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Analysis of Shear Lag in Steel Angle Connectors

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Previous research has found an empirically based method for calculating the effective net area defined by stress distributions created by tensile loads in steel connections. Based on the results from that method a theoretical alternative is explored to simplify the process of determining the effective net area.

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Introduction

Material properties have been studied throughout the history of constructed facilities because the natural differences at a microscopic level cause every piece of material and every section of each piece to behave slightly differently. This is problematic since consistent properties are the basis for linear elastic designs using the materials. The strength of a material is of particular concern in structural engineering. The strength of the material must be a known, useable value in order to adequately design structures to withstand the expected loads. The materials and methods used to connect steel members is particularly interesting because the connections can easily be the weakest point in a structure due to the reliance on the small cross-sectional areas of welds or bolts to transfer loads from member to member. The results discussed in this report focus on bolted connections on steel angle members.

There are three ways that tension connection members typically fail. One is yielding which occurs when the member experiences a stress high enough that the entire cross-section of the member begins to elongate in the direction of the loading without any further increase in load magnitude. Another mode of failure is rupture which occurs when the member experiences a stress that causes the member to crack and split apart along stress planes. The third mode of failure is bearing at the bolt hole which occurs when the material fails locally at the bolt hole due to yielding or rupture of the material directly in contact with the bolt transferring the load to the connection member.

While failure due to yielding is a well known and described phenomenon, failure due to rupture is more difficult to define because the loading through the bolts causes non-uniform stress distributions which can be difficult to describe mathematically. However a reasonable approximation of the stress distribution is necessary for determining the load that will cause the member to fail. This non-uniform stress distribution created by the loading is known as shear lag. In 1952, R.E. Whitmore published the results of experiments he performed that described the shapes of different stress distributions in connection members (Whitmore, 1952), and further research done by E. Chesson, Jr. and W.H. Munse in prior to 1963 led to the equation that is currently used to account for shear lag (Chesson & Munse, 1963).

Background

Prior to 1952, design of gusset plates was fairly arbitrary: the engineer would design the plate to be large enough to place all the necessary rivets properly and then the thickness was chosen in accordance with similar trusses. R.E. Whitmore noted that other structural members in trusses had been researched and could be accurately designed, but gusset plates were severely lacking in research to identify the distribution of stresses (Whitmore, p. 2). Whitmore's research addressed this problem and identified the stress contours for both tensile and compressive loads. The figures he created from the data showed that the stresses dispersed outward from the loading point as was expected (Whitmore, p. 17). Whitmore concluded that the best method for determining the stresses was to assume the stress was uniformly distributed over an area at the end of diagonals spread out 30° from the point of loading (Whitmore, p. 30). This area is known as the Whitmore section.

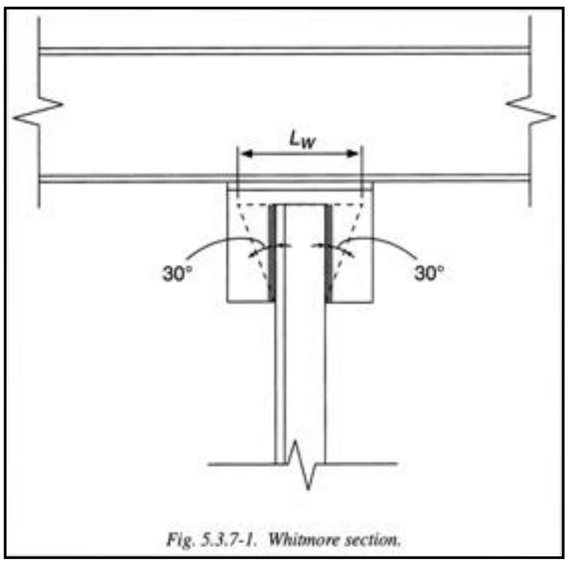

Figure 1: Whitmore section defined by L_W in AISC Steel Construction Manual, 13th Edition

While Whitmore's research was essential to finding the stress distributions, his work involved only a small number of samples and there was still no simple way to describe the strength of the gusset plates. Then in 1963, E. Chesson, Jr. and W. H. Munse conducted further research on the subject and used a larger number of samples. Their work also accounted for different types of failure in the connection.

Chesson and Munse found that the method provided at that time by the American Institute of Steel Construction (AISC), used the full net are to define the strength of the connection and considerably overestimated the strength. They determined that a new relationship was needed to predict the strength more accurately.

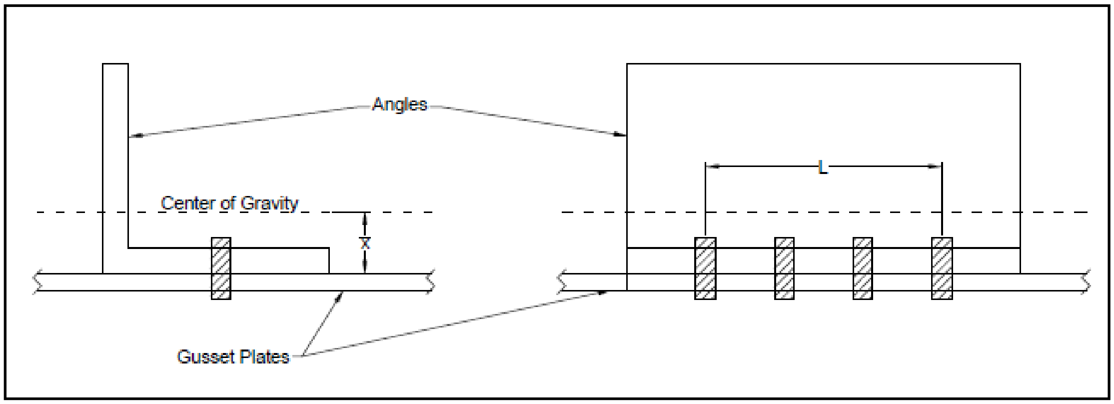

Figure 2: Chesson and Munse Parameters

They found two parameters that greatly affected the strength: the distance from the centroid of the connection member to the interface with the gusset plate ($\bar{x}$), and the length between the first and last row of rivets in the connection (L) (Chesson & Munse, p. 101). The tests they had conducted showed that the strength of the members decreased when $\bar{x}$ increased and the strength increased when L increased. From these relationships they related the two factors with the simple ratio $\bar{x}/_L$. From that ratio they were able to create a simple expression that more accurately predicted the effective net area of the members (Chesson & Munse, p. 104).

$$Effective\ Net\ Area, A_e = \left(1 - \frac{\bar{x}}{L}\right) A_N \quad \textbf{[Eq. 1]}$$

Where:

A_e = Effective net area
A_N = Net area
$\bar{x}$ = Distance from connection plane to member centroid
L = Length of connection

The $\left(1 - \bar{x}/_{L}\right)$ term is referred to as the shear lag factor (U) and is currently used in the AISC Steel Construction Manual[1] from the calculation of the effective net area in certain tension members.

Following Chesson and Munse’s work AISC determined that the method using the shear lag factor was simpler, yet still effective for determining the effective net area, so it was adapted to be used in multiple circumstances beyond what Chesson and Munse’s equation was intended for.

$$A_e = UA_N \qquad \textbf{[Eq. 2]}$$

Using Equation 2, AISC can specify alternative shear lag factors values for different member connector configurations than the ones Chesson and Munse tested (Easterling & Giroux, pp. 77-78).

While Equation 1 is effective, it is empirically based and requires the additional step of calculating the net area of the member and the shear lag factor. Instead of using the empirically based formula, a theoretical equation can be created through mathematical analysis to directly calculate the effective net area without finding the net area or shear lag factor. In order for the theoretical equation to give accurate results, it can be compared to the results of the empirically based formula since that equation was based on actually experimental results.

[1] AISC Steel Construction Manual 14th Edition, Table D3.1, p. 16.1-28

Methods

In order to compare the theoretical results with the empirically based results found by Chesson and Munse (1963), a theoretical shear lag factor needed to be calculated. Using the relation between net area and effective net area in Equation 2, the theoretical shear lag factor was solved for by dividing the effective net area by the net area.

$$Theoretical\ shear\ lag\ factor, U_T = \frac{A_e}{A_N} \quad \textbf{[Eq. 3]}$$

While A_N was calculated using known values, the equation for A_e needed to be obtained using geometric methods. For angle members, this method involved mathematically flattening the angle to create a flat surface for determining the effective width of the stress distribution.

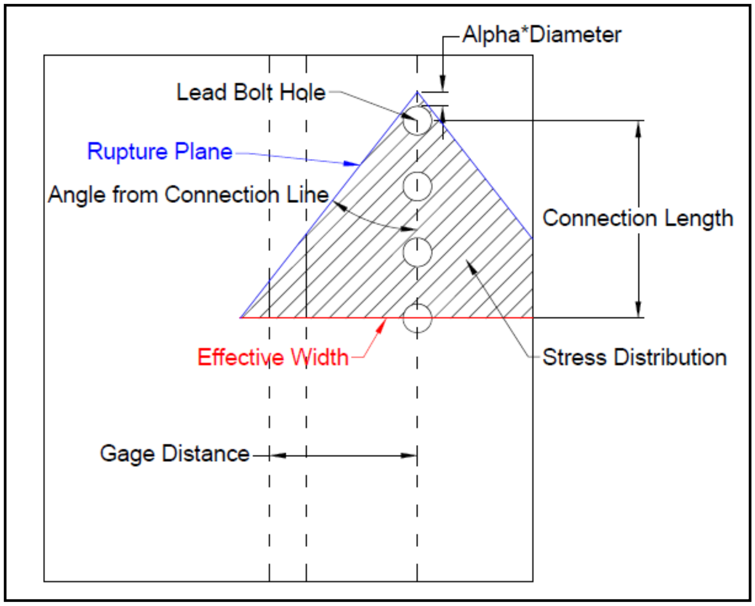

Figure 3: Flattened Angle

The total width of the flattened angle is equivalent to a line taken through the centerline of the thickness of both legs and it is equal to the sum of the leg lengths minus the thickness of the angle. This width times the thickness gives the same gross area as the normal angle.

To create a realistic approximation of the distribution of forces through the section, two parameters were included: an offset from the lead bolt hole and angle from the connection line.

The offset, termed in this study as the alpha factor (α), was varied in terms of a percentage of the bolt hole diameter. This offset ranged from zero to 800% of the bolt hole diameter. Using these two parameters, the stress distribution was approximated as shown in Figure 1. Using this distribution, the effective net area is equal to the effective width times the thickness. The effective width was calculated as two separate parts since each side of the connection line had different conditions.

$$Effective\ width\ left\ of\ connection\ line, D_L = Minimum\{h - t + g, [L + \varphi_{BH} \times (\alpha + 0.5)] \times \tan\theta\}$$ **[Eq. 4]**

$$Effective\ width\ right\ of\ connection\ line, D_R = Minimum\{w - g, [L + \varphi_{BH} \times (\alpha + 0.5)] \times \tan\theta\}$$ **[Eq. 5]**

$$Effective\ Net\ Area, A_e = (D_L + D_R + \varphi_{BH}) \times t$$ **[Eq. 6]**

Where:

h = Height of angle	L = Length of connection
w = Width of angle	φ_{BH} = Bolt hole diameter
t = Thickness of angle	α = Alpha factor
g = gage distance[2]	θ = Angle of stress distribution

Once the method for calculating the theoretical shear lag factor was determined, the empirically based shear lag factors could be used to determine reasonable values for the alpha factor and angle. These values were determined using the least squares method on the theoretical and empirically based shear lag factors. One of the tables used to calculate the least squares of the shear lag factors can be found in Appendix A.

