Case 1, the majority of the applied load, P, is resisted by the larger, shear area.



(a) (b)

Figure 2.3: (a) Case 1, (b) Case 2

Because of this, shear fracture, and not shear yielding controls in this case. In Case 2, however, the majority of the applied load is resisted by the tension area, and thus, tension fracture should control here. Because the block shear phenomenon is fundamentally a tearing or fracture state of failure, the equation with the largest fracture term should be used. It is often difficult to determine by inspection which mode is larger and so it seems appropriate to evaluate **both** equations, and use the larger force. Unfortunately, this can be a time-consuming effort for the structural designer.

It is clear that the block shear capacity of a member is dependent on the geometries of the member and its respective connection pattern, as well as the strength parameter of the material used. The main intent of this paper is to identify and examine the more commonly used connections and to develop easy to use design aids that will make block shear capacity calculations easier and faster to preform. Three types of conditions will be considered for design aids which conform to both the AISC ASD and LRFD Specifications.[2,3] These conditions are: welded plates, bolted plates and bolted angles.

The design aids for welded connections which conform to the AISC LRFD Specifications are given in Tables 1 and 2. Each of these tables have two parts; one is for the shear yield - tension fracture condition and the other is for the tension yield - shear fracture condition. The shear yield - tension fracture tables for the welded connections were developed as follows:

$$P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$$
$$= 0.75[0.6F_y(\text{weld lengths})t + F_u(\text{weld length})t]$$
$$= 0.75[0.6F_y(L_1 + L_2) + F_u(L_3)]t$$

so, $P_{BS} = Ct$

where C is the block shear coefficient obtained from the tables, and t is the thickness of the plate, and L_1, L_2, and L_3 are shown in Figure 2.4.

The tables for tension yield - shear fracture are developed in a similar fashion:

$$P_{BS} = \phi[F_yA_{tg} + 0.6F_uA_{vn}]$$
$$= 0.75[F_y(\text{weld length})t + 0.6F_u(\text{weld lengths})t]$$
$$= 0.75[F_y(L_3) + 0.6F_u(L_1 + L_2)]t$$

so, $P_{BS} = Ct$

where C is the block shear coefficient obtained from the tables, and t is the thickness of the plate.

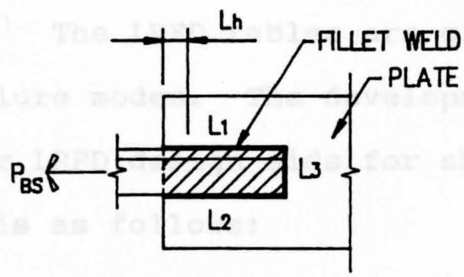


Figure 2.4

The design aids for welded connections conforming to the ASD Specification are given in Tables 3 and 4. Figure 2.4 applies to these tables as well. These design aids are developed as follows:

$$P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn}$$
$$= 0.3F_u(\text{weld lengths})t + 0.5F_u(\text{weld length})t$$
$$= [0.3F_u(L_1 + L_2) + 0.5F_u(L_3)]t$$

so, $P_{BS} = Ct$

where C is the block shear coefficient obtained from the tables, and t is the thickness of the plate, and L_1, L_2, and L_3 are again shown in Figure 2.4.

The tables for welded connections are set-up such that $L_1 + L_2$ are tabulated vertically, ranging from 2" to 30". The L_3 values are listed horizontally, and range from 2" to 12". The value for C is obtained by intersecting the appropriate row and column. It is also possible to interpolate between the values on these tables.

Tables 5 through 8 are the design aids for bolted plates. Figure 2.5 shows the appropriate parameters for this condition. Again, design aids for this condition were prepared to comply with both the ASD and LRFD Specifications.[2,3] The LRFD tables are given for both of the potential failure modes. The development of the bolted plate, block shear LRFD design aids for shear yield and tension fracture is as follows:

$$P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$$
$$= \phi[0.6F_y(2 \times \text{shear length})t + F_u(\text{tension length-bolt hole diameter})t]$$

so, $$P_{BS} = (C_1 + C_2)t$$

where C_1 and C_2 are block shear coefficients obtained from the table, and t is the thickness of the plate, m is the number of bolts perpendicular to the applied load, and n is the number of bolts parallel to the applied load.

The development of the block shear LRFD design aids for the tension yield - shear fracture condition is similar to that of the shear yield - tension fracture condition. The tables are set-up for connections ranging from 2 bolts by 2 bolts up to 10 bolts by 10 bolts. A variety of end

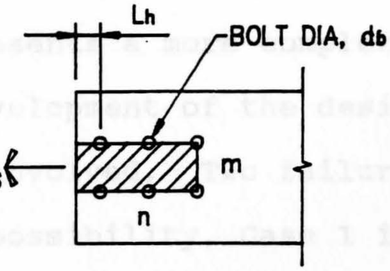


Figure 2.5

distances, L_h, (See Figure 2.5) are also given. These tables are valid for 3/4", 7/8", and 1" diameter bolts, with bolt spacing set at a standard three inches.

Referring again to Figure 2.5, the development of the ASD bolted plate block shear design aid is:

$$P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn}$$

$$= (0.3F_u(\text{shear length - bolt hole diameters} + 0.5F_u(\text{tension length - bolt hole diameters})]t$$

so, $$P_{BS} = (C_1 + C_2)t$$

The ASD tables are valid for the same bolt hole and edge distance conditions as in the LRFD tables. In all cases, tables are provided for the two most common grades of steel, i.e., F_y=36 ksi, and F_y=50 ksi.

The block shear capacity for bolted angles with a single row of bolts can be found using the block shear design aids found in Table 1-G of both the AISC ASD and LRFD Specifications.[2,3]

The calculations required to determine the block shear strength of angles which are bolted with two rows of staggered bolts represents a more complex problem. Consequently, the development of the design aids for this case is also rather involved. Two failure modes need to be checked. The first possibility, Case 1 in Figure 2.6, occurs when the failure is along the outermost bolt lines. The second possibility occurs when one of the bolts is left out, as in Case 2 in Figure 2.6. These two cases are common to both the LRFD and the ASD methods.

The tables for bolted angles under the LRFD have coefficients which consider both the shear yield - tension fracture and the tension yield - shear fracture cases.

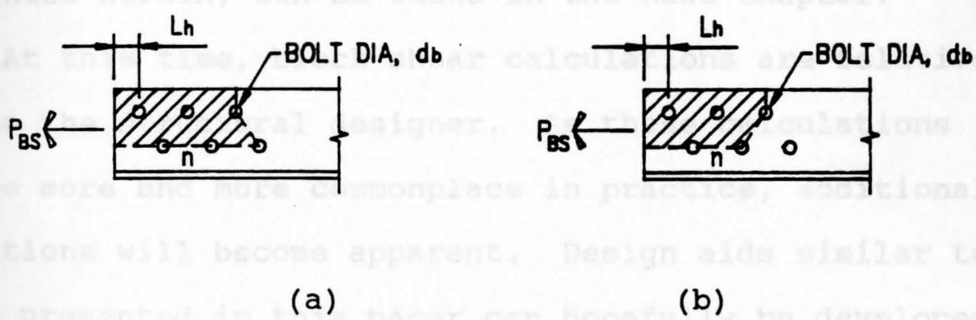


Figure 2.6: (a) Case 1, (b) Case 2

Unfortunately, for LRFD, four capacities need to be found, then compared. In this case, the controlling capacity is the maximum value from Case 1 or Case 2. Another way to look at this is to pick the "minimum maximum" of the four capacities.

These design aids were developed using the same equations described earlier. The parameters used here, with regards to bolt size and spacing, are the same as used for the bolted plate. When determining the effective net tension area, the use of the traditional $s^2/4g$ term is appropriate to account for the diagonal failure line.

In the second instance, the load is transmitted through a fewer number of bolts. This fact dictates that a multiplying factor must be used.

$$[(2n-1)/2n]\ P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$$

so, $$P_{BS} = [2n/(2n-1)]\ \phi[0.6F_yA_{vg} + F_uA_{tn}]$$

The C_5 factor as shown in the tables is this multiplier.

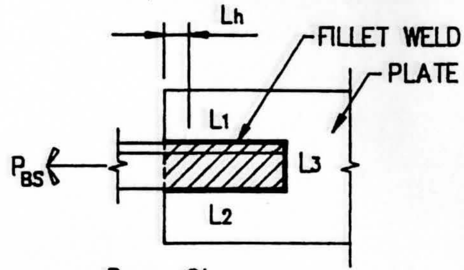
Numerous examples, detailing the use of the design aids presented herein, can be found in the next chapter.

At this time, block shear calculations are relatively new to the structural designer. As these calculations become more and more commonplace in practice, additional conditions will become apparent. Design aids similar to those presented in this paper can hopefully be developed to accommodate these new conditions.

TABLE 1a
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

WELDED CONNECTIONS

L R F D
SHEAR YIELD – TENSION FRACTURE
Fy=36 KSI



$P_{BS} = Ct$

t = PLATE THICKNESS
L1, L2, L3 = WELD LENGTHS

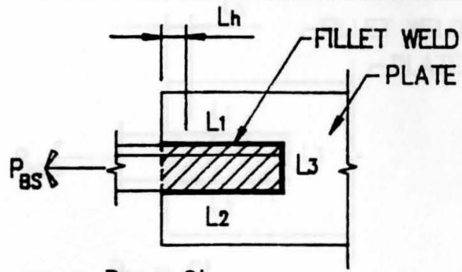
COEFFICIENT, C

WELD LENGTHS L1 + L2 (INCHES)	TRANSVERSE DISTANCE BETWEEN WELDS, L3 (INCHES)										
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
4.0	151.8	195.3	238.8	282.3	325.8	369.3	412.8	456.3	499.8	543.3	586.8
5.0	168.0	211.3	255.0	298.5	342.0	385.5	429.0	472.5	516.0	559.5	603.0
6.0	184.2	227.7	271.2	314.7	358.2	401.7	445.2	488.7	532.2	575.7	619.2
7.0	200.4	243.9	287.4	330.9	374.4	417.9	461.4	504.9	548.4	591.9	635.4
8.0	216.6	260.1	303.6	347.1	390.6	434.1	477.6	521.1	564.6	608.1	651.6
9.0	232.8	276.3	319.8	363.3	406.8	450.3	493.8	537.3	580.8	624.3	667.8
10.0	249.0	292.5	336.0	379.5	423.0	466.5	510.0	553.5	597.0	640.5	684.0
11.0	265.2	308.7	352.2	395.7	439.2	482.7	526.2	569.7	613.2	656.7	700.2
12.0	281.4	324.9	368.4	411.9	455.4	498.9	542.4	585.9	629.4	672.9	716.4
13.0	297.6	341.1	384.6	428.1	471.6	515.1	558.6	602.1	645.6	689.1	732.6
14.0	313.8	357.3	400.8	444.3	487.8	531.3	574.8	618.3	661.8	705.3	748.8
15.0	330.0	373.5	417.0	460.5	504.0	547.5	591.0	634.5	678.0	721.5	765.0
16.0	346.2	389.7	433.2	476.7	520.2	563.7	607.2	650.7	694.2	737.7	781.2
17.0	362.4	405.9	449.4	492.9	536.4	579.9	623.4	666.9	710.4	753.9	797.4
18.0	378.6	422.1	465.6	509.1	552.6	596.1	639.6	683.1	726.6	770.1	813.6
19.0	394.8	438.3	481.8	525.3	568.8	612.3	655.8	699.3	742.8	786.3	829.8
20.0	411.0	454.5	498.0	541.5	585.0	628.5	672.0	715.5	759.0	802.5	846.0
21.0	427.3	470.7	514.2	557.7	601.2	644.7	688.2	731.7	775.2	818.7	862.2
22.0	443.4	486.9	530.4	573.9	617.4	660.9	704.4	747.9	791.4	834.9	878.4
23.0	459.6	503.1	546.6	590.1	633.6	677.1	720.6	764.1	807.6	851.1	894.6
24.0	475.8	519.3	562.8	606.3	649.8	693.3	736.8	780.3	823.8	867.3	910.8
25.0	492.0	535.5	579.0	622.5	666.0	709.5	753.0	796.5	840.0	883.5	927.0
26.0	508.2	551.7	595.2	638.7	682.2	725.7	769.2	812.7	856.2	899.7	943.2
27.0	524.4	567.9	611.4	654.9	698.4	741.9	785.4	828.9	872.4	915.9	959.4
28.0	540.6	584.1	627.6	671.1	714.6	758.1	801.6	845.1	888.6	932.1	975.6
29.0	556.8	600.3	643.8	687.3	730.8	744.3	817.8	961.3	904.8	948.3	991.8
30.0	573.0	616.5	660.0	703.5	747.0	790.5	834.0	877.5	921.0	964.5	1008.0

