EVALUATION OF THE FLEXURAL STRENGTH OF COLD-FORMED STEEL STUDS WITH EMBOSSED FLANGES

by

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B.S., Kansas State University, 2009

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

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KANSAS STATE UNIVERSITY
Manhattan, Kansas

2009

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Abstract

Cold-formed steel studs, though they are a relatively new building material, have become a mainstay in modern construction. They are favored over traditional lumber studs for their high strength to weight ratio and resistance to insects and rot. Due to their relative newness as a material, new advances in their design and implementation are being developed quite rapidly. One such advancement is flange embossing, a technique used to increase the strength of the connection of screws into the studs. Currently, embossed flanges are not specifically addressed in the *North American Specification for the Design of Cold-Formed Steel Structural Members* (AISI S100), thereby preventing current design equations from being used to calculate an embossed stud's member properties.

An experimental investigation was undertaken to determine what effect, if any, flange embossing has on the nominal flexural strength of cold-formed steel studs as determined using the provisions of AISI S100-07. Studs with embossed flanges were tested in bending and their actual flexural strength was computed. This data was then compared with the nominal flexural strength determined using the AISI Specification, without embossing, to determine if these equations would still be appropriate for the design of embossed studs.

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Acknowledgments

I would first like to express my thanks to my graduate committee, Dr. Sutton Stephens, Kimberly Kramer, and Rhonda Wilkinson, for their instruction and direction in this project. I would like to thank especially my advisor, Dr. Sutton Stephens for all of his assistance in the completion of this research. His guidance and expertise have been invaluable to me in every phase of this research.

I would like to express my gratitude to Ryan Beteman, for all of his assistance given during the experimental portion of this report.

My appreciation is extended to Roger LaBoube, of Missouri University of Science and Technology, for arranging this investigation and assisting with the coupon testing and the use of the CFS software.

A special thanks to Andrew Cott, for all his help assembling the specimens and setting up the tests.

All studs used in this investigation were donated by Telling Industries of Cambridge, OH.

1.0 Introduction

1.1 Overview

Structural steel is divided into two main categories. The first, and more familiar to most structural engineers, is hot rolled steel. The second, lesser known category is cold-formed steel. Cold-formed steel members are formed from thinner, sheet steel, which is worked through rollers or a braking operation without the addition of heat to form the final finished shape. Typical thicknesses for cold-formed steel members range from 0.0149 inch up to ¼ inch, although plates as thick as 1" can be cold-formed. One of the advantages of cold-formed steel is the ability to make many different shapes economically, allowing for the creation of an ideal member for a specific task. This, along with its very light weight, has led to cold-formed steel becoming a popular building material, used in a wide variety of light structural applications (Yu 2000).

The use of cold-formed steel in building construction began in the United States in about the 1850s, though it was not a common material until almost a hundred years later. In recent years, its use has increased tremendously, especially in residential and light commercial construction. In these applications, it is often used in locations where structural timber would traditionally be used. The popularity of cold-formed steel has risen as good quality structural wood has become more difficult and costly to obtain. Steel has the highest strength to weight ratio of any building material used today, and it is a recyclable material. Unlike the timber it often replaces, cold-form steel does not shrink or warp as timber can, and it is noncombustible and resistant to insects and rot, reducing the costs of maintaining the building throughout its lifespan.

The design of cold-formed steel is governed by the *North American Specification for the Design of Cold-Formed Steel Structural Members* (AISI 2007a). This industry wide standard has accelerated the development and implementation of cold-formed steel since its first publication in 1946 (Yu 2000). The AISI North American Specification, as well as the *AISI North American Standard for Cold-Formed Steel Framing - Wall Stud Design* (AISI 2007c) are included by reference in the International

Building Code in section 2210.

1.2 Cold-Formed Steel Studs

One application that has become an extremely common use of cold-formed steel is as wall studs in light frame and commercial construction. In commercial buildings, where they are often used as non-structural members, which support no more than 200 lbs. of superimposed axial load, and no more than 10 psf of transverse load, they have become particularly common. They are also often used as structural members, and can be used in almost every application that dimensional lumber can, including trusses. Cold-formed steel studs can be produced in various gage thicknesses, as needed for a particular project (Yu 2000).

