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Behavior of Arc Spot Weld Connections Subjected to Combined Shear and Tension Forces

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Abstract

In North America the design of arc spot weld connections is currently limited by the lack of understanding of the behavior of the welded connection when it is subject to combined shear and tension forces. An experimental investigation was conducted at the University of Missouri – Rolla to study the behavior and to develop design recommendations for the relationship (interaction) of the tension and shear forces on an arc spot weld connection. The experimental study focused on six variables that were deemed to be the key parameters that may influence the strength of the arc spot weld connection. These variables were the sheet thickness; sheet material properties to included yield strength, tensile strength and ductility of the sheet; visible diameter of the arc spot weld; and the relationship between the magnitude of the shear force and tension force. Based on an analysis of the test results, both a linear and non-linear interaction equation was developed and design recommendations were formulated based on these equations.

INTRODUCTION

Since the early 1940's, cold-formed steel construction has been widely used throughout the United States and other countries. In building construction, arc spot welds, commonly known as puddle welds, are widely used for connecting roof deck to support members (Figure 1). These support members are typically hot-rolled steel beams or girders, or open web steel joists. An arc spot weld is formed by burning a hole through the decking and then filling it with weld metal, thus fusing the sheet to the structural member.

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An arc spot weld will be subjected to different stress conditions as a result of imposed loading conditions. For example, a wind load acting on a structural system may impose both a shear and tension force on the roof when the deck is functioning as a structural diaphragm.

The use of cold-formed steel in the United States has been guided by the American Iron and Steel Institute (AISI) since it published the first edition of Light Gage Cold-Formed Steel Design Manual in 1946 (AISI, 1946). The most recent edition, published in 2007, includes specifications that extend the use of the document into Canada and Mexico (AISI, 2007). This resource for structural design only provides design information for arc spot weld connections in pure tension or pure shear.

Additional design guidance was needed for predicting the strength when the weld connection was subjected to simultaneous shear forces and tension forces. A study at the University of Missouri-Rolla focused on spot weld connections for steel deck and structural members in combined tension and shear loading.

Figure 1. Arc Spot Weld Connected Roof System

LITERATURE REVIEW

Studies have been completed regarding a pure shear force and a pure tension force on arc spot weld connections (Pekoz and McGuire, 1979; LaBoube and Yu, 1991; LaBoube, 2001), but no test data concerning a combination load is available.

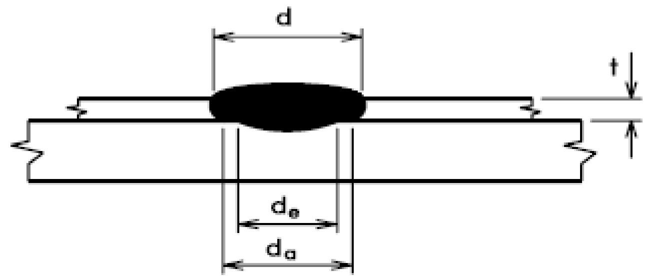


Figure 2. Definition of Parameters

The American Iron and Steel Institute's *North American Specification for the Design of Cold Formed Steel Members* (2007) provides criteria for the design of cold-formed steel members and connections. The specification includes the most updated design guidelines for the industry's use. The specification includes equations for the design arc spot weld connections subjected to either pure shear or pure tension as summarized by Yu (2000). Contained in the specification are recommendations for double sheet connections, connections with weld washers, connections that are concentrically or eccentrically loaded, side lap connections, and connections made at an edge of roof. The applicable nominal strength, P_n, equations are as follows:

For Shear Alone:

If $(d_a / t) \leq 0.815\sqrt{(E/F_u)}$, then

$$P_n = 2.20 t d_a F_u \qquad \text{(Eq. 2-11)}$$

If $0.815\sqrt{(E/F_u)} < (d_a / t) < 1.397\sqrt{(E/F_u)}$, then

$$P_n = 0.280\left[1 + 5.59\frac{\sqrt{E/F_u}}{d_a / t}\right] t d_a F_u \qquad \text{(Eq. 2-12)}$$