TABLE 1b
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

WELDED CONNECTIONS

L R F D
TENSION YIELD – SHEAR FRACTURE
Fy=36 KSI



$P_{BS} = Ct$

t = PLATE THICKNESS
L_1, L_2, L_3 = WELD LENGTHS

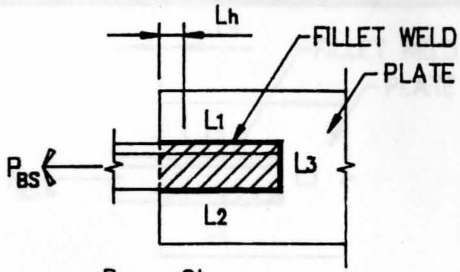
COEFFICIENT, C

WELD LENGTHS $L_1 + L_2$ (INCHES)	TRANSVERSE DISTANCE BETWEEN WELDS, L_3 (INCHES)										
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
4.0	158.4	185.4	212.4	239.4	266.4	293.4	320.4	347.4	374.4	401.4	428.4
5.0	184.5	211.5	238.5	265.5	292.5	319.5	346.5	373.5	400.5	427.5	454.5
6.0	210.6	237.6	264.6	291.6	318.6	345.6	372.6	399.6	426.6	453.6	480.6
7.0	236.7	263.7	290.7	317.7	344.7	371.7	398.7	425.7	452.7	479.7	506.7
8.0	262.8	289.8	316.8	343.8	370.8	397.8	424.8	451.8	478.8	505.8	532.8
9.0	288.9	315.9	342.9	369.9	396.9	423.9	450.9	477.9	504.9	531.9	558.9
10.0	315.0	342.0	369.0	396.0	423.0	450.0	477.0	504.0	531.0	558.0	585.0
11.0	341.1	368.1	395.1	422.1	449.1	476.1	503.1	530.1	557.1	584.1	611.1
12.0	367.2	394.2	421.2	448.2	475.2	502.2	529.2	556.2	583.2	610.2	637.2
13.0	393.3	420.3	447.3	474.3	501.3	528.3	555.3	582.3	609.3	636.3	663.3
14.0	419.4	446.4	473.4	500.4	527.4	554.4	581.4	608.4	635.4	662.4	689.4
15.0	445.5	472.5	499.5	526.5	553.5	580.5	607.5	634.5	661.5	688.5	715.5
16.0	471.6	498.6	525.6	552.6	579.6	606.6	633.6	660.6	687.6	714.6	741.6
17.0	497.7	524.7	551.7	578.7	605.7	632.7	659.7	686.7	713.7	740.7	767.7
18.0	523.8	550.8	577.8	604.8	631.8	658.8	685.8	712.8	739.8	766.8	793.8
19.0	549.9	576.9	603.9	630.9	657.9	684.9	711.9	738.9	765.9	792.9	819.9
20.0	576.0	603.0	630.0	657.0	684.0	711.0	738.0	765.0	792.0	819.0	846.0
21.0	602.1	629.1	656.1	683.1	710.1	737.1	764.1	791.1	818.1	845.1	872.1
22.0	628.2	655.2	682.2	709.2	736.2	763.2	790.2	817.2	844.2	871.2	898.2
23.0	654.3	681.3	708.3	735.3	762.3	789.3	816.3	843.3	870.3	897.3	924.3
24.0	680.4	707.4	734.4	761.4	788.4	815.4	842.4	869.4	896.4	923.4	950.4
25.0	706.5	733.5	760.5	787.5	814.5	841.5	868.5	895.5	922.5	949.5	976.5
26.0	732.6	759.6	786.6	813.6	840.6	867.6	894.6	921.6	948.6	975.6	1002.6
27.0	758.7	785.7	812.7	839.7	866.7	893.7	920.7	947.7	974.7	1001.7	1028.7
28.0	784.8	811.8	838.8	865.8	892.8	919.8	946.8	973.8	1000.8	1027.8	1054.8
29.0	810.9	837.9	864.9	891.9	918.9	945.9	972.9	999.9	1026.9	1053.9	1080.9
30.0	837.0	864.0	891.0	918.0	945.0	972.0	999.0	1026.0	1053.0	1080.0	1107.0

TABLE 2a
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

WELDED CONNECTIONS

L R F D
SHEAR YIELD – TENSION FRACTURE
Fy=50 KSI



$P_{BS} = Ct$

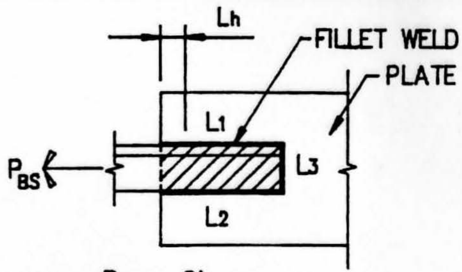
t = PLATE THICKNESS
L_1, L_2, L_3 = WELD LENGTHS

WELD LENGTHS $L_1 + L_2$ (INCHES)	COEFFICIENT, C — TRANSVERSE DISTANCE BETWEEN WELDS, L_3 (INCHES)										
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
4.0	187.5	236.3	285.0	333.8	382.5	431.3	480.0	528.8	577.5	626.3	675.0
5.0	210.0	258.8	307.5	356.3	405.0	453.8	502.5	551.3	600.0	648.8	697.5
6.0	232.5	281.3	330.0	378.8	427.5	476.3	525.0	573.8	622.5	671.3	720.0
7.0	255.0	303.8	352.5	401.3	450.0	498.8	547.5	596.3	645.0	693.8	742.5
8.0	277.5	326.3	375.0	423.8	472.5	521.3	570.0	618.8	667.5	716.3	765.0
9.0	300.0	348.8	397.5	446.3	495.0	543.8	592.5	641.3	690.0	738.8	787.5
10.0	322.5	371.3	420.0	468.8	517.5	566.3	615.0	663.8	712.5	761.3	810.0
11.0	345.0	393.8	442.5	491.3	540.0	588.8	637.5	686.3	735.0	783.8	832.5
12.0	367.5	416.3	465.0	513.8	562.5	611.3	660.0	708.8	757.5	806.3	855.0
13.0	390.0	438.8	487.5	536.3	585.0	633.8	682.5	731.3	780.0	828.8	877.5
14.0	412.5	461.3	510.0	558.8	607.5	656.3	705.0	753.8	802.5	851.3	900.0
15.0	435.0	483.8	532.5	581.3	630.0	678.8	727.5	776.3	825.0	873.8	922.5
16.0	457.5	506.3	555.0	603.8	652.5	701.3	750.0	798.8	847.5	896.3	945.0
17.0	480.0	528.8	577.5	626.3	675.0	723.8	772.5	821.3	870.0	918.8	967.5
18.0	502.5	551.3	600.0	648.8	697.5	746.3	795.0	843.8	892.5	941.3	990.0
19.0	525.0	573.8	622.5	671.3	720.0	768.8	817.5	866.3	915.0	963.8	1012.5
20.0	547.5	596.3	645.0	693.8	742.5	791.3	840.0	888.8	937.5	986.3	1035.0
21.0	570.0	618.8	667.5	716.3	765.0	813.8	862.5	911.3	960.0	1008.8	1057.5
22.0	592.5	641.3	690.0	738.8	787.5	836.3	885.0	933.8	982.5	1031.3	1080.0
23.0	615.0	663.8	712.5	761.3	810.0	858.8	907.5	956.3	1005.0	1053.8	1102.5
24.0	637.5	686.3	735.0	783.8	832.5	881.3	930.0	978.8	1027.5	1076.3	1125.0
25.0	660.0	708.8	757.5	806.3	855.0	903.8	952.5	1001.3	1050.0	1098.8	1147.5
26.0	682.5	731.3	780.0	828.8	877.5	926.3	975.0	1023.8	1072.5	1121.3	1170.0
27.0	705.0	753.8	802.5	851.3	900.0	948.8	997.5	1046.3	1095.0	1143.8	1192.5
28.0	727.5	776.3	825.0	873.8	922.5	971.3	1020.0	1068.8	1117.5	1166.3	1215.0
29.0	750.0	798.8	847.5	896.3	945.0	993.8	1042.5	1091.3	1140.0	1188.8	1237.5
30.0	772.5	821.3	870.0	918.8	967.5	1016.3	1065.0	1113.8	1162.5	1211.3	1260.0

TABLE 2b
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

WELDED CONNECTIONS

L R F D
TENSION YIELD – SHEAR FRACTURE
Fy=50 KSI



$P_{BS} = Ct$

t = PLATE THICKNESS
L1, L2, L3 = WELD LENGTHS

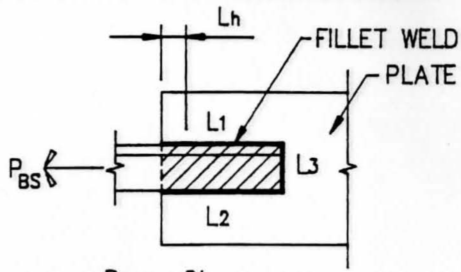
COEFFICIENT, C

WELD LENGTHS L1 + L2 (INCHES)	TRANSVERSE DISTANCE BETWEEN WELDS, L3 (INCHES)										
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
4.0	192.0	229.5	267.0	304.5	342.0	379.5	417.0	454.5	492.0	529.5	567.0
5.0	221.3	258.8	296.3	333.8	371.3	408.8	446.3	483.8	521.3	558.8	596.3
6.0	250.5	288.0	325.5	363.0	400.5	438.0	475.5	513.0	550.5	588.0	625.5
7.0	279.8	317.3	354.8	392.3	429.8	467.3	504.8	542.3	579.8	617.3	654.8
8.0	309.0	346.5	384.0	421.5	459.0	496.5	534.0	571.5	609.0	646.5	684.0
9.0	338.3	375.8	413.3	450.8	488.3	525.8	563.3	600.8	638.3	675.8	713.3
10.0	367.5	405.0	442.5	480.0	517.5	555.0	592.5	630.0	667.5	705.0	742.5
11.0	396.8	434.3	471.8	509.3	546.8	584.3	621.8	659.3	696.8	734.3	771.8
12.0	426.0	463.5	501.0	538.5	576.0	613.5	651.0	688.5	726.0	763.5	801.0
13.0	455.3	492.8	530.3	567.8	605.3	642.8	680.3	717.8	755.3	792.8	830.3
14.0	484.5	522.0	559.5	597.0	634.5	672.0	709.5	747.0	784.5	822.0	859.5
15.0	513.8	551.3	588.8	626.3	663.8	701.3	738.8	776.3	813.8	851.3	888.8
16.0	543.0	580.5	618.0	655.5	693.0	730.5	768.0	805.5	843.0	880.5	918.0
17.0	572.3	609.8	647.3	684.8	722.3	759.8	797.3	834.8	872.3	909.8	947.3
18.0	601.5	639.0	676.5	714.0	751.5	789.0	826.5	864.0	901.5	939.0	976.5
19.0	630.8	668.3	705.8	743.3	780.8	818.3	855.8	893.3	930.8	968.3	1005.8
20.0	660.0	697.5	735.0	772.5	810.0	847.5	885.0	922.5	960.0	997.5	1035.0
21.0	689.3	726.8	764.3	801.8	839.3	876.8	914.3	951.8	989.3	1026.8	1064.3
22.0	718.5	756.0	793.5	831.0	868.5	906.0	943.5	981.0	1018.5	1056.0	1093.5
23.0	747.8	785.3	822.8	860.3	897.8	935.3	972.8	1010.3	1047.8	1085.3	1122.8
24.0	777.0	814.5	852.0	889.5	927.0	964.5	1002.0	1039.5	1077.0	1114.5	1152.0
25.0	806.3	843.8	881.3	918.8	956.3	993.8	1031.3	1068.8	1106.3	1143.8	1181.3
26.0	835.5	873.0	910.5	948.0	985.5	1023.0	1060.5	1098.0	1135.5	1173.0	1210.5
27.0	864.8	902.3	939.8	977.3	1014.8	1052.3	1089.8	1127.3	1164.8	1202.3	1239.8
28.0	894.0	931.5	969.0	1006.5	1044.0	1081.5	1119.0	1156.5	1194.0	1231.5	1269.0
29.0	923.3	960.8	998.3	1035.8	1073.3	1110.8	1148.3	1185.8	1223.3	1260.8	1298.3
30.0	952.5	990.0	1027.5	1065.0	1102.5	1140.0	1177.5	1215.0	1252.5	1290.0	1327.5

TABLE 3
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

WELDED CONNECTIONS

A S D
Fy=36 KSI



$P_{BS} = Ct$

t = PLATE THICKNESS
L1 ,L2,L3 = WELD LENGTHS

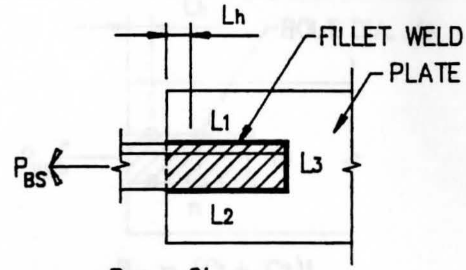
COEFFICIENT, C

WELD LENGTHS L1 + L2 (INCHES)	TRANSVERSE DISTANCE BETWEEN WELDS, L3 (INCHES)										
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
4.0	127.6	156.6	185.6	214.6	243.6	272.6	301.6	330.6	359.6	388.6	417.6
5.0	145.0	174.0	203.0	232.0	261.0	290.0	319.0	348.0	377.0	406.0	435.0
6.0	162.4	191.4	220.4	249.4	278.4	307.4	336.4	365.4	394.4	423.4	452.4
7.0	179.8	208.8	237.8	266.8	295.8	324.8	353.8	382.8	411.8	440.8	469.8
8.0	197.2	226.2	255.2	284.2	313.2	342.2	371.2	400.2	429.2	458.2	487.2
9.0	214.6	243.6	272.6	301.6	330.6	359.6	388.6	417.6	446.6	475.6	504.6
10.0	232.0	261.0	290.0	319.0	348.0	377.0	406.0	435.0	464.0	493.0	522.0
11.0	249.4	278.4	307.4	336.4	365.4	394.4	423.4	452.4	481.4	510.4	539.4
12.0	266.8	295.8	324.8	353.8	382.8	411.8	440.8	469.8	498.8	527.8	556.8
13.0	284.2	313.2	342.2	371.2	400.2	429.2	458.2	487.2	516.2	545.2	574.2
14.0	301.6	330.6	359.6	388.6	417.6	446.6	475.6	504.6	533.6	562.6	591.6
15.0	319.0	348.0	377.0	406.0	435.0	464.0	493.0	522.0	551.0	580.0	609.0
16.0	336.4	365.4	394.4	423.4	452.4	481.4	510.4	539.4	568.4	597.4	626.4
17.0	353.8	382.8	411.8	440.8	469.8	498.8	527.8	556.8	585.8	614.8	643.8
18.0	371.2	400.2	429.2	458.2	487.2	516.2	545.2	574.2	603.2	632.2	661.2
19.0	388.6	417.6	446.6	475.6	504.6	533.6	562.6	591.6	620.6	649.6	678.6
20.0	406.0	435.0	464.0	493.0	522.0	551.0	580.0	609.0	638.0	667.0	696.0
21.0	423.4	452.4	481.4	510.4	539.4	568.4	597.4	626.4	655.4	684.4	713.4
22.0	440.8	469.8	498.8	527.8	556.8	585.8	614.8	643.8	672.8	701.8	730.8
23.0	458.2	487.2	516.2	545.2	574.2	603.2	632.2	661.2	690.2	719.2	748.2
24.0	475.6	504.6	533.6	562.6	591.6	620.6	649.6	678.6	707.6	736.6	765.6
25.0	493.0	522.0	551.0	580.0	609.0	638.0	667.0	696.0	725.0	754.0	783.0
26.0	510.4	539.4	568.4	597.4	626.4	655.4	684.4	713.4	742.2	771.4	800.4
27.0	527.8	556.8	585.8	614.8	643.8	672.8	701.8	730.8	759.8	788.8	817.8
28.0	545.2	574.2	603.2	632.2	661.2	690.2	719.2	748.2	777.2	806.2	835.2
29.0	562.6	591.6	620.6	649.6	678.6	707.6	736.6	765.6	794.6	823.6	852.6
30.0	580.0	609.0	638.0	667.0	696.0	725.0	754.0	783.0	812.0	841.0	870.0

