



# Withdrawal and Shear Values Of Aerosmith .144 Pins

Based on Report No: LGSRG 2-96

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## **Design Provisions for Aerosmith, Inc. Steel Pins**

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## 1.0 INTRODUCTION

The purpose of the test program described in this report was to develop, through testing and a review of the literature, design values and recommendations for the withdrawal (tension) and shear strength of steel pin connections in light gauge steel-to-steel connections. The tests included a wide combination of steel thickness (covering most residential applications).

## 2.0 SCOPE

Lap shear and withdrawal tests were conducted for different combinations of steel thickness (gauge) and two sizes of steel pins (0.100 in. and 0.144 in. diameters). The overall scope of the test program is summarized in Tables 1 through 4. For each configuration listed in the tables, a set of three tests were performed in an effort to provide reliable test data.

**Table 1** Lap shear tests using 0.100 in. diameter helical thread pins

		Main Plate <sup>1</sup>				
		22 ga.	20 ga.	18 ga.	16 ga.	14 ga.
Holding Plate <sup>2</sup>	20 ga.		○	○	○	
	18 ga.		○	○	○	
	16 ga.	○	○	○	○	
	14 ga.		○			○
	12 ga.		○			

<sup>1</sup> plate in contact with head of the steel pin

<sup>2</sup> plate on side with tip of the steel pin

**Table 2** Withdrawal (tension) tests using 0.100 in. diameter helical thread pins

		Main Plate <sup>1</sup>				
		22 ga.	20 ga.	18 ga.	16 ga.	14 ga.
Holding Plate <sup>2</sup>	20 ga.		○	○	○	
	18 ga.		○	○	○	
	16 ga.	○	○	○	○	
	14 ga.		○			○
	12 ga.		○			

<sup>1</sup> plate in contact with head of the steel pin

<sup>2</sup> plate on side with tip of the steel pin

Based on the data provided by Aerosmith, Inc., the nominal thickness and strength of the steels used in the test program were interpreted and the values are summarized in Table 5. Tension coupon testing was not part of the scope of this project. The values given in Table 5 are based on data taken from Working Draft #4 of NAHB's prescriptive design recommendations for cold-formed steel framing, the Metal Stud Manufacturers Association (MSMA) member catalog, and ASTM Standard A653.

**Table 3** Lap shear tests using 0.144 in. diameter helical thread pins

		Main Plate <sup>1</sup>			
		20 ga.	18 ga.	16 ga.	14 ga.
Holding Plate <sup>2</sup>	20 ga.	○			
	18 ga.	○	○		
	16 ga.	○	○	○	
	14 ga.		○	○	○
	12 ga.		○	○	○

<sup>1</sup> plate in contact with head of the steel pin

<sup>2</sup> plate on side with tip of the steel pin

**Table 4** Withdrawal (tension) tests using 0.144 in. diameter helical thread pins

		Main Plate <sup>1</sup>			
		20 ga.	18 ga.	16 ga.	14 ga.
Holding Plate <sup>2</sup>	20 ga.	○			
	18 ga.	○	○		
	16 ga.	○	○	○	
	14 ga.		○	○	○
	12 ga.		○	○	○

<sup>1</sup> plate in contact with head of the steel pin

<sup>2</sup> plate with tip of the steel pin

**Table 5** Nominal thickness and minimum yield and tensile strength values

Designation (mils)	Min. Thickness, in (mm)	Reference Gauge	Yield Strength <sup>1</sup> , ksi	Min. Tensile Strength <sup>1</sup> , ksi
18	0.0179 (0.455)	25	33	45
27	0.0269 (0.683)	22	33	45
33	0.0329 (0.836)	20	33	45
43	0.0428 (1.087)	18	33	45
54	0.0538 (1.367)	16	50	65
68	0.0677 (1.720)	14	50	65
97	0.0966 (2.454)	12	50	65