If $(d_a / t) \geq 1.397\sqrt{(E/F_u)}$, then $P_n = 1.40 t d_a F_u$ (Eq. 2-13)

For Tension Alone:

$$P_n = 0.8(F_u / F_y)^2 t d_a F_u \qquad \text{(Eq. 2-14)}$$

$$P_n = \frac{\pi d_e^2}{4} 0.75 F_{xx} \qquad \text{(Eq. 2-15)}$$

For tension the following limits apply: $t d_a F_u \leq 3$ kips (13.34 kN), $e_{min} \geq d$, $F_{xx} \geq$ 60 ksi, $F_u \geq 60$ ksi, and $F_{xx} > F_u$.

Where, as illustrated by Figure 2, P_n = Nominal strength (resistance) of arc spot weld, d = visible diameter of outer surface of arc spot weld, d_a = the average diameter of the arc spot weld at mid thickness of t (where d_a= (d-t) for single or multiple sheets not more than four lapped sheets over a supporting member), d_e = $0.7d – 1.5t \leq 0.55d$, d_e = effective diameter of fused area at plane of maximum shear transfer, t = total combined base steel thickness (exclusive of coatings) of sheets involved in shear transfer above plane of maximum shear transfer. Also, F_{xx} = tensile strength of electrode classification, F_u = tensile strength as specified in Section A2.1, A2.2 or A2.3.2 (AISI 2007) and e_{min}= minimum edge distance.

EXPERIMENTAL INVESTIGATION

Six parameters were considered in the UMR test program. These parameters included the sheet thickness, yield strength, tensile strength and ductility of the sheet, diameter of the weld, and the variation in the relationship between the shear force and tension force.

Standard B deck was used for all deck that was tested. The nominal deck dimensions are shown in Figure 3.

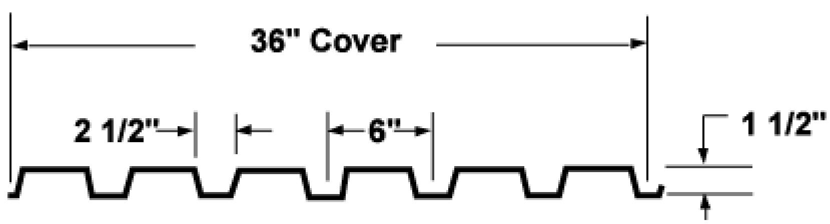


Figure 3. Typical B Deck Profile

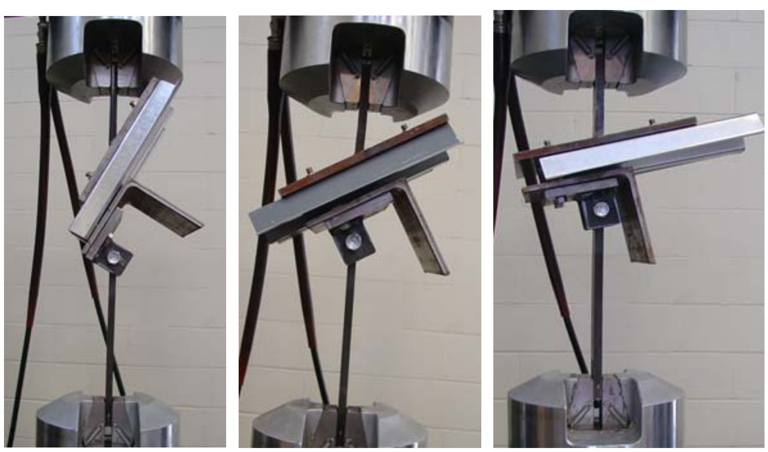
The mechanical properties of the deck material were determined by performing standard tensile coupon tests in accordance with ASTM A370. A summary of the average results can be found in Table 3.

In addition to the thickness of the sheet, yield strength, tensile strength and ductility of the sheet, the weld diameter varied between 0.498 in. and 1.062 in.

To vary the interaction of shear and tension forces on the spot weld connection, the test setup considered three orientation angles, measuring from the vertical plane were tested: thirty degrees, sixty degrees, and seventy-five degrees (Figure 4).