1.3 Curtain Walls

One common use for cold-formed steel studs is curtain walls. According to the AISI S200*, North American Standard for Cold-Formed Steel Framing—General Provisions* (AISI 2007b), a curtain wall is "[a] wall that transfers transverse (out of plane) loads and is limited to a superimposed vertical load, exclusive of sheathing materials, of not more than 100 pounds per foot or a superimposed vertical load of not more than 200 lbs." The studs tested in this investigation are designed for use in curtain walls. These studs are generally sheathed with gypsum or OSB attached with screws, and resist distributed loads applied to surface of the sheathing. This type of loading means that their flexural strength is very important, while their axial capacity is less important, because the main loads that they resist are transverse loads.

1.4 Smooth vs. Embossed

One shape commonly used for steel studs is a C-section. This shape consists of relatively large web with top and bottom flanges, each with a stiffener (Figures 1.1 and 1.2). Traditionally, the only working done to the sheet steel is four bends to form the different elements of the shape. Each of the elements (web, flanges, and stiffeners) are smooth along the length of the member.

Figure 1.1: C-shaped stud.

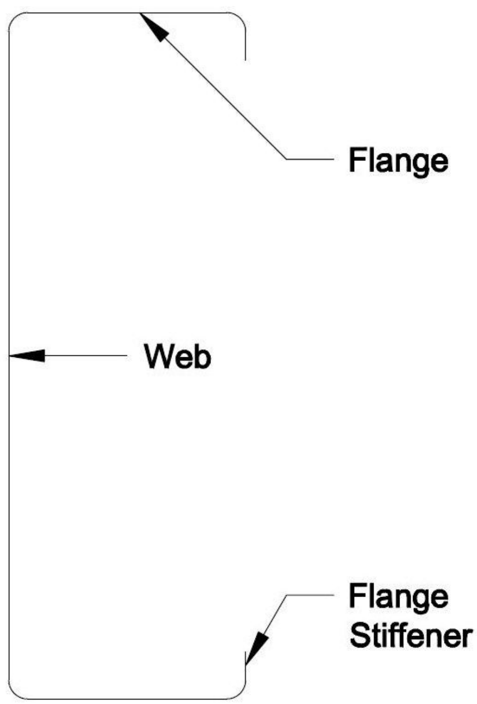

Figure 1.2: Elements of a C-stud.

Some manufacturers now offer studs with *embossed* flanges. Embossing is a process where small indentations, called knurls, are pressed into the flange of the stud as shown in Figure 1.3. Embossing is not done to enhance the strength of the member, but rather to improve the connection of screws into the flanges. However, as these embossed studs are a relatively new product, they are not currently specifically addressed in AISI S100 for either determination of member properties or nominal strength. This precludes the use of the standard AISI equations to determine the capacities of this type of stud. In order to get a new product approved for use that is not covered by the AISI S100 analysis procedures, a manufacturer must evaluate the product through the testing prescribed in Chapter F of the AISI S100.

