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Lateral Bracing Connections for C-Sections Subjected to Bending

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Abstract

The overall behavior under bending moment of cold-formed steel C-sections assemblies was investigated. Each test assembly consisted of C-sections acting as beams having a track to restrain the ends. Lateral bracing to restrain C-sections from rotation was provided at mid-span. To better understand the influence of the brace connection on the bending behavior, an experimental investigation was carried out with particular emphasis placed on the study of the effect of the mid-span brace connection on the bending behavior, and the effect of attaching dry wall to the tension flange. For the dry wall test specimens, lateral bracing was also provided at mid-span. The tested moment capacities are compared to predictions based on the 1996 American Iron and Steel Institutes' *Specification for Design of Cold-formed Steel Structural Members.*

Introduction

The structural behavior of cold-formed steel C-sections subjected to bending is significantly influenced by the member's bracing condition. The primary emphasis of this study was to investigate the effect of the different bracing connections on the C-section's bending behavior. The light-steel framing industry employs typically three different bracing techniques: a channel passing through the web at the mid-span of the C-section, commonly called a bridge channel; steel straps attached with screws to each flange of the C-section at mid-height of a wall stud; and gypsum wallboard attached to each flange of the C-section. This study concentrated on the bridge channel bracing.

The bridge channel may be attached to the stud by either welding the bridge channel to the C-Section stud (Fig. 1) or by using a screw-attached clip (Fig. 2). This study focused primarily on the screw-attached clip. An experimental study was performed at the Dietrich Design Group's laboratory in Hammond, Indiana. The study investigated the bending capacity of three C-sections depths (3 5/8, 6 and 8 in.) for different bracing connections using compression flange loading applied at 1/3 points along the beam's span. This loading condition may yield conservative tested moment capacities as compared with the AISI Specification. Additional tests are on going to study the effect of using a uniform load condition applied to the tension flange. The bracing connections investigated used an industry standard clip and the STEEL Network BridgeClip™ (Fig. 3). Both screw attached and weld attached connections were tested. The industry clip was prepunched to ensure proper placement of the self-drilling screws. The intent of the test program was to provide a comparison between the behavior of various bracing connections, not to justify the AISI design equations.

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Several tests were also carried out with gypsum wallboard attached to the tension flange of the C-section to determine the effect of the wallboard on the C-section's flexural behavior.

Material Properties

The mechanical properties for C-sections were determined in accordance with American Standard of Testing Materials (ASTM A370, 1996). Three coupon specimens were cut from each C-section and the galvanized coating was removed and the actual base steel thickness was measured. The yield strength and ultimate strength were recorded for each test as well as the elongation based on 2.0 in. gage length. Summarized in Table 1 are the average yield and tensile strengths, thickness, and percent of elongation.

Test Specimen and Test Set-Up

The test specimen consisted of six C-sections each 10 ft. in length. The C-sections were spaced 24 inches on-center. To restrain the end of the C-sections from rotation, track sections were provided at each support and were connected to the C-sections by using self-drilling screws. The C-sections were simply supported by placing a roller at each support. Each C-section was laterally braced at mid-span. The load was applied by use of a hydraulic jack and spreader beams were used to create 1/3 point loading condition. See Figures 4a and 4b for details of the test setup. The following C-section brace attachments were studied:

1- Industry standard clip and industry standard bridge channel with four screws (two screws attached the clip to the C-section and two screws attached the bridge channel to the clip).
2- The STEEL Network BridgeClip™ and industry standard bridge channel with one screw attaching the bridge channel to the BridgeClip™.
3- The industry standard bridge channel welded to the C-section web.

The mid-span brace was restrained from lateral movement at each end. Two point loads were applied to each C-section at the third-points (See Fig. 4a and 4b).

To determine the effect of the wallboard on the bending capacity, a number of tests were performed with Gypsum wallboard (0.5" thick) attached to the tension flange of each C-section.

In addition to recording the failure load, both vertical and horizontal displacements for the two middle C-section of the test assembly were recorded during the test. Vertical displacements were measured at midspan and the horizontal displacements were measured at the top and bottom flange-to-web corner.

Connection Failure Modes

The failure mode for each brace and clip configuration is briefly discussed.

Industry Clip Test Specimens

The failure modes of the industry clip test specimens varied as a function of the C-section depth and thickness. For thin C-sections (20 and 16 gage), a local buckle developed in the flange and the web in the vicinity of the brace (Fig. 5). Also, the C-section experienced rotation and ultimately a lateral-torsional buckling.