Table 3. Materials Properties

Deck Type	Uncoated Thickness	Yield Point	Tensile Strength	F_u/F_y	Percent Elongation
	T	F_y	F_u		
	(in.)	(ksi)	(ksi)		%
B1	0.0577	97.57	99.50	1.02	0.60
B2	0.0293	100.63	104.77	1.04	0.83
B3	0.0580	48.10	59.30	1.23	20.06
B4	0.0300	42.10	52.70	1.25	20.98



(a) 30° (b) 60° (c) 75°

Figure 4. Orientation of Test Setup

Test Specimen Fabrication. Each test specimen consisted of a 12 in. x 12 in. deck section spot welded to a 6 in. x 6 in. x 3/8 in. hot-rolled angle (Figure 5). Details of the test specimen fabrication are given by Stirnemann and LaBoube (2007).

Figure 5. Test Specimen

Test Fixture. The test fixture consisted of an upper welded T-section (Figure 6) and a rotating arm (Figure 6). The welded T-section consisted of a flat plate 12 in. x 12 in. x 3/8 in. welded to a stem plate 2 in. x 9 in. x 3/8 in. The T-sections were fabricated at angles of 30°, 60°, and 75° the 30° and 60° T-section.

Each test specimen was attached to the test fixture. The completed test specimen attached to the test fixture and mounted in the test machine is shown by Figure 6.

Test Procedure. The test specimen was placed in a MTS 880 Universal Testing machine where it was loaded in tension. The test fixture's rotating arm, allowed the test specimen to be pulled through the vertical line of action of the spot weld, such that there was no out-of-plane bending forces applied to the specimen. The tension load was continuously applied until the test specimen failed.

TEST RESULTS

A total of seventy-nine tests were performed in this test program. Thirty-five test specimens had $F_u/F_y \leq 1.04$ (Deck Type B1 and B2) and forty-four test specimens had $F_u/F_y \geq 1.23$ (Deck Type B3 and B4).

A typical failure mode, regardless of weld size, was a peeling, fracture and tearing of the deck around the perimeter of the weld, as shown in Figure 7.

Figure 6. Test Specimen Mounted in the Test Fixture

Figure 7. Typical Failed Test Specimen

Deck Types B3 and B4. For the decks with $F_u/F_y \geq 1.23$, two thicknesses were tested, 0.058 in. and 0.030 in. Each thickness was tested using a thirty degree T-section and a sixty degree T-section. A limited number of the Deck Type B4 were also tested using a seventy-five degree T-section.

Fracture of the deck was reached for all of the tests. In both Deck Types B3 and B4 the deck experienced large amounts of plastic deformation before the sheet failed, as depicted in Figure 8. As the deck was loaded the deck around the contour of the weld became noticeably deformed. Although the load application for the 44 test specimens was concentric with respect to the center of the weld, the distortion of the sheet during loading resulted in a non-uniform deformation around the perimeter of the weld. This can be seen in Figure 9.

Figure 8. Deformation of Deck Type B3 and B4

Figure 9. Deformed Deck Around Contour of Weld

For each test specimen the average diameter, d_a, and the effective diameter, d_e, computed per the AISI specification, the ultimate test load, P_u, and the tension and shear components of the ultimate load, P_{ut} and P_{uv} were recorded and can be found in Stirnemann and LaBoube (2007).

Deck Types B1 and B2. For the decks with a $F_u/F_y \leq 1.04$ there were two thicknesses tested, 0.058 in. and 0.030 in. Each thickness was tested using a thirty degree welded T-section and a sixty degree T-section. A limited number of the Deck Type B2 were also tested using a seventy-five degree T-section.

Similar to Deck Types B3 and B4, the ultimate capacity of the deck was reached for all of the tests. However, the lower ductility steel did not show the same signs of deformation as the higher ductility steel. For the lower ductility steel typical deformations can be seen in Figure 10. The failure mode of the lower ductility deck was most often a simultaneous fracture around the entire weld instead of a tearing failure exhibited by the normal ductility deck types. Test specimen details and test results for the low ductility specimens can be found in Stirnemann and LaBoube (2007).