TABLE 4
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

WELDED CONNECTIONS

A S D
Fy=50 KSI



$P_{BS} = Ct$

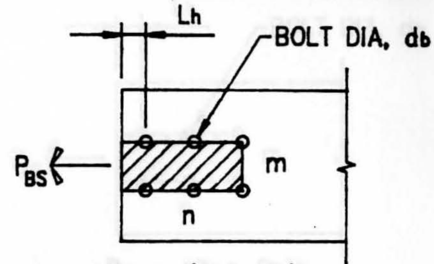
t = PLATE THICKNESS
L_1, L_2, L_3 = WELD LENGTHS

WELD LENGTHS $L_1 + L_2$ (INCHES)	COEFFICIENT, C — TRANSVERSE DISTANCE BETWEEN WELDS, L_3 (INCHES)										
	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0
4.0	143.0	175.5	208.0	240.5	273.0	305.5	338.0	370.5	403.5	435.5	468.0
5.0	162.5	195.0	227.5	260.0	292.5	325.0	357.5	390.0	422.5	455.0	487.5
6.0	182.0	214.5	247.0	279.5	312.0	344.5	377.0	409.5	442.0	474.5	507.0
7.0	201.5	234.0	266.5	299.0	331.5	364.0	396.5	429.0	461.5	494.0	526.5
8.0	221.0	253.5	286.0	318.5	351.0	383.5	416.0	448.5	481.0	513.5	546.0
9.0	240.5	273.0	305.5	338.0	370.5	403.0	435.5	468.0	500.5	533.0	565.5
10.0	260.0	292.5	325.0	357.5	390.0	422.5	455.0	487.5	520.0	552.5	585.0
11.0	279.5	312.0	344.5	377.0	409.5	442.0	474.5	507.0	539.5	572.0	604.5
12.0	299.0	331.5	364.0	396.5	429.0	461.5	494.0	526.5	559.0	591.5	624.0
13.0	318.5	351.0	383.5	416.0	448.5	481.0	513.5	546.0	578.5	611.0	643.5
14.0	338.0	370.5	403.0	435.5	468.0	500.5	533.0	565.5	598.0	630.5	663.0
15.0	357.5	390.0	422.5	455.0	487.5	520.0	552.5	585.0	617.5	650.0	682.5
16.0	377.0	409.5	442.0	474.5	507.0	539.5	572.0	604.5	637.0	669.5	702.0
17.0	396.5	429.0	461.5	494.0	526.5	559.0	591.5	624.0	656.5	689.0	721.5
18.0	416.0	448.5	481.0	513.5	546.0	578.5	611.0	643.5	676.0	708.5	741.0
19.0	435.5	468.0	500.5	533.0	565.5	598.0	630.5	663.0	695.5	728.0	760.5
20.0	455.0	487.5	520.0	552.5	585.0	617.5	650.0	682.5	715.0	747.5	780.0
21.0	474.0	507.0	539.5	572.0	604.5	637.0	669.5	702.0	734.5	767.0	799.5
22.0	494.0	526.5	559.0	591.5	624.0	656.5	689.0	721.5	754.0	786.5	819.0
23.0	513.5	546.0	578.5	611.0	643.5	676.0	708.5	741.0	773.5	806.0	838.5
24.0	533.0	565.5	598.0	630.5	663.0	695.5	728.0	760.5	793.0	825.5	858.0
25.0	552.5	585.0	617.5	650.0	682.5	715.0	747.5	780.0	812.5	845.0	877.5
26.0	572.0	604.5	637.0	669.5	702.0	734.5	767.0	799.5	832.0	864.5	897.0
27.0	591.5	624.0	656.5	689.0	721.5	754.0	786.5	819.0	851.5	884.0	916.5
28.0	611.0	643.5	676.0	708.5	741.0	773.5	806.0	838.5	871.0	903.5	936.0
29.0	630.5	663.0	695.5	728.0	760.5	793.0	825.5	858.0	890.5	923.0	955.5
30.0	650.0	682.5	715.0	747.5	780.0	812.5	845.0	877.5	910.0	942.5	975.0

TABLE 5a
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

BASED ON STANDARD HOLES AND 3" FASTENER SPACING

L R F D
SHEAR YIELD – TENSION FRACTURE
Fy=36 KSI



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

t = PLATE THICKNESS
m,n = NUMBER OF BOLTS

COEFFICIENT C_1

BOLT DIAMETER (INCHES)	NUMBER OF BOLTS, m								
	2	3	4	5	6	7	8	9	10
3/4	95.2	190.3	285.5	380.6	475.8	570.9	666.1	761.3	856.4
7/8	89.7	179.4	269.2	358.9	448.6	538.3	628.0	717.8	807.5
1	84.3	168.6	252.8	337.1	421.4	505.7	590.0	674.3	758.5

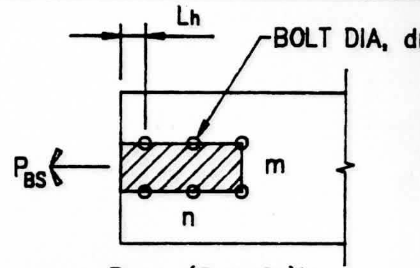
COEFFICIENT C_2

Lh (INCHES)	NUMBER OF BOLTS, n								
	2	3	4	5	6	7	8	9	10
1.0	129.6	226.8	324.0	421.2	518.4	615.6	712.8	810.0	907.2
1.5	145.8	243.0	340.2	437.4	534.6	631.8	729.0	826.2	923.4
2.0	162.0	259.2	356.4	453.6	550.8	648.0	745.2	842.4	939.6
2.5	178.2	275.4	372.6	469.8	567.0	664.2	761.4	858.6	955.8
3.0	194.4	291.6	388.8	486.0	583.2	680.4	777.6	874.8	972.0

TABLE 5b
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

BASED ON STANDARD HOLES AND 3" FASTENER SPACING

L R F D
SHEAR FRACTURE – TENSION YIELD
Fy=36 KSI



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

t = PLATE THICKNESS
m,n = NUMBER OF BOLTS

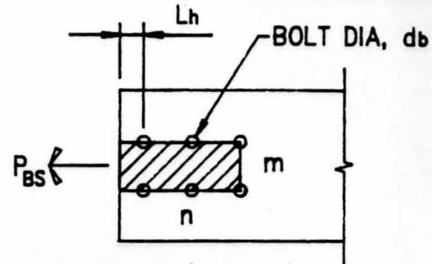
COEFFICIENT C1

COEFFICIENT	NUMBER OF BOLTS, m								
	2	3	4	5	6	7	8	9	10
C1	81.0	162.0	243.0	324.0	405.0	486.0	567.0	648.0	729.0

COEFFICIENT C2

BOLT DIAMETER (INCHES)	Lh (INCHES)	NUMBER OF BOLTS, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	145.2	259.4	373.6	487.7	601.9	716.1	830.3	944.5	1058.7
	1.5	171.3	285.5	399.7	513.8	628.0	742.2	856.4	970.6	1084.8
	2.0	197.4	311.6	425.8	539.9	654.1	768.3	882.5	996.7	1110.9
	2.5	223.5	337.7	451.9	566.0	680.2	794.4	908.6	1022.8	1137.0
	3.0	249.6	363.8	478.0	592.1	706.3	820.5	934.7	1048.9	1163.1
7/8	1.0	135.4	243.1	350.7	458.4	566.0	673.7	781.4	889.0	996.7
	1.5	161.5	269.2	376.8	484.5	592.1	699.8	807.5	915.1	1022.8
	2.0	187.6	295.3	402.9	510.6	618.2	725.9	833.6	941.2	1048.9
	2.5	213.7	321.4	429.0	536.7	644.3	752.0	859.7	967.3	1075.0
	3.0	239.8	347.5	455.1	562.8	670.4	778.1	885.8	993.4	1101.1
1	1.0	125.6	226.7	327.9	429.0	530.2	631.3	732.4	833.6	934.7
	1.5	151.7	252.8	354.0	455.1	556.3	657.4	758.5	859.7	960.8
	2.0	177.8	278.9	380.1	481.2	582.4	683.5	784.6	885.8	986.9
	2.5	203.9	305.0	406.2	507.3	608.5	709.6	810.7	911.9	1013.0
	3.0	230.0	331.1	432.3	533.4	634.6	735.7	836.8	938.0	1039.1

TABLE 6a
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)



BASED ON STANDARD HOLES AND 3" FASTENER SPACING

L R F D
SHEAR YIELD – TENSION FRACTURE
Fy=50 KSI

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

t = PLATE THICKNESS
m,n = NUMBER OF BOLTS

COEFFICIENT C_1

BOLT DIAMETER (INCHES)	NUMBER OF BOLTS, m								
	2	3	4	5	6	7	8	9	10
3/4	106.6	213.3	319.9	426.6	533.2	639.8	746.5	853.1	959.8
7/8	100.5	201.1	301.6	402.2	502.7	603.3	703.8	804.4	904.9
1	94.5	188.9	283.4	377.8	472.3	566.7	661.2	755.6	850.1

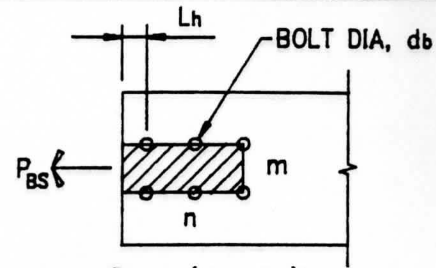
COEFFICIENT C_2

Lh (INCHES)	NUMBER OF BOLTS, n								
	2	3	4	5	6	7	8	9	10
1.0	180.0	315.0	450.0	585.0	720.0	855.0	990.0	1125.0	1260.0
1.5	202.5	337.5	472.5	607.5	742.5	877.5	1012.5	1147.5	1282.5
2.0	225.0	360.0	495.0	630.0	765.0	900.0	1035.0	1170.0	1305.0
2.5	247.5	382.5	517.5	652.5	787.5	922.5	1057.5	1192.5	1327.5
3.0	270.0	405.0	540.0	675.0	810.0	945.0	1080.0	1215.0	1350.0

TABLE 6b
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

BASED ON STANDARD HOLES AND 3" FASTENER SPACING

L R F D
SHEAR FRACTURE – TENSION YIELD
Fy=50 KSI



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

t = PLATE THICKNESS
m,n = NUMBER OF BOLTS

COEFFICIENT C1

COEFFICIENT	NUMBER OF BOLTS, m								
	2	3	4	5	6	7	8	9	10
C1	112.5	225.0	337.5	450.0	562.5	675.0	787.5	900.0	1012.5

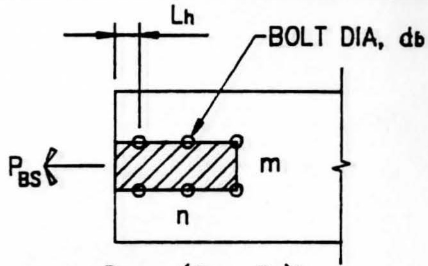
COEFFICIENT C2

BOLT DIAMETER (INCHES)	Lh (INCHES)	NUMBER OF BOLTS, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	162.7	290.7	418.6	546.6	674.6	802.5	930.5	1058.5	1186.5
	1.5	192.0	319.9	447.9	575.9	703.8	831.8	959.8	1087.7	1215.7
	2.0	221.2	349.2	477.1	605.1	733.1	861.0	989.0	1117.0	1245.0
	2.5	250.5	378.4	506.4	634.4	762.3	890.3	1018.3	1146.2	1274.2
	3.0	279.7	407.7	535.6	663.6	791.6	919.5	1047.5	1175.5	1303.5
7/8	1.0	151.7	272.4	393.0	513.7	634.4	755.0	875.7	996.3	1117.0
	1.5	181.0	301.6	422.3	543.0	663.6	784.3	904.9	1025.6	1146.2
	2.0	210.2	330.9	451.5	572.2	692.9	813.5	934.2	1054.8	1175.5
	2.5	239.5	360.1	480.8	601.5	722.1	842.8	963.4	1084.1	1204.7
	3.0	268.7	389.4	510.0	630.7	751.4	872.0	992.7	1113.3	1234.0
1	1.0	140.8	254.1	367.5	480.8	594.1	707.5	820.8	934.2	1047.5
	1.5	170.0	283.4	396.7	510.0	623.4	736.7	850.1	963.4	1076.8
	2.0	199.3	312.6	426.0	539.3	652.6	766.0	879.3	992.7	1106.0
	2.5	228.5	341.9	455.2	568.5	681.9	795.2	908.6	1021.9	1135.3
	3.0	257.8	371.1	484.5	597.8	711.1	824.5	937.8	1051.2	1164.5

TABLE 7
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

BASED ON STANDARD HOLES AND 3" FASTENER SPACING

A S D
Fy=36 KSI



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

t = PLATE THICKNESS
m,n = NUMBER OF BOLTS

COEFFICIENT C_1

BOLT DIAMETER (INCHES)	NUMBER OF BOLTS, m								
	2	3	4	5	6	7	8	9	10
3/4	63.4	126.9	190.3	253.8	317.2	380.6	444.1	507.5	570.9
7/8	59.8	119.6	179.4	239.3	299.1	358.9	418.7	478.5	538.3
1	56.2	112.4	168.6	224.8	280.9	337.1	393.3	449.5	505.7