When gypsum wallboard was attached to the tension flange of the 8 in., 20 gage C-section, failure was a local buckling in the flange and the web, similar to the failure without the wallboard. For thicker 12 gage, the failure occurred due to rotation and ultimately lateral-torsional buckling. No local buckling was observed in either the C-section flange or web of the 12 gage section. No screw connection failures of the clip to bridge channel occurred.

BridgeClip™ Test Specimens

For C-sections having a thickness of 20 gage, the failure mode was similar to that for the tests using the industry standard clip. However, for 16 and 12 gage C-sections there was no local buckling in either the flange or the web, but there was excessive rotation which led to premature failure. Because attachment of the BridgeClip™ to the C-section relies on friction, during several of the tests (i.e. 16 and 12 gage sections), the BridgeClip™ moved and rotated along with the bridge channel (Figs. 6 and 7). Similar failure modes were experienced when Gypsum wallboard was attached to the tension flange of C-sections.

Bridge Channel Welded to the C-Section Test Specimens

Only two welded connection tests were carried out in this test series, 3 5/8 and 8 in. depths with 16 and 12 gage thickness respectively. For C-section geometries studied, no local buckling appeared in either the flange or the web. Although several welds broke during the test, the system continued to carry the load. Failure occurred as the result of excessive rotation of the C-section because of the failure of the bracing connection weld (Fig. 9).

Test Results

For each test specimen, the failure load was recorded (Table 2) as well as the vertical and horizontal displacements. Figures 10 through 12 show typical load deflection characteristics for the tested C-sections. Table 3 presents the calculated failure moment as well as the computed nominal strength based on the AISI Specification (1996) using C_b equal to 1.0.

A comparison of the tested moment capacity to the computed nominal moment capacity is presented in Table 4. In all cases, the nominal moment capacity was limited by stability. For the test specimens using the industry clip, the ratio of $M_{test}/M_{n(Stabililty)}$ ranged from 0.74 to 1.30 with an average value of 1.02. The moment ratios indicate that when the industry standard clip was used, adequate performance of the C-sections was attained.

The ratio of $M_{test}/M_{n(Stabililty)}$ indicates that the proprietary braces did not provide adequate bracing to the C-section. The moment ratios ranged from 0.38 to 0.80 for the BridgeClip™ .

For the two C-section geometries tested using a weld-attached bridge channel, the ratio of $M_{test}/M_{n(Stabililty)}$ indicates that adequate performance was achieved for 3 5/8 in. deep section, and lower performance for 8.0 in. deep section. The moment ratios were 0.92 and 0.77.

Comparing the serviceability, that is displacement and rotation, the industry clip provided a higher resistance against rotation. Figures 10 through 12 show typical load-deflection characteristics for the brace clips studied in this test program. In all cases, significantly larger displacements and rotations were obtained for the test specimens using a proprietary brace.

When Gypsum wallboard was attached to the tension flange of the C-sections, the test results show a minimum increase of 25 percent in the failure load for the BridgeClip™ test specimens. No change in load capacity was discovered for the industry clip test specimens. Thus, for the C-sections in this test program, the industry clip alone provided adequate stability to the C-section.

Observations

The structural behavior of a laterally braced C-section subjected to bending was investigated. Mid-span braces alone as well as mid-span braces in combination with tension flange wallboard bracing was studied. Based on the findings of the experimental and analytical study, the following observations are made:

- The screw-attached industry standard clip provided adequate bracing to achieve the AISI computed moment capacity.
- The weld-attached industry standard bridge channel sufficiently braced the 3 5/8 in. section but it showed lower performance with 8.0 in. deep section.
- The BridgeClip™ did not provide sufficient bracing to achieve the AISI computed moment capacity for tested sections having depths of 6 inches. The deeper the section, the poorer the performance of the BridgeClip™ braced C-sections.
- The BridgeClip™ permitted significant lateral displacements and rotations for all depth C-section test specimens.
- Gypsum wallboard enhanced the load carrying performance of C-sections braced by the BridgeClip™ . The wallboard did not alter the performance of the C-sections braced by the industry standard clip. Also, the presence of wallboard had little effect on the rotation of the C-sections.