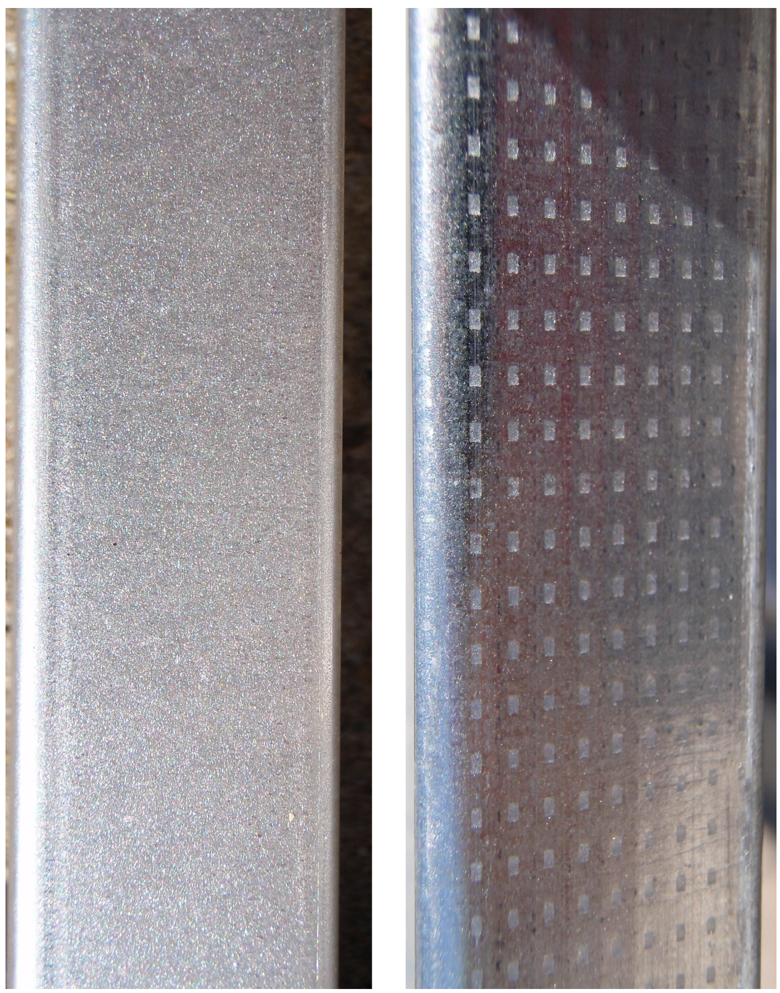

Figure 1.3: Flange of a normal smooth stud and one with an Embossed Flange.

1.5 Purpose of Investigation

The purpose of this investigation was to determine whether the embossing affects the member properties of cold-formed studs. Studs with embossed flanges were tested in bending in an effort to determine if embossed flanges adversely affects the nominal flexural strength of a curtain wall stud in a fully braced condition. The flexural strengths determined by testing were compared to the calculated nominal flexural strength assuming the knurls were not present to determine if the capacities are altered by the presence of the knurls. Two common depths of cold-formed steel studs, 3.625 inches and 6 inches, both 18 mil minimum thicknesses and with embossed flanges, were investigated.

2.0 Experimental Investigation

2.1 Material Properties

The cold-formed steel studs used in this investigation were donated by Telling Industries of Cambridge, OH. Two sizes of studs were tested, the first was designated 362S125-18, which is a 3⅝" C-stud, and the second was 600125-18, a 6" C-stud. Both sections were produced using F_y=33 ksi steel and were 8'-0" long. All studs had 1½" web punchouts spaced at 24" OC, starting 12" from the end of the stud. All specimens were assembled with #8 x ¾" self-drilling screws.

Figure 2.1: Tensile Test Coupon (right end has been stripped of galvanization).

To determine the actual mechanical properties of the steel, after the completion of the bending tests, 1 inch x 8 inch coupons were cut from the web of two specimens of each size. Coupons were cut from the center of the webs to avoid a potential increase in F_y which might be present in the corners, or the flanges due to forming or embossing. Coupons were sent to Missouri University of Science and Technology, where they were milled to width and subject to an ASTM A370 standard tensile test. To accurately measure the base metal thicknesses of the coupons, one end of each was dipped in a 30% sulfuric acid solution to strip the galvanization. The base metal thickness was then measured with a micrometer. Each coupon was tested to failure to determine F_y and maximum tensile strength, F_u. The results of the tensile test are shown in Table 2.1. Additionally, the cross sections were carefully measured to determine the cross section dimensions (Figure 2.2), including radii of bends and angles of the flange stiffeners.

These values are shown in Table 2.2. The specified section dimensions, from the manufacturer's designations stamped on the studs, were also determined based on the AISI *North American Standard for Cold-Formed Steel Framing - Product Data* (AISI 2007d) and are given for a comparison in Table 2.3. When these two tables are compared, most of the measured dimensions fit quite closely with specified dimensions. The dimensions of the knurls were also measured, and are listed in Table 2.4.

Table 2.1: Tensile Test Results.