[2] As defined in AISC Steel Construction Manual, 14th Edition, Table 1-7A

Results

Table 1: Least Squares for Varying Connections Lengths

NOTE: All samples in this table assume a bolt diameter of 0.75 inches

1.5" Bolt Hole Spacing

# Bolts	α	θ (°)	$\Sigma(\Delta U)^2$	$\alpha*\Sigma(\Delta U)^2$	$\theta*\Sigma(\Delta U)^2$
2	2.61	22.88	2.861	7.45	65.46
3	6.07	23.99	1.729	10.49	41.48
4	7.20	24.86	2.121	15.28	52.73
5	6.08	24.86	1.605	9.76	39.90
6	6.38	25.51	1.193	7.61	30.43
SUM			9.509	50.59	230.00
AVG				**5.32**	**24.19**

2" Bolt Hole Spacing

# Bolts	α	θ (°)	$\Sigma(\Delta U)^2$	$\alpha*\Sigma(\Delta U)^2$	$\theta*\Sigma(\Delta U)^2$
2	3.65	23.16	2.495	9.10	57.78
3	6.46	24.14	1.236	7.98	29.84
4	6.52	24.16	1.605	10.46	38.78
5	6.41	24.97	1.079	6.91	26.94
6	5.59	24.43	0.786	4.39	19.20
SUM			7.201	38.85	172.54
AVG				**5.39**	**23.96**

2.5" Bolt Hole Spacing

# Bolts	α	θ (°)	$\Sigma(\Delta U)^2$	$\alpha*\Sigma(\Delta U)^2$	$\theta*\Sigma(\Delta U)^2$
2	4.48	23.44	2.157	9.65	50.56
3	6.36	24.02	1.016	6.46	24.40
4	7.12	24.49	1.193	8.49	29.22
5	5.81	24.16	0.786	4.56	18.99
6	5.75	24.23	0.565	3.25	13.69
SUM			5.717	32.42	136.86
AVG				**5.67**	**23.94**

3" Bolt Hole Spacing

# Bolts	α	θ (°)	$\Sigma(\Delta U)^2$	$\alpha*\Sigma(\Delta U)^2$	$\theta*\Sigma(\Delta U)^2$
2	5.09	23.69	1.745	8.89	41.34
3	6.27	23.87	0.963	6.04	22.99
4	6.71	23.88	0.911	6.11	21.75
5	6.04	24.17	0.603	3.64	14.57
6	3.96	23.88	0.428	1.70	10.22
SUM			4.650	26.38	110.88
AVG				**5.67**	**23.84**

3.5" Bolt Hole Spacing

# Bolts	α	θ (°)	$\Sigma(\Delta U)^2$	$\alpha*\Sigma(\Delta U)^2$	$\theta*\Sigma(\Delta U)^2$
2	5.86	24.08	1.400	8.20	33.71
3	6.00	23.56	0.983	5.90	23.16
4	6.31	23.18	0.735	4.64	17.04
5	5.52	23.23	0.473	2.61	10.99
6	5.30	22.37	0.346	1.84	7.74
SUM			3.937	23.18	92.64
AVG				**5.89**	**23.53**

4" Bolt Hole Spacing

# Bolts	α	θ (°)	$\Sigma(\Delta U)^2$	$\alpha*\Sigma(\Delta U)^2$	$\theta*\Sigma(\Delta U)^2$
2	4.91	26.80	1.184	5.81	31.73
3	5.01	26.57	0.927	4.64	24.63
4	4.56	25.73	0.603	2.75	15.52
5	3.36	23.77	0.392	1.32	9.32
6	2.81	22.64	0.273	0.77	6.18
SUM			3.379	15.29	87.38
AVG				**4.53**	**25.86**

Total $\alpha*\Sigma(\Delta U)^2$	186.7
Total $\theta*\Sigma(\Delta U)^2$	830
Total $\Sigma(\Delta U)^2$	34.4
Total Avg α	**5.43**
Total Avg θ (°)	**24.14**

Weighted Total $\alpha*\Sigma(\Delta U)^2$	120.4
Weighted Total $\theta*\Sigma(\Delta U)^2$	528
Weighted Total $\Sigma(\Delta U)^2$	21.9
Weighted Total Avg α	**5.49**
Weighted Total Avg θ (°)	**24.07**

Weight Factors for Averages

Spacing	Factor	Spacing	Factor
1.5 in	50%	3.0 in	100%
2.0 in	50%	3.5 in	75%
2.5 in	75%	4.0 in	50%

The least squares method was used for a range of connection lengths, with differing number of bolts and the spacing, to produce α and θ for a variety of possible configurations as shown in Table 1. As shown in Table 1, α for connections with two bolts tended to diverge from the other values for corresponding connections with the same spacing and more bolts. The values of θ were much more consistent however. Averages of α and θ were calculated for each bolt hole spacing as well as for all the variations. However in steel connection construction, a three inch bolt hole spacing is the most common spacing used so another average was calculated weighing the bolt hole spacings closer to three inches more heavily. This weighted average results in $\alpha = 5.49$ and $\theta = 24.07°$ which is not a significant difference from the averages that were not weighted.

As an additional check of the variance between the empirically based values and the theoretical values, the weighted average values were used in Equations 4-6 and compared to the empirically based shear lag factors. In Figures 2-4, the bold line represents where the theoretical and empirically based shear lag factors are equal.

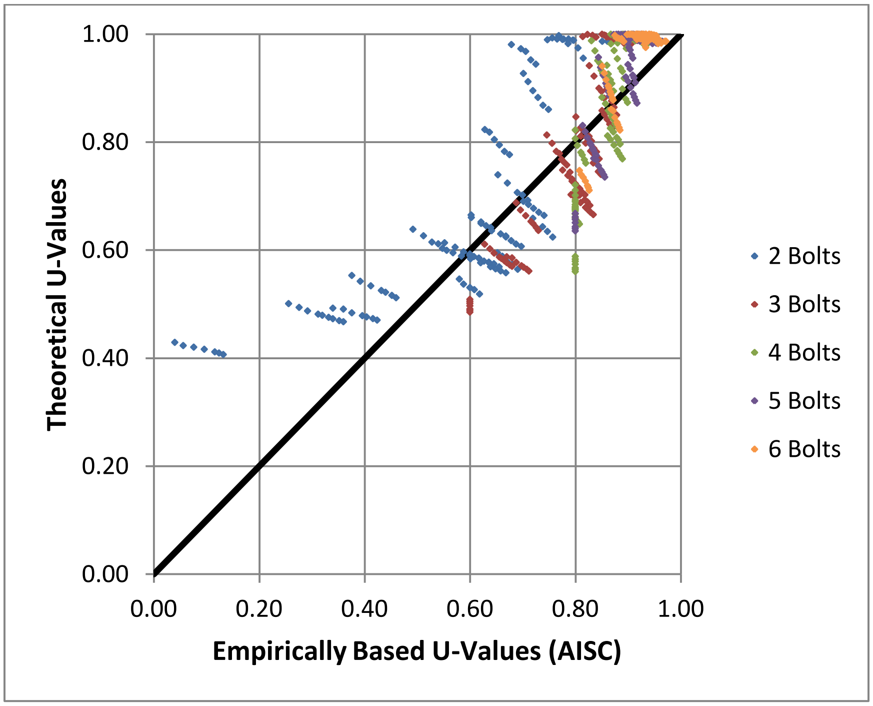

Figure 4: Shear Lag Factors for 2.5in. Spacing

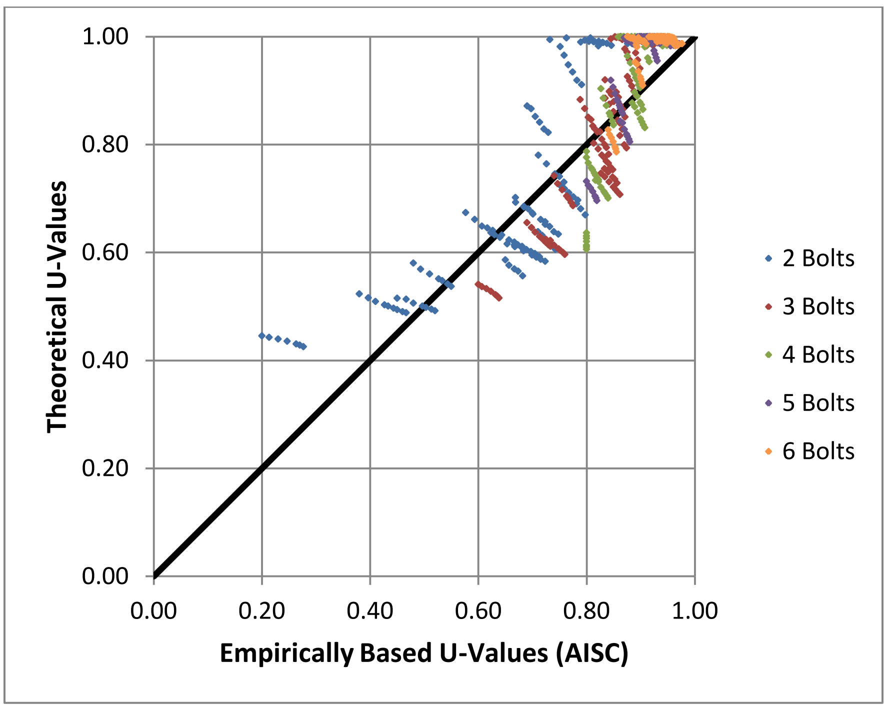

Figure 5: Shear Lag Factors for 3in. Spacing

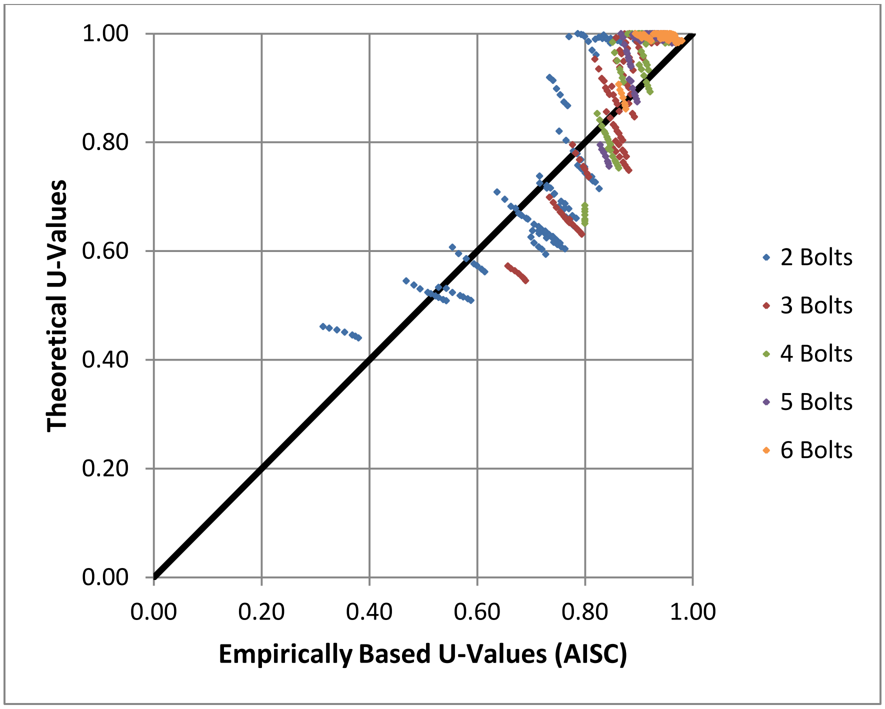

Figure 6: Shear Lag Factors for 3.5in. Spacing

Discussion

Figures 2-4 show that α = 5.49 and θ = 24.07° are acceptable approximations because data points fall generally along the line that represents equal shear lag factors. These figures also show that more bolts in the connection correlate to higher accuracy for the theoretical formulas. However, this may also correlate to the empirically based shear lag factor approaching a value of 1.0 asymptotically as the length of the connection increases. It should also be noted that the accuracy of the theoretical formula varies depending on the angle size. For the same bolt hole spacing and number of bolt holes, the shear lag factors are very different based on the inclusion of $\bar{x}$ in the "U" calculation.