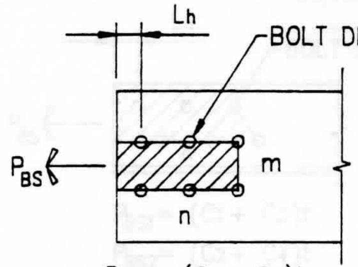
COEFFICIENT C_2

BOLT DIAMETER (INCHES)	Lh (INCHES)	NUMBER OF BOLTS, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	96.8	172.9	249.0	325.2	401.3	477.4	553.5	629.7	705.8
	1.5	114.2	190.3	266.4	342.6	418.7	494.8	570.9	647.1	723.2
	2.0	131.6	207.7	283.8	360.0	436.1	512.2	588.3	664.5	740.6
	2.5	149.0	225.1	301.2	377.4	453.5	529.6	605.7	681.9	758.0
	3.0	166.4	242.5	318.6	394.8	470.9	547.0	623.1	699.3	775.4
7/8	1.0	90.3	162.0	233.8	305.6	377.4	449.1	520.9	592.7	664.5
	1.5	107.7	179.4	251.2	323.0	394.8	466.5	538.3	610.1	681.9
	2.0	125.1	196.8	268.6	340.4	412.2	483.9	555.7	627.5	699.3
	2.5	142.5	214.2	286.0	357.8	429.6	501.3	573.1	644.9	716.7
	3.0	159.9	231.6	303.4	375.2	447.0	518.7	590.5	662.3	734.1
1	1.0	83.7	151.2	218.6	286.0	353.4	420.9	488.3	555.7	623.1
	1.5	101.1	168.6	236.0	303.4	370.8	438.3	505.7	573.1	640.5
	2.0	118.5	186.0	253.4	320.8	388.2	455.7	523.1	590.5	657.9
	2.5	135.9	203.4	270.8	338.2	405.6	473.1	540.5	607.9	675.3
	3.0	153.3	220.8	288.2	355.6	423.0	490.5	557.9	625.3	692.7

TABLE 8
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

BASED ON STANDARD HOLES AND 3" FASTENER SPACING

A S D
$F_y = 50$ KSI



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

t = PLATE THICKNESS
m,n = NUMBER OF BOLTS

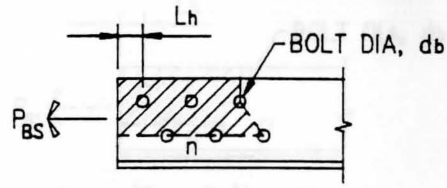
COEFFICIENT C_1

BOLT DIAMETER (INCHES)	NUMBER OF BOLTS, m								
	2	3	4	5	6	7	8	9	10
3/4	71.1	142.2	213.3	284.4	355.5	426.6	497.7	568.8	639.8
7/8	67.0	134.1	201.1	268.1	335.2	402.2	469.2	536.3	603.3
1	63.0	125.9	18.9	251.9	314.8	377.8	440.8	503.8	566.7

COEFFICIENT C_2

BOLT DIAMETER (INCHES)	L_h (INCHES)	NUMBER OF BOLTS, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	108.5	193.8	279.1	364.4	449.7	535.0	620.3	705.7	791.0
	1.5	128.0	213.3	298.6	383.9	469.2	554.5	639.8	725.2	810.5
	2.0	147.5	232.8	318.1	403.4	488.7	574.0	659.3	744.7	830.0
	2.5	167.0	252.3	337.6	422.9	508.2	593.5	678.8	764.2	849.5
	3.0	186.5	271.8	357.1	442.4	527.7	613.0	698.3	783.7	869.0
7/8	1.0	101.2	181.6	262.0	342.5	422.9	503.3	583.8	664.2	744.7
	1.5	120.7	201.1	281.5	362.0	442.4	522.8	603.3	683.7	764.2
	2.0	140.2	220.6	301.0	381.5	461.9	542.3	622.8	703.2	783.7
	2.5	159.7	240.1	320.5	401.0	481.4	561.8	642.3	722.7	803.2
	3.0	179.2	259.6	340.0	420.5	500.9	581.3	661.8	742.2	822.7
1	1.0	93.8	169.4	245.0	320.5	396.1	471.7	547.2	622.8	698.3
	1.5	113.3	188.9	264.5	340.0	415.6	491.2	566.7	642.3	717.8
	2.0	132.8	208.4	284.0	359.5	435.1	510.7	586.2	661.8	737.3
	2.5	152.3	227.9	303.5	379.0	454.6	530.2	605.7	681.3	756.8
	3.0	171.8	247.4	323.0	398.5	474.1	549.7	625.2	700.8	776.3

TABLE 9a
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)



BASED ON STANDARD HOLES, 3" FASTENER SPACING AND STANDARD ANGLE GAGES

L R F D

P_{BS1} = SHEAR YIELD – TENSION FRACTURE
P_{BS2} = TENSION YIELD – SHEAR FRACTURE
Fy=36 KSI

$P_{BS1} = (C_1 + C_3)t$
$P_{BS2} = (C_2 + C_4)t$

USE LARGER OF P_{BS1} AND P_{BS2}
t = PLATE THICKNESS
n = NUMBER OF BOLTS PER LINE

COEFFICIENT C_1

Lh (INCHES)	NUMBER OF BOLTS PER ROW, n								
	2	3	4	5	6	7	8	9	10
1.0	89.1	137.7	186.3	234.9	283.5	332.1	380.7	429.3	477.9
1.5	97.2	145.8	194.4	243.0	291.6	340.2	388.8	437.4	486.0
2.0	105.3	153.9	202.5	251.1	299.7	348.3	396.9	445.5	494.1
2.5	113.4	162.0	210.6	259.2	307.8	356.4	405.0	453.6	502.2
3.0	121.5	170.1	218.7	267.3	315.9	364.5	413.1	461.7	510.3

COEFFICIENT C_2

BOLT DIAMETER (INCHES)	Lh (INCHES)	NUMBER OF BOLTS PER ROW, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	111.7	168.8	225.9	283.0	340.1	397.2	454.3	511.4	568.5
	1.5	124.8	181.9	239.0	296.1	353.2	410.3	467.4	524.4	581.5
	2.0	137.8	194.9	252.0	309.1	366.2	423.3	480.4	537.5	594.6
	2.5	150.9	208.0	265.1	322.2	379.3	436.4	493.5	550.5	607.6
	3.0	163.9	221.0	278.1	335.2	392.3	449.4	506.5	563.6	620.7
7/8	1.0	106.8	160.7	214.5	268.3	322.2	376.0	429.8	483.7	537.5
	1.5	119.9	173.7	227.6	281.4	335.2	389.1	442.9	496.7	550.5
	2.0	132.9	186.8	240.6	294.4	348.3	402.1	455.9	509.8	563.6
	2.5	146.0	199.8	253.7	307.5	361.3	415.2	469.0	522.8	576.6
	3.0	159.0	212.9	266.7	320.5	374.4	428.2	482.0	535.9	589.7
1	1.0	102.0	152.5	203.1	253.7	304.2	354.8	405.4	455.9	506.5
	1.5	115.0	165.6	216.1	266.7	317.3	367.8	418.4	469.0	519.6
	2.0	128.1	178.6	229.2	279.8	330.3	380.9	431.5	482.0	532.6
	2.5	141.1	191.7	242.2	292.8	343.4	393.9	444.5	495.1	545.7
	3.0	154.2	204.7	255.3	305.9	356.4	407.0	457.6	508.1	558.7

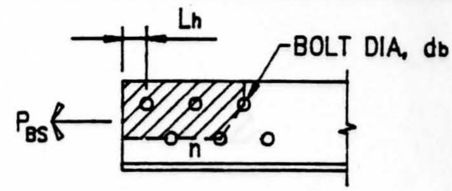
COEFFICIENT C_3

BOLT DIAMETER (INCHES)	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
3/4	91.5	119.9	150.9	172.6
7/8	83.3	111.7	142.7	164.5
1	75.2	103.6	134.6	156.3

COEFFICIENT C_4

COEFFICIENT	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
C4	81.0	101.3	121.5	135.0

TABLE 9b
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)



BASED ON STANDARD HOLES, 3" FASTENER SPACING AND STANDARD ANGLE GAGES

L R F D

P_{BS1} = SHEAR YIELD – TENSION FRACTURE
P_{BS2} = TENSION YIELD – SHEAR FRACTURE
Fy=36 KSI

$P_{BS1} = (C_1 + C_3)t \times C_5$

$P_{BS2} = (C_2 + C_4)t \times C_5$

USE LARGER OF P_{BS1} AND P_{BS2}
t = PLATE THICKNESS
n = NUMBER OF BOLTS PER LINE

COEFFICIENT C_1

L_h (INCHES)	NUMBER OF BOLTS PER ROW, n								
	2	3	4	5	6	7	8	9	10
1.0	40.5	89.1	137.7	186.3	234.9	283.5	332.1	380.7	429.3
1.5	48.6	97.2	145.8	194.4	243.0	291.6	340.2	388.8	437.4
2.0	56.7	105.3	153.9	202.5	251.1	299.7	348.3	396.9	445.5
2.5	64.8	113.4	162.0	210.6	259.2	307.8	356.4	405.0	453.6
3.0	72.9	121.5	170.1	218.7	267.3	315.9	364.5	413.1	461.7

COEFFICIENT C_2

BOLT DIAMETER (INCHES)	L_h (INCHES)	NUMBER OF BOLTS PER ROW, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	54.6	111.7	168.8	225.9	283.0	340.1	397.2	454.3	511.4
	1.5	67.7	124.8	181.9	239.0	296.1	353.2	410.3	467.4	524.4
	2.0	80.7	137.8	194.9	252.0	309.1	366.2	423.3	480.4	537.5
	2.5	93.8	150.9	208.0	265.1	322.2	379.3	436.4	493.5	550.5
	3.0	106.8	163.9	221.0	278.1	335.2	392.3	449.4	506.5	563.6
7/8	1.0	53.0	106.8	160.7	214.5	268.3	322.2	376.0	429.8	483.7
	1.5	66.1	119.9	173.7	227.6	281.4	335.2	389.1	442.9	496.7
	2.0	79.1	132.9	186.8	240.6	294.4	348.3	402.1	455.9	509.8
	2.5	92.2	146.0	199.8	253.7	307.5	361.3	415.2	469.0	522.8
	3.0	105.2	159.0	212.9	266.7	320.5	374.4	428.2	482.0	535.9
1	1.0	51.4	102.0	152.5	203.1	253.7	304.2	354.8	405.4	455.9
	1.5	64.4	115.0	165.6	216.1	266.7	317.3	367.8	418.4	469.0
	2.0	77.5	128.1	178.6	229.2	279.8	330.3	380.9	431.5	482.0
	2.5	90.5	141.1	191.7	242.2	292.8	343.4	393.9	444.5	495.1
	3.0	103.6	154.2	204.7	255.3	305.9	356.4	407.0	457.6	508.1

COEFFICIENT C_3

BOLT DIAMETER (INCHES)	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
3/4	91.5	119.9	150.9	172.6
7/8	83.3	111.7	142.7	164.5
1	75.2	103.6	134.6	156.3

COEFFICIENT C_4

COEFFICIENT	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
C_4	81.0	101.3	121.5	135.0

COEFFICIENT C_5

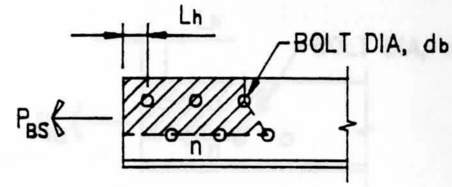
COEFFICIENT	NUMBER OF BOLTS PER ROW, n								
	2	3	4	5	6	7	8	9	10
C_5	1.333	1.200	1.143	1.111	1.091	1.077	1.067	1.059	1.053

TABLE 10a
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

BASED ON STANDARD HOLES, 3" FASTENER SPACING AND STANDARD ANGLE GAGES

L R F D

P_{BS1} = SHEAR YIELD – TENSION FRACTURE
P_{BS2} = TENSION YIELD – SHEAR FRACTURE
Fy=50 KSI



$P_{BS1} = (C_1 + C_3)t$
$P_{BS2} = (C_2 + C_4)t$

USE LARGER OF P_{BS1} AND P_{BS2}
t = PLATE THICKNESS
n = NUMBER OF BOLTS PER LINE

COEFFICIENT C_1

L_h (INCHES)	NUMBER OF BOLTS PER ROW, n								
	2	3	4	5	6	7	8	9	10
1.0	123.8	191.3	258.8	326.3	393.8	461.3	528.8	596.3	663.8
1.5	135.0	202.5	270.0	337.5	405.0	472.5	540.0	607.5	675.0
2.0	146.3	213.8	281.3	348.8	416.3	483.8	551.3	618.8	686.3
2.5	157.5	225.0	292.5	360.0	427.5	495.0	562.5	630.0	697.5
3.0	168.8	236.3	303.8	371.3	438.8	506.3	573.8	641.3	708.8

COEFFICIENT C_2

BOLT DIAMETER (INCHES)	L_h (INCHES)	NUMBER OF BOLTS PER ROW, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	125.2	189.2	253.2	317.2	381.2	445.1	509.1	573.1	637.1
	1.5	139.9	203.8	267.8	331.8	395.8	459.8	523.8	587.7	651.7
	2.0	154.5	218.5	282.4	346.4	410.4	474.4	538.4	602.4	666.4
	2.5	169.1	233.1	297.1	361.1	425.0	489.0	553.0	617.0	681.0
	3.0	183.7	247.7	311.7	375.7	439.7	503.6	567.6	631.6	695.6
7/8	1.0	119.7	180.1	240.4	300.7	361.1	421.4	481.7	542.0	602.4
	1.5	134.4	194.7	255.0	315.4	375.7	436.0	496.3	556.7	617.0
	2.0	149.0	209.3	269.6	330.0	390.3	450.6	511.0	571.3	631.6
	2.5	163.6	223.9	284.3	344.6	404.9	465.3	525.6	585.9	646.2
	3.0	178.2	238.6	298.9	359.2	419.6	479.9	540.2	600.5	660.9
1	1.0	114.3	170.9	227.6	284.3	340.9	397.6	454.3	511.0	567.6
	1.5	128.9	185.6	242.2	298.9	355.6	412.2	468.9	525.6	582.3
	2.0	143.5	200.2	256.9	313.5	370.2	426.9	483.5	540.2	596.9
	2.5	158.1	214.8	271.5	328.1	384.8	441.5	498.2	554.8	611.5
	3.0	172.8	229.4	286.1	342.8	399.4	456.1	512.8	569.5	626.1

COEFFICIENT C_3

BOLT DIAMETER (INCHES)	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
3/4	102.5	134.4	169.1	193.4
7/8	93.4	125.2	159.9	184.4
1	84.3	116.1	150.8	175.2