The above observations are based upon a study that used a top flange loading condition, additional tests are on going to study the effect of using a uniform load condition applied to the tension flange.

References

American Iron and Steel Institute (1996), "Specification for Design Cold Formed Steel Structural Members", 1996 Edition, Washington, DC.

American Society for Testing and Materials (1996), ASTM 370-96.

Table 1 C-Section Material Properties

Section	Thickness (in.)	Yield Strength (ksi)	Ultimate Strength (ksi)	Elongation % (2.0") *
3 5/8" x 20 GA	0.04033	54.21	64.47	25
3 5/8" x 16 GA	0.05433	44.42	55.46	27
3 5/8" x 12 GA	0.09868	64.31	79.31	20
6.0" x 20 GA	0.04127	33.93	48.30	28
6.0" x 16 GA	0.05888	45.31	47.78	28.7
6.0" x 12 GA	0.09840	97.43	103.99	19.3
8.0" x 20 GA	0.03125	25.52	41.96	42.5
8.0" x 16 GA	0.05700	65.43	79.65	23.3
8.0" x 12 GA	0.10068	64.81	66.06	20

* Based on 2.0 in. gage length

Table 2 Test Load Cell Reading at Failure

Connection Between C-Section and Bracing	Failure Load, lbs.								
	3 5/8"			6"			8"		
	20	16	12	20	16	12	20	16	12
Industry Standard Clip	3170	4442	8481	3930	9460	13070	3209	------	17170*
BridgeClip	2269	2971	6553	1940	4840	10001	1663	5122	11262
Welded Bridge Channel	------	3532	------	------	------	------	------	------	13670
Industry Standard Clip w/WallBoard	------	------	8555	------	------	------	3190	------	------
BridgeClip w/ Wallboard	------	------	8260	------	------	------	2192	------	------

* 5 ¾ in. Industry Clip used.

Table 3 Tested and Calculated Bending Moments

Connection Between C-Section and Bracing	Tested Moment Capacities, in-lb.								
	3 5/8"			6"			8"		
	20	16	12	20	16	12	20	16	12
Indusry Standard Clip	10303	14437	27563	12773	30745	42478	10429	------	55803
BridgeClip	7374	9656	21297	6305	15730	32503	5405	16647	36602
Welded Bridge Channel	------	11479	------	------	------	------	------	------	44428
Industry Standard Clip w/ Wallboard	------	------	27804	------	------	------	10368	------	------
BridgeClip w/ Wallboard	------	------	26845	------	------	------	7124	------	------
	Calculated Moment Capacities, Mn, in-lb.								
AISI-Nominal Calculated Moment (Strength)	16839	20318	50156	24024	44614	148000	17828	79800	157160
AISI-Nominal Calculated Moment (Stability)	9258	12446	28021	15282	23631	42584	14157	31586	57329

- Stability calculated moment based on kly = 59", klt = 118"
- Wallboard self-weight not included in moment calculation

Table 4 $M_{Calculated}/M_{n(Stability)}$

Connection Between C-Section and Bracing	3 5/8"			6"			8"		
	20	16	12	20	16	12	20	16	12
Industry Standard Clip	1.11	1.16	0.98	0.84	1.30	1.00	0.74	------	0.97
BridgeClip	0.80	0.78	0.76	0.41	0.67	0.76	0.38	0.53	0.64
Welded Bridge Channel	------	0.92	------	------	------	------	------	------	0.77
Industry Standard Clip w/ Wallboard	------	------	0.99	------	------	------	0.73	------	------
BridgeClip w/ Wallboard	------	------	0.96	------	------	------	0.50	------	------