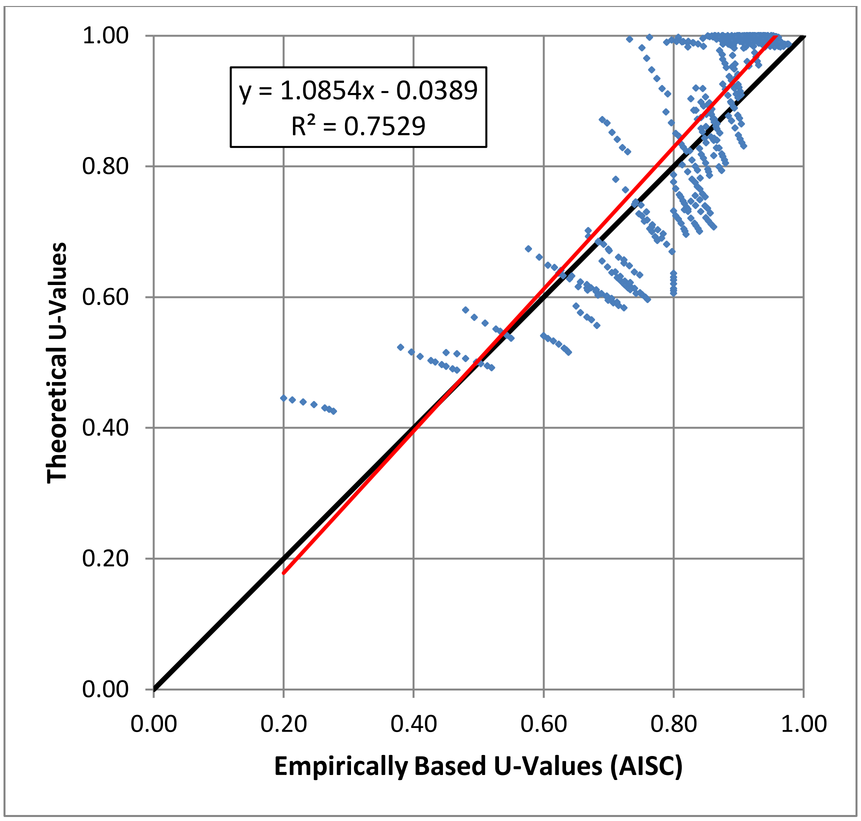

Figure 7: Correlation of Shear Lag Factors for 3in. Spacing

Figure 5 shows the approximate linear relationship, between the theoretical and empirically based shear lag factors. The R^2 term shows that while the relation is close, it is not very accurate. The inherent variability from the large variety of connection configurations is the main reason for the inaccuracy. However, the relationship is still a reasonable correlation between the two factors.

Since the correlation between the two factors is acceptable, the weighted average values found using least squares for α and θ can be utilized. Using $\alpha = 5.49$ and $\theta = 24.07°$, Equations 3 and 4 can be simplified to a more convenient form.

$$D_L = Minimum\{h - t + g, 0.445L + 2.67\varphi_{BH}\}$$ **[Eq. 7]**

$$D_R = Minimum\{w - g, 0.445L + 2.67\varphi_{BH}\}$$ **[Eq. 8]**

Equations 7 and 8 along with Equation 6 provide a simple and easy method to calculate the effective net area. Most of the variables used are set by the design or by convention since the bolt hole diameter is constrained by the bolt size, and the bolt used most is the A325 bolt which has a set diameter. These equations also do not require the additional step of calculating a shear lag factor.

Conclusion

Beginning in 1952 with R. E. Whitmore's essential research that defined the shape and size of the stress contours in gusset plates, the study of steel connections has changed very little over time. Following Whitmore's definition of the Whitmore section, E. Chesson, Jr. and W. H. Munse performed more research to simplify the process of calculating the effective net area the Whitmore section defines. They found that their test results could be accurately explained using the empirically based equation they created. Shortly after they published their research in 1963, AISC adapted their method to be used in the Steel Construction Manual and it has remained unchanged since then.

Chesson and Munse's equation accurately describes the test results, but it requires the calculation of the net area of the connected member as well as a shear lag factor. In an attempted to simplify the process, a theoretical approach was taken. Two variables were used to modify the shape of the stress distribution. These variables were then determined using the results from Chesson and Munse's empirically based equation and a least squares approach. Applying the average values of these variables to geometrically derived equations yielded a simpler equation for finding the effective net area.

While the simpler equation is determined using the empirical results, laboratory and analytical tests should be performed to verify the accuracy of the theoretical equation. In an initial attempt to look into performing a small number of experiments, it was found that the member size and connection setup necessary to make the sample fail in the correct mode would make the experiments difficult to perform[3]. Another problem with performing the experiments was the equipment available was fairly limited and could not fit most of the sample sizes. Finding appropriately sized samples and equipment to test them in should be the next step in the analysis of this theoretical method.

This study was limited to a proof-of-concept comparison of "U". It also only considered a limited number of sample connection configurations, and more configurations should be tested.

[3] Tables A1 and A2 in Appendix A shows the connection setups that were considered and that would fail in the necessary mode.

Another consideration for future analysis is different bolt sizes since this study only considered the most common size: ¾ inch. Other future work should include finite element analysis and lab experimentation with instrumentation in order to analyze the stress distribution in connection members.

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Appendix A

Table A1: Shear Lag Factor Differences for 4 Bolts at 3in Spacing

AISC Manual Label	A (in^2)	d (in)	b (in)	t (in)	x (in)	y (in)	x_p (in)	y_p (in)	A_e (in^2)	A_N (in^2)	Test U	AISC U	ΔU	$(ΔU)^2$
L8X8X1-1/8	16.8	8.00	8.00	1.13	2.40	2.40	1.05	1.05	10.551	15.81	0.6673	0.800	-0.133	0.0176
L8X8X1	15.1	8.00	8.00	1.00	2.36	2.36	0.944	0.944	9.402	14.23	0.6610	0.800	-0.139	0.0193
L8X8X7/8	13.3	8.00	8.00	0.875	2.31	2.31	0.831	0.831	8.227	12.53	0.6564	0.800	-0.144	0.0206
L8X8X3/4	11.5	8.00	8.00	0.750	2.26	2.26	0.719	0.719	7.052	10.84	0.6503	0.800	-0.150	0.0224
L8X8X5/8	9.69	8.00	8.00	0.625	2.21	2.21	0.606	0.606	5.876	9.14	0.6427	0.800	-0.157	0.0247
L8X8X9/16	8.77	8.00	8.00	0.563	2.19	2.19	0.548	0.548	5.293	8.28	0.6395	0.800	-0.160	0.0258
L8X8X1/2	7.84	8.00	8.00	0.500	2.17	2.17	0.490	0.490	4.701	7.40	0.6351	0.800	-0.165	0.0272
L8X6X1	13.1	6.00	8.00	1.00	1.65	2.65	0.819	1.45	9.402	12.23	0.7691	0.817	-0.048	0.0023
L8X6X7/8	11.5	6.00	8.00	0.875	1.60	2.60	0.719	1.43	8.227	10.73	0.7664	0.822	-0.056	0.0031
L8X6X3/4	9.99	6.00	8.00	0.750	1.56	2.55	0.624	1.34	7.052	9.33	0.7555	0.827	-0.071	0.0051
L8X6X5/8	8.41	6.00	8.00	0.625	1.51	2.50	0.526	1.27	5.876	7.86	0.7473	0.832	-0.085	0.0072
L8X6X9/16	7.61	6.00	8.00	0.563	1.49	2.48	0.476	1.24	5.293	7.12	0.7437	0.834	-0.091	0.0082
L8X6X1/2	6.80	6.00	8.00	0.500	1.46	2.46	0.425	1.20	4.701	6.36	0.7389	0.838	-0.099	0.0098
L8X6X7/16	5.99	6.00	8.00	0.438	1.44	2.43	0.374	1.15	4.118	5.61	0.7345	0.840	-0.105	0.0111
L8X4X1	11.1	4.00	8.00	1.00	1.04	3.03	0.694	2.45	9.402	10.23	0.9195	0.884	0.035	0.0012
L8X4X7/8	9.79	4.00	8.00	0.875	0.997	2.99	0.612	2.41	8.227	9.02	0.9116	0.889	0.022	0.0005
L8X4X3/4	8.49	4.00	8.00	0.750	0.949	2.94	0.531	2.34	7.052	7.83	0.9002	0.895	0.006	0.0000
L8X4X5/8	7.16	4.00	8.00	0.625	0.902	2.89	0.448	2.27	5.876	6.61	0.8886	0.900	-0.011	0.0001
L8X4X9/16	6.49	4.00	8.00	0.563	0.878	2.86	0.406	2.23	5.293	6.00	0.8826	0.902	-0.020	0.0004
L8X4X1/2	5.80	4.00	8.00	0.500	0.854	2.84	0.363	2.20	4.701	5.36	0.8767	0.905	-0.028	0.0008
L8X4X7/16	5.11	4.00	8.00	0.438	0.829	2.81	0.319	2.16	4.118	4.73	0.8713	0.908	-0.037	0.0013
L7X4X3/4	7.74	4.00	7.00	0.750	1.00	2.50	0.553	1.84	6.677	7.08	0.9425	0.889	0.054	0.0029
L7X4X5/8	6.50	4.00	7.00	0.625	0.958	2.45	0.464	1.80	5.564	5.95	0.9346	0.894	0.041	0.0017
L7X4X1/2	5.26	4.00	7.00	0.500	0.910	2.40	0.376	1.74	4.451	4.82	0.9230	0.899	0.024	0.0006
L7X4X7/16	4.63	4.00	7.00	0.438	0.886	2.38	0.331	1.71	3.899	4.25	0.9182	0.902	0.017	0.0003
L7X4X3/8	4.00	4.00	7.00	0.375	0.861	2.35	0.286	1.67	3.338	3.67	0.9092	0.904	0.005	0.0000
L6X6X1	11.0	6.00	6.00	1.00	1.86	1.86	0.917	0.917	8.402	10.13	0.8299	0.800	0.030	0.0009
L6X6X7/8	9.75	6.00	6.00	0.875	1.81	1.81	0.813	0.813	7.352	8.98	0.8183	0.800	0.018	0.0003
L6X6X3/4	8.46	6.00	6.00	0.750	1.77	1.77	0.705	0.705	6.302	7.80	0.8075	0.803	0.004	0.0000
L6X6X5/8	7.13	6.00	6.00	0.625	1.72	1.72	0.594	0.594	5.251	6.58	0.7977	0.809	-0.011	0.0001
L6X6X9/16	6.45	6.00	6.00	0.563	1.70	1.70	0.538	0.538	4.730	5.96	0.7941	0.811	-0.017	0.0003
L6X6X1/2	5.77	6.00	6.00	0.500	1.67	1.67	0.481	0.481	4.201	5.33	0.7878	0.814	-0.027	0.0007
L6X6X7/16	5.08	6.00	6.00	0.438	1.65	1.65	0.423	0.423	3.680	4.70	0.7836	0.817	-0.033	0.0011
L6X6X3/8	4.38	6.00	6.00	0.375	1.62	1.62	0.365	0.365	3.151	4.05	0.7776	0.820	-0.042	0.0018
L6X6X5/16	3.67	6.00	6.00	0.313	1.60	1.60	0.306	0.306	2.630	3.40	0.7744	0.822	-0.048	0.0023
L6X4X7/8	8.00	4.00	6.00	0.875	1.12	2.12	0.667	1.43	7.219	7.23	0.9978	0.876	0.122	0.0150
L6X4X3/4	6.94	4.00	6.00	0.750	1.07	2.07	0.578	1.37	6.281	6.28	0.9996	0.881	0.118	0.0140
L6X4X5/8	5.86	4.00	6.00	0.625	1.03	2.03	0.488	1.31	5.251	5.31	0.9884	0.886	0.103	0.0106