COEFFICIENT C_4

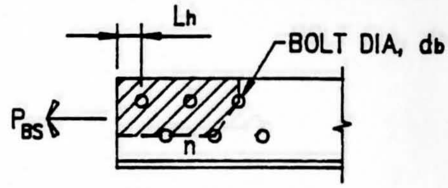
COEFFICIENT	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
C_4	112.5	140.6	168.8	187.5

TABLE 10b
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

BASED ON STANDARD HOLES, 3" FASTENER SPACING AND STANDARD ANGLE GAGES

L R F D

P_{BS1} = SHEAR YIELD – TENSION FRACTURE
P_{BS2} = TENSION YIELD – SHEAR FRACTURE
Fy=50 KSI



$P_{BS1} = (C_1 + C_3)t \times C_5$

$P_{BS2} = (C_2 + C_4)t \times C_5$

USE LARGER OF P_{BS1} AND P_{BS2}
t = PLATE THICKNESS
n = NUMBER OF BOLTS PER LINE

COEFFICIENT C_1

L_h (INCHES)	NUMBER OF BOLTS PER ROW, n								
	2	3	4	5	6	7	8	9	10
1.0	56.3	123.8	191.3	258.8	326.3	393.8	461.3	528.8	596.3
1.5	67.5	135.0	202.5	270.0	337.5	405.0	472.5	540.0	607.5
2.0	78.8	146.3	213.8	281.3	348.8	416.3	483.8	551.3	618.8
2.5	90.0	157.5	225.0	292.5	360.0	427.5	495.0	562.5	630.0
3.0	101.3	168.8	236.3	303.8	371.3	438.8	506.3	573.8	641.3

COEFFICIENT C_2

BOLT DIAMETER (INCHES)	L_h (INCHES)	NUMBER OF BOLTS PER ROW, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	61.2	125.2	189.2	253.2	317.2	381.2	445.1	509.1	573.1
	1.5	75.9	139.9	203.8	267.8	331.8	395.8	459.8	523.8	587.7
	2.0	90.5	154.5	218.5	282.4	346.4	410.4	474.4	538.4	602.4
	2.5	105.1	169.1	233.1	297.1	361.1	425.0	489.0	553.0	617.0
	3.0	119.7	183.7	247.7	311.7	375.7	439.7	503.6	567.6	631.6
7/8	1.0	59.4	119.7	180.1	240.4	300.7	361.1	421.4	481.7	542.0
	1.5	74.0	134.4	194.7	255.0	315.4	375.7	436.0	496.3	556.7
	2.0	88.7	149.0	209.3	269.6	330.0	390.3	450.6	511.0	571.3
	2.5	103.3	163.6	223.9	284.3	344.6	404.9	465.3	525.6	585.9
	3.0	117.9	178.2	238.6	298.9	359.2	419.6	479.9	540.2	600.5
1	1.0	57.6	114.3	170.9	227.6	284.3	340.9	397.6	454.3	511.0
	1.5	72.2	128.9	185.6	242.2	298.9	355.6	412.2	468.9	525.6
	2.0	86.8	143.5	200.2	256.9	313.5	370.2	426.9	483.5	540.2
	2.5	101.5	158.1	214.8	271.5	328.1	384.8	441.5	498.2	554.8
	3.0	116.1	172.8	229.4	286.1	342.8	399.4	456.1	512.8	569.5

COEFFICIENT C_3

BOLT DIAMETER (INCHES)	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
3/4	102.5	134.4	169.1	193.4
7/8	93.4	125.2	159.9	184.4
1	84.3	116.1	150.8	175.2

COEFFICIENT C_4

COEFFICIENT	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
C_4	112.5	140.6	168.8	187.5

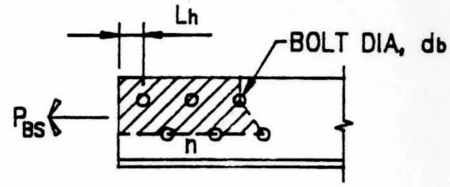
COEFFICIENT C_5

COEFFICIENT	NUMBER OF BOLTS PER ROW, n								
	2	3	4	5	6	7	8	9	10
C_5	1.333	1.200	1.143	1.111	1.091	1.077	1.067	1.059	1.053

TABLE 11a
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

BASED ON STANDARD HOLES, 3" FASTENER SPACING AND STANDARD ANGLE GAGES

A S D
F_y=36 KSI



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

t = PLATE THICKNESS
n = NUMBER OF BOLTS PER LINE

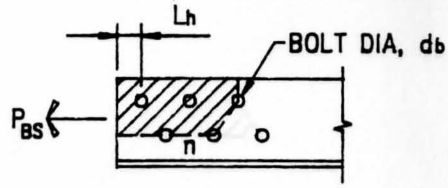
COEFFICIENT C_1

BOLT DIAMETER (INCHES)	L_h (INCHES)	NUMBER OF BOLTS PER ROW, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	74.5	112.6	150.6	188.7	226.7	264.8	302.9	340.9	379.0
	1.5	83.2	121.3	159.3	197.4	235.4	273.5	311.6	349.6	387.7
	2.0	91.9	130.0	168.0	206.1	244.1	282.2	320.3	358.3	396.4
	2.5	100.6	138.7	176.7	214.8	252.8	290.9	329.0	367.0	405.1
	3.0	109.3	147.4	185.4	223.5	261.5	299.6	337.7	375.7	413.8
7/8	1.0	71.2	107.1	143.0	178.9	214.8	250.7	286.6	322.4	358.3
	1.5	79.9	115.8	151.7	187.6	223.5	259.4	295.3	331.1	367.0
	2.0	88.6	124.5	160.4	196.3	232.2	268.1	304.0	339.8	375.7
	2.5	97.3	133.2	169.1	205.0	240.9	276.8	312.7	348.5	384.4
	3.0	106.0	141.9	177.8	213.7	249.6	285.5	321.4	357.2	393.1
1	1.0	68.0	101.7	135.4	169.1	202.8	236.5	270.2	304.0	337.7
	1.5	76.7	110.4	144.1	177.8	211.5	245.2	278.9	312.7	346.4
	2.0	85.4	119.1	152.8	186.5	220.2	253.9	287.6	321.4	355.1
	2.5	94.1	127.8	161.5	195.2	228.9	262.6	296.3	330.1	363.8
	3.0	102.8	136.5	170.2	203.9	237.6	271.3	305.0	338.8	372.5

COEFFICIENT C_2

BOLT DIAMETER (INCHES)	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
3/4	61.0	79.9	100.6	115.1
7/8	55.5	74.5	95.2	109.7
1	50.1	69.1	89.7	104.2

TABLE 11b
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)



BASED ON STANDARD HOLES, 3" FASTENER SPACING AND STANDARD ANGLE GAGES

A S D
Fy=36 KSI

$P_{BS} = (C_1 + C_2)t \times C_3$

t = PLATE THICKNESS
n = NUMBER OF BOLTS PER LINE

COEFFICIENT C_1

BOLT DIAMETER (INCHES)	L_h (INCHES)	NUMBER OF BOLTS PER ROW, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	36.4	74.5	112.6	150.6	188.7	226.7	264.8	302.9	340.9
	1.5	45.1	83.2	121.3	159.3	197.4	235.4	273.5	311.6	349.6
	2.0	53.8	91.9	130.0	168.0	206.1	244.1	282.2	320.3	358.3
	2.5	62.5	100.6	138.7	176.7	214.8	252.8	290.9	329.0	367.0
	3.0	71.2	109.3	147.4	185.4	223.5	261.5	299.6	337.7	375.7
7/8	1.0	35.3	71.2	107.1	143.0	178.9	214.8	250.7	286.6	322.4
	1.5	44.0	79.9	115.8	151.7	187.6	223.5	259.4	295.3	331.1
	2.0	52.7	88.6	124.5	160.4	196.3	232.2	268.1	304.0	339.8
	2.5	61.4	97.3	133.2	169.1	205.0	240.9	276.8	312.7	348.5
	3.0	70.1	106.0	141.9	177.8	213.7	249.6	285.5	321.4	357.2
1	1.0	34.3	68.0	101.7	135.4	169.1	202.8	236.5	270.2	304.0
	1.5	43.0	76.7	110.4	144.1	177.8	211.5	245.2	278.9	312.7
	2.0	51.7	85.4	119.1	152.8	186.5	220.2	253.9	287.6	321.4
	2.5	60.4	94.1	127.8	161.5	195.2	228.9	262.6	296.3	330.1
	3.0	69.1	102.8	136.5	170.2	203.9	237.6	271.3	305.0	338.8

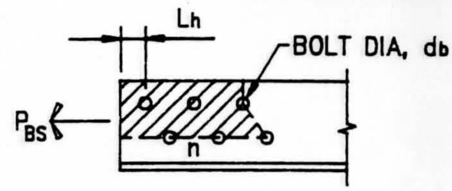
COEFFICIENT C_2

BOLT DIAMETER (INCHES)	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
3/4	61.0	79.9	100.6	115.1
7/8	55.5	74.5	95.2	109.7
1	50.1	69.1	89.7	104.2

COEFFICIENT C_3

COEFFICIENT	NUMBER OF BOLTS PER ROW, n								
	2	3	4	5	6	7	8	9	10
C_3	1.333	1.200	1.143	1.111	1.091	1.077	1.067	1.059	1.053

TABLE 12a
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)



BASED ON STANDARD HOLES, 3" FASTENER SPACING AND STANDARD ANGLE GAGES

A S D
Fy=50 KSI

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

t = PLATE THICKNESS
n = NUMBER OF BOLTS PER LINE

COEFFICIENT C1

BOLT DIAMETER (INCHES)	Lh (INCHES)	NUMBER OF BOLTS PER ROW, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	83.5	126.1	168.8	211.5	254.1	296.8	339.4	382.1	424.7
	1.5	93.2	135.9	178.5	221.2	263.9	306.5	349.2	391.8	434.5
	2.0	103.0	145.6	188.3	231.0	273.6	316.3	358.9	401.6	444.2
	2.5	112.7	155.4	198.0	240.7	283.4	326.0	368.7	411.3	454.0
	3.0	122.5	165.1	207.8	250.5	293.1	335.8	378.4	421.1	463.7
7/8	1.0	79.8	120.0	160.3	200.5	240.7	280.9	321.1	361.4	401.6
	1.5	89.6	129.8	170.0	210.2	250.5	290.7	330.9	371.1	411.3
	2.0	99.3	139.5	179.8	220.0	260.2	300.4	340.6	380.9	421.1
	2.5	109.1	149.3	189.5	229.7	270.0	310.2	350.4	390.6	430.8
	3.0	118.8	159.0	199.3	239.5	279.7	319.9	360.1	400.4	440.6
1	1.0	76.2	114.0	151.7	189.5	227.3	265.1	302.9	340.6	378.4
	1.5	85.9	123.7	161.5	199.3	237.0	274.8	312.6	350.4	388.2
	2.0	95.7	133.5	171.2	209.0	246.8	284.6	322.4	360.1	397.9
	2.5	105.4	143.2	181.0	218.8	256.5	294.3	332.1	369.9	407.7
	3.0	115.2	153.0	190.7	228.5	266.3	304.1	341.9	379.6	417.4

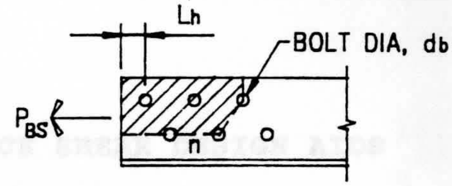
COEFFICIENT C2

BOLT DIAMETER (INCHES)	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
3/4	68.3	89.6	112.7	129.0
7/8	62.2	83.5	106.6	122.9
1	56.1	77.4	100.5	116.8

TABLE 12b
BLOCK SHEAR COEFFICIENTS
(KIPS/INCH)

BASED ON STANDARD HOLES, 3" FASTENER SPACING
AND STANDARD ANGLE GAGES

A S D
Fy=50 KSI



$P_{BS} = (C_1 + C_2)t \times C_3$

t = PLATE THICKNESS
n = NUMBER OF BOLTS PER LINE

COEFFICIENT C_1

BOLT DIAMETER (INCHES)	Lh (INCHES)	NUMBER OF BOLTS PER ROW, n								
		2	3	4	5	6	7	8	9	10
3/4	1.0	40.8	83.5	126.1	168.8	211.5	254.1	296.8	339.4	382.1
	1.5	50.6	93.2	135.9	178.5	221.2	263.9	306.5	349.2	391.8
	2.0	60.3	103.0	145.6	188.3	231.0	273.6	316.3	358.9	401.6
	2.5	70.1	112.7	155.4	198.0	240.7	283.4	326.0	368.7	411.3
	3.0	79.8	122.5	165.1	207.8	250.5	293.1	335.8	378.4	421.1
7/8	1.0	39.6	79.8	120.0	160.3	200.5	240.7	280.9	321.1	361.4
	1.5	49.4	89.6	129.8	170.0	210.2	250.5	290.7	330.9	371.1
	2.0	59.1	99.3	139.5	179.8	220.0	260.2	300.4	340.6	380.9
	2.5	68.9	109.1	149.3	189.5	229.7	270.0	310.2	350.4	390.6
	3.0	78.6	118.8	159.0	199.3	239.5	279.7	319.9	360.1	400.4
1	1.0	38.4	76.2	114.0	151.7	189.5	227.3	265.1	302.9	340.6
	1.5	48.1	85.9	123.7	161.5	199.3	237.0	274.8	312.6	350.4
	2.0	57.9	95.7	133.5	171.2	209.0	246.8	284.6	322.4	360.1
	2.5	67.6	105.4	143.2	181.0	218.8	256.5	294.3	332.1	369.9
	3.0	77.4	115.2	153.0	190.7	228.5	266.3	304.1	341.9	379.6

COEFFICIENT C_2

BOLT DIAMETER (INCHES)	ANGLE LEG LENGTH (INCHES)			
	5	6	7	8
3/4	68.3	89.6	112.7	129.0
7/8	62.2	83.5	106.6	122.9
1	56.1	77.4	100.5	116.8

COEFFICIENT C_3

COEFFICIENT	NUMBER OF BOLTS PER ROW, n								
	2	3	4	5	6	7	8	9	10
C_3	1.333	1.200	1.143	1.111	1.091	1.077	1.067	1.059	1.053

CHAPTER 3

EXAMPLES AND VERIFICATION OF BLOCK SHEAR DESIGN AIDS

The examples presented in this chapter are included to clarify the use of the inherent block shear design aids. In order to verify the accuracy of these newly developed block shear design aids, each of the following example problems will be initially solved using the appropriate AISC equations. The example problem will then be re-solved using the developed block shear design aids. The results of each method will then be compared, thereby demonstrating the accuracy of each of the design aid tables.