Figure 10. Deformation of Deck Type B1 and B2

DATA ANALYSIS

The data obtained from this test program was analyzed using the current nominal tensile and shear strengths provided by AISI in the 2001 Specification, Equations 2-11 through 2-15.

DATA ANALYSIS USING AISI SPECIFICATION

The data obtained from this test program was analyzed with the current nominal tensile and shear strengths provided by AISI in the 2007 Specification, Equations 12 through 15. Data from LaBoube and Yu (1991) and Pekoz and McGuire (1979) is presented to define the limits of pure tension and pure shear strength.

Nominal Strength. For each test specimen the nominal tensile strength, P_{nt}, and nominal shear strength, P_{nv}, were computed by AISI Equations 2-11 through 2-15 and are listed in Tables 2 to 5. Also summarized in Tables 4-5 to 4.8 are the tension and shear ultimate load components, P_{ut} and P_{uv}. Ratios of P_{ut}/P_{nt} and P_{uv}/P_{nv} were computed and the values can be found for Deck Types B3, B1, B2, and B4 in Tables 2, 3, 4, and 5, respectively.

Table 2 AISI Analysis for Deck Type B3

Deck Type B3 Specimen No.	P_u (lbs.)	P_{ut} (lbs.)	P_{uv} (lbs.)	P_{nt} (lbs.)	P_{nv} (lbs.)	$\frac{P_{ut}}{P_{nt}}$	$\frac{P_{uv}}{P_{nv}}$
B3-1	2817	1408	2439	2325	4207	0.606	0.580
B3-2	2803	1401	2427	2180	3944	0.643	0.616
B3-3	2335	1168	2022	2355	4260	0.496	0.475
B3-4	2288	1144	1982	2191	3964	0.522	0.500
B3-5	2731	1365	2365	2116	3829	0.645	0.618
B3-6	2772	1386	2401	2168	3923	0.639	0.612
B3-7	3379	1690	2926	2973	5380	0.568	0.544
B3-8	2602	1301	2253	2939	5318	0.443	0.424
B3-9	2803	1401	2427	2076	3757	0.675	0.646
B3-10	3387	1693	2933	2935	5311	0.577	0.552
B3-11	1703	1475	852	2189	3960	0.674	0.215
B3-12	3119	2701	1559	3037	5495	0.889	0.284
B3-13	1003	868	501	1929	3490	0.450	0.144
B3-14	2620	2269	1310	3042	5503	0.746	0.238
B3-15	2798	2423	1399	2700	4886	0.897	0.286
B3-16	3832	3318	1916	3123	5651	1.062	0.339
B3-17	2856	2474	1428	2817	5096	0.878	0.280
B3-18	1599	1385	799	2044	3699	0.677	0.216
B3-19	1228	1064	614	2179	3942	0.488	0.156
B3-20	1821	1577	910	2114	3825	0.746	0.238

Ultimate Capacity vs. Nominal Capacity. To assess the interaction between the tension force and shear force in an arc spot weld connection, the ratios of the ultimate capacity and the nominal capacity were evaluated. The P_{ut}/P_{nt} and P_{uv}/P_{nv} ratios are listed in Tables 2 through 5 and illustrated in Figure 11. Data from LaBoube and Yu (1991) and Pekoz and McGuire (1979) are included on Figure 11 to provide boundary conditions for pure tension and pure shear.