L6X4X9/16	5.31	4.00	6.00	0.563	1.00	2.00	0.443	1.28	4.730	4.82	0.9820	0.889	0.093	0.0087
L6X4X1/2	4.75	4.00	6.00	0.500	0.981	1.98	0.396	1.25	4.201	4.31	0.9742	0.891	0.083	0.0069
L6X4X7/16	4.18	4.00	6.00	0.438	0.957	1.95	0.348	1.22	3.680	3.80	0.9693	0.894	0.076	0.0057
L6X4X3/8	3.61	4.00	6.00	0.375	0.933	1.93	0.301	1.19	3.151	3.28	0.9601	0.896	0.064	0.0041
L6X4X5/16	3.03	4.00	6.00	0.313	0.908	1.90	0.253	1.15	2.630	2.76	0.9542	0.899	0.055	0.0030
L6X3-1/2X1/2	4.50	3.50	6.00	0.500	0.829	2.07	0.375	1.50	4.063	4.06	1.0000	0.908	0.092	0.0085
L6X3-1/2X3/8	3.44	3.50	6.00	0.375	0.781	2.02	0.287	1.41	3.094	3.11	0.9942	0.913	0.081	0.0066
L6X3-1/2X5/16	2.89	3.50	6.00	0.313	0.756	2.00	0.241	1.38	2.602	2.62	0.9945	0.916	0.078	0.0062
L5X5X7/8	8.00	5.00	5.00	0.875	1.56	1.56	0.800	0.800	6.914	7.23	0.9558	0.827	0.129	0.0167
L5X5X3/4	6.98	5.00	5.00	0.750	1.52	1.52	0.698	0.698	5.927	6.32	0.9372	0.831	0.106	0.0113
L5X5X5/8	5.90	5.00	5.00	0.625	1.47	1.47	0.590	0.590	4.939	5.35	0.9226	0.837	0.086	0.0074
L5X5X1/2	4.79	5.00	5.00	0.500	1.42	1.42	0.479	0.479	3.951	4.35	0.9078	0.842	0.066	0.0043
L5X5X7/16	4.22	5.00	5.00	0.438	1.40	1.40	0.422	0.422	3.461	3.84	0.9021	0.844	0.058	0.0033
L5X5X3/8	3.65	5.00	5.00	0.375	1.37	1.37	0.365	0.365	2.963	3.32	0.8921	0.848	0.044	0.0020
L5X5X5/16	3.07	5.00	5.00	0.313	1.35	1.35	0.307	0.307	2.473	2.80	0.8846	0.850	0.035	0.0012
L5X3-1/2X3/4	5.85	3.50	5.00	0.750	0.993	1.74	0.585	1.10	5.156	5.19	0.9928	0.890	0.103	0.0106
L5X3-1/2X5/8	4.93	3.50	5.00	0.625	0.947	1.69	0.493	1.06	4.375	4.38	0.9981	0.895	0.103	0.0107
L5X3-1/2X1/2	4.00	3.50	5.00	0.500	0.901	1.65	0.400	1.00	3.563	3.56	1.0000	0.900	0.100	0.0100
L5X3-1/2X3/8	3.05	3.50	5.00	0.375	0.854	1.60	0.305	0.933	2.719	2.72	0.9989	0.905	0.094	0.0088
L5X3-1/2X5/16	2.56	3.50	5.00	0.313	0.829	1.57	0.256	0.904	2.289	2.29	1.0011	0.908	0.093	0.0087
L5X3-1/2X1/4	2.07	3.50	5.00	0.250	0.804	1.55	0.207	0.860	1.844	1.85	0.9959	0.911	0.085	0.0073
L5X3X1/2	3.75	3.00	5.00	0.500	0.746	1.74	0.375	1.25	3.313	3.31	1.0000	0.917	0.083	0.0069
L5X3X7/16	3.31	3.00	5.00	0.438	0.722	1.72	0.331	1.22	2.929	2.93	1.0007	0.920	0.081	0.0066
L5X3X3/8	2.86	3.00	5.00	0.375	0.698	1.69	0.286	1.19	2.531	2.53	0.9998	0.922	0.077	0.0060
L5X3X5/16	2.41	3.00	5.00	0.313	0.673	1.67	0.241	1.14	2.132	2.14	0.9981	0.925	0.073	0.0053
L5X3X1/4	1.94	3.00	5.00	0.250	0.648	1.64	0.194	1.12	1.719	1.72	0.9985	0.928	0.071	0.0050
L4X4X3/4	5.44	4.00	4.00	0.750	1.27	1.27	0.680	0.680	4.781	4.78	0.9995	0.859	0.141	0.0198
L4X4X5/8	4.61	4.00	4.00	0.625	1.22	1.22	0.576	0.576	4.063	4.06	0.9998	0.864	0.135	0.0183
L4X4X1/2	3.75	4.00	4.00	0.500	1.18	1.18	0.469	0.469	3.313	3.31	1.0000	0.869	0.131	0.0172
L4X4X7/16	3.30	4.00	4.00	0.438	1.15	1.15	0.413	0.413	2.929	2.92	1.0042	0.872	0.132	0.0174
L4X4X3/8	2.86	4.00	4.00	0.375	1.13	1.13	0.358	0.358	2.531	2.53	0.9998	0.874	0.125	0.0157
L4X4X5/16	2.40	4.00	4.00	0.313	1.11	1.11	0.300	0.300	2.132	2.13	1.0028	0.877	0.126	0.0159
L4X4X1/4	1.93	4.00	4.00	0.250	1.08	1.08	0.241	0.241	1.719	1.71	1.0044	0.880	0.124	0.0155
L4X3-1/2X1/2	3.50	3.50	4.00	0.500	0.994	1.24	0.438	0.500	3.063	3.06	1.0000	0.890	0.110	0.0122
L4X3-1/2X3/8	2.68	3.50	4.00	0.375	0.947	1.20	0.335	0.427	2.344	2.35	0.9965	0.895	0.102	0.0104
L4X3-1/2X5/16	2.25	3.50	4.00	0.313	0.923	1.17	0.281	0.400	1.976	1.98	0.9998	0.897	0.102	0.0105
L4X3-1/2X1/4	1.82	3.50	4.00	0.250	0.897	1.14	0.228	0.360	1.594	1.60	0.9953	0.900	0.095	0.0090
L4X3X5/8	3.99	3.00	4.00	0.625	0.867	1.37	0.499	0.808	3.438	3.44	0.9984	0.904	0.095	0.0090
L4X3X1/2	3.25	3.00	4.00	0.500	0.822	1.32	0.406	0.750	2.813	2.81	1.0000	0.909	0.091	0.0083
L4X3X3/8	2.49	3.00	4.00	0.375	0.775	1.27	0.311	0.680	2.156	2.16	0.9974	0.914	0.084	0.0070
L4X3X5/16	2.09	3.00	4.00	0.313	0.750	1.25	0.261	0.656	1.819	1.82	1.0017	0.917	0.085	0.0072
L4X3X1/4	1.69	3.00	4.00	0.250	0.725	1.22	0.211	0.620	1.469	1.47	0.9983	0.919	0.079	0.0062