EXAMPLE 1:

An angle, L4"x4"x1/2", is welded to a 3/4" thick gusset plate as shown in Figure 3.1. Check the block shear capacity of the gusset plate using AISC LRFD if A36 steel is used.

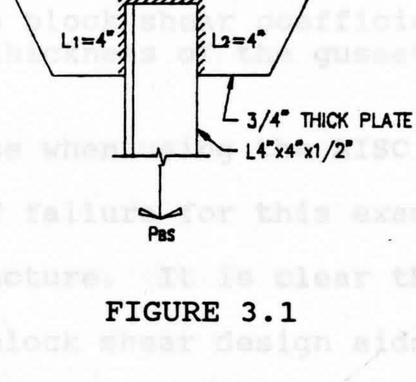


FIGURE 3.1

AISC LRFD EQUATIONS:

SHEAR YIELD AND TENSION FRACTURE:

$P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$
$= 0.75[0.6(36 \text{ ksi})(4"+4")(3/4") + 58 \text{ ksi}(4")(3/4")]$
$= 227.7$ kips

TENSION YIELD AND SHEAR FRACTURE:

$P_{BS} = \phi[F_yA_{tg} + 0.6F_uA_{vn}]$
$= 0.75[36 \text{ ksi}(4")(3/4") + 0.6(58 \text{ ksi})(4"+4")(3/4")]$
$= 237.6$ kips

For this problem, the controlling block shear mode of failure is tension yield and shear fracture.

BLOCK SHEAR DESIGN AID METHOD:

Using Figure 3.1, $L_1+L_2 = 8"$, and $L_3 = 4"$.

SHEAR YIELD AND TENSION FRACTURE:

$P_{BS} = Ct$
$= 303.6$ kips/inch x 3/4"
$= 227.7$ kips

where C is the block shear coefficient from Table 1a, and t is the thickness of the gusset plate.

TENSION YIELD AND SHEAR FRACTURE:

$P_{BS} = Ct$
$= 316.8$ kips/inch x 3/4"
$= 237.6$ kips

where C is the block shear coefficient from Table 1b, and t is the thickness of the gusset plate.

As was the case when using the AISC equations, the block shear mode of failure for this example is tension yield and shear fracture. It is clear that the results obtained from the block shear design aids are identical to the results obtained from the AISC LRFD equations.

EXAMPLE 2:

A structural tee, WT5x11, is welded to a 3/8" thick gusset plate as shown in Figure 3.2. Check the block shear capacity of the gusset plate using AISC LRFD if ASTM A-572, Grade 50 steel is used.

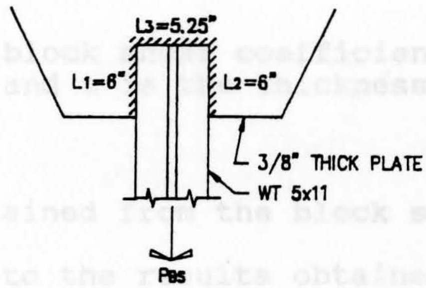


FIGURE 3.2

AISC LRFD EQUATIONS:

SHEAR YIELD AND TENSION FRACTURE:

$$P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$$
$$= 0.75[0.6(50\text{ ksi})(6"+6")(3/8")+65\text{ ksi}(5.25")(3/8)]$$
$$= 197.2\text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$P_{BS} = \phi[F_yA_{tg} + 0.6F_uA_{vn}]$$
$$= 0.75[50\text{ ksi}(5.25")(3/8")+0.6(65\text{ ksi})(6"+6")(3/8")]$$
$$= 205.5\text{ kips}$$

The controlling block shear mode of failure for Example 2 is again tension yield and shear fracture.

BLOCK SHEAR DESIGN AID METHOD:

Using Figure 3.2, L_1+L_2 = 12", and $L_3 = b_f$ = 5.25"

SHEAR YIELD AND TENSION FRACTURE:

$$P_{BS} = Ct$$
$$= 526.0\text{ kips/inch} \times 3/8"$$
$$= 197.2\text{ kips}$$

where C is the block shear coefficient interpolated from Table 2a, and t is the thickness of the gusset plate.

TENSION YIELD AND SHEAR FRACTURE:

P_{BS} = Ct
= 547.9 kips/inch x 3/8"
= 205.5 kips

where C is the block shear coefficient interpolated from Table 2b, and t is the thickness of the gusset plate.

The results obtained from the block shear design aids are again identical to the results obtained from the AISC equations. The controlling block shear mode of failure is, therefore, the same regardless of the procedure used.

It should be noted that block shear coefficient values can be interpolated from any of Tables 1a, 1b, 2a, and 2b. It is possible to interpolate between values of L_3, as in the preceding example, or between values of L_1+L_2. It is, therefore, possible to use the block shear design aids for practically any weldment.

EXAMPLE 3:

An angle, L5"x5"x1/2", is welded to a 7/8" thick gusset plate as shown in Figure 3.3. Check the block shear capacity of the gusset plate using AISC LRFD if A36 steel is used.

AISC LRFD EQUATIONS:

SHEAR YIELD AND TENSION FRACTURE:

P_{BS} = ϕ[0.6F_yA_{vg} + F_uA_{tn}]
= 0.75[0.6(36 ksi)(5"+10")(7/8")+58 ksi(5")(7/8")]
= 402.9 kips

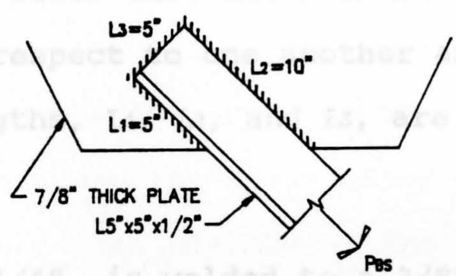


Figure 3.3

TENSION YIELD AND SHEAR FRACTURE:

$P_{BS} = \phi[F_yA_{tg} + 0.6F_uA_{vn}]$
$= 0.75[36\text{ ksi}(5")(7/8")+0.6(58\text{ ksi})(5"+10")(7/8")]$
$= 460.7$ kips

In this case, tension yield and shear fracture is the controlling block shear mode of failure.

BLOCK SHEAR DESIGN AID METHOD:

SHEAR YIELD AND TENSION FRACTURE:

$P_{BS} = Ct$
$= 460.5$ kips/inch x 7/8"
$= 402.9$ kips

where C is the block shear coefficient from Table 1a, and t is the thickness of the gusset plate.

TENSION YIELD AND SHEAR FRACTURE:

$P_{BS} = Ct$
$= 526.5$ kips/inch x 7/8"
$= 460.7$ kips

where C is the block shear coefficient from Table 1b, and t is the thickness of the gusset plate.

Again, the results obtained from the block shear design aids are identical to the values achieved from the AISC LRFD equations. It is clear that the members can be oriented in any fashion with respect to one another as long as the required weld lengths, L_1, L_2, and L_3, are known.

EXAMPLE 4:

An angle, L3"x3"x1/4", is welded to a 3/8" thick gusset plate as shown in Figure 3.4. Check the block shear capacity of the gusset plate using AISC ASD if A36 steel is used.

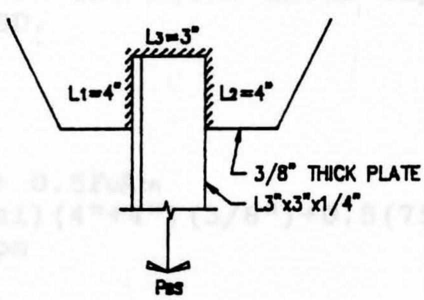


FIGURE 3.4

AISC ASD EQUATION:

$P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn}$
$= 0.3(58\text{ ksi})(4"+4")(3/8")+0.5(58\text{ ksi})(3")(3/8")$
$= 84.8\text{ kips}$

BLOCK SHEAR DESIGN AID METHOD:

Using Figure X4, L_1+L_2 = 8", and L_3 = 3"

$P_{BS} = Ct$
$= 226.2\text{ kips/inch} \times 3/8"$
$= 84.8\text{ kips}$

where C is the block shear coefficient from Table 3, and t is the thickness of the gusset plate.

It is clear that the value for the block shear capacity of the gusset plate obtained from the block shear design aid is the same as the value obtained from the AISC ASD equation. Although the ASD equation is easier to calculate than the LRFD equations, the block shear design aids still offer a considerable time savings to the structural designer.

EXAMPLE 5:

If the gusset plate in Example 4 were made of ASTM A-572, Grade 60 steel, check the block shear capacity of the gusset plate using AISC ASD.

AISC ASD EQUATION:

$$P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn}$$
$$= 0.3(75\text{ ksi})(4"+4")(3/8")+0.5(75\text{ ksi})(3")(3/8")$$
$$= 109.7\text{ kips}$$

BLOCK SHEAR DESIGN AID METHOD:

$$P_{BS} = \text{factor} \times Ct$$
$$= 1.154(253.5\text{ kips/inch})(3/8")$$
$$= 109.7\text{ kips}$$

where C is the block shear coefficient from Table 4, t is the thickness of the gusset plate, and the "factor" is a ratio of minimum tensile strengths of the Grade 60 material to the Grade 50 material, which is the basis of Table 4.

Note that this procedure can only be performed using Table 3 and Table 4. This is due to the fact that these tables are based solely on the specified minimum tensile strength of the material, and not on the yield strength.

EXAMPLE 6:

An angle, L3-1/2"x3-1/2"x1/4", is welded to a 3/8" gusset plate as shown in Figure 3.5. Using AISC ASD, check the block shear capacity of the gusset plate if Grade 50 steel is used.

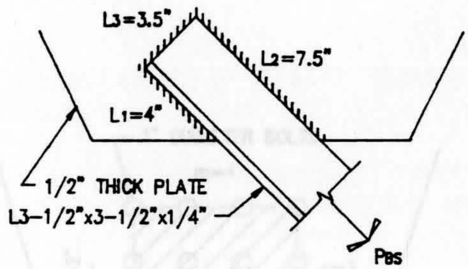


FIGURE 3.5

AISC ASD EQUATION:

$P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn}$
$= 0.3(65 \text{ ksi})(4"+7.5")(3/8")+0.5(65 \text{ ksi})(3.5")(3/8")$
$= 126.8$ kips

BLOCK SHEAR DESIGN AID METHOD:

From Figure 3.5, L_1+L_2 = 11.5", and L_3 = 3.5"

$P_{BS} = Ct$
$= 338.0$ kips/inch x 3/8"
$= 126.8$ kips

where C is the block shear coefficient interpolated from Table 4, and t is the thickness of the gusset plate.

The value obtained for the block shear capacity of the gusset plate using the block shear design aids again yields the same value as using the AISC ASD equation. This example also demonstrates the wide range of usefulness that the design aids possess when interpolating values.

EXAMPLE 7:

The bolt pattern for a bolted gusset plate is shown in Figure 3.6. Check the block shear capacity of the bolted plate using AISC LRFD if A36 steel is used. (The cross-hatched section of the plate is the likely portion assumed to tear away.)

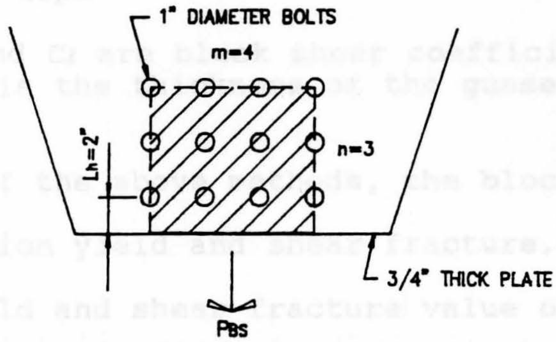


FIGURE 3.6

AISC LRFD EQUATIONS:

SHEAR YIELD AND TENSION FRACTURE:

$$P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$$
$$= 0.75[0.6(36\text{ ksi})(2)(3"+3"+2")(3/4")+58\text{ ksi}((3(3")-3(1.0625"))(3/4")]$$
$$= 384.0\text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$P_{BS} = \phi[F_yA_{tg} + 0.6F_uA_{vn}]$$
$$= 0.75[36\text{ ksi}(3)(3")(3/4")+0.6(58\text{ ksi})(2)((2"+2(3")-2.5(1.0625"))(3/4")]$$
$$= 391.5\text{ kips}$$

BLOCK SHEAR DESIGN AID METHOD:

From Figure 3.6, m=4, n=3, and L_h=2"

SHEAR YIELD AND TENSION FRACTURE:

P_{BS} = (C_1 + C_2)t
= (252.8 kips/inch + 259.2 kips/inch)(3/4")
= 384.0 kips

where C_1 and C_2 are block shear coefficients from Table 5a, and t is the thickness of the gusset plate.

TENSION YIELD AND SHEAR FRACTURE:

P_{BS} = (C_1 + C_2)t
= (243.0 kips/inch + 278.9 kips/inch)(3/4")
= 391.4 kips

where C_1 and C_2 are block shear coefficients from Table 5b, and t is the thickness of the gusset plate.

For both of the above methods, the block shear mode of failure is tension yield and shear fracture. Notice that the tension yield and shear fracture value obtained from the block shear design aid method is slightly lower than the value obtained from the AISC equations. The amount that these figures differ by is insignificant, and since the design aid value is lower than that yielded by the AISC equations, the block shear design aid gives a slightly conservative solution. In general, if there are any differences between the AISC equation values and the values obtained from the block shear design aids, they are negligible.

EXAMPLE 8:

A W12x50 column is subjected to tension. The bolt pattern for a splice in this column is as shown in Figure 3.7. Check the block shear capacity of the column web using AISC LRFD if Grade 50 steel is used.