Table 3. AISI Analysis of Deck Type B1

Deck Type B1 Specimen No.	P_u (lbs.)	P_{ut} (lbs.)	P_{uv} (lbs.)	P_{nt} (lbs.)	P_{nv} (lbs.)	$\frac{P_{ut}}{P_{nt}}$	$\frac{P_{uv}}{P_{nv}}$	$.75P_{nt}$	$.75P_{nv}$	$\frac{P_{ut}}{.75P_{nt}}$	$\frac{P_{uv}}{.75P_{nv}}$	$.60P_{nt}$	$.60P_{nv}$	$\frac{P_{ut}}{.60P_{nt}}$	$\frac{P_{uv}}{60P_{nv}}$
B1-1	2771	1385	2399	3074	8127	0.451	0.295	2305	6095	0.600	0.393	1844	4876	0.751	0.492
B1-2	2657	1329	2301	3083	8152	0.431	0.282	2312	6114	0.574	0.376	1850	4891	0.718	0.470
B1-3	2545	1273	2204	2622	6933	0.485	0.318	1967	5200	0.647	0.423	1573	4160	0.809	0.530
B1-4	3078	1539	2666	3109	8222	0.495	0.324	2332	6167	0.660	0.432	1865	4933	0.825	0.540
B1-5	3006	1503	2604	2964	7837	0.507	0.332	2223	5878	0.676	0.442	1778	4702	0.845	0.554
B1-6	2561	1280	2217	2733	7228	0.468	0.307	2050	5421	0.624	0.409	1640	4337	0.781	0.511
B1-7	2412	1206	2089	2385	6306	0.506	0.331	1788	4729	0.674	0.441	1431	3783	0.843	0.552
B1-8	2495	1248	2161	2772	7331	0.450	0.295	2079	5498	0.600	0.393	1663	4399	0.750	0.491
B1-9	2622	1311	2270	2812	7436	0.466	0.304	2109	5610	0.621	0.404	1687	4488	0.777	0.506
B1-10	1908	1652	954	2753	7280	0.600	0.131	2065	5460	0.800	0.174	1652	4368	1.000	0.218
B1-11	2469	2139	1235	3841	10157	0.557	0.122	2881	7618	0.742	0.162	2305	6094	0.928	0.203
B1-12	2836	2456	1418	3673	9712	0.669	0.146	2754	7284	0.891	0.194	2204	5827	1.115	0.243
B1-13	2700	2338	1350	3741	9892	0.625	0.136	2806	7419	0.833	0.181	2245	5935	1.042	0.227
B1-14	1806	1564	903	2557	6761	0.612	0.134	1918	5071	0.815	0.178	1534	4057	1.019	0.223

Table 4. AISI Analysis of Deck Type B2

Deck Type B2 Specimen No.	P_u (lbs.)	P_{ut} (lbs.)	P_{uv} (lbs.)	P_{nt} (lbs.)	P_{nv} (lbs.)	$\frac{P_{ut}}{P_{nt}}$	$\frac{P_{uv}}{P_{nv}}$	$.75P_{nt}$	$.75P_{nv}$	$\frac{P_{ut}}{.75P_{nt}}$	$\frac{P_{uv}}{.75P_{nv}}$	$.60P_{nt}$	$.06P_{nv}$	$\frac{P_{ut}}{.60P_{nt}}$	$\frac{P_{uv}}{.60P_{nv}}$
B2-1	976	488	846	1336	2726	0.365	0.310	1002	2045	0.487	0.413	801	1636	0.609	0.517
B2-2	731	366	633	1400	2747	0.261	0.230	1050	2060	0.348	0.307	840	1648	0.435	0.384
B2-3	960	480	832	1307	2716	0.367	0.306	980	2037	0.489	0.408	784	1630	0.612	0.510
B2-4	928	464	804	1234	3132	0.376	0.257	926	2349	0.501	0.342	741	1879	0.626	0.428
B2-5	1323	662	1146	1996	3222	0.332	0.356	1497	2417	0.442	0.474	1198	1933	0.553	0.593
B2-6	1449	724	1254	2322	3749	0.312	0.335	1742	2812	0.415	0.446	1393	2249	0.520	0.558
B2-7	1230	615	1065	2096	3383	0.293	0.315	1572	2537	0.391	0.419	1257	2030	0.489	0.525
B2-8	1261	631	1092	2250	3633	0.280	0.301	1688	2725	0.373	0.400	1350	2180	0.467	0.501
B2-9	712	356	617	1386	2742	0.257	0.225	1039	2057	0.342	0.299	832	1645	0.428	0.375
B2-10	955	477	827	1350	2730	0.354	0.303	1013	2048	0.471	0.403	810	1638	0.589	0.505
B2-11	1002	868	501	2075	3350	0.418	0.150	1556	2513	0.557	0.199	1245	2010	0.697	0.249
B2-12	890	771	445	2098	3387	0.368	0.131	1573	2540	0.490	0.175	1259	2032	0.613	0.219
B2-13	695	602	347	1407	2749	0.428	0.126	1055	2062	0.570	0.168	844	1649	0.713	0.211
B2-14	603	522	301	1361	2734	0.384	0.110	1021	2051	0.511	0.146	817	1640	0.639	0.184
B2-15	735	636	367	1389	2743	0.458	0.134	1042	2057	0.610	0.178	833	1646	0.763	0.223
B2-16	571	495	286	1425	2755	0.347	0.104	1069	2066	0.462	0.138	855	1653	0.578	0.173
B2-17	971	841	486	2222	3587	0.379	0.135	1666	2690	0.505	0.180	1333	2152	0.631	0.226
B2-18	1050	909	525	2204	3559	0.412	0.147	1653	2669	0.549	0.196	1323	2135	0.687	0.246
B2-19	730	632	365	1483	2773	0.426	0.132	1112	2080	0.568	0.175	890	1664	0.711	0.219
B2-20	773	670	387	1980	3197	0.338	0.121	1485	2398	0.450	0.161	1188	1918	0.563	0.202
B2-21	745	720	193	1653	2828	0.435	0.068	1240	2121	0.580	0.090	992	1697	0.726	0.114