Specimen	t (in.)	w (in.)	F_y (kips)	f_y (ksi)	F_u (kips)	f_u (ksi)
3A	0.0170	0.95	0.82	50.5	0.95	58.4
3B	0.0168	0.95	0.83	51.5	0.96	59.6
6A	0.0188	0.95	0.91	51.0	1.08	60.0
6B	0.0185	0.95	0.92	52.0	1.09	61.7

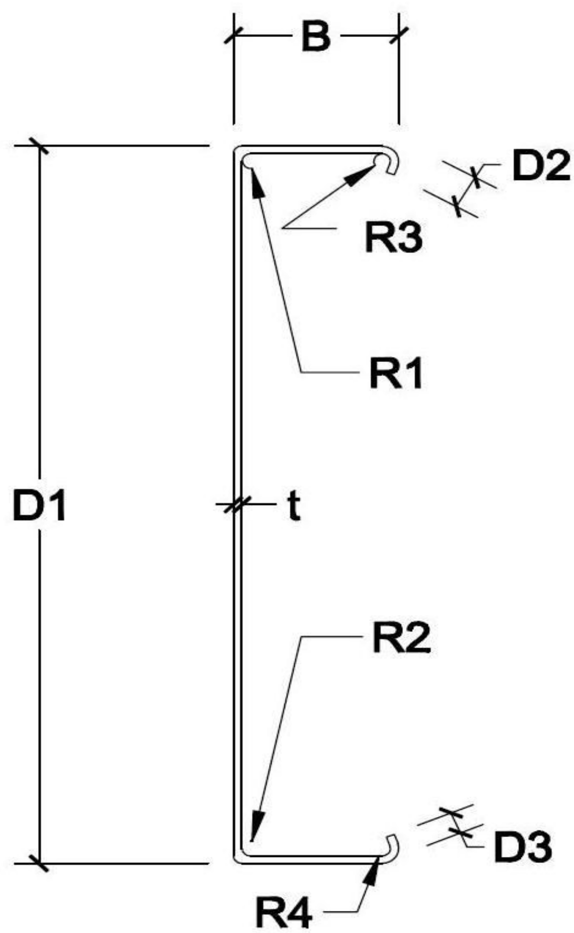

Figure 2.2: Typical Stud Dimensions.

Table 2.2: Measured Section Dimensions.

Section Size	t (in.)	D1 (in.)	D2 (in.)	D3 (in.)	B (in.)
362S125-18	0.0 170	3.656	0.250	0.281	1.219
600S125-18	0.0186	6.031	0.281	0.281	1.219

	R1 (in.)	R2 (in.)	R3 (in.)	R4 (in.)	Angle R3	Angle R4
362S125-18	0.043	0.039	0.057	0.053	64.8	67.0
600S125-18	0.043	0.047	0.063	0.063	53.2	64.1
	Note: Ref. Figure 2.2					

Table 2.3: Specified Dimensions of Stud Sections.

Section Designation	t (in.)	D1 (in.)	D2 (in.)	B (in.)	R (in.)
362S125-18	0.0179	3.625	0.188	1.25	0.0843
600S125-18	0.0179	6.00	0.188	1.25	0.0843
Note: Ref. Figure 2.2 t is minimum dimension, all others are design dimensions.					

The measured dimensions were then input into RSG Software's CFS program, (RSG 2009), to compute the nominal flexural strength of the sections using provisions from the AISI *Specification* (AISI 2007a).

2.2 Failure Modes

This section will discuss the different analysis procedures used in this investigation to determine the nominal flexural strength.

2.2.1 Elastic Effective Section

As a side effect to the braking process used to form cold-formed steel, higher yield stresses are found at corners of elements or anywhere the shape has cold-formed. Combined with the effects of bracing between elements of a shape, the stress distribution for a cold-formed steel section is a curve, making it rather difficult to use in calculations. To simplify design, for Procedure I, a constant stress is applied over an effective area, similar to the Whitney stress block in concrete. Once this effective area is found, effective section properties can be computed. The effective section properties can be used for an elastic section analysis. Nominal flexural strength, M_