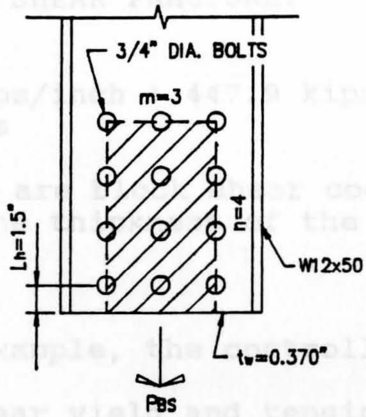


FIGURE 3.7

AISC LRFD EQUATIONS:

SHEAR YIELD AND TENSION FRACTURE:

$P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$
$= 0.75[0.6(50 \text{ ksi})(2)(1.5"+3(3"))(0.37")+65 \text{ ksi} \times(2(3")-2(0.8125"))(0.37")]$
$= 253.7$ kips

TENSION YIELD AND SHEAR FRACTURE:

$P_{BS} = \phi[F_yA_{tg} + 0.6F_uA_{vn}]$
$= 0.75[50 \text{ ksi}(3"+3")(0.37")+0.6(65 \text{ ksi})(2) \times(1.5"+3(3")-3.5(0.8125"))(0.37")]$
$= 249.0$ kips

BLOCK SHEAR DESIGN AID METHOD:

From Figure 3.7, m=3, n=4, and L_h=1.5"

SHEAR YIELD AND TENSION FRACTURE:

$P_{BS} = (C_1 + C_2)t$
$= (213.3 \text{ kips/inch} + 472.5 \text{ kips/inch})(0.37")$
$= 253.7$ kips

where C_1 and C_2 are block shear coefficients from Table 6a, and t is the thickness of the plate, or column web in this case.

TENSION YIELD AND SHEAR FRACTURE:

P_{BS} = (C1 + C2)t
= (225.0 kips/inch + 447.9 kips/inch)(0.37")
= 249.0 kips

where C1 and C2 are block shear coefficients from Table 6b, and t is the thickness of the plate, or column web in this case.

In the above example, the controlling mode of block shear failure is shear yield and tension fracture. The values obtained from both methods were identical. It is clear, however, that the block shear design aid method is much easier to calculate in this case.

EXAMPLE 9:

The bolt pattern for a bolted gusset plate is shown in Figure 3.8. Check the block shear capacity of the bolted plate using AISC ASD if A36 steel is used. (Again, the cross-hatched area has been assumed to be the most likely failure mode.)

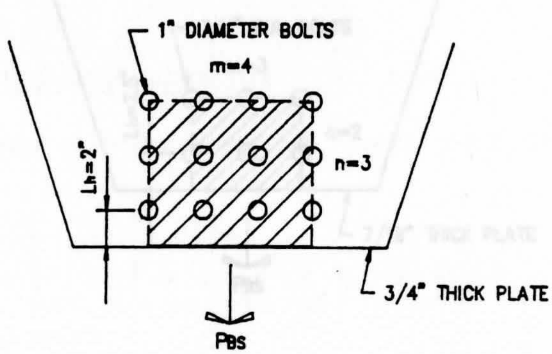


Figure 3.8

AISC ASD EQUATION:

P_{BS} = 0.3FuAvn + 0.5FuAtn
= 0.3(58 ksi)(2)(2"+2(3")-2.5(1.0625"))(3/4")
+0.5(58 ksi)(3(3")-3(1.0625))(3/4")]
= 265.9 kips

BLOCK SHEAR DESIGN AID METHOD:

From Figure 3.8, m=4, n=3, and L_h=2".

$$P_{BS} = (C_1 + C_2)t$$
$$= (168.6 \text{ kips/inch} + 186.0 \text{ kips/inch})(3/4")$$
$$= 266.0 \text{ kips}$$

where C_1 and C_2 are block shear coefficients from Table 7, and t is the thickness of the gusset plate.

The difference in the block shear capacity of the gusset plate is essentially the same regardless of the method used. The difference between the methods, 0.1 kips, is negligible.

EXAMPLE 10:

The bolt pattern for a bolted gusset plate is shown in Figure 3.9. Check the block shear capacity of the bolted plate using AISC ASD if Grade 50 steel is used.

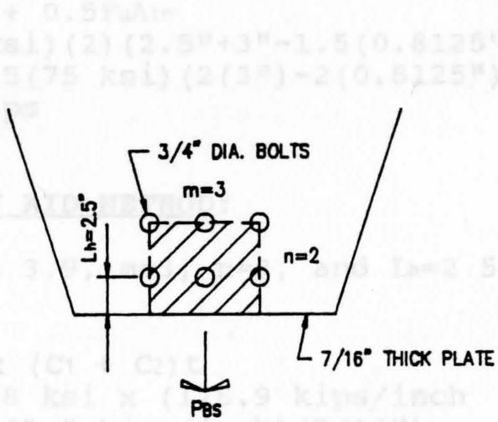


Figure 3.9

AISC ASD EQUATION:

$$P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn}$$
$$= 0.3(65 \text{ ksi})(2)(2.5"+3"-1.5(0.8125")(7/16")$$
$$+0.5(65 \text{ ksi})(2(3")-2(0.8125"))(7/16")$$
$$= 135.3 \text{ kips}$$

BLOCK SHEAR DESIGN AID METHOD:

From Figure 3.9, m=3, n=2, and L_h=2.5"

$$P_{BS} = (C_1 + C_2)t$$
$$= (142.2 \text{ kips/inch} + 167.0 \text{ kips/inch})(7/16")$$
$$= 135.3 \text{ kips}$$

where C_1 and C_2 are block shear coefficients from Table 8, and t is the thickness of the gusset plate.

Identical solutions are once again achieved. In this case, the block shear design aids provide a much faster approach than the AISC equation.

EXAMPLE 11:

Check the block shear capacity of the gusset plate in Example 10 if ASTM A-572 Grade 60 steel is used.

AISC ASD EQUATION:

$$P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn}$$
$$= 0.3(75 \text{ ksi})(2)(2.5"+3"-1.5(0.8125"))(7/16")$$
$$+0.5(75 \text{ ksi})(2(3")-2(0.8125"))(7/16")$$
$$= 156.1 \text{ kips}$$

BLOCK SHEAR DESIGN AID METHOD:

Again, from Figure 3.9, m=3, n=2, and L_h=2.5"

$$P_{BS} = \text{factor} \times (C_1 + C_2)t$$
$$= 75 \text{ ksi}/58 \text{ ksi} \times (126.9 \text{ kips/inch} + 149.0 \text{ kips/inch})(7/16")$$
$$= 156.1 \text{ kips}$$

where C_1 and C_2 are block shear coefficients from Table 7, t is the thickness of the gusset plate, and the "factor" is a ratio of ultimate strengths of Grade 60 steel to A36 steel, which is the basis of Table 7.

The solution is again the same for both methods. It should be noted that Table 8 could have also been used in

Example 11. In that case, however, the "factor" would have been the ratio of specified minimum tensile strengths of Grade 60 steel to Grade 50 steel, or 75 ksi/65 ksi. Since all of the design equations, and thus the design aids for AISC ASD, are based solely on the specified minimum tensile strength of the material, F_u, it is possible to use a strength ratio factor (75 ksi/58 ksi in this instance) in order to use these tables for any grade of steel. This **is NOT** a possible scenario for the AISC LRFD design aids since those are based on the LRFD equations which use the specified minimum tensile strength in one term and the yield strength in the other term.

EXAMPLE 12:

The bolt pattern for a bolted gusset plate is shown in Figure 3.10a. Check the block shear capacity of the bolted plate using AISC ASD if A36 steel is used.

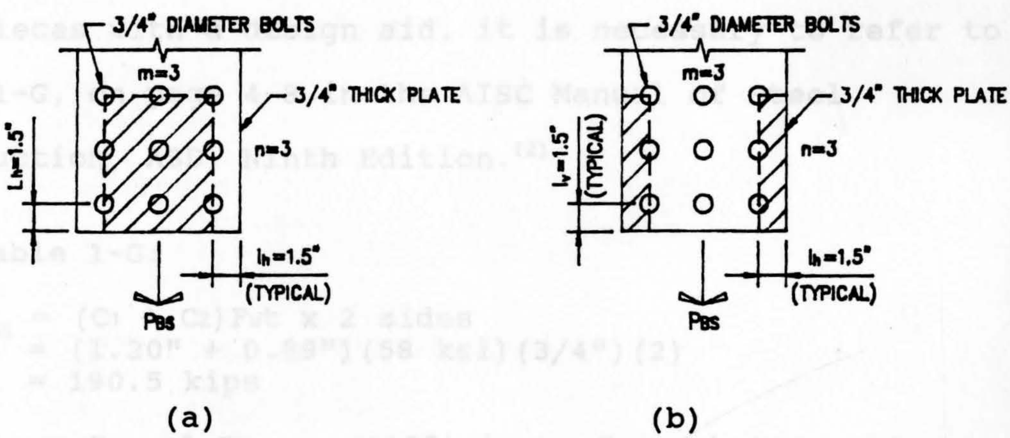


Figure 3.10: (a) Case 1, (b) Case 2

AISC ASD EQUATION, CASE 1:

$$
\begin{aligned}
P_{BS} &= 0.3F_uA_{vn} + 0.5F_uA_{tn} \\
&= 0.3(58\text{ ksi})(2)(1.5"+2(3")-2.5(0.8125"))(3/4") \\
&\quad +0.5(58\text{ ksi})(2(3")-2(0.8125"))(3/4") \\
&= 237.9\text{ kips}
\end{aligned}
$$

AISC ASD EQUATION, CASE 2:

$$
\begin{aligned}
P_{BS} &= 0.3F_uA_{vn} + 0.5F_uA_{tn} \\
&= 0.3(58\text{ ksi})(2)(1.5"+2(3")-2.5(0.8125")(3/4") \\
&\quad +0.5(58\text{ ksi})(2)(1.5"-0.5(0.8125"))(3/4") \\
&= 190.3\text{ kips}
\end{aligned}
$$

BLOCK SHEAR DESIGN AID METHOD, CASE 1:

From Figure 3.10a, m=3, n=3, and L_h=1.5".

$$
\begin{aligned}
P_{BS} &= (C_1 + C_2)t \\
&= (126.9\text{ kips/inch} + 190.3\text{ kips/inch})(3/4") \\
&= 237.9\text{ kips}
\end{aligned}
$$

where C_1 and C_2 are block shear coefficients from Table 7, and t is the thickness of the bolted gusset plate.

In this example, the two edge pieces, shown cross-hatched in Figure 3.10b, will break away before the center portion tears out. In order to check the adequacy of the edge pieces with a design aid, it is necessary to refer to Table 1-G, on page 4-8 in the AISC Manual of Steel Construction, ASD, Ninth Edition.[2]

From Table 1-G:

$$
\begin{aligned}
R_{BS} &= (C_1 + C_2)F_ut \times 2\text{ sides} \\
&= (1.20" + 0.99")(58\text{ ksi})(3/4")(2) \\
&= 190.5\text{ kips}
\end{aligned}
$$

where C_1 and C_2 are coefficients for web tear-out (block shear) from Table 1-G, F_u is the specified minimum tensile strength of the gusset plate, and t is the thickness of the gusset plate.

Caution must be used when determining the mode of failure in a plate when the edge distances are small. The capacity of the edge pieces can similarly be determined using AISC LRFD. The designer can refer to Table 1-G, on pages 5-10 through 5-13 in the AISC Manual of Steel Construction, LRFD, First Edition.[3]

EXAMPLE 13:

Determine the block shear capacity of the angle, L5"x5"x1/2", if bolt holes are placed as shown in Figure 3.11. The angle is made of A36 steel. Use AISC LRFD.

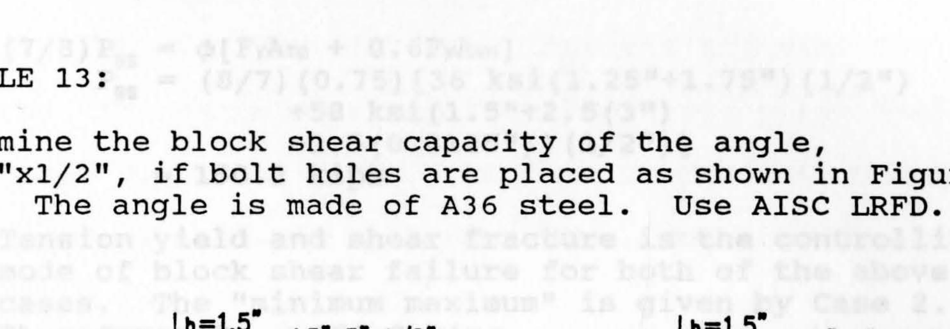


FIGURE 3.11: (a) Case 1, (b) Case 2

<u>AISC LRFD EQUATIONS, CASE 1</u>:

SHEAR YIELD AND TENSION FRACTURE:

$$P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$$
$$= 0.75[0.6(36\text{ ksi})(1.5"+3.5(3"))(1/2")$$
$$+58\text{ ksi}(1.25"+1.75"+(1.5(1.5)/(4(1.75))$$
$$-1.5(0.8125"))(1/2")]$$
$$= 142.9\text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$P_{BS} = \phi[F_yA_{tg} + 0.6F_uA_{vn}]$$
$$= 0.75[36\text{ ksi}(1.75"+1.25")(1/2")$$
$$+0.6(58\text{ ksi})(1.5"+3.5(3")$$
$$-3.5(0.8125"))(1/2")]$$
$$= 160.0\text{ kips}$$

AISC LRFD EQUATIONS, CASE 2:

SHEAR YIELD AND TENSION FRACTURE:

$$(7/8)P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$$

$$P_{BS} = (8/7)(0.75)[0.6(36\text{ ksi})(1.5"+2.5(3"))(1/2") +58\text{ ksi}(1.25"+1.75"+(1.5(1.5)/(4(1.75)) -1.5(0.8125"))(1/2")]$$

$$= 135.6\text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$(7/8)P_{BS} = \phi[F_yA_{tg} + 0.6F_yA_{vn}]$$

$$P_{BS} = (8/7)(0.75)[36\text{ ksi}(1.25"+1.75")(1/2") +58\text{ ksi}(1.5"+2.5(3") -2.5(0.8125"))(1/2")]$$

$$= 150.2\text{ kips}$$

Tension yield and shear fracture is the controlling mode of block shear failure for both of the above cases. The "minimum maximum" is given by Case 2. Therefore, P_{BS} = 150.2 kips.