<sup>1</sup> assumed based on literature

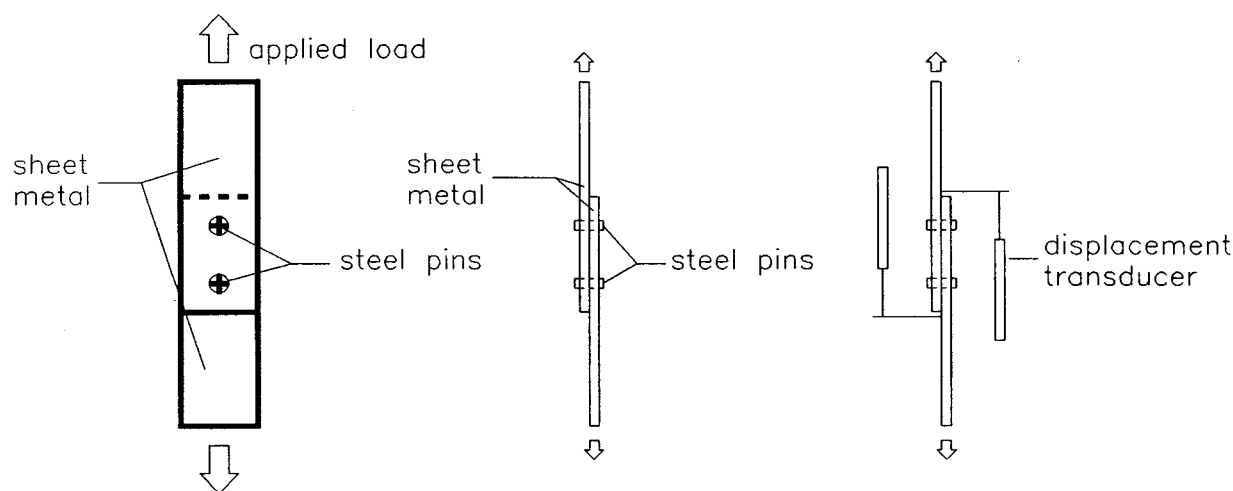
### 3.0 TEST SETUP and PROCEDURE

#### 3.1 Lap Shear Tests

All shear test specimens consisted of a single lap joint with two pins aligned in the direction of the applied shear load. The width dimension of the shear specimen was such that failure by yield

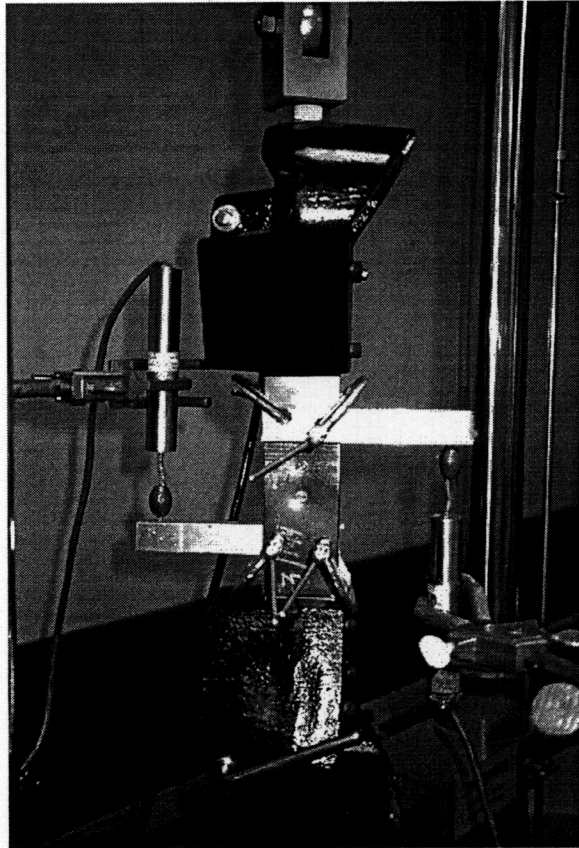
in the gross section or fracture across the net section was not possible before failure at the connection. Figure 1 shows a schematic of the typical test specimen and physical dimensions are given in Appendix A. The lap shear tests were conducted in a 10 kip Applied Testing Systems universal testing machine. Figure 2 shows the overall test setup. The specimens were loaded to failure at a rate of 0.2 in. per minute, based on the free running crosshead speed. Data recorded during the test included the applied load and the relative displacement across the joint. Displacement at the joint was measured using a system of two transducers (dcdt) across the lap.