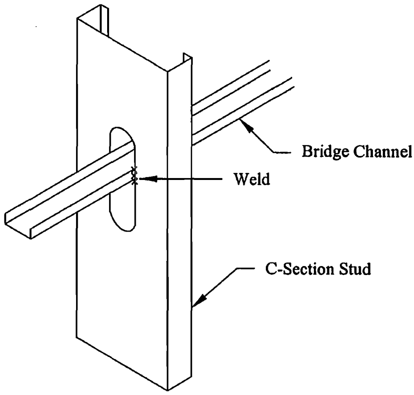


Figure 1 Weld-Attached Bridge Channel Connection

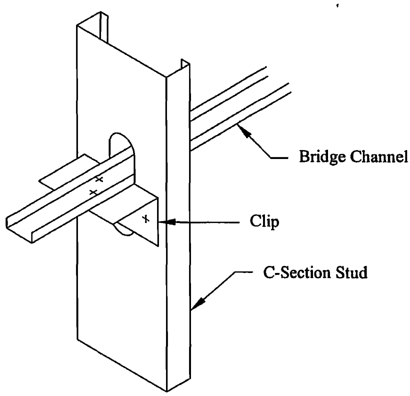
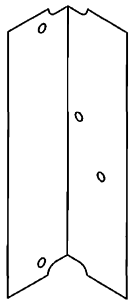
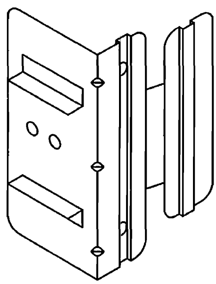


Figure 2 Clip-Attached Bridge Channel Connection



Industry Standard Clip



STEEL Network BridgeClip™

Figure 3 Typical Types of Clips for Bracing Connections

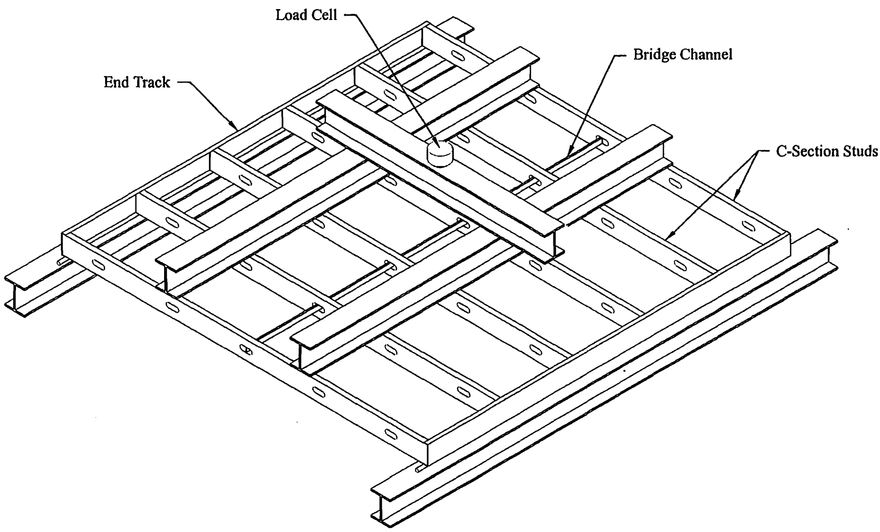


Figure 4a Test Setup

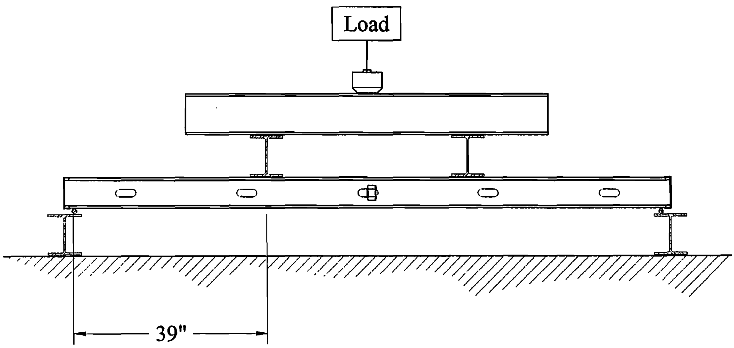
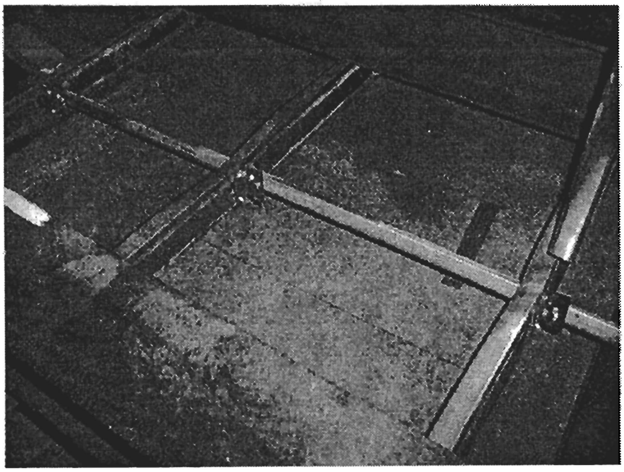