L3-1/2X3-1/2X1/2	3.25	3.50	3.50	0.500	1.05	1.05	0.464	0.464	2.813	2.81	1.0000	0.883	0.117	0.0136
L3-1/2X3-1/2X7/16	2.89	3.50	3.50	0.438	1.03	1.03	0.413	0.413	2.491	2.51	0.9937	0.886	0.108	0.0117
L3-1/2X3-1/2X3/8	2.50	3.50	3.50	0.375	1.00	1.00	0.357	0.357	2.156	2.17	0.9928	0.889	0.104	0.0108
L3-1/2X3-1/2X5/16	2.10	3.50	3.50	0.313	0.979	0.979	0.300	0.300	1.819	1.83	0.9962	0.891	0.105	0.0110
L3-1/2X3-1/2X1/4	1.70	3.50	3.50	0.250	0.954	0.954	0.243	0.243	1.469	1.48	0.9916	0.894	0.098	0.0095
L3-1/2X3X1/2	3.02	3.00	3.50	0.500	0.869	1.12	0.431	0.480	2.563	2.58	0.9923	0.903	0.089	0.0079
L3-1/2X3X7/16	2.67	3.00	3.50	0.438	0.846	1.09	0.381	0.449	2.272	2.29	0.9935	0.906	0.088	0.0077
L3-1/2X3X3/8	2.32	3.00	3.50	0.375	0.823	1.07	0.331	0.407	1.969	1.99	0.9884	0.909	0.080	0.0064
L3-1/2X3X5/16	1.95	3.00	3.50	0.313	0.798	1.05	0.279	0.380	1.663	1.68	0.9920	0.911	0.081	0.0065
L3-1/2X3X1/4	1.58	3.00	3.50	0.250	0.773	1.02	0.226	0.340	1.344	1.36	0.9871	0.914	0.073	0.0053
L3-1/2X2-1/2X1/2	2.77	2.50	3.50	0.500	0.701	1.20	0.396	0.730	2.313	2.33	0.9914	0.922	0.069	0.0048
L3-1/2X2-1/2X3/8	2.12	2.50	3.50	0.375	0.655	1.15	0.303	0.673	1.781	1.79	0.9941	0.927	0.067	0.0045
L3-1/2X2-1/2X5/16	1.79	2.50	3.50	0.313	0.632	1.13	0.256	0.636	1.506	1.52	0.9934	0.930	0.064	0.0041
L3-1/2X2-1/2X1/4	1.45	2.50	3.50	0.250	0.607	1.10	0.207	0.600	1.219	1.23	0.9898	0.933	0.057	0.0033
L3X3X1/2	2.76	3.00	3.00	0.500	0.929	0.929	0.460	0.460	2.313	2.32	0.9957	0.897	0.099	0.0098
L3X3X7/16	2.43	3.00	3.00	0.438	0.907	0.907	0.405	0.405	2.053	2.05	1.0030	0.899	0.104	0.0108
L3X3X3/8	2.11	3.00	3.00	0.375	0.884	0.884	0.352	0.352	1.781	1.78	0.9996	0.902	0.098	0.0096
L3X3X5/16	1.78	3.00	3.00	0.313	0.860	0.860	0.297	0.297	1.506	1.51	1.0000	0.904	0.096	0.0091
L3X3X1/4	1.44	3.00	3.00	0.250	0.836	0.836	0.240	0.240	1.219	1.22	0.9980	0.907	0.091	0.0083
L3X3X3/16	1.09	3.00	3.00	0.188	0.812	0.812	0.182	0.182	0.928	0.93	1.0029	0.910	0.093	0.0087
L3X2-1/2X1/2	2.50	2.50	3.00	0.500	0.746	0.995	0.417	0.500	2.063	2.06	1.0000	0.917	0.083	0.0069
L3X2-1/2X7/16	2.22	2.50	3.00	0.438	0.724	0.972	0.370	0.463	1.834	1.84	0.9985	0.920	0.079	0.0062
L3X2-1/2X3/8	1.93	2.50	3.00	0.375	0.701	0.949	0.322	0.427	1.594	1.60	0.9949	0.922	0.073	0.0053
L3X2-1/2X5/16	1.63	2.50	3.00	0.313	0.677	0.925	0.272	0.392	1.350	1.36	0.9952	0.925	0.070	0.0050
L3X2-1/2X1/4	1.32	2.50	3.00	0.250	0.653	0.900	0.220	0.360	1.094	1.10	0.9932	0.927	0.066	0.0043
L3X2-1/2X3/16	1.00	2.50	3.00	0.188	0.627	0.874	0.167	0.333	0.834	0.84	0.9984	0.930	0.068	0.0046
L3X2X1/2	2.26	2.00	3.00	0.500	0.580	1.08	0.377	0.740	1.813	1.82	0.9945	0.936	0.059	0.0035
L3X2X3/8	1.75	2.00	3.00	0.375	0.535	1.03	0.292	0.667	1.406	1.42	0.9890	0.941	0.048	0.0023
L3X2X5/16	1.48	2.00	3.00	0.313	0.511	1.01	0.247	0.632	1.193	1.21	0.9892	0.943	0.046	0.0021
L3X2X1/4	1.20	2.00	3.00	0.250	0.487	0.980	0.200	0.600	0.969	0.98	0.9873	0.946	0.041	0.0017
L3X2X3/16	0.917	2.00	3.00	0.188	0.462	0.952	0.153	0.555	0.740	0.75	0.9836	0.949	0.035	0.0012
L2-1/2X2-1/2X1/2	2.26	2.50	2.50	0.500	0.803	0.803	0.452	0.452	1.813	1.82	0.9945	0.911	0.084	0.0070
L2-1/2X2-1/2X3/8	1.73	2.50	2.50	0.375	0.758	0.758	0.346	0.346	1.406	1.40	1.0031	0.916	0.087	0.0076
L2-1/2X2-1/2X5/16	1.46	2.50	2.50	0.313	0.735	0.735	0.292	0.292	1.193	1.19	1.0059	0.918	0.088	0.0077
L2-1/2X2-1/2X1/4	1.19	2.50	2.50	0.250	0.711	0.711	0.238	0.238	0.969	0.97	0.9974	0.921	0.076	0.0058
L2-1/2X2-1/2X3/16	0.901	2.50	2.50	0.188	0.687	0.687	0.180	0.180	0.740	0.74	1.0050	0.924	0.081	0.0066
L2-1/2X2X3/8	1.55	2.00	2.50	0.375	0.578	0.826	0.310	0.433	1.219	1.22	0.9974	0.936	0.062	0.0038
L2-1/2X2X5/16	1.32	2.00	2.50	0.313	0.555	0.803	0.264	0.388	1.037	1.05	0.9909	0.938	0.053	0.0028
L2-1/2X2X1/4	1.07	2.00	2.50	0.250	0.532	0.779	0.214	0.360	0.844	0.85	0.9912	0.941	0.050	0.0025
L2-1/2X2X3/16	0.818	2.00	2.50	0.188	0.508	0.754	0.164	0.319	0.646	0.65	0.9888	0.944	0.045	0.0020
L2-1/2X1-1/2X1/4	0.947	1.50	2.50	0.250	0.372	0.866	0.189	0.606	0.719	0.73	0.9870	0.959	0.028	0.0008
L2-1/2X1-1/2X3/16	0.724	1.50	2.50	0.188	0.347	0.839	0.145	0.569	0.552	0.56	0.9869	0.961	0.025	0.0006
L2X2X3/8	1.37	2.00	2.00	0.375	0.632	0.632	0.343	0.343	1.031	1.04	0.9898	0.930	0.060	0.0036

L2X2X5/16	1.16	2.00	2.00	0.313	0.609	0.609	0.290	0.290	0.880	0.89	0.9933	0.932	0.061	0.0037
L2X2X1/4	0.944	2.00	2.00	0.250	0.586	0.586	0.236	0.236	0.719	0.73	0.9910	0.935	0.056	0.0032
L2X2X3/16	0.722	2.00	2.00	0.188	0.561	0.561	0.181	0.181	0.552	0.56	0.9904	0.938	0.053	0.0028
L2X2X1/8	0.491	2.00	2.00	0.125	0.534	0.534	0.123	0.123	0.375	0.38	0.9826	0.941	0.042	0.0018

Appendix B

Table B1: Sample Sizing for a Connection with 2 Bolt Holes

Bolt Hole Spacing (in)	Bolt Diameter (in)	Plate Thickness (in)	Bolt Hole Diameter (in)	Gross Area (in^2)	Net Area (in^2)	Bearing Strength (k)	Rupture Strength (k)	Yielding Strength (k)	Testable
1	0.125	0.125	0.25	0.375	0.344	8.70	19.94	13.50	NO
1	0.125	0.25	0.25	0.75	0.688	17.40	39.88	27.00	NO
1	0.125	0.375	0.25	1.125	1.031	26.10	59.81	40.50	NO
1	0.125	0.5	0.25	1.5	1.375	34.80	79.75	54.00	NO
1	0.25	0.125	0.375	0.375	0.328	11.96	19.03	13.50	NO
1	0.25	0.25	0.375	0.75	0.656	23.93	38.06	27.00	NO
1	0.25	0.375	0.375	1.125	0.984	35.89	57.09	40.50	NO
1	0.25	0.5	0.375	1.5	1.313	47.85	76.13	54.00	NO
1	0.375	0.125	0.5	0.375	0.313	10.88	18.13	13.50	NO
1	0.375	0.25	0.5	0.75	0.625	21.75	36.25	27.00	NO
1	0.375	0.375	0.5	1.125	0.938	32.63	54.38	40.50	NO
1	0.375	0.5	0.5	1.5	1.250	43.50	72.50	54.00	NO
1	0.5	0.125	0.625	0.375	0.297	9.24	17.22	13.50	NO
1	0.5	0.25	0.625	0.75	0.594	18.49	34.44	27.00	NO
1	0.5	0.375	0.625	1.125	0.891	27.73	51.66	40.50	NO
1	0.5	0.5	0.625	1.5	1.188	36.98	68.88	54.00	NO
1	0.625	0.125	0.75	0.375	0.281	7.61	16.31	13.50	NO
1	0.625	0.25	0.75	0.75	0.563	15.23	32.63	27.00	NO
1	0.625	0.375	0.75	1.125	0.844	22.84	48.94	40.50	NO
1	0.625	0.5	0.75	1.5	1.125	30.45	65.25	54.00	NO
1	0.75	0.125	0.875	0.375	0.266	5.98	15.41	13.50	NO
1	0.75	0.25	0.875	0.75	0.531	11.96	30.81	27.00	NO
1	0.75	0.375	0.875	1.125	0.797	17.94	46.22	40.50	NO
1	0.75	0.5	0.875	1.5	1.063	23.93	61.63	54.00	NO
1	0.875	0.125	1	0.375	0.250	4.35	14.50	13.50	NO
1	0.875	0.25	1	0.75	0.500	8.70	29.00	27.00	NO
1	0.875	0.375	1	1.125	0.750	13.05	43.50	40.50	NO
1	0.875	0.5	1	1.5	1.000	17.40	58.00	54.00	NO
1.25	0.125	0.125	0.25	0.375	0.344	8.70	19.94	13.50	NO
1.25	0.125	0.25	0.25	0.75	0.688	17.40	39.88	27.00	NO
1.25	0.125	0.375	0.25	1.125	1.031	26.10	59.81	40.50	NO
1.25	0.125	0.5	0.25	1.5	1.375	34.80	79.75	54.00	NO
1.25	0.25	0.125	0.375	0.375	0.328	13.05	19.03	13.50	NO
1.25	0.25	0.25	0.375	0.75	0.656	26.10	38.06	27.00	NO
1.25	0.25	0.375	0.375	1.125	0.984	39.15	57.09	40.50	NO
1.25	0.25	0.5	0.375	1.5	1.313	52.20	76.13	54.00	NO
1.25	0.375	0.125	0.5	0.375	0.313	15.23	18.13	13.50	NO

1.25	0.375	0.25	0.5	0.75	0.625	30.45	36.25	27.00	NO
1.25	0.375	0.375	0.5	1.125	0.938	45.68	54.38	40.50	NO
1.25	0.375	0.5	0.5	1.5	1.250	60.90	72.50	54.00	NO
1.25	0.5	0.125	0.625	0.375	0.297	13.59	17.22	13.50	NO
1.25	0.5	0.25	0.625	0.75	0.594	27.19	34.44	27.00	NO
1.25	0.5	0.375	0.625	1.125	0.891	40.78	51.66	40.50	NO
1.25	0.5	0.5	0.625	1.5	1.188	54.38	68.88	54.00	NO
1.25	0.625	0.125	0.75	0.375	0.281	11.96	16.31	13.50	NO
1.25	0.625	0.25	0.75	0.75	0.563	23.93	32.63	27.00	NO
1.25	0.625	0.375	0.75	1.125	0.844	35.89	48.94	40.50	NO
1.25	0.625	0.5	0.75	1.5	1.125	47.85	65.25	54.00	NO
1.25	0.75	0.125	0.875	0.375	0.266	10.33	15.41	13.50	NO
1.25	0.75	0.25	0.875	0.75	0.531	20.66	30.81	27.00	NO
1.25	0.75	0.375	0.875	1.125	0.797	30.99	46.22	40.50	NO
1.25	0.75	0.5	0.875	1.5	1.063	41.33	61.63	54.00	NO
1.25	0.875	0.125	1	0.375	0.250	8.70	14.50	13.50	NO
1.25	0.875	0.25	1	0.75	0.500	17.40	29.00	27.00	NO
1.25	0.875	0.375	1	1.125	0.750	26.10	43.50	40.50	NO
1.25	0.875	0.5	1	1.5	1.000	34.80	58.00	54.00	NO
1.25	1	0.125	1.125	0.375	0.234	7.07	13.59	13.50	NO
1.25	1	0.25	1.125	0.75	0.469	14.14	27.19	27.00	NO
1.25	1	0.375	1.125	1.125	0.703	21.21	40.78	40.50	NO
1.25	1	0.5	1.125	1.5	0.938	28.28	54.38	54.00	NO
1.25	1.125	0.125	1.25	0.375	0.219	5.44	12.69	13.50	NO
1.25	1.125	0.25	1.25	0.75	0.438	10.88	25.38	27.00	NO
1.25	1.125	0.375	1.25	1.125	0.656	16.31	38.06	40.50	NO
1.25	1.125	0.5	1.25	1.5	0.875	21.75	50.75	54.00	NO
1.5	0.125	0.125	0.25	0.375	0.344	8.70	19.94	13.50	NO
1.5	0.125	0.25	0.25	0.75	0.688	17.40	39.88	27.00	NO
1.5	0.125	0.375	0.25	1.125	1.031	26.10	59.81	40.50	NO
1.5	0.125	0.5	0.25	1.5	1.375	34.80	79.75	54.00	NO
1.5	0.25	0.125	0.375	0.375	0.328	13.05	19.03	13.50	NO
1.5	0.25	0.25	0.375	0.75	0.656	26.10	38.06	27.00	NO
1.5	0.25	0.375	0.375	1.125	0.984	39.15	57.09	40.50	NO
1.5	0.25	0.5	0.375	1.5	1.313	52.20	76.13	54.00	NO
1.5	0.375	0.125	0.5	0.375	0.313	17.40	18.13	13.50	NO
1.5	0.375	0.25	0.5	0.75	0.625	34.80	36.25	27.00	NO
1.5	0.375	0.375	0.5	1.125	0.938	52.20	54.38	40.50	NO
1.5	0.375	0.5	0.5	1.5	1.250	69.60	72.50	54.00	NO
1.5	0.5	0.125	0.625	0.375	0.297	17.94	17.22	13.50	NO
1.5	0.5	0.25	0.625	0.75	0.594	35.89	34.44	27.00	NO