Each lap shear specimen was given a designation identifying the main plate, the holding (substrate) plate, and the diameter of the steel pin used. For example S20-18-100 implied a lap shear test (S), the main plate is 20 gauge (20), and the holding plate is 18 gauge (18).



**Figure 1** Typical lap shear test specimen





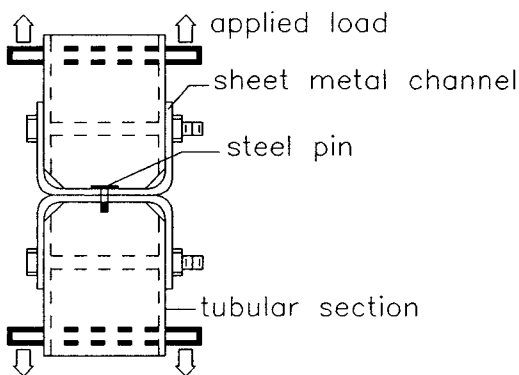
**Figure 2** Overall test setup for lap shear test

### ***3.2 Withdrawal (Tension) Tests***

The tension test specimen comprised two plates bent to form channel sections. The web of the channel sections were attached back to back with a single pin (see Figure 3). The physical dimensions of the test specimens are given in Appendix A. Load was applied perpendicular to the connected web elements, through the flanges, at a free running crosshead speed of 0.2 in. per minute (in the universal testing machine). Each specimen was tested to destruction. Data recorded during the test included the applied load and the stroke of the test machine (this was a

relative measure of the joint displacement). Figure 4 shows the overall test setup. To limit bending in the web of the channel section, an attempt was made to fit the tubular section tightly against the web of the channel. In many cases, however, a close fit at the web could not be achieved, thus, there was some bending in the web.

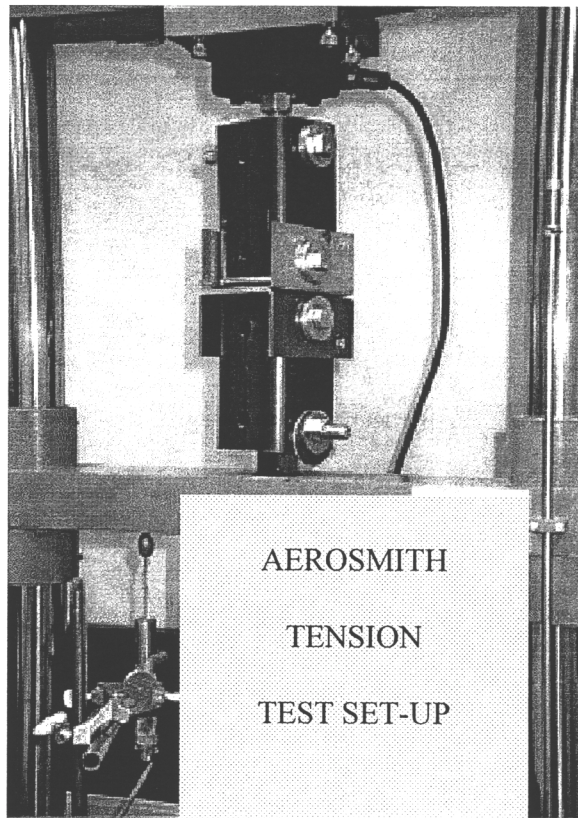
Each withdrawal (tension) specimen was given a designation identifying the main plate, the holding (substrate) plate, and the diameter of the steel pin used. For example T20-18-144 implied a withdrawal (tension) test (T), the main plate is 20 gauge (20), and the holding plate is 18 gauge (18).



**Figure 3** Typical withdrawal (tension) test specimen

#### **4.0 TEST RESULTS**

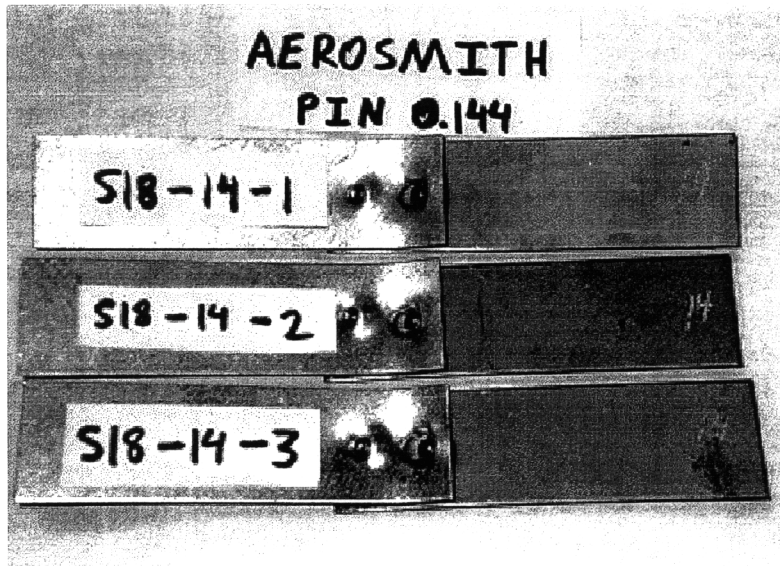
In the lap shear tests, the displacement across the connection was relatively small up to the maximum load. As the maximum resistance in the lap shear connection was reached the displacement at the joint increased rapidly. This increase in displacement was derived from two



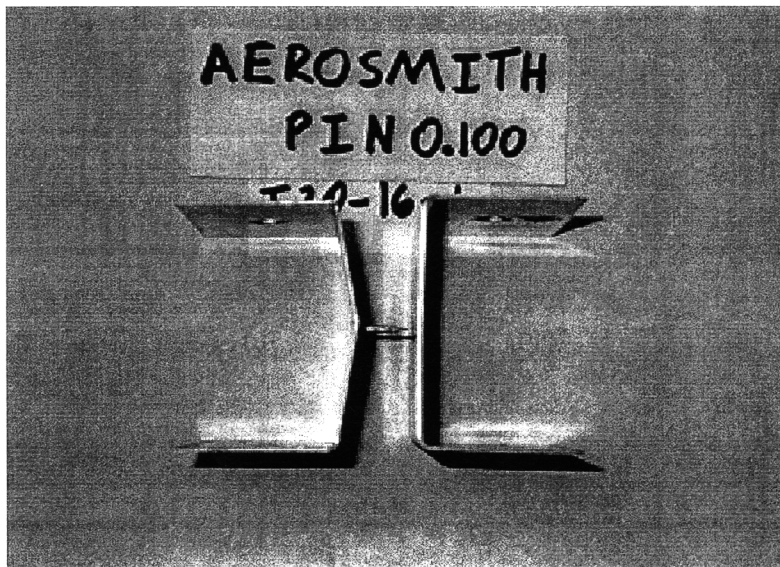
**Figure 4** Overall test setup for withdrawal (tension) test

sources: (i) pin slip in the holding plate and (ii) deformation in the main plate (at the head of the pin). In the withdrawal test, the main source of displacement across the joint was pin slip (apart from bending of the channel web). In none of the withdrawal tests did the head of the pin pull through the main plate. Figures 5 (a and b) and 6 show the overall failure modes for the lap shear and withdrawal tests, respectively.

The nominal maximum loads for each configuration tested are given in Tables 6 through 9. Appendix B gives the test data for each specimen. For each set of three tests (Appendix B), the



**Figure 5b** Typical mode of failure for the lap shear test



**Figure 6** Typical mode of failure for the withdrawal (tension) test

**Table 8** Overall test results for shear using 0.144 in. diameter steel pins

Specimen	Failure Load (per pin), lb.	Main Plate $t_1$ , in.	Holding Plate $t_2$ , in.	Pin Diameter, in.	Tensile Strength $F_{u1}$ , ksi	Tensile Strength $F_{u2}$ , ksi
S20-20	452.64	0.0329	0.0329	0.144	45	45
S20-18	670.82	0.0329	0.0428	0.144	45	45
S20-16	868.92	0.0329	0.0538	0.144	45	65
S18-18	743.78	0.0428	0.0428	0.144	45	45
S18-16	980.23	0.0428	0.0538	0.144	45	65
S18-14	1,252.58	0.0428	0.0677	0.144	45	65
S18-12	1,522.51	0.0428	0.0966	0.144	45	65
S16-16	977.41	0.0538	0.0538	0.144	65	65
S16-14	1,325.51	0.0538	0.0677	0.144	65	65
S16-12	1,917.64	0.0538	0.0966	0.144	65	65
S14-14	1,392.88	0.0677	0.0677	0.144	65	65
S14-12	2,147.73	0.0677	0.0966	0.144	65	65

**Table 9** Overall test results for withdrawal (tension) using 0.144 in. diameter steel pins

Specimen	Failure Load (per pin), lb.	Main Plate $t_1$ , in.	Holding Plate $t_2$ , in.	Pin Diameter, in.	Tensile Strength $F_{u1}$ , ksi	Tensile Strength $F_{u2}$ , ksi
T20-20	241.15	0.0329	0.0329	0.144	45	45
T20-18	421.23	0.0329	0.0428	0.144	45	45
T20-16	545.17	0.0329	0.0538	0.144	45	65
T18-18	426.01	0.0428	0.0428	0.144	45	45
T18-16	557.39	0.0428	0.0538	0.144	45	65
T18-14	669.44	0.0428	0.0677	0.144	45	65
T18-12	1,010.05	0.0428	0.0966	0.144	45	65
T16-16	596.36	0.0538	0.0538	0.144	65	65
T16-14	613.2	0.0538	0.0677	0.144	65	65
T16-12	902.72	0.0538	0.0966	0.144	65	65
T14-14	659.51	0.0677	0.0677	0.144	65	65
T14-12	894.39	0.0677	0.0966	0.144	65	65

**5.0 DISCUSSION**

A comparison of the nominal measured shear values with computed values based on the AISI design equations for screws (Tables 10 and 11 for 0.100 in. and 0.144 in. diameter pins, respectively) shows that the AISI screw equations (equations (1) through (5)) may be very conservative for the Aerosmith pins in shear (using the assumed material properties in Table 5). Based on the test data, the equations (6) and (7) are recommended for computing the capacity of the lap shear steel pin connection.

**Table 10** Measured vs. predicted shear connection capacities for 0.100 in. diameter pins

Specimen	Measured Capacity, lb.	Predicted Capacity (LGSRG), lb.	Predicted Capacity (AISI), lb.
S22-16	669.83	618.19	326.84
S20-20	402.32	370.13	356.66
S20-18	582.52	422.16	399.74
S20-16	746.04	683.66	399.74
S20-14	929.25	766.91	399.74
S20-12	921.12	916.09	399.74
S18-20	444.94	422.16	356.66
S18-18	619.82	481.5	520.02
S18-16	811.49	779.77	520.02
S16-20	485.91	473.31	356.66
S16-18	699.65	539.84	520.02
S16-16	865.47	874.25	944.19
S14-14	1,120.21	1,100.13	1,188.14

**Table 11** Measured vs. predicted shear connection capacities for 0.144 in. diameter pins

Specimen	Measured Capacity lb.	Predicted Capacity (LGSRG) lb.	Predicted Capacity (AISI) lb.
S20-20	452.64	532.98	427.99
S20-18	670.82	607.9	575.62
S20-16	868.92	984.48	575.62
S18-18	743.78	693.36	635.05
S18-16	980.23	1,122.87	748.83
S18-14	1,252.58	1,259.6	748.83
S18-12	1,522.51	1,504.62	748.83
S16-16	977.41	1,258.92	1,292.76
S16-14	1,325.51	1,412.22	1,359.63
S16-12	1,917.64	1,686.92	1,359.63
S14-14	1,392.88	1,584.18	1,710.91
S14-12	2,147.73	1,892.34	1,710.91

***AISI equations for lap shear screw connections:***

For  $t_2/t_1 \leq 1.0$ , the nominal strength per fastener is the smallest of

$$P_{ns} = 4.2(t_2^3 d)^{1/2} F_{u2} \dots\dots\dots (1)$$

$$P_{ns} = 2.7t_1 d F_{u1} \dots\dots\dots (2)$$

$$P_{ns} = 2.7t_2 d F_{u2} \dots\dots\dots (3)$$

For  $t_2/t_1 > 2.5$ , the nominal strength per fastener is taken as the smaller of

$$P_{ns} = 2.7t_1 d F_{u1} \dots\dots\dots (4)$$

$$P_{ns} = 2.7t_2 d F_{u2} \dots\dots\dots (5)$$

Interpolate between the two limits of  $t_2/t_1$ .

***Recommended equations for lap shear steel pin connections:***

For  $t_2/t_1 \leq 3.0$ , the nominal strength per fastener may be taken as

$$P_{ns} = 2.5(t_1 t_2)^{1/2} d F_{u2} \dots\dots\dots (6)$$

For  $t_2/t_1 > 3.0$ , the nominal strength per fastener may be taken as

$$P_{ns} = 2.7t_1dF_{u1} \dots\dots\dots (7)$$

For the withdrawal tests, Tables 12 and 13 (0.100 in. and 0.144 in. diameter pins, respectively) show that the AISI screws equation gives a relative good prediction of the withdrawal capacity of the steel pin connection.

***AISI equation for screw pull-out in withdrawal connections (equation may also be used for steel pin):***

$$P_{not} = 0.85t_2dF_{u2}$$

**Table 12** Measured vs. predicted withdrawal connection capacities for 0.100 in. diameter pins

Specimen	Measured Capacity lb.	Predicted Capacity (AISI) lb.
T22-16	340.88	297.25
T20-20 (r)	131.02	125.84
T20-20	104.98	125.84
T20-18	190.06	163.71
T20-16	255.54	297.25
T20-14	438.38	374.04
T20-12	524.94	533.72
T18-20	139.24	125.84
T18-18	251.77	163.71
T18-16	371.79	297.25
T16-20*	69.94	125.84
T16-18	244.92	163.71
T16-16	321.81	297.25
T14-14	439.17	374.04

\* value unexpectedly low



**Table 13** Measured vs. predicted withdrawal connection capacities for 0.144 in. diameter pins

Specimen	Measured Capacity, lb.	Predicted Capacity (AISI), lb.
T20-20	241.15	181.21
T20-18	421.23	235.74
T20-16	545.17	428.03
T18-18	426.01	235.74
T18-16	557.39	428.03
T18-14	669.44	538.62
T18-12	1,010.05	768.55
T16-16	596.36	428.03
T16-14	613.2	538.62
T16-12	902.72	768.55
T14-14	659.51	538.62
T14-12	894.39	768.55

## 6.0 CONCLUSION

Results from a comprehensive series of lap shear and withdrawal (tension) light gauge metal-to-metal connections tests were presented for Aerosmith, Inc.'s 0.100 in. and 0.144 in. diameter helical thread pins. The test data cover a wide combination of main and holding (substrate) plates thickness that may be used in the field. Overall, the measured results are very good compared with the predicted values based on the AISI screw equations.