Figure 4b   Test Setup



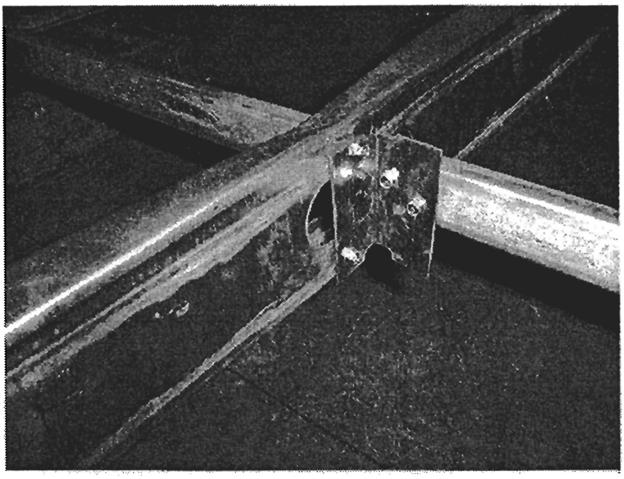


Figure 5 Failure Mode for 3 5/8 in x 20 gage Section for Industry Clip

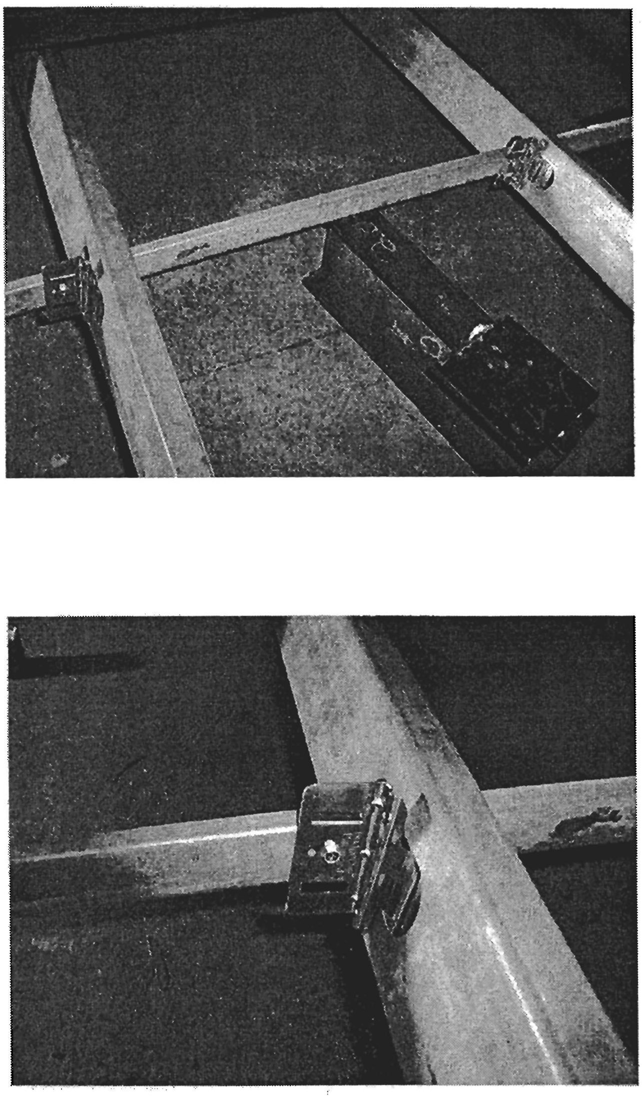


Figure 6 Failure Mode for 3 5/8 in x 20 gage Section for BridgeClip^{TM}