1.5	0.5	0.375	0.625	1.125	0.891	53.83	51.66	40.50	NO
1.5	0.5	0.5	0.625	1.5	1.188	71.78	68.88	54.00	NO
1.5	0.625	0.125	0.75	0.375	0.281	16.31	16.31	13.50	NO
1.5	0.625	0.25	0.75	0.75	0.563	32.63	32.63	27.00	NO
1.5	0.625	0.375	0.75	1.125	0.844	48.94	48.94	40.50	NO
1.5	0.625	0.5	0.75	1.5	1.125	65.25	65.25	54.00	NO
1.5	0.75	0.125	0.875	0.375	0.266	14.68	15.41	13.50	NO
1.5	0.75	0.25	0.875	0.75	0.531	29.36	30.81	27.00	NO
1.5	0.75	0.375	0.875	1.125	0.797	44.04	46.22	40.50	NO
1.5	0.75	0.5	0.875	1.5	1.063	58.73	61.63	54.00	NO
1.5	0.875	0.125	1	0.375	0.250	13.05	14.50	13.50	NO
1.5	0.875	0.25	1	0.75	0.500	26.10	29.00	27.00	NO
1.5	0.875	0.375	1	1.125	0.750	39.15	43.50	40.50	NO
1.5	0.875	0.5	1	1.5	1.000	52.20	58.00	54.00	NO
1.5	1	0.125	1.125	0.375	0.234	11.42	13.59	13.50	NO
1.5	1	0.25	1.125	0.75	0.469	22.84	27.19	27.00	NO
1.5	1	0.375	1.125	1.125	0.703	34.26	40.78	40.50	NO
1.5	1	0.5	1.125	1.5	0.938	45.68	54.38	54.00	NO
1.5	1.125	0.125	1.25	0.375	0.219	9.79	12.69	13.50	NO
1.5	1.125	0.25	1.25	0.75	0.438	19.58	25.38	27.00	NO
1.5	1.125	0.375	1.25	1.125	0.656	29.36	38.06	40.50	NO
1.5	1.125	0.5	1.25	1.5	0.875	39.15	50.75	54.00	NO
1.5	1.25	0.125	1.375	0.375	0.203	8.16	11.78	13.50	NO
1.5	1.25	0.25	1.375	0.75	0.406	16.31	23.56	27.00	NO
1.5	1.25	0.375	1.375	1.125	0.609	24.47	35.34	40.50	NO
1.5	1.25	0.5	1.375	1.5	0.813	32.63	47.13	54.00	NO
1.5	1.375	0.125	1.5	0.375	0.188	6.53	10.88	13.50	NO
1.5	1.375	0.25	1.5	0.75	0.375	13.05	21.75	27.00	NO
1.5	1.375	0.375	1.5	1.125	0.563	19.58	32.63	40.50	NO
1.5	1.375	0.5	1.5	1.5	0.750	26.10	43.50	54.00	NO
1.75	0.125	0.125	0.25	0.375	0.344	8.70	19.94	13.50	NO
1.75	0.125	0.25	0.25	0.75	0.688	17.40	39.88	27.00	NO
1.75	0.125	0.375	0.25	1.125	1.031	26.10	59.81	40.50	NO
1.75	0.125	0.5	0.25	1.5	1.375	34.80	79.75	54.00	NO
1.75	0.25	0.125	0.375	0.375	0.328	13.05	19.03	13.50	NO
1.75	0.25	0.25	0.375	0.75	0.656	26.10	38.06	27.00	NO
1.75	0.25	0.375	0.375	1.125	0.984	39.15	57.09	40.50	NO
1.75	0.25	0.5	0.375	1.5	1.313	52.20	76.13	54.00	NO
1.75	0.375	0.125	0.5	0.375	0.313	17.40	18.13	13.50	NO
1.75	0.375	0.25	0.5	0.75	0.625	34.80	36.25	27.00	NO
1.75	0.375	0.375	0.5	1.125	0.938	52.20	54.38	40.50	NO

1.75	0.375	0.5	0.5	1.5	1.250	69.60	72.50	54.00	NO
1.75	0.5	0.125	0.625	0.375	0.297	20.66	17.22	13.50	NO
1.75	0.5	0.25	0.625	0.75	0.594	41.33	34.44	27.00	NO
1.75	0.5	0.375	0.625	1.125	0.891	61.99	51.66	40.50	NO
1.75	0.5	0.5	0.625	1.5	1.188	82.65	68.88	54.00	NO
1.75	0.625	0.125	0.75	0.375	0.281	20.66	16.31	13.50	NO
1.75	0.625	0.25	0.75	0.75	0.563	41.33	32.63	27.00	NO
1.75	0.625	0.375	0.75	1.125	0.844	61.99	48.94	40.50	NO
1.75	0.625	0.5	0.75	1.5	1.125	82.65	65.25	54.00	NO
1.75	0.75	0.125	0.875	0.375	0.266	19.03	15.41	13.50	NO
1.75	0.75	0.25	0.875	0.75	0.531	38.06	30.81	27.00	NO
1.75	0.75	0.375	0.875	1.125	0.797	57.09	46.22	40.50	NO
1.75	0.75	0.5	0.875	1.5	1.063	76.13	61.63	54.00	NO
1.75	0.875	0.125	1	0.375	0.250	17.40	14.50	13.50	NO
1.75	0.875	0.25	1	0.75	0.500	34.80	29.00	27.00	NO
1.75	0.875	0.375	1	1.125	0.750	52.20	43.50	40.50	NO
1.75	0.875	0.5	1	1.5	1.000	69.60	58.00	54.00	NO
1.75	1	0.125	1.125	0.375	0.234	15.77	13.59	13.50	NO
1.75	1	0.25	1.125	0.75	0.469	31.54	27.19	27.00	NO
1.75	1	0.375	1.125	1.125	0.703	47.31	40.78	40.50	NO
1.75	1	0.5	1.125	1.5	0.938	63.08	54.38	54.00	NO
1.75	1.125	0.125	1.25	0.375	0.219	14.14	12.69	13.50	YES
1.75	1.125	0.25	1.25	0.75	0.438	28.28	25.38	27.00	YES
1.75	1.125	0.375	1.25	1.125	0.656	42.41	38.06	40.50	YES
1.75	1.125	0.5	1.25	1.5	0.875	56.55	50.75	54.00	YES
1.75	1.25	0.125	1.375	0.375	0.203	12.51	11.78	13.50	YES
1.75	1.25	0.25	1.375	0.75	0.406	25.01	23.56	27.00	YES
1.75	1.25	0.375	1.375	1.125	0.609	37.52	35.34	40.50	YES
1.75	1.25	0.5	1.375	1.5	0.813	50.03	47.13	54.00	YES
1.75	1.375	0.125	1.5	0.375	0.188	10.88	10.88	13.50	YES
1.75	1.375	0.25	1.5	0.75	0.375	21.75	21.75	27.00	YES
1.75	1.375	0.375	1.5	1.125	0.563	32.63	32.63	40.50	YES
1.75	1.375	0.5	1.5	1.5	0.750	43.50	43.50	54.00	YES
1.75	1.5	0.125	1.625	0.375	0.172	9.24	9.97	13.50	NO
1.75	1.5	0.25	1.625	0.75	0.344	18.49	19.94	27.00	NO
1.75	1.5	0.375	1.625	1.125	0.516	27.73	29.91	40.50	NO
1.75	1.5	0.5	1.625	1.5	0.688	36.98	39.88	54.00	NO
1.75	1.625	0.125	1.75	0.375	0.156	7.61	9.06	13.50	NO
1.75	1.625	0.25	1.75	0.75	0.313	15.23	18.13	27.00	NO
1.75	1.625	0.375	1.75	1.125	0.469	22.84	27.19	40.50	NO
1.75	1.625	0.5	1.75	1.5	0.625	30.45	36.25	54.00	NO

2	0.125	0.125	0.25	0.375	0.344	8.70	19.94	13.50	NO
2	0.125	0.25	0.25	0.75	0.688	17.40	39.88	27.00	NO
2	0.125	0.375	0.25	1.125	1.031	26.10	59.81	40.50	NO
2	0.125	0.5	0.25	1.5	1.375	34.80	79.75	54.00	NO
2	0.25	0.125	0.375	0.375	0.328	13.05	19.03	13.50	NO
2	0.25	0.25	0.375	0.75	0.656	26.10	38.06	27.00	NO
2	0.25	0.375	0.375	1.125	0.984	39.15	57.09	40.50	NO
2	0.25	0.5	0.375	1.5	1.313	52.20	76.13	54.00	NO
2	0.375	0.125	0.5	0.375	0.313	17.40	18.13	13.50	NO
2	0.375	0.25	0.5	0.75	0.625	34.80	36.25	27.00	NO
2	0.375	0.375	0.5	1.125	0.938	52.20	54.38	40.50	NO
2	0.375	0.5	0.5	1.5	1.250	69.60	72.50	54.00	NO
2	0.5	0.125	0.625	0.375	0.297	21.75	17.22	13.50	NO
2	0.5	0.25	0.625	0.75	0.594	43.50	34.44	27.00	NO
2	0.5	0.375	0.625	1.125	0.891	65.25	51.66	40.50	NO
2	0.5	0.5	0.625	1.5	1.188	87.00	68.88	54.00	NO
2	0.625	0.125	0.75	0.375	0.281	23.93	16.31	13.50	NO
2	0.625	0.25	0.75	0.75	0.563	47.85	32.63	27.00	NO
2	0.625	0.375	0.75	1.125	0.844	71.78	48.94	40.50	NO
2	0.625	0.5	0.75	1.5	1.125	95.70	65.25	54.00	NO
2	0.75	0.125	0.875	0.375	0.266	23.38	15.41	13.50	NO
2	0.75	0.25	0.875	0.75	0.531	46.76	30.81	27.00	NO
2	0.75	0.375	0.875	1.125	0.797	70.14	46.22	40.50	NO
2	0.75	0.5	0.875	1.5	1.063	93.53	61.63	54.00	NO
2	0.875	0.125	1	0.375	0.250	21.75	14.50	13.50	NO
2	0.875	0.25	1	0.75	0.500	43.50	29.00	27.00	NO
2	0.875	0.375	1	1.125	0.750	65.25	43.50	40.50	NO
2	0.875	0.5	1	1.5	1.000	87.00	58.00	54.00	NO
2	1	0.125	1.125	0.375	0.234	20.12	13.59	13.50	NO
2	1	0.25	1.125	0.75	0.469	40.24	27.19	27.00	NO
2	1	0.375	1.125	1.125	0.703	60.36	40.78	40.50	NO
2	1	0.5	1.125	1.5	0.938	80.48	54.38	54.00	NO
2	1.125	0.125	1.25	0.375	0.219	18.49	12.69	13.50	YES
2	1.125	0.25	1.25	0.75	0.438	36.98	25.38	27.00	YES
2	1.125	0.375	1.25	1.125	0.656	55.46	38.06	40.50	YES
2	1.125	0.5	1.25	1.5	0.875	73.95	50.75	54.00	YES
2	1.25	0.125	1.375	0.375	0.203	16.86	11.78	13.50	YES
2	1.25	0.25	1.375	0.75	0.406	33.71	23.56	27.00	YES
2	1.25	0.375	1.375	1.125	0.609	50.57	35.34	40.50	YES
2	1.25	0.5	1.375	1.5	0.813	67.43	47.13	54.00	YES
2	1.375	0.125	1.5	0.375	0.188	15.23	10.88	13.50	YES