Table 5 AISI Analysis for Deck Type B4

Deck Type B4 Specimen No.	P_u (lbs.)	P_{ut} (lbs.)	P_{uv} (lbs.)	P_{nt} (lbs.)	P_{nv} (lbs.)	$\frac{P_{ut}}{P_{nt}}$	$\frac{P_{uv}}{P_{nv}}$
B4-1	1562	781	1353	913	1602	0.856	0.845
B4-2	1562	781	1353	1224	2015	0.638	0.671
B4-3	1562	781	1353	1511	2079	0.517	0.651
B4-4	1030	515	892	1036	1817	0.497	0.491
B4-5	985	493	853	1026	1801	0.480	0.474
B4-6	1021	510	884	868	1523	0.588	0.580
B4-7	1076	538	932	951	1669	0.566	0.558
B4-8	1236	618	1071	1963	2180	0.315	0.491
B4-9	1561	781	1352	1424	2060	0.548	0.657
B4-10	864	748	432	1148	1198	0.652	0.361
B4-11	938	812	469	1150	1998	0.706	0.235
B4-12	739	640	370	1020	1790	0.628	0.206
B4-13	877	760	439	1070	1877	0.710	0.234
B4-14	1051	911	526	1187	2007	0.767	0.262
B4-15	676	585	338	1743	2131	0.336	0.159
B4-16	738	639	369	1531	2083	0.418	0.177
B4-17	1106	958	553	2046	2285	0.468	0.242
B4-18	1125	974	563	1729	2128	0.564	0.264
B4-19	656	634	170	1048	1839	0.605	0.092
B4-20	745	720	193	1261	2023	0.571	0.095
B4-21	638	616	165	1020	1790	0.604	0.092
B4-22	931	899	241	1292	2030	0.696	0.119
B4-23	1139	1100	295	1313	2035	0.837	0.145
B4-24	600	579	155	1140	1996	0.508	0.078

Adjustment For Low Ductility Steel. To better align the normal and low ductility test results, the nominal strengths of Deck Type B1 and B2 were multiplied by a factor, L, equal to 0.75. Interestingly, the 0.75 factor is required by AISI Specification Section A.2.3.2 for low ductile steels. For Deck Type B3 and B4 L, was taken as unity. Figure 4.4 illustrates this modified interaction relationship.