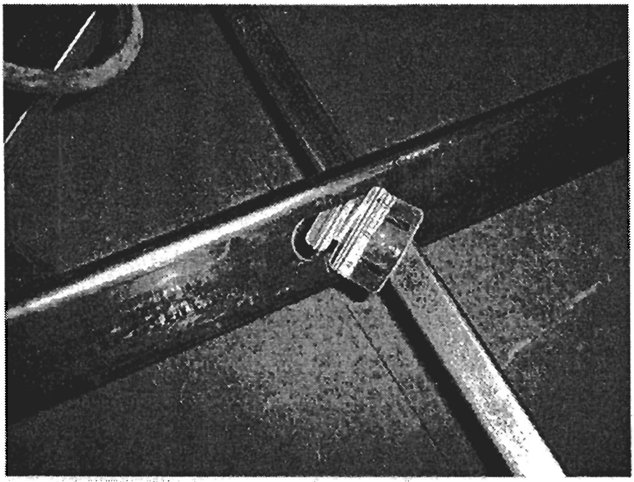


Figure 7 Failure Mode for 3 5/8 in x 12 gage Section for BridgeClip™

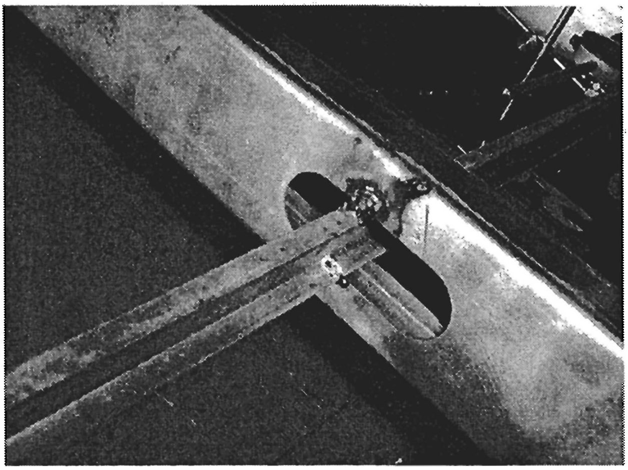
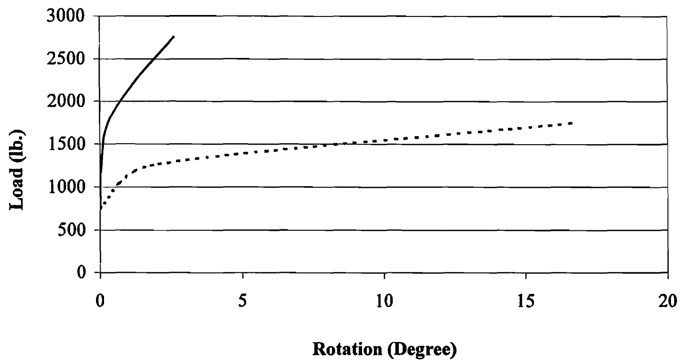
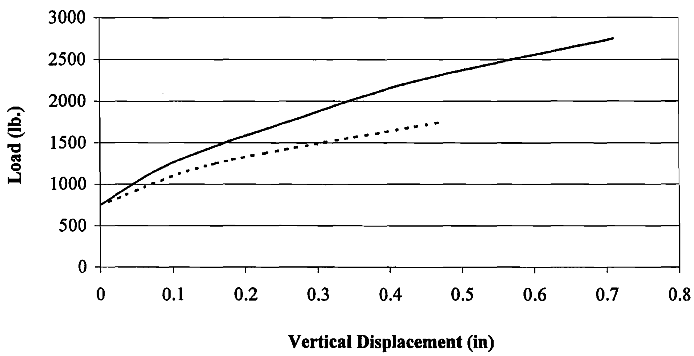