2	1.375	0.25	1.5	0.75	0.375	30.45	21.75	27.00	YES
2	1.375	0.375	1.5	1.125	0.563	45.68	32.63	40.50	YES
2	1.375	0.5	1.5	1.5	0.750	60.90	43.50	54.00	YES
2	1.5	0.125	1.625	0.375	0.172	13.59	9.97	13.50	YES
2	1.5	0.25	1.625	0.75	0.344	27.19	19.94	27.00	YES
2	1.5	0.375	1.625	1.125	0.516	40.78	29.91	40.50	YES
2	1.5	0.5	1.625	1.5	0.688	54.38	39.88	54.00	YES
2	1.625	0.125	1.75	0.375	0.156	11.96	9.06	13.50	YES
2	1.625	0.25	1.75	0.75	0.313	23.93	18.13	27.00	YES
2	1.625	0.375	1.75	1.125	0.469	35.89	27.19	40.50	YES
2	1.625	0.5	1.75	1.5	0.625	47.85	36.25	54.00	YES
2	1.75	0.125	1.875	0.375	0.141	10.33	8.16	13.50	YES
2	1.75	0.25	1.875	0.75	0.281	20.66	16.31	27.00	YES
2	1.75	0.375	1.875	1.125	0.422	30.99	24.47	40.50	YES
2	1.75	0.5	1.875	1.5	0.563	41.33	32.63	54.00	YES
2	1.875	0.125	2	0.375	0.125	8.70	7.25	13.50	YES
2	1.875	0.25	2	0.75	0.250	17.40	14.50	27.00	YES
2	1.875	0.375	2	1.125	0.375	26.10	21.75	40.50	YES
2	1.875	0.5	2	1.5	0.500	34.80	29.00	54.00	YES

Table B2: Sample Sizing for a Connection with 3 Bolt Holes

Bolt Hole Spacing (in)	Bolt Diameter (in)	Plate Thickness (in)	Bolt Hole Diameter (in)	Gross Area (in^2)	Net Area (in^2)	Bearing Strength (k)	Rupture Strength (k)	Yielding Strength (k)	Testable
1	0.125	0.125	0.25	0.375	0.344	13.05	19.94	13.50	NO
1	0.125	0.25	0.25	0.75	0.688	26.10	39.88	27.00	NO
1	0.125	0.375	0.25	1.125	1.031	39.15	59.81	40.50	NO
1	0.125	0.5	0.25	1.5	1.375	52.20	79.75	54.00	NO
1	0.25	0.125	0.375	0.375	0.328	17.40	19.03	13.50	NO
1	0.25	0.25	0.375	0.75	0.656	34.80	38.06	27.00	NO
1	0.25	0.375	0.375	1.125	0.984	52.20	57.09	40.50	NO
1	0.25	0.5	0.375	1.5	1.313	69.60	76.13	54.00	NO
1	0.375	0.125	0.5	0.375	0.313	15.23	18.13	13.50	NO
1	0.375	0.25	0.5	0.75	0.625	30.45	36.25	27.00	NO
1	0.375	0.375	0.5	1.125	0.938	45.68	54.38	40.50	NO
1	0.375	0.5	0.5	1.5	1.250	60.90	72.50	54.00	NO
1	0.5	0.125	0.625	0.375	0.297	12.51	17.22	13.50	NO
1	0.5	0.25	0.625	0.75	0.594	25.01	34.44	27.00	NO
1	0.5	0.375	0.625	1.125	0.891	37.52	51.66	40.50	NO
1	0.5	0.5	0.625	1.5	1.188	50.03	68.88	54.00	NO
1	0.625	0.125	0.75	0.375	0.281	9.79	16.31	13.50	NO
1	0.625	0.25	0.75	0.75	0.563	19.58	32.63	27.00	NO
1	0.625	0.375	0.75	1.125	0.844	29.36	48.94	40.50	NO
1	0.625	0.5	0.75	1.5	1.125	39.15	65.25	54.00	NO
1	0.75	0.125	0.875	0.375	0.266	7.07	15.41	13.50	NO
1	0.75	0.25	0.875	0.75	0.531	14.14	30.81	27.00	NO
1	0.75	0.375	0.875	1.125	0.797	21.21	46.22	40.50	NO
1	0.75	0.5	0.875	1.5	1.063	28.28	61.63	54.00	NO
1	0.875	0.125	1	0.375	0.250	4.35	14.50	13.50	NO
1	0.875	0.25	1	0.75	0.500	8.70	29.00	27.00	NO
1	0.875	0.375	1	1.125	0.750	13.05	43.50	40.50	NO
1	0.875	0.5	1	1.5	1.000	17.40	58.00	54.00	NO
1.25	0.125	0.125	0.25	0.375	0.344	13.05	19.94	13.50	NO
1.25	0.125	0.25	0.25	0.75	0.688	26.10	39.88	27.00	NO
1.25	0.125	0.375	0.25	1.125	1.031	39.15	59.81	40.50	NO
1.25	0.125	0.5	0.25	1.5	1.375	52.20	79.75	54.00	NO
1.25	0.25	0.125	0.375	0.375	0.328	19.58	19.03	13.50	NO
1.25	0.25	0.25	0.375	0.75	0.656	39.15	38.06	27.00	NO
1.25	0.25	0.375	0.375	1.125	0.984	58.73	57.09	40.50	NO
1.25	0.25	0.5	0.375	1.5	1.313	78.30	76.13	54.00	NO
1.25	0.375	0.125	0.5	0.375	0.313	21.75	18.13	13.50	NO
1.25	0.375	0.25	0.5	0.75	0.625	43.50	36.25	27.00	NO

1.25	0.375	0.375	0.5	1.125	0.938	65.25	54.38	40.50	NO
1.25	0.375	0.5	0.5	1.5	1.250	87.00	72.50	54.00	NO
1.25	0.5	0.125	0.625	0.375	0.297	19.03	17.22	13.50	NO
1.25	0.5	0.25	0.625	0.75	0.594	38.06	34.44	27.00	NO
1.25	0.5	0.375	0.625	1.125	0.891	57.09	51.66	40.50	NO
1.25	0.5	0.5	0.625	1.5	1.188	76.13	68.88	54.00	NO
1.25	0.625	0.125	0.75	0.375	0.281	16.31	16.31	13.50	NO
1.25	0.625	0.25	0.75	0.75	0.563	32.63	32.63	27.00	NO
1.25	0.625	0.375	0.75	1.125	0.844	48.94	48.94	40.50	NO
1.25	0.625	0.5	0.75	1.5	1.125	65.25	65.25	54.00	NO
1.25	0.75	0.125	0.875	0.375	0.266	13.59	15.41	13.50	NO
1.25	0.75	0.25	0.875	0.75	0.531	27.19	30.81	27.00	NO
1.25	0.75	0.375	0.875	1.125	0.797	40.78	46.22	40.50	NO
1.25	0.75	0.5	0.875	1.5	1.063	54.38	61.63	54.00	NO
1.25	0.875	0.125	1	0.375	0.250	10.88	14.50	13.50	NO
1.25	0.875	0.25	1	0.75	0.500	21.75	29.00	27.00	NO
1.25	0.875	0.375	1	1.125	0.750	32.63	43.50	40.50	NO
1.25	0.875	0.5	1	1.5	1.000	43.50	58.00	54.00	NO
1.25	1	0.125	1.125	0.375	0.234	8.16	13.59	13.50	NO
1.25	1	0.25	1.125	0.75	0.469	16.31	27.19	27.00	NO
1.25	1	0.375	1.125	1.125	0.703	24.47	40.78	40.50	NO
1.25	1	0.5	1.125	1.5	0.938	32.63	54.38	54.00	NO
1.25	1.125	0.125	1.25	0.375	0.219	5.44	12.69	13.50	NO
1.25	1.125	0.25	1.25	0.75	0.438	10.88	25.38	27.00	NO
1.25	1.125	0.375	1.25	1.125	0.656	16.31	38.06	40.50	NO
1.25	1.125	0.5	1.25	1.5	0.875	21.75	50.75	54.00	NO
1.5	0.125	0.125	0.25	0.375	0.344	13.05	19.94	13.50	NO
1.5	0.125	0.25	0.25	0.75	0.688	26.10	39.88	27.00	NO
1.5	0.125	0.375	0.25	1.125	1.031	39.15	59.81	40.50	NO
1.5	0.125	0.5	0.25	1.5	1.375	52.20	79.75	54.00	NO
1.5	0.25	0.125	0.375	0.375	0.328	19.58	19.03	13.50	NO
1.5	0.25	0.25	0.375	0.75	0.656	39.15	38.06	27.00	NO
1.5	0.25	0.375	0.375	1.125	0.984	58.73	57.09	40.50	NO
1.5	0.25	0.5	0.375	1.5	1.313	78.30	76.13	54.00	NO
1.5	0.375	0.125	0.5	0.375	0.313	26.10	18.13	13.50	NO
1.5	0.375	0.25	0.5	0.75	0.625	52.20	36.25	27.00	NO
1.5	0.375	0.375	0.5	1.125	0.938	78.30	54.38	40.50	NO
1.5	0.375	0.5	0.5	1.5	1.250	104.40	72.50	54.00	NO
1.5	0.5	0.125	0.625	0.375	0.297	25.56	17.22	13.50	NO
1.5	0.5	0.25	0.625	0.75	0.594	51.11	34.44	27.00	NO
1.5	0.5	0.375	0.625	1.125	0.891	76.67	51.66	40.50	NO