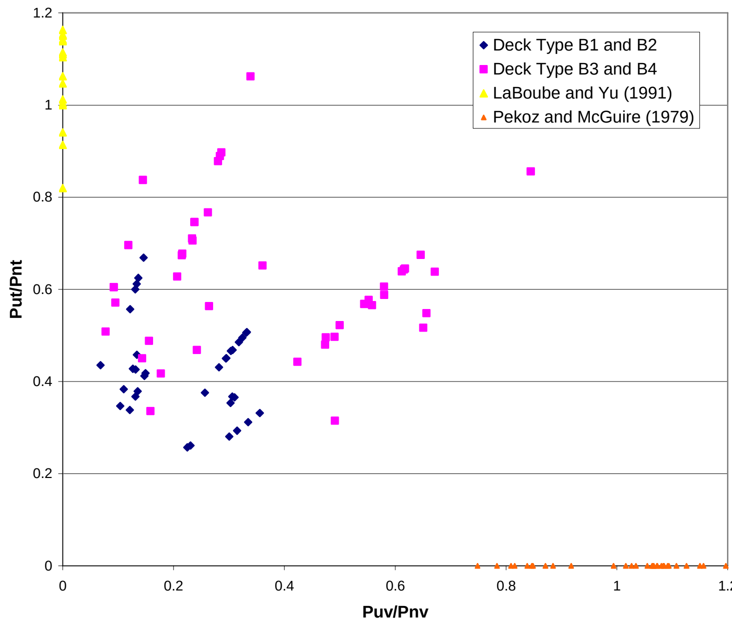


Figure 11. Interaction of Shear and Tension using AISI Equations

DEVELOPMENT OF INTERACTION EQUATION

Based on the data analysis, both a non-linear and linear interaction equation was developed.

Non-linear Interaction Equation. Using the data of Figure 11 an interaction equation was developed and can be seen graphically by Figure 12. To better align the normal and low ductility test results, the nominal strengths of Deck Type B1 and B2 were multiplied by a factor, L, equal to 0.75. Interestingly, the 0.75 factor is required by AISI Specification Section A.2.3.2 for low ductile steels. For Deck Type B3 and B4, L, was taken as unity.

The test data for Figure 11 can be found in Tables 2 through 5.

$$\left(\frac{P_{ut}}{LP_{nt}}\right)^{.6} + \left(\frac{P_{uv}}{LP_{nv}}\right) \le 1.0 \qquad \text{(Eq. 17)}$$

where:

$L = 1.0$, for $F_u/F_y \geq 1.23$
$L = 0.75$, for $F_u/F_y \leq 1.04$
P_{nv} = AISI Nominal Shear Strength (Eqs. 12 and 13)
P_{nt} = AISI Nominal Tension Strength (Eq. 15)

Linear Interaction Equation. A linear equation was developed however an L value of 0.60 for Deck Types B1 and B2 was used for both P_{nt} and P_{nv}. For normal ductility decks, Deck Types B3 and B4, L was taken as unity.

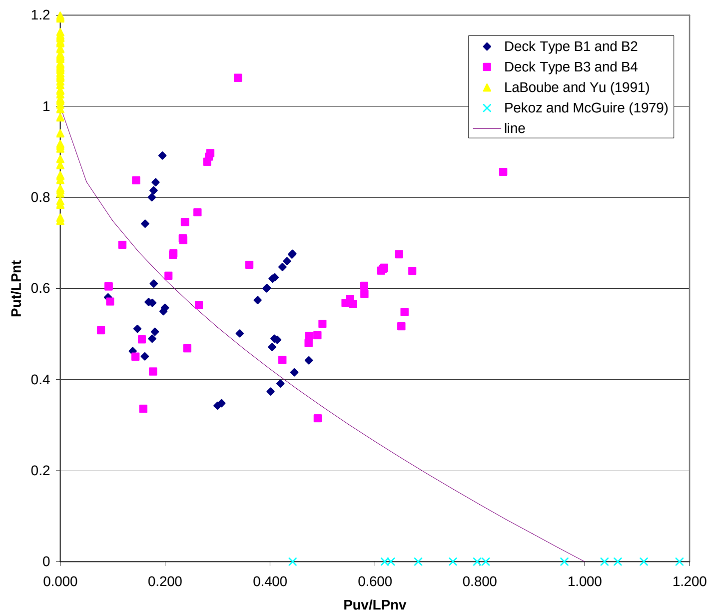


Figure 12. Non-linear Interaction Relationship

The linear interaction Equation 18 can be seen graphically by Figure 13.