BLOCK SHEAR DESIGN AID METHOD, CASE 1:

From Figure 3.11, n=4, and L_h=1.5"

SHEAR YIELD AND TENSION FRACTURE:

$$P_{BS1} = (C_1 + C_3)t$$
$$= (194.4\text{ kips/inch} + 91.5\text{ kips/inch})(1/2")$$
$$= 143.0\text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$P_{BS2} = (C_2 + C_4)t$$
$$= (239.0\text{ kips/inch} + 81.0\text{ kips/inch})(1/2")$$
$$= 160.0\text{ kips}$$

where C_1, C_2, C_3, and C_4 are block shear coefficients from Table 9a, and t is the thickness of the angle.

BLOCK SHEAR DESIGN AID METHOD, CASE 2:

SHEAR YIELD AND TENSION FRACTURE:

$$P_{BS1} = (C_1 + C_3)t \times C_5$$
$$= (145.8\text{ kips/inch} + 91.5\text{ kips/inch})(1/2")(1.143)$$
$$= 135.6\text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$P_{BS2} = (C_2 + C_4)t \times C_5$$
$$= (181.9 \text{ kips/inch} + 81.0 \text{ kips/inch})(1/2")(1.143)$$
$$= 150.2 \text{ kips}$$

where C_1, C_2, C_3, C_4, and C_5 are block shear coefficients from Table 9b, and t is the thickness of the angle.

In this example, the values obtained for block shear capacity are, for the most part, exactly the same for both methods. The value obtained from the block shear design aid method for P_{BS1}, Case 1, is 0.05 kips larger than the value obtained from the AISC LRFD equation. This difference is negligible.

EXAMPLE 14:

Use AISC LRFD to determine the block shear capacity of the angle, L7"x4"x3/8", shown in Figure 3.12, if 7/8" diameter bolts are used as shown. The angle is made of Grade 50 steel.

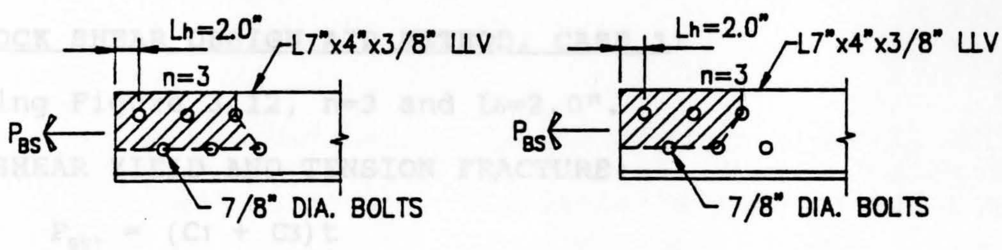


Figure 3.12: (a) Case 1, (b) Case 2

<u>AISC LRFD EQUATIONS, CASE 1</u>:

SHEAR YIELD AND TENSION FRACTURE:

$$P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$$
$$= 0.75[0.6(50 \text{ ksi})(2.0"+2.5(3"))(3/8")+65 \text{ ksi} \times (1.5"+3"+(1.5)(1.5)/(4(3"))-1.5(0.9375"))(3/8")]$$
$$= 140.1 \text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$P_{BS} = \phi[F_yA_{tg} + 0.6F_uA_{vn}]$$
$$= 0.75[50\text{ ksi}(1.5"+3")(3/8")+0.6(65\text{ ksi}) \times (2.0"+2.5(3")-2.5(0.9375"))(3/8")]$$
$$= 141.8\text{ kips}$$

AISC LRFD EQUATIONS, CASE 2:

SHEAR YIELD AND TENSION FRACTURE:

$$(5/6)P_{BS} = \phi[0.6F_yA_{vg} + F_uA_{tn}]$$
$$P_{BS} = (6/5)0.75[0.6(50\text{ ksi})(2.0"+1.5(3"))(3/8") +65\text{ ksi}(1.5"+3"+(1.5)(1.5)/(4(3"))-1.5(0.9375"))(3/8")]$$
$$= 137.8\text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$(5/6)P_{BS} = \phi[F_yA_{tg} + 0.6F_uA_{vn}]$$
$$P_{BS} = (6/5)0.75[50\text{ ksi}(1.5"+3")(3/8")+0.6(65\text{ ksi}) \times (2.0"+1.5(3")-1.5(0.9375"))(3/8")]$$
$$= 143.0\text{ kips}$$

For this example, the block shear mode of failure is tension yield and shear fracture given in Case 2.

BLOCK SHEAR DESIGN AID METHOD, CASE 1:

Using Figure 3.12, $n=3$ and $L_h=2.0"$.

SHEAR YIELD AND TENSION FRACTURE:

$$P_{BS1} = (C_1 + C_3)t$$
$$= (213.8\text{ kips/inch} + 159.9\text{ kips/inch})(3/8")$$
$$= 140.1\text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$P_{BS2} = (C_2 + C_4)t$$
$$= (209.3\text{ kips/inch} + 168.8\text{ kips/inch})(3/8")$$
$$= 141.8\text{ kips}$$

where C_1, C_2, C_3, and C_4 are block shear coefficients from Table 10a, and t is the thickness of the angle.

BLOCK SHEAR DESIGN AID METHOD, CASE 2:

SHEAR YIELD AND TENSION FRACTURE:

$$P_{BS1} = (C_1 + C_3)t \times C_5$$
$$= (146.3 \text{ kips/inch} + 159.9 \text{ kips/inch})(3/8")(1.200)$$
$$= 137.8 \text{ kips}$$

TENSION YIELD AND SHEAR FRACTURE:

$$P_{BS1} = (C_2 + C_4)t \times C_5$$
$$= (149.0 \text{ kips/inch} + 168.8 \text{ kips/inch})(3/8")(1.200)$$
$$= 143.0 \text{ kips}$$

where C_1, C_2, C_3, C_4, and C_5 are block shear coefficients from Table 10b, and t is the thickness of the angle.

It is clear that the developed design aid method is much easier to use than the AISC LRFD equations. The results are the same regardless of the method used. The design aid method can save much time when designing an angle to carry a given load. The block shear calculations are reduced drastically.

EXAMPLE 15:

Use AISC ASD to determine the block shear capacity of the angle, L6"x6"x5/8", shown in Figure 3.13, if 1" diameter bolts are used as shown. The angle is made of A36 steel.

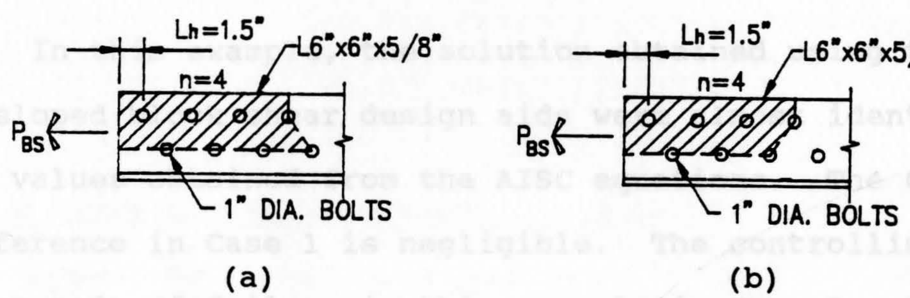


Figure 3.13: (a) Case 1, (b) Case 2

AISC ASD EQUATION, CASE 1:

$$
\begin{aligned}
P_{BS} &= 0.3FuAvn + 0.5FuAtn \\
&= 0.3(58\text{ ksi})(1.5"+3.5(3")-3.5(1.0625"))(5/8") \\
&\quad +0.5(58\text{ ksi})(1.25"+2.5"+1.5(1.5)/(4(2.5")) \\
&\quad -1.5(1.0625"))(5/8") \\
&= 133.2\text{ kips}
\end{aligned}
$$

AISC ASD EQUATION, CASE 2:

$$
\begin{aligned}
(7/8)P_{BS} &= 0.3FuAvn + 0.5FuAtn \\
P_{BS} &= (8/7)[0.3(58\text{ ksi})(1.5"+2.5(3") \\
&\quad -2.5(1.0625"))(5/8")+0.5(58\text{ ksi}) \\
&\quad \times (1.25"+2.5"+1.5(1.5)/(4(2.5")) \\
&\quad -1.5(1.0625"))(5/8")] \\
&= 128.2\text{ kips}
\end{aligned}
$$

BLOCK SHEAR DESIGN AID METHOD, CASE 1:

From Figure 3.13, n=4, and L_h=1.5".

$$
\begin{aligned}
P_{BS} &= (C_1 + C_2)t \\
&= (144.1\text{ kips/inch} + 69.1\text{ kips/inch})(5/8") \\
&= 133.3\text{ kips}
\end{aligned}
$$

where C_1 and C_2 are block shear coefficients from Table 11a, and t is the thickness of the angle.

BLOCK SHEAR DESIGN AID METHOD, CASE 2:

$$
\begin{aligned}
P_{BS} &= (C_1 + C_2)t \times C_3 \\
&= (110.4\text{ kips/inch} + 69.1\text{ kips/inch})(5/8")(1.143) \\
&= 128.2\text{ kips}
\end{aligned}
$$

where C_1, C_2, and C_3 are block shear coefficients from Table 11b, and t is the thickness of the angle.

In this example, the solution obtained using the developed block shear design aids were almost identical to the values obtained from the AISC equations. The 0.1 kip difference in Case 1 is negligible. The controlling block shear mode of failure in this example is Case 2. Again, the equation developed from the design aid is much easier to solve than the AISC equation.

EXAMPLE 16:

Use AISC ASD to determine the block shear capacity of the angle, L8"x4"x1/2", shown in Figure 3.14, if 1" diameter bolts are used as shown. The angle is made of Grade 50 steel.

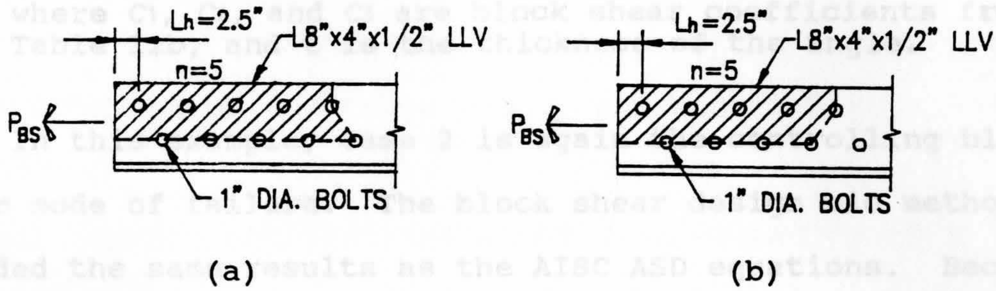


Figure 3.14: (a) Case 1, (b) Case 2

AISC ASD EQUATION, CASE 1:

$$P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn}$$
$$= 0.3(65\text{ ksi})(2.5"+4.5(3")-4.5(1.0625"))(1/2") +0.5(65\text{ ksi})(2.0"+3.0"+1.5(1.5)/(4(3")) -1.5(1.0625"))(1/2")$$
$$= 167.8\text{ kips}$$

AISC ASD EQUATION, CASE 2:

$$(9/10)P_{BS} = 0.3F_uA_{vn} + 0.5F_uA_{tn}$$
$$P_{BS} = (10/9)[0.3(65\text{ ksi})(2.5"+3.5(3") -3.5(1.0625"))(1/2")+0.5(65\text{ ksi}) \times (2.0"+3.0"+1.5(1.5)/(4(3")) -1.5(1.0625"))(1/2")]$$
$$= 165.4\text{ kips}$$

BLOCK SHEAR DESIGN AID METHOD, CASE 1:

From Figure 3.14, n=5, and L_h=2.5".

$P_{BS} = (C_1 + C_2)t$
$= (218.8 \text{ kips/inch} + 116.8 \text{ kips/inch})(1/2")$
$= 167.8 \text{ kips}$

where C_1 and C_2 are block shear coefficients from Table 12a, and t is the thickness of the angle.

BLOCK SHEAR DESIGN AID METHOD, CASE 2:

$P_{BS} = (C_1 + C_2)t \times C_3$
$= (181.0 \text{ kips/inch} + 116.8 \text{ kips/inch})(1/2")(1.111)$
$= 165.4 \text{ kips}$

where C_1, C_2, and C_3 are block shear coefficients from Table 12b, and t is the thickness of the angle.

In this example, Case 2 is again the controlling block shear mode of failure. The block shear design aid method yielded the same results as the AISC ASD equations. Because the procedure associated with the use of the block shear design aids is basically so simple to use, these design aids become extremely effective in the design arena where usually "time is money."

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Design aids to compute the block shear capacity of several types of structural steel tension configurations have been developed and presented. These design aids, in addition to the existing design aids found in the AISC Specifications,[2,3] permit almost any commonly encountered block shear condition to be easily and accurately considered.

It is apparent that the block shear capacity of a fastened tension member is dependent on both the geometry of the member and the strength parameters of the material used. Since fabrication techniques usually lean towards standard assemblies, the block shear capacity of members can be readily tabulated for the most common conditions. In order to be as complete as possible, block shear design aids have been developed for tension members with welded connections and bolted plates, and for bolted angles in tension.

Because these newly developed design aids have evolved directly from the block shear equations given by the AISC, they possess a degree of accuracy which is equal to that obtained from hand calculations using the AISC equations. The use of these new design aids, therefore, complies with the applicable AISC ASD or AISC LRFD Specifications for Structural Steel Buildings.[2,3]

The newly developed block shear design aids have been shown to make block shear capacity calculations easier and less time-consuming for the structural designer. This time savings is gained without a loss in reliability. In fact, the calculation errors often made in calculating block shear capacities with the traditional AISC equations, are minimized by using the design aids. The structural designer can use these design aids with increased confidence in his/her work, while saving time and avoiding mundane calculations.

More important, however, is the fact that examination of block shear is a relatively new consideration under both ASD and LRFD Specifications. It can, therefore, be easily omitted during the design sequence. The presence of the design aids will serve as a convenient reminder to consider this important design mode, which, in many cases, can be the controlling design factor.

As the consideration of block shear becomes more and more second nature in the design sequence, there will be more situations encountered where block shear will need to be considered and yet no design aid is available. It is hoped that such aids can be easily developed, even for complex geometric conditions, with this study serving as a basic example for such further development.

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