1.5	0.5	0.5	0.625	1.5	1.188	102.23	68.88	54.00	NO
1.5	0.625	0.125	0.75	0.375	0.281	22.84	16.31	13.50	NO
1.5	0.625	0.25	0.75	0.75	0.563	45.68	32.63	27.00	NO
1.5	0.625	0.375	0.75	1.125	0.844	68.51	48.94	40.50	NO
1.5	0.625	0.5	0.75	1.5	1.125	91.35	65.25	54.00	NO
1.5	0.75	0.125	0.875	0.375	0.266	20.12	15.41	13.50	NO
1.5	0.75	0.25	0.875	0.75	0.531	40.24	30.81	27.00	NO
1.5	0.75	0.375	0.875	1.125	0.797	60.36	46.22	40.50	NO
1.5	0.75	0.5	0.875	1.5	1.063	80.48	61.63	54.00	NO
1.5	0.875	0.125	1	0.375	0.250	17.40	14.50	13.50	NO
1.5	0.875	0.25	1	0.75	0.500	34.80	29.00	27.00	NO
1.5	0.875	0.375	1	1.125	0.750	52.20	43.50	40.50	NO
1.5	0.875	0.5	1	1.5	1.000	69.60	58.00	54.00	NO
1.5	1	0.125	1.125	0.375	0.234	14.68	13.59	13.50	NO
1.5	1	0.25	1.125	0.75	0.469	29.36	27.19	27.00	NO
1.5	1	0.375	1.125	1.125	0.703	44.04	40.78	40.50	NO
1.5	1	0.5	1.125	1.5	0.938	58.73	54.38	54.00	NO
1.5	1.125	0.125	1.25	0.375	0.219	11.96	12.69	13.50	NO
1.5	1.125	0.25	1.25	0.75	0.438	23.93	25.38	27.00	NO
1.5	1.125	0.375	1.25	1.125	0.656	35.89	38.06	40.50	NO
1.5	1.125	0.5	1.25	1.5	0.875	47.85	50.75	54.00	NO
1.5	1.25	0.125	1.375	0.375	0.203	9.24	11.78	13.50	NO
1.5	1.25	0.25	1.375	0.75	0.406	18.49	23.56	27.00	NO
1.5	1.25	0.375	1.375	1.125	0.609	27.73	35.34	40.50	NO
1.5	1.25	0.5	1.375	1.5	0.813	36.98	47.13	54.00	NO
1.5	1.375	0.125	1.5	0.375	0.188	6.53	10.88	13.50	NO
1.5	1.375	0.25	1.5	0.75	0.375	13.05	21.75	27.00	NO
1.5	1.375	0.375	1.5	1.125	0.563	19.58	32.63	40.50	NO
1.5	1.375	0.5	1.5	1.5	0.750	26.10	43.50	54.00	NO
1.75	0.125	0.125	0.25	0.375	0.344	13.05	19.94	13.50	NO
1.75	0.125	0.25	0.25	0.75	0.688	26.10	39.88	27.00	NO
1.75	0.125	0.375	0.25	1.125	1.031	39.15	59.81	40.50	NO
1.75	0.125	0.5	0.25	1.5	1.375	52.20	79.75	54.00	NO
1.75	0.25	0.125	0.375	0.375	0.328	19.58	19.03	13.50	NO
1.75	0.25	0.25	0.375	0.75	0.656	39.15	38.06	27.00	NO
1.75	0.25	0.375	0.375	1.125	0.984	58.73	57.09	40.50	NO
1.75	0.25	0.5	0.375	1.5	1.313	78.30	76.13	54.00	NO
1.75	0.375	0.125	0.5	0.375	0.313	26.10	18.13	13.50	NO
1.75	0.375	0.25	0.5	0.75	0.625	52.20	36.25	27.00	NO
1.75	0.375	0.375	0.5	1.125	0.938	78.30	54.38	40.50	NO
1.75	0.375	0.5	0.5	1.5	1.250	104.40	72.50	54.00	NO

1.75	0.5	0.125	0.625	0.375	0.297	30.45	17.22	13.50	NO
1.75	0.5	0.25	0.625	0.75	0.594	60.90	34.44	27.00	NO
1.75	0.5	0.375	0.625	1.125	0.891	91.35	51.66	40.50	NO
1.75	0.5	0.5	0.625	1.5	1.188	121.80	68.88	54.00	NO
1.75	0.625	0.125	0.75	0.375	0.281	29.36	16.31	13.50	NO
1.75	0.625	0.25	0.75	0.75	0.563	58.73	32.63	27.00	NO
1.75	0.625	0.375	0.75	1.125	0.844	88.09	48.94	40.50	NO
1.75	0.625	0.5	0.75	1.5	1.125	117.45	65.25	54.00	NO
1.75	0.75	0.125	0.875	0.375	0.266	26.64	15.41	13.50	NO
1.75	0.75	0.25	0.875	0.75	0.531	53.29	30.81	27.00	NO
1.75	0.75	0.375	0.875	1.125	0.797	79.93	46.22	40.50	NO
1.75	0.75	0.5	0.875	1.5	1.063	106.58	61.63	54.00	NO
1.75	0.875	0.125	1	0.375	0.250	23.93	14.50	13.50	NO
1.75	0.875	0.25	1	0.75	0.500	47.85	29.00	27.00	NO
1.75	0.875	0.375	1	1.125	0.750	71.78	43.50	40.50	NO
1.75	0.875	0.5	1	1.5	1.000	95.70	58.00	54.00	NO
1.75	1	0.125	1.125	0.375	0.234	21.21	13.59	13.50	NO
1.75	1	0.25	1.125	0.75	0.469	42.41	27.19	27.00	NO
1.75	1	0.375	1.125	1.125	0.703	63.62	40.78	40.50	NO
1.75	1	0.5	1.125	1.5	0.938	84.83	54.38	54.00	NO
1.75	1.125	0.125	1.25	0.375	0.219	18.49	12.69	13.50	YES
1.75	1.125	0.25	1.25	0.75	0.438	36.98	25.38	27.00	YES
1.75	1.125	0.375	1.25	1.125	0.656	55.46	38.06	40.50	YES
1.75	1.125	0.5	1.25	1.5	0.875	73.95	50.75	54.00	YES
1.75	1.25	0.125	1.375	0.375	0.203	15.77	11.78	13.50	YES
1.75	1.25	0.25	1.375	0.75	0.406	31.54	23.56	27.00	YES
1.75	1.25	0.375	1.375	1.125	0.609	47.31	35.34	40.50	YES
1.75	1.25	0.5	1.375	1.5	0.813	63.08	47.13	54.00	YES
1.75	1.375	0.125	1.5	0.375	0.188	13.05	10.88	13.50	YES
1.75	1.375	0.25	1.5	0.75	0.375	26.10	21.75	27.00	YES
1.75	1.375	0.375	1.5	1.125	0.563	39.15	32.63	40.50	YES
1.75	1.375	0.5	1.5	1.5	0.750	52.20	43.50	54.00	YES
1.75	1.5	0.125	1.625	0.375	0.172	10.33	9.97	13.50	YES
1.75	1.5	0.25	1.625	0.75	0.344	20.66	19.94	27.00	YES
1.75	1.5	0.375	1.625	1.125	0.516	30.99	29.91	40.50	YES
1.75	1.5	0.5	1.625	1.5	0.688	41.33	39.88	54.00	YES
1.75	1.625	0.125	1.75	0.375	0.156	7.61	9.06	13.50	NO
1.75	1.625	0.25	1.75	0.75	0.313	15.23	18.13	27.00	NO
1.75	1.625	0.375	1.75	1.125	0.469	22.84	27.19	40.50	NO
1.75	1.625	0.5	1.75	1.5	0.625	30.45	36.25	54.00	NO
2	0.125	0.125	0.25	0.375	0.344	13.05	19.94	13.50	NO

2	0.125	0.25	0.25	0.75	0.688	26.10	39.88	27.00	NO
2	0.125	0.375	0.25	1.125	1.031	39.15	59.81	40.50	NO
2	0.125	0.5	0.25	1.5	1.375	52.20	79.75	54.00	NO
2	0.25	0.125	0.375	0.375	0.328	19.58	19.03	13.50	NO
2	0.25	0.25	0.375	0.75	0.656	39.15	38.06	27.00	NO
2	0.25	0.375	0.375	1.125	0.984	58.73	57.09	40.50	NO
2	0.25	0.5	0.375	1.5	1.313	78.30	76.13	54.00	NO
2	0.375	0.125	0.5	0.375	0.313	26.10	18.13	13.50	NO
2	0.375	0.25	0.5	0.75	0.625	52.20	36.25	27.00	NO
2	0.375	0.375	0.5	1.125	0.938	78.30	54.38	40.50	NO
2	0.375	0.5	0.5	1.5	1.250	104.40	72.50	54.00	NO
2	0.5	0.125	0.625	0.375	0.297	32.63	17.22	13.50	NO
2	0.5	0.25	0.625	0.75	0.594	65.25	34.44	27.00	NO
2	0.5	0.375	0.625	1.125	0.891	97.88	51.66	40.50	NO
2	0.5	0.5	0.625	1.5	1.188	130.50	68.88	54.00	NO
2	0.625	0.125	0.75	0.375	0.281	34.80	16.31	13.50	NO
2	0.625	0.25	0.75	0.75	0.563	69.60	32.63	27.00	NO
2	0.625	0.375	0.75	1.125	0.844	104.40	48.94	40.50	NO
2	0.625	0.5	0.75	1.5	1.125	139.20	65.25	54.00	NO
2	0.75	0.125	0.875	0.375	0.266	33.17	15.41	13.50	NO
2	0.75	0.25	0.875	0.75	0.531	66.34	30.81	27.00	NO
2	0.75	0.375	0.875	1.125	0.797	99.51	46.22	40.50	NO
2	0.75	0.5	0.875	1.5	1.063	132.68	61.63	54.00	NO
2	0.875	0.125	1	0.375	0.250	30.45	14.50	13.50	NO
2	0.875	0.25	1	0.75	0.500	60.90	29.00	27.00	NO
2	0.875	0.375	1	1.125	0.750	91.35	43.50	40.50	NO
2	0.875	0.5	1	1.5	1.000	121.80	58.00	54.00	NO
2	1	0.125	1.125	0.375	0.234	27.73	13.59	13.50	NO
2	1	0.25	1.125	0.75	0.469	55.46	27.19	27.00	NO
2	1	0.375	1.125	1.125	0.703	83.19	40.78	40.50	NO
2	1	0.5	1.125	1.5	0.938	110.93	54.38	54.00	NO
2	1.125	0.125	1.25	0.375	0.219	25.01	12.69	13.50	YES
2	1.125	0.25	1.25	0.75	0.438	50.03	25.38	27.00	YES
2	1.125	0.375	1.25	1.125	0.656	75.04	38.06	40.50	YES
2	1.125	0.5	1.25	1.5	0.875	100.05	50.75	54.00	YES
2	1.25	0.125	1.375	0.375	0.203	22.29	11.78	13.50	YES
2	1.25	0.25	1.375	0.75	0.406	44.59	23.56	27.00	YES
2	1.25	0.375	1.375	1.125	0.609	66.88	35.34	40.50	YES
2	1.25	0.5	1.375	1.5	0.813	89.18	47.13	54.00	YES
2	1.375	0.125	1.5	0.375	0.188	19.58	10.88	13.50	YES
2	1.375	0.25	1.5	0.75	0.375	39.15	21.75	27.00	YES

2	1.375	0.375	1.5	1.125	0.563	58.73	32.63	40.50	YES
2	1.375	0.5	1.5	1.5	0.750	78.30	43.50	54.00	YES
2	1.5	0.125	1.625	0.375	0.172	16.86	9.97	13.50	YES
2	1.5	0.25	1.625	0.75	0.344	33.71	19.94	27.00	YES
2	1.5	0.375	1.625	1.125	0.516	50.57	29.91	40.50	YES
2	1.5	0.5	1.625	1.5	0.688	67.43	39.88	54.00	YES
2	1.625	0.125	1.75	0.375	0.156	14.14	9.06	13.50	YES
2	1.625	0.25	1.75	0.75	0.313	28.28	18.13	27.00	YES
2	1.625	0.375	1.75	1.125	0.469	42.41	27.19	40.50	YES
2	1.625	0.5	1.75	1.5	0.625	56.55	36.25	54.00	YES
2	1.75	0.125	1.875	0.375	0.141	11.42	8.16	13.50	YES
2	1.75	0.25	1.875	0.75	0.281	22.84	16.31	27.00	YES
2	1.75	0.375	1.875	1.125	0.422	34.26	24.47	40.50	YES
2	1.75	0.5	1.875	1.5	0.563	45.68	32.63	54.00	YES
2	1.875	0.125	2	0.375	0.125	8.70	7.25	13.50	YES
2	1.875	0.25	2	0.75	0.250	17.40	14.50	27.00	YES
2	1.875	0.375	2	1.125	0.375	26.10	21.75	40.50	YES
2	1.875	0.5	2	1.5	0.500	34.80	29.00	54.00	YES