$$\left(\frac{P_{ut}}{LP_{nt}}\right)+\left(\frac{P_{uv}}{LP_{nv}}\right)\leq 1.0 \qquad \text{(Eq. 18)}$$

where:

$L = 1.0$, for $F_u/F_y \geq 1.23$

L = 0.60, for $F_u/F_y \leq 1.04$
P_{nv} = AISI Nominal Shear Strength (Eqs. 12 and 13)
P_{nt} = AISI Nominal Tension Strength (Eq. 15)

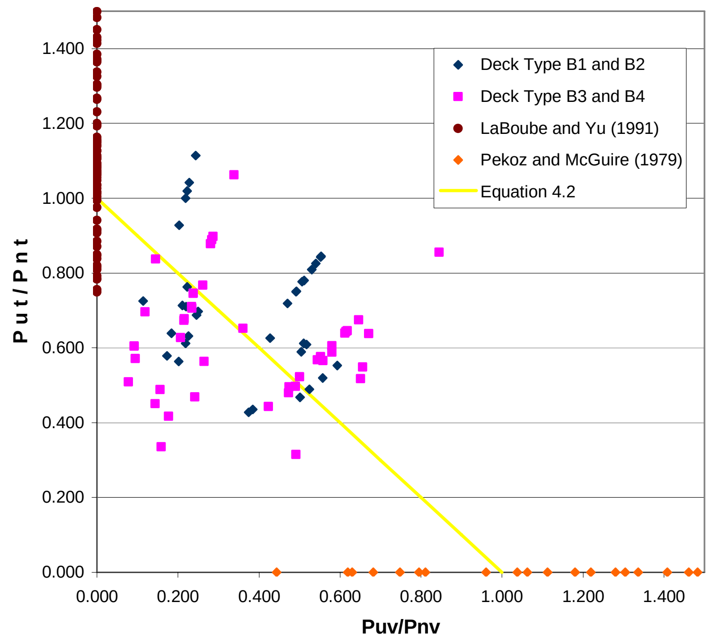


Figure 13. Linear Interaction Relationship

CONCLUSIONS AND DESIGN RECOMMENDATIONS

A total of seventy-five specimens were tested in order to establish an understanding of the behavior of arc spot weld connections subjected to combined shear and tension and develop a design methodology. Based on an analysis of the test data, an interaction equation was derived.

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BIBLIOGRAPHY

American Iron Steel Institute, AISI. (2007). "North American Specification for the Design of Cold-Formed Steel Structural Members." 2007 Edition, Washington DC

American Iron Steel Insititute, AISI. (1946). "Light Gage Cold-Formed Steel Design Manual." 1946. New York.

LaBoube, R. A., (2001), "Tension on Arc Spot Welded Connections – AISI Section E2.2.2," University of Missouri – Rolla, Rolla, MO

LaBoube, R. A., and Yu, W. W. (1991). "Tensile Strength of Welded Connections." Civil Engineering Study 91-3 Cold Formed Steel Series. Rolla, MO., June, 1991, University of Missouri-Rolla, Center for Cold-Formed Steel Structures.

Pekoz, T., and McGuire, W. (1979). "Welding of Sheet Steel." Report SG 79-2. American Iron and Steel Institute, Washington, DC

Steel Deck Institute, SDI. (2004). "Diaphragm Design Manual." Third Edition. Fox River Grove, IL.

Stirnemann, L.K. and LaBoube, R.A. (2007). "Behavior of Arc Spot Weld Connections Subjected to Combined Shear and Tension Forces." Final Report, Cold-Formed Steel Series, Department of Civil Engineering, Wei-Wen Yu Center for Cold-Formed Steel Structures, University of Missouri-Rolla, Rolla, Missouri

Yu, W. W. (2000). "Cold-Formed Steel Design." Second Edition. John Wiley and Sons, Inc, New York, NY.