TEST REPORT ON

CENTRAL STATES MANUFACTURING, INC.'S R-LOC PANELS (26 GA., 80 KSI, 36" WIDE) AT 7' 6" & 5' 0" PANEL SPANS IN ACCORDANCE WITH AISI S907-08 & AC43

TESTED FOR:
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TEST WITNESSED BY:
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TESTING DATE: March 12, 2015
REPORTING DATE: March 19, 2015

ENCON® Project C2006-1

ACCREDITED
TL-327

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TEST SUMMARY

1.1 SUMMARY

Tests were conducted on Central States Manufacturing's 26 ga., 80 ksi R-Loc panels at ENCON® Technology, Inc. Test Facility, Tulsa, Oklahoma. The purpose of the tests was to determine the diaphragm shear strength and shear stiffness of R-Loc panel construction under simulated loading conditions. These tests meet the provisions of AISI S907-08 *"Cantilever Test Method for Cold-Formed Steel Diaphragms"* and AC43 *"Acceptance Criteria for Steel Roof Deck and Floor Systems"*.

These tests were conducted for two different panel spans. The tests are listed below according to date tested.

Test #1 & 2: R-Loc panels at two spans of 7' 6". The panel to structural fasteners spacing was 1' 0" at the top, interior and bottom supports. Tested on March 12, 2015.

Test #3: R-Loc panels at three spans of 5' 0". The panel to structural fasteners spacing was 1' 0" at the top, interior and bottom supports. Tested on March 12, 2015.

The panels were fastened to 16 ga. supports. The sidelap fastener spacing was 24" o.c. for all tests. The above-defined tests were witnessed by Bala Sockalingam, Ph.D., P.E. of ENCON Technology, Inc.

1.2 PANEL SYSTEM DESCRIPTION

R-Loc panels were 26 ga., 1.25" high and 36" wide, 80 ksi through fastened panels. Each panel consisted of 4 ribs spaced at 12" o.c. as shown on Page 3.

The panels were fastened to nominal 16 ga. cee supports with #12-14 x 1.25" long hex head self-drilling screws with washers (Sealtite Building Fasteners). Each panel spanned continuously over two equal spans of 7' 6" or three equal spans of 5' 0". The sidelap fasteners were 1/4"-14 x 7/8" long self-drilling lap screws (Sealtite Building Fasteners) and were spaced at 24" o.c. for all tests. The two sides of the panel assembly were fastened to 16 ga. side angles with panel fastener spaced at 24" o.c. The side angles were fastened to the side posts of the interior frame.

1.3 TEST RESULTS

Load was applied incrementally and deflections of the test construction were recorded for 'no load' condition and at each load increment. The failure mode in Test #1 and #2 was panel buckling. The average ultimate shear strength from the two test constructions with 7' 6" panel span was 338.4 lb/ft and average shear stiffness was 22686 lb/in. The failure mode in Test #3 was tilting and bearing failure of sidelap fastener. The ultimate shear strength from the test construction with 5' 0" panel span was 400.0 lb/ft and shear stiffness was 22857 lb/in. The ultimate shear load and shear stiffness for each test are shown on Table 1.

TEST SUMMARY

Table 1. Shear Load Test Results

Test No.	a (ft)	b (ft)	Panel Span	Maximum Shear Load P_u (lb)	$0.4P_u$ (lb)	Net Deflection Δ_n (in)	Shear Stiffness G' (Lb/in)	Ultimate Shear (lb/ft)
1	15	15	7' 6"	5250	2100.0	0.093	22581	350.0
2	15	15	7' 6"	4900	1960.0	0.086	22791	326.7
3	15	15	5' 0"	6000	2400.0	0.105	22857	400.0

Notes:

P_u = Maximum applied load in the cantilever beam test (lb)

P = $0.4P_u$ in the cantilever beam test (lb)

G' = Shear stiffness of the diaphragm as determined from test measurements

a = Length of diaphragm test frame = 15 ft

b = Depth of diaphragm test frame = 15 ft

Δ_n = Net shear deflection of diaphragm (in) at $0.4P_u$ load.

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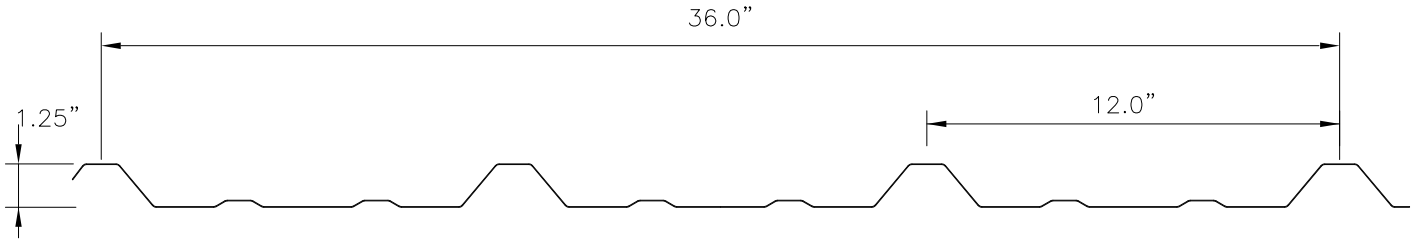
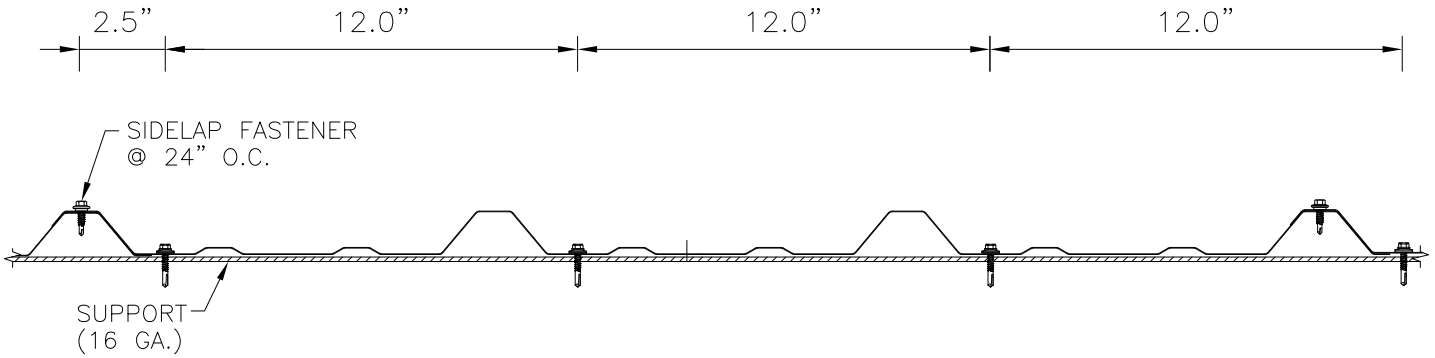


R-LOC PANEL

26 GA., 80 KSI



ALL SUPPORTS

FASTENER PATTERN

2.1 DESCRIPTION OF TEST

OBJECTIVES

Tests were conducted to determine shear strength and shear stiffness of the panels under simulated loading conditions. The test method consisted of the following:

1. assembling the test panel on an interior test frame to form a typical roof or wall construction;
2. loading the test frame incrementally; and
3. observing, measuring, and recording the deflections, deformations, and nature of any failures of principal or critical elements of the test construction.

The increments of load application were chosen such that a sufficient number of readings were obtained to determine the load deformation curve of the system.

TEST SETUP

The test setup consisted of an exterior reaction truss and interior panel support frame as shown in the applicable drawings in the appendix. The L-shaped reaction truss was constructed of two built-up tube sections with cross-braced angle sections to form a truss. The interior frame consisted of two side posts and panel supports. The panel supports were constructed of cold-formed cee or zee sections having equal or lower strength and stiffness than that intended for use in the typical constructions. The end and interior supports were fastened to the side posts with pinned connections.

Both the truss and frame lay in the same horizontal plane. The reaction frame was supported by short columns, which rested on the laboratory floor. Two corners of the interior frame were connected to the exterior frame with hinge and roller supports. The side opposite to these corners was held up by columns with roller bases.

LOADING DEVICE

Load was applied using a 25 kip capacity hydraulic ram and manual pump. The load was monitored with a calibrated 25 kip capacity load cell and associated instrumentation. The accuracy of the load cell was estimated to be $\pm$ 0.01 kips. The hydraulic ram was attached to the reaction truss and the load cell was attached to the interior frame. The load was applied parallel to and in close proximity to one of the points of contact between the diaphragm web and frame.

DEFLECTION MEASUREMENT

Deflection measurements were taken by means of dial indicators calibrated to 1/1000 of an inch. Deflections were measured at locations as shown on the drawings in the appendix. The deflection locations are based on AISI S907-08.

DESCRIPTION OF TEST

DIAPHRAGM SIZE

The overall dimension of each construction was in excess of 15' x 15' for all tests. The panels covered two spans of 7' 6" or three spans of 5' 0". The construction width contained five full panels. The panels were fastened to end and interior supports with self-drilling screws. The panels were also fastened to the side posts of the interior frame. The details of the methods of construction are depicted in the enclosed test drawings. All the material used in the construction represented a typical construction.

NUMBER OF TESTS

Two tests were conducted for constructions with 7' 6" panel span and one test for construction with 5' 0" panel span.

TEST PROCEDURE

The interior frame was loaded to determine its bare frame stiffness. The bare frame stiffness for support spacing at 5' 0" was insignificant, deflecting more than 2" under 42-lb load.

The loading procedure on the completed diaphragm construction consisted of loads applied in increments. The diaphragm was loaded to 5% of the anticipated ultimate load and unloaded. Deflection measurements were recorded at 'no load' conditions. The diaphragm was loaded in equal load increments. At approximately 25% and 50% of estimated maximum load, the load was lowered to zero load and the recovery of the diaphragm was recorded after 5 minutes. Deflection measurements were recorded at every load increment.

TEST DURATION

The test was stopped when the test specimen was unable to carry additional load or visual failure of one or more components of the diaphragm occurred.

2.2 CALCULATIONS

The ultimate shear strength S_u (lb/ft) of a given construction is
where

$$S_u = \frac{P_u}{b}$$

P_u = Maximum applied load in the cantilever beam test (lb),
b = Depth of diaphragm test frame (ft).

The net shear deflections (Δ) at any load level in the cantilever beam test is

$$\Delta = \Delta_3 - \left[\Delta_1 + \frac{a}{b}(\Delta_2 + \Delta_4) \right]$$

where Δ_1, Δ_2, Δ_3 and Δ_4 are measured deformations with appropriate signs at locations shown in

the test drawings.

The apparent shear stiffness G' (lb/in) of a given construction is

$$G' = \frac{P}{\Delta_n}\left(\frac{a}{b}\right)$$

where

P = $0.4P_u$ in the cantilever beam test (lb),
a = Length of diaphragm test frame (ft).
Δ_n = Net shear deflection of diaphragm (in) at $0.4P_u$ load.

TEST RESULTS

3.1 SPECIMEN IDENTIFICATION

Panel Manufacturer:	Central States Manufacturing
Model Type:	R-Loc panel
Dimensions:	1.25" high, 36" wide coverage
Panel Thickness (Ga.):	26
Base Metal Thickness:	0.017" (average)
Panel Yield Stress:	Nom. 80 ksi (96.2 ksi tested average)
Elongation in 2":	6 %
Panel Fasteners:	#12-14 x 1.25" long hex head self-drilling screws with washer (Steelbinder Maxx S-D Sealtite Building Fasteners)
Sidelap Fasteners:	¼"-14 x 7/8" long hex washer head self-drilling screws with bond seal washer (Steelbinder Maxx S-D Sealtite Building Fasteners)
Supports:	Cee 8" x 2.5" x 16 ga.
Support Thickness:	0.060" (Coated thickness)

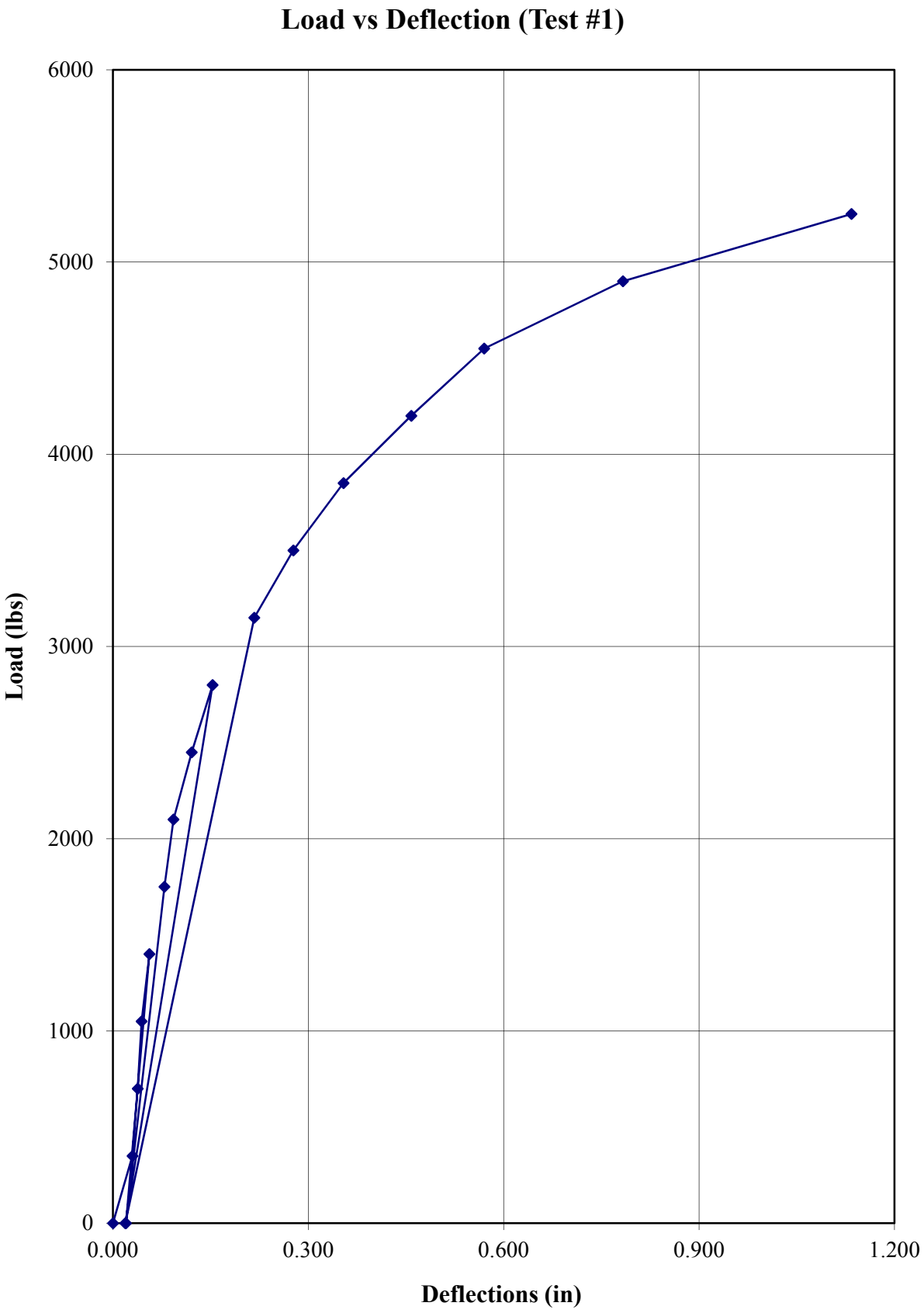
Note: All the test materials were supplied by Central States Manufacturing and were not sampled by ENCON.

3.2.1 TEST #1: R-LOC PANEL AT 7' 6" SPAN

Date:	3.12.15
Panel Type:	R-Loc
Gauge:	26 ga.
Thickness:	0.017"
Panel Width:	36"
Support Spacing:	7' 6"-7' 6" (Two spans)
Type of Structural Fastener:	#12-14 x 1.25" long SDS
Fastener Spacing at End Supports:	12" o.c.
Fastener Spacing at Intermediate Supports:	12" o.c.
Fastener Spacing along sides:	24" o.c
Type of Sidelap Fastener:	1/4"-14 x 7/8" long Lap SDS
Sidelap Fastener Spacing	24" o.c
a = span length of diaphragm (ft):	15
b = depth of diaphragm (ft):	15

Load (lb)	Dial Indicator Reading (in)				Shear Deformation Δ (in)
	1	2	3	4	
0	0.000	0.000	0.000	0.000	0.000
350	0.058	0.001	0.341	0.252	0.030
700	0.114	0.005	0.440	0.283	0.038
1050	0.132	-0.020	0.458	0.302	0.044
1400	0.151	-0.052	0.472	0.317	0.056
0	-0.012	-0.051	0.178	0.221	0.020
1750	0.157	-0.070	0.495	0.329	0.079
2100	0.166	-0.070	0.526	0.337	0.093
2450	0.173	-0.070	0.570	0.346	0.121
2800	0.179	-0.067	0.625	0.360	0.153
0	-0.030	-0.075	0.162	0.248	0.019
3150	0.168	-0.070	0.676	0.361	0.217
3500	0.175	-0.070	0.750	0.368	0.277
3850	0.180	-0.070	0.839	0.375	0.354
4200	0.187	-0.069	0.961	0.385	0.458
4550	0.193	-0.070	1.090	0.397	0.570
4900	0.213	-0.066	1.330	0.400	0.783
5250	0.262	-0.069	1.730	0.403	1.134
0	0.030	-0.100	0.618	0.261	0.427

Failure Mode:	Panel buckling
Duration of test:	17 minutes

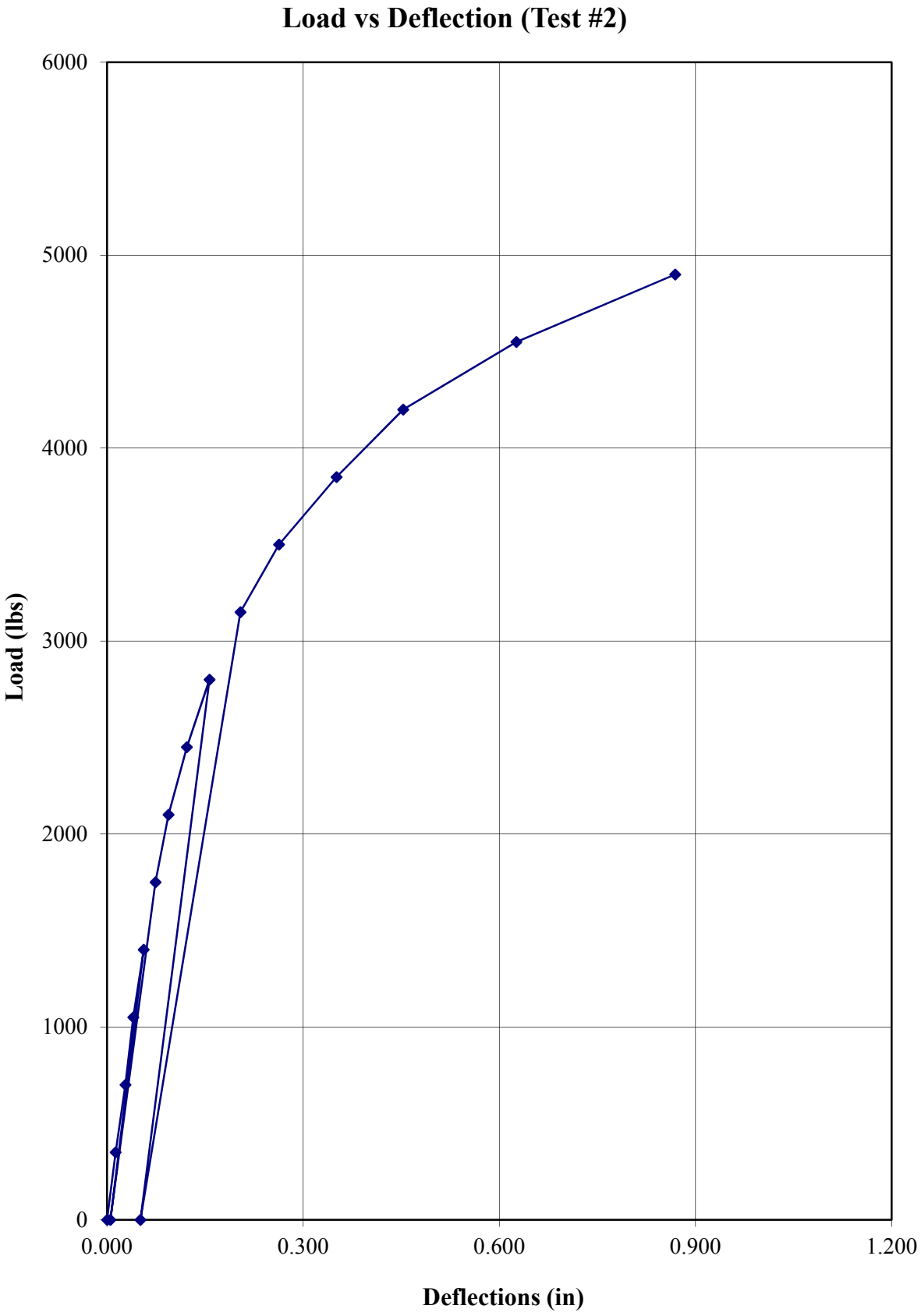

Load vs Deflection (Test #1)
6000
5000
4000
3000
2000
1000
0
Load (lbs)
0.000
0.300
0.600
0.900
1.200
Deflections (in)

3.2.2 TEST #2: R-LOC PANEL AT 7' 6" SPAN

Date:	3.12.15
Panel Type:	R-Loc
Gauge:	26 ga.
Thickness:	0.017"
Panel Width:	36"
Support Spacing:	7' 6"-7' 6" (Two spans)
Type of Structural Fastener:	#12-14 x 1.25" long SDS
Fastener Spacing at End Supports:	12" o.c.
Fastener Spacing at Intermediate Supports:	12" o.c.
Fastener Spacing along sides:	24" o.c
Type of Sidelap Fastener:	1/4"-14 x 7/8" long Lap SDS
Sidelap Fastener Spacing	24" o.c
a = span length of diaphragm (ft):	15
b = depth of diaphragm (ft):	15

Load (lb)	Dial Indicator Reading (in)				Shear Deformation Δ (in)
	1	2	3	4	
0	0.000	0.000	0.000	0.000	0.000
350	0.034	-0.009	0.065	0.027	0.013
700	0.069	-0.012	0.136	0.051	0.028
1050	0.096	-0.007	0.198	0.069	0.040
1400	0.129	0.001	0.270	0.084	0.056
0	0.031	-0.005	0.060	0.029	0.005
1750	0.155	0.007	0.334	0.098	0.074
2100	0.168	0.014	0.387	0.111	0.094
2450	0.182	0.019	0.449	0.126	0.122
2800	0.194	0.021	0.509	0.137	0.157
0	0.030	-0.005	0.102	0.026	0.051
3150	0.197	0.023	0.566	0.142	0.204
3500	0.203	0.024	0.638	0.148	0.263
3850	0.212	0.026	0.744	0.155	0.351
4200	0.219	0.029	0.866	0.165	0.453
4550	0.225	0.033	1.071	0.187	0.626
4900	0.235	0.039	1.336	0.193	0.869
0	0.039	0.011	0.486	0.073	0.363

Failure Mode: Panel buckling
Duration of test: 16 minutes

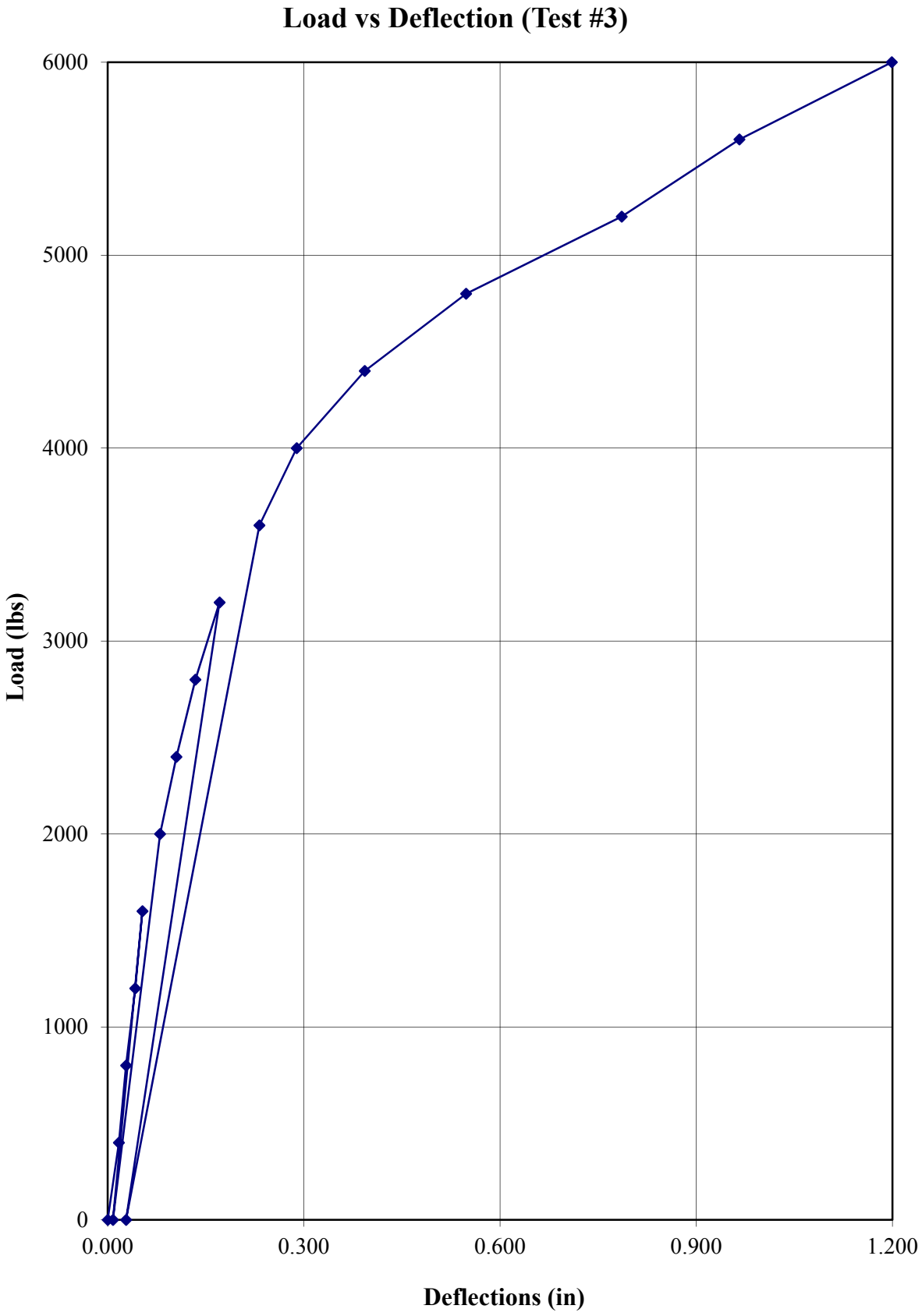

Load vs Deflection (Test #2)
6000
5000
4000
3000
2000
1000
0
Load (lbs)
0.000
0.300
0.600
0.900
1.200
Deflections (in)

3.2.3 TEST #3: R-LOC PANEL AT 5' 0" SPAN

Date:	3.12.15
Panel Type:	R-Loc
Gauge:	26 ga.
Thickness:	0.017"
Panel Width:	36"
Support Spacing:	5' 0" - 5' 0" -5' 0" (Three spans)
Type of Structural Fastener:	#12-14 x 1.25" long SDS
Fastener Spacing at End Supports:	12" o.c.
Fastener Spacing at Intermediate Supports:	12" o.c.
Fastener Spacing along sides:	24" o.c
Type of Sidelap Fastener:	1/4"-14 x 7/8" long Lap SDS
Sidelap Fastener Spacing	24" o.c
a = span length of diaphragm (ft):	15
b = depth of diaphragm (ft):	15

Load (lb)	Dial Indicator Reading (in)				Shear Deformation Δ (in)
	1	2	3	4	
0	0.000	0.000	0.000	0.000	0.000
400	0.043	-0.002	0.080	0.022	0.017
800	0.104	-0.004	0.173	0.045	0.028
1200	0.136	0.004	0.237	0.055	0.042
1600	0.156	0.014	0.291	0.068	0.053
0	0.022	-0.004	0.025	-0.001	0.008
2000	0.164	0.014	0.336	0.078	0.080
2400	0.170	0.015	0.376	0.086	0.105
2800	0.181	0.017	0.427	0.095	0.134
3200	0.189	0.018	0.482	0.104	0.171
0	0.021	-0.016	0.043	0.010	0.028
3600	0.181	0.020	0.537	0.104	0.232
4000	0.191	0.019	0.610	0.111	0.289
4400	0.201	0.023	0.736	0.119	0.393
4800	0.209	0.028	0.910	0.125	0.548
5200	0.221	0.033	1.170	0.130	0.786
5600	0.236	0.041	1.378	0.135	0.966
6000	0.251	0.052	1.646	0.144	1.199
0	0.058	-0.022	0.943	0.015	0.892

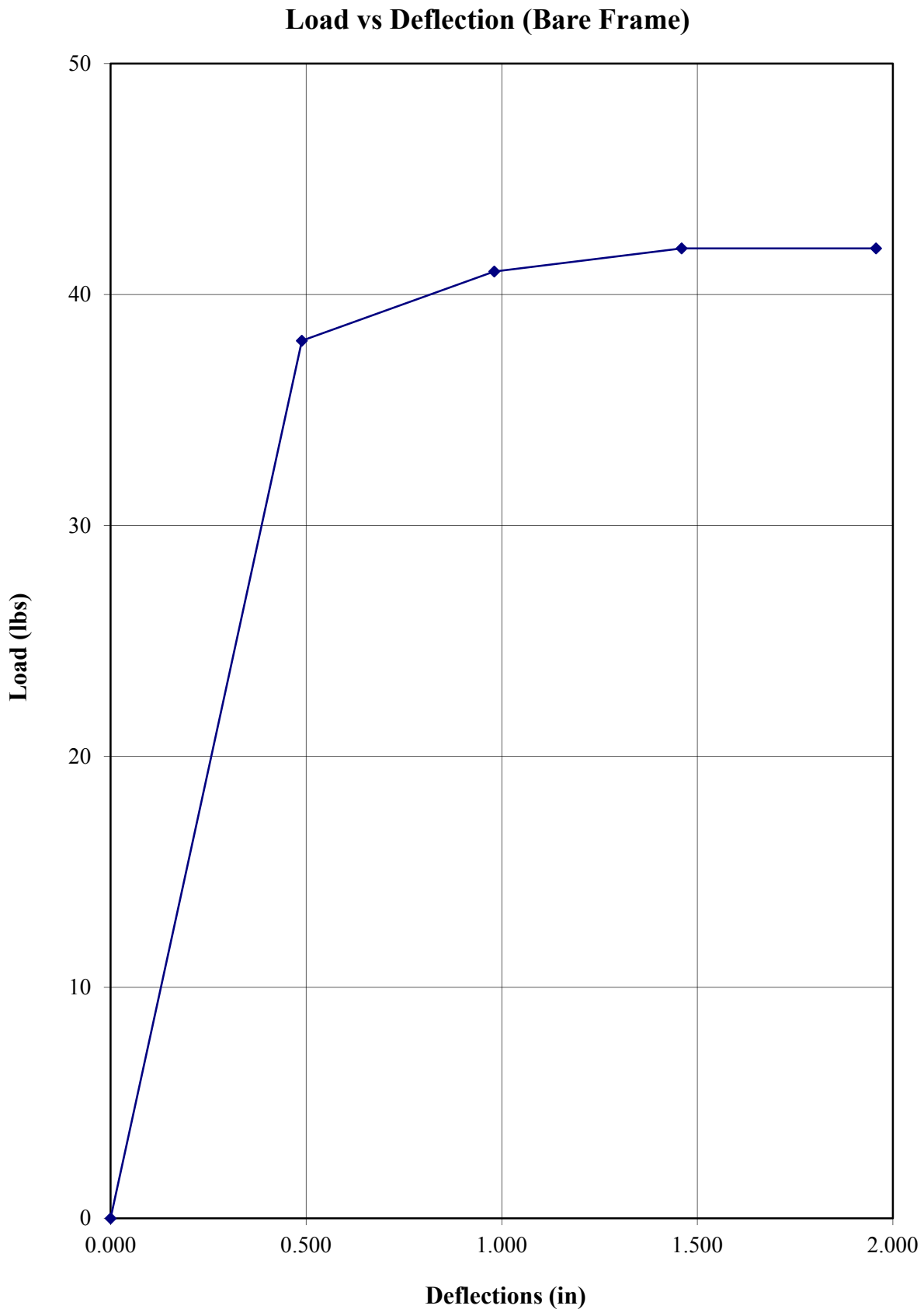
Failure Mode:	Sidelap fastener bearing and tilting
Duration of test:	18 minutes


Load vs Deflection (Test #3)
6000
5000
4000
3000
2000
1000
0
Load (lbs)
0.000
0.300
0.600
0.900
1.200
Deflections (in)

3.3.1 BARE FRAME AT SUPPORT SPANS OF 5' 0"

Test No:	Bare Frame
Date:	3.12.2015
Support Spacing:	5' 0" - 5' 0" -5' 0" (Three spans)
End Supports	C8.0 x 2.5 x 16 ga.
Interior Supports	C8.0 x 2.5 x 16 ga.
Additional weight	(5) 26 ga. R-Loc panels
a = span length of diaphragm (ft):	15
b = depth of diaphragm (ft):	15

Load (lb)	Dial Indicator Reading (in)				Shear Deformation Δ (in)
	1	2	3	4	
0	0.000	0.000	0.000	0.000	0.000
38	0.004	0.007	0.496	-0.004	0.489
41	0.024	0.006	1.007	-0.004	0.981
42	0.041	-0.002	1.495	-0.004	1.460
42	0.056	-0.009	2.001	-0.003	1.957


Load vs Deflection (Bare Frame)
50
40
30
20
10
0
Load (lbs)
0.000
0.500
1.000
1.500
2.000
Deflections (in)

PHOTOGRAPHS

PHOTO 1 View of the panel and sidelap fasteners used in all tests. (DSCN3201)

PHOTO 2 Overview of the diaphragm test setup of R-Loc panels. (DSCN3179)

PHOTOGRAPHS

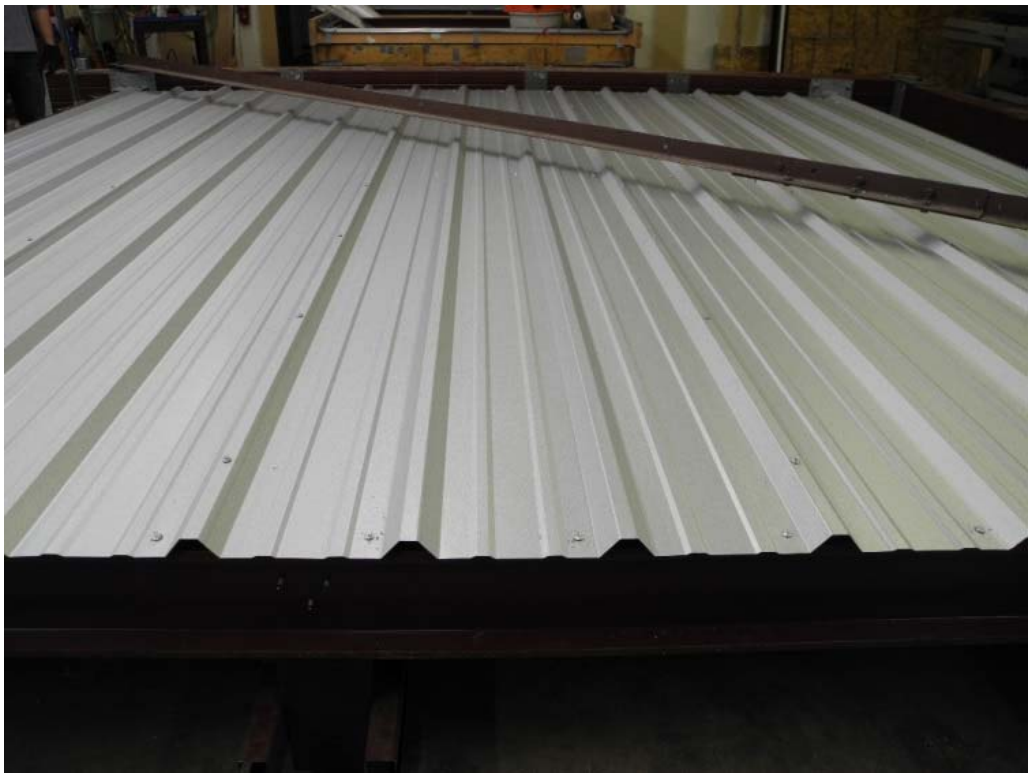


PHOTO 3 View of panel and sidelap fasteners at end and interior supports (Tests #1 & 2). (DSCN3180)

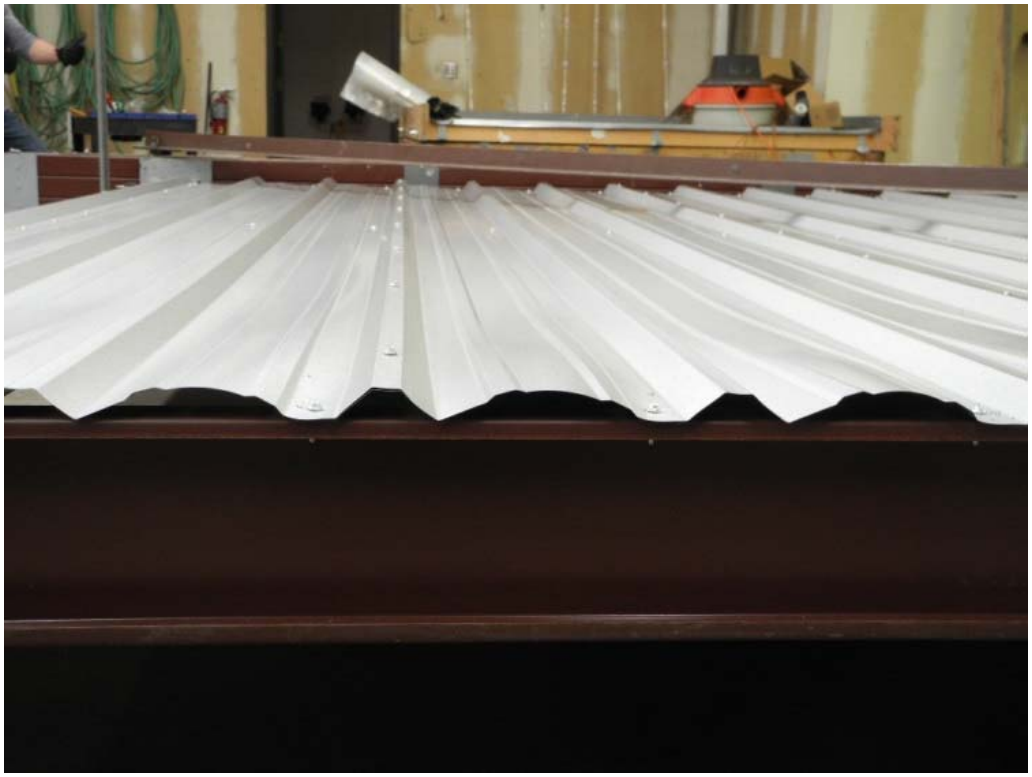


PHOTO 4 View of panel deformation under shear load in Test #1. (DSCN3181)

PHOTOGRAPHS

PHOTO 5 View of panel buckling in Test #1.
(DSCN3183)

PHOTO 6 View of panel buckling in Test #2.
(DSCN3189)

PHOTOGRAPHS

PHOTO 7 View of sidelap and panel fasteners at end and interior supports. (Test #3) (DSCN3193)

PHOTO 8 View of bearing and tilting failure of sidelap fastener in Test #3. (DSCN3199)

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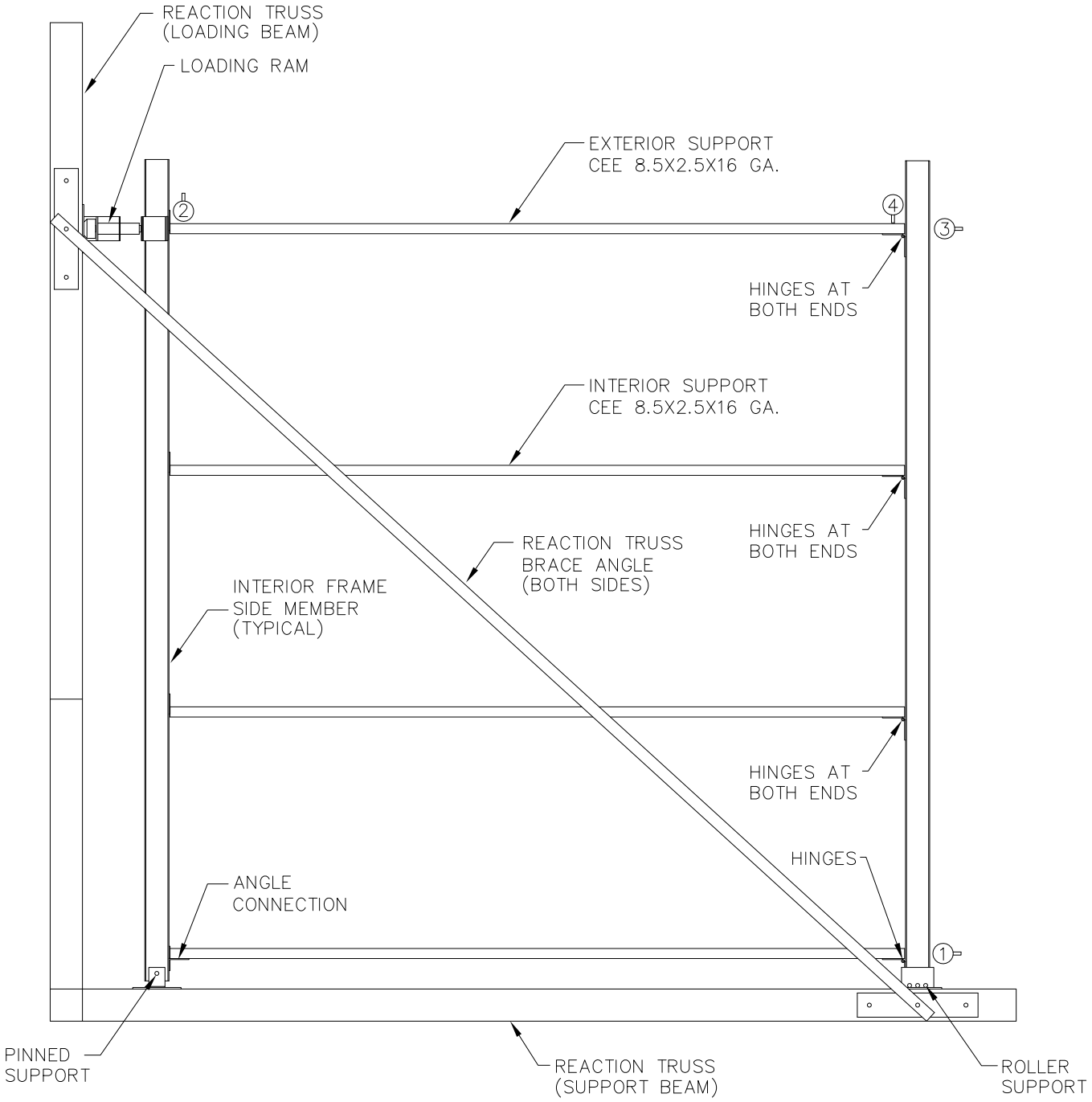

1/1 TEST SETUP PLAN VIEW

NOTES:

① DIAL INDICATOR LOCATION

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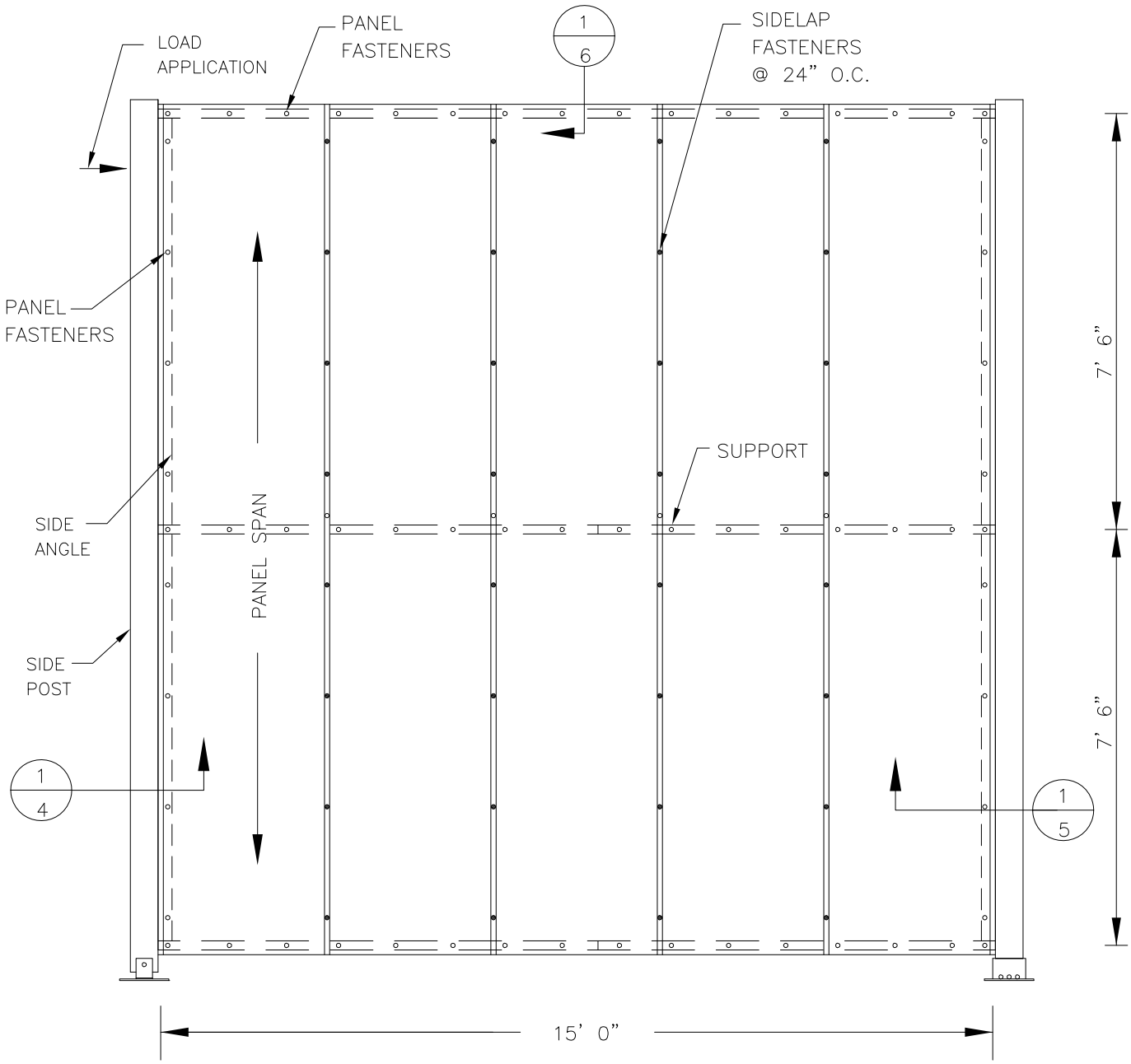

1/2 PLAN VIEW OF TEST
7' 6" PANEL SPAN

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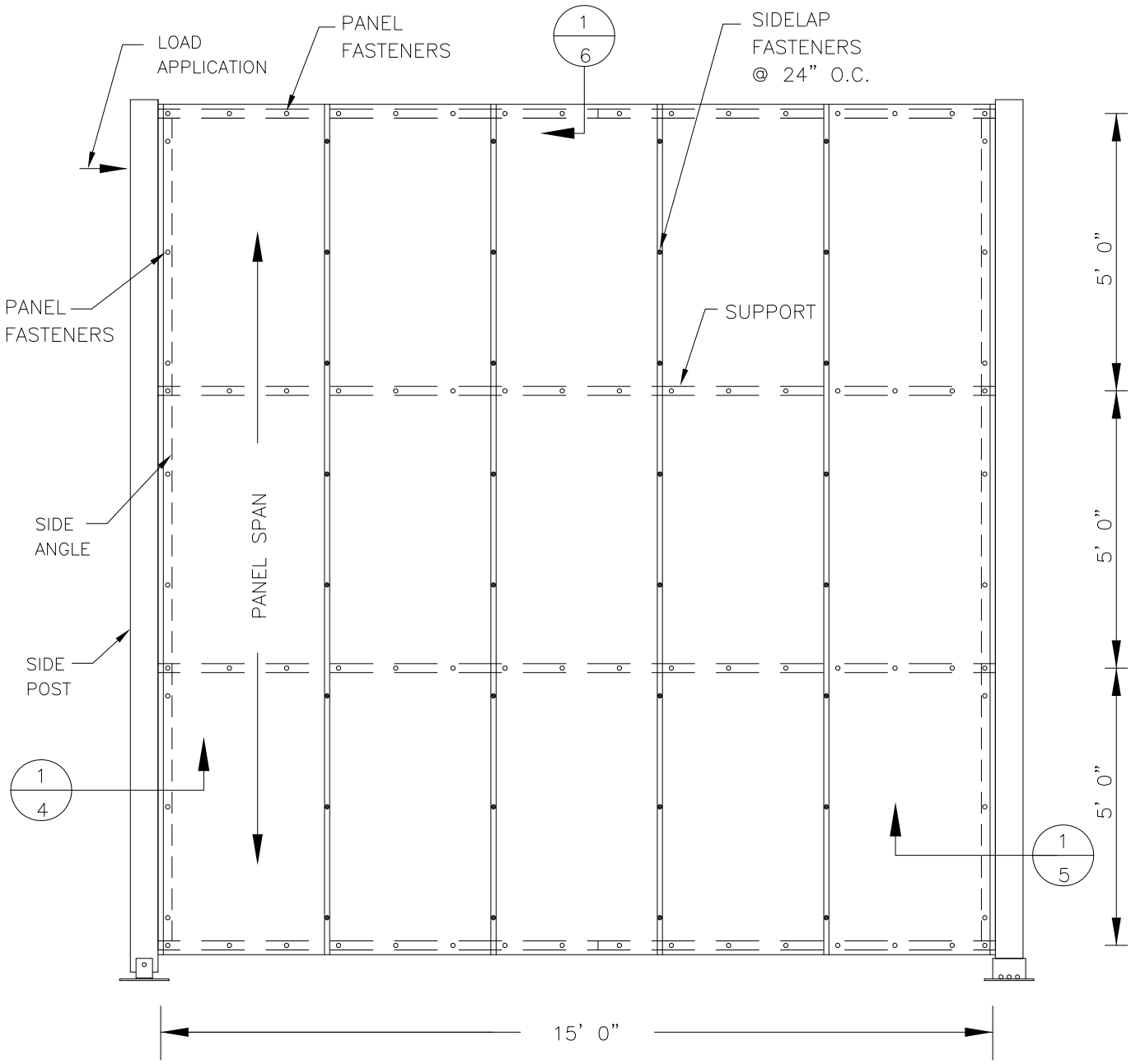

1/3 PLAN VIEW OF TEST
5' 0" PANEL SPAN

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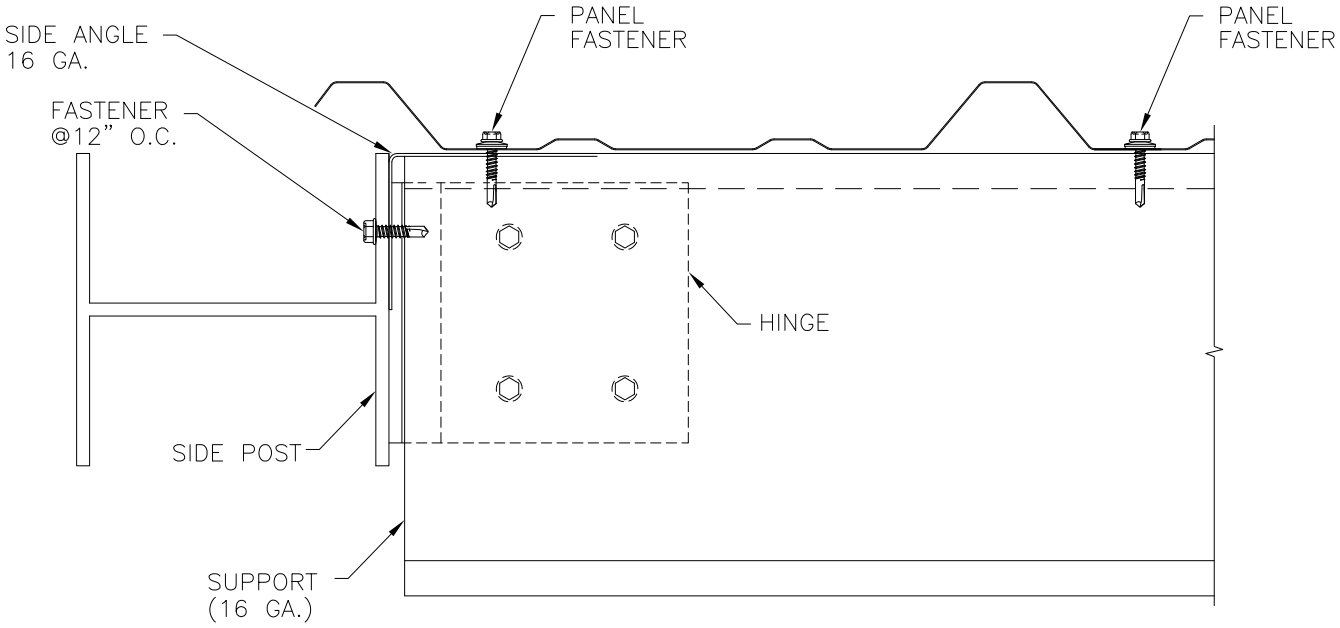
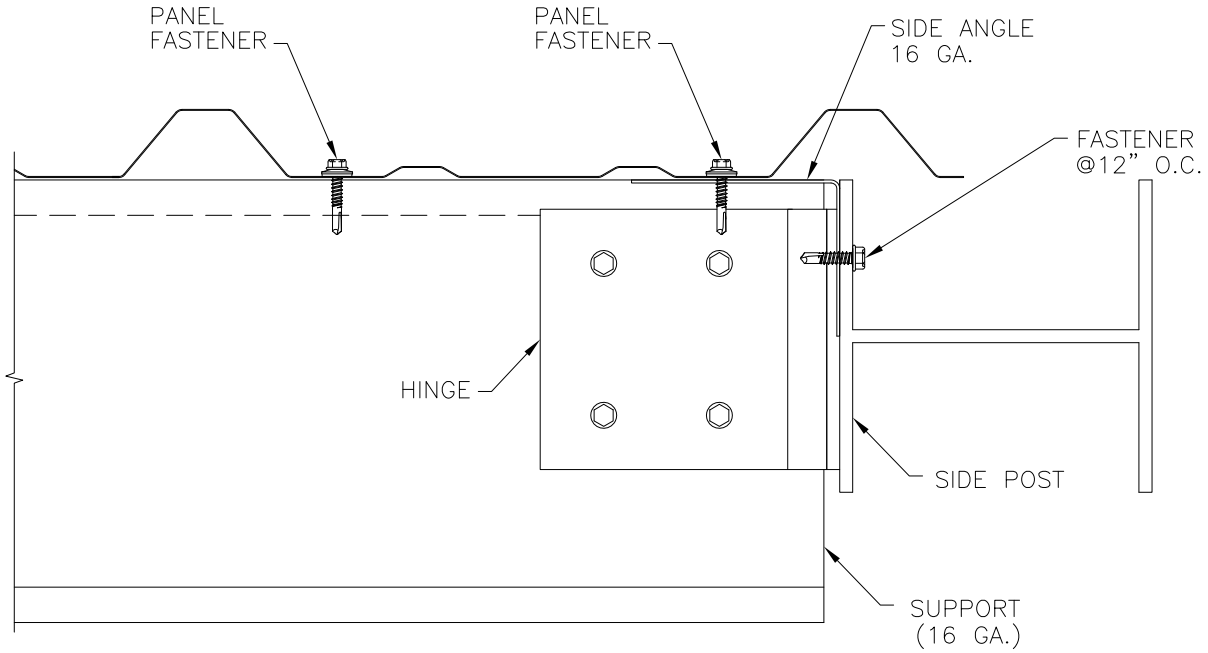


1/4 DETAILS OF "STARTER EDGE"



1/5 DETAILS OF "FINISH EDGE"

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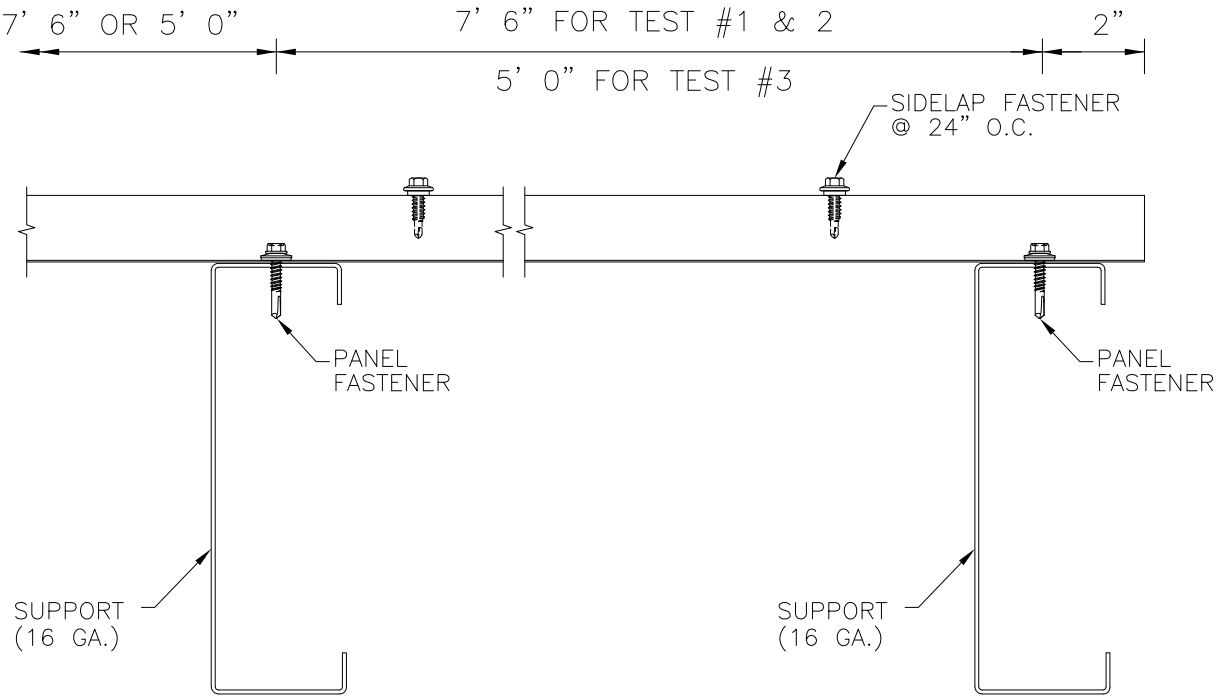

1/6 DETAILS OF "END SUPPORTS"

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Laboratory Report - EAR-Controlled Data

Attn: **Bala Sockalingam**
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1216 N. Lansing Ave. Suite C
Tulsa, OK 74106 US

Report No: **B15030523**
Date Reported: **3/18/2015**
P.O. No: **Verbal**

Material: **Steel**

Description: **(3) 26 ga. R-Loc, Material: Steel**

Room Temperature Tensile Testing ASTM E8/E8M-13a, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
Sample 1	0.498	0.016	100400	97500	6	Inside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-13a, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
Sample 2	0.498	0.017	97800	95000	7	Inside Middle Half of Gage

Room Temperature Tensile Testing ASTM E8/E8M-13a, Parallel to Length of the Specimen, As Received

Sample ID	Width, Initial, in	Thickness, Initial, in	Tensile Strength, psi	Yield (0.2% Offset), psi	Elongation (4W), %	Location of Fracture
Sample 3	0.498	0.017	98400	96100	6	Inside Middle Half of Gage

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Approved by:

Doug Kooken
Operations Manager, Metals

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APPENDIX

5.3 TEST CONDITIONS

A. OWNERSHIP OF ENCON WORK PRODUCT

All test results developed as a part of this work shall be CUSTOMER's property. All samples submitted to ENCON for testing shall become the property of ENCON. CUSTOMER understands that any test program including procedures and test machines incorporated as a part of this work is a result of continuing long-term research and development by ENCON and because of this all ENCON test procedures, test drawings and other intellectual property relating to this work is and shall remain the property of ENCON. Test samples were disposed of shortly after completion of the tests unless other arrangements were agreed to in writing prior to the test.

ENCON will use its normal procedures to retain copies of the information developed as a part of this test for a period of three years from the date the work was done. This material may be routinely destroyed thereafter.

B. ENCON GUARANTEE

ENCON guarantees it used its best effort to accomplish this test work. Work done by ENCON was carefully completed by personnel believed to be competent. ENCON tests were based on what was currently believed to be good engineering practices in use at the time of the test.

The safety factors used are generally accepted as suitable to produce safe results. However, good engineering practices and applicable codes and insurance requirements must be taken into consideration in determining if a test procedure is satisfactory for a specific end use. Applicable specifications, good engineering practices and applicable safety factors may change in the future. CUSTOMER should be alert to these changes.

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APPENDIX

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