Figure 8 Failure Mode for 3 5/8 in x 16 gage for Welded Bridge Channel





----- BridgeClip™
——— Industry Clip

Figure 9 Deflection and Displacement Behavior for 3 5/8 in x 20 gage

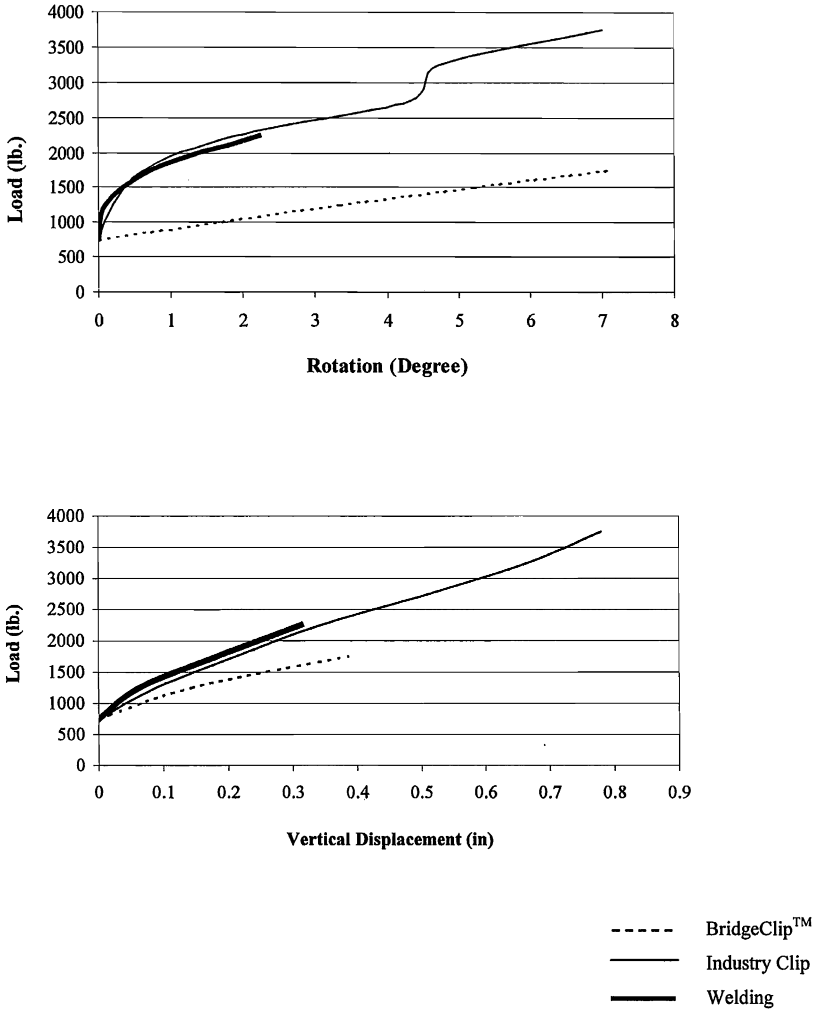
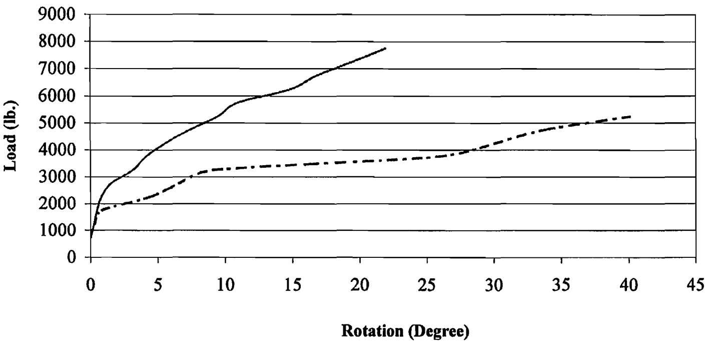


Figure 10 Deflection and Displacement Behavior for 3 5/8 in x 16 gage



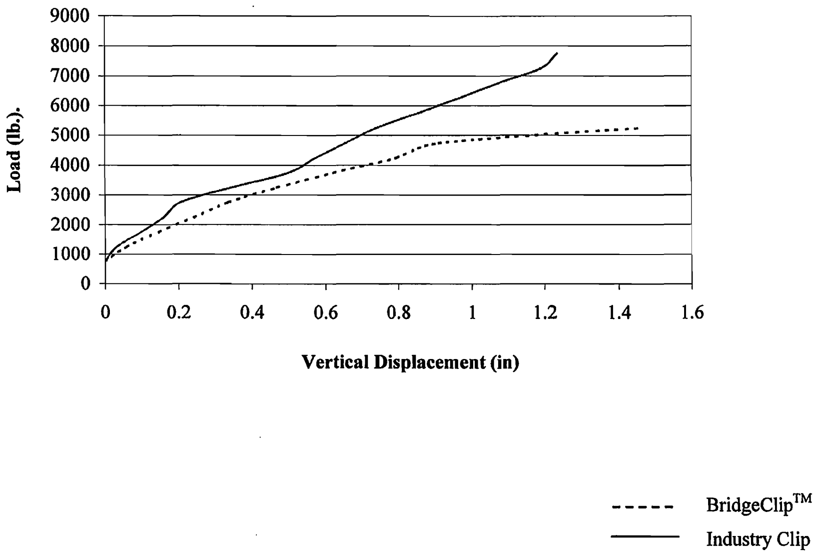


Figure 11 Deflection and Rotation Behavior for 3 5/8 in x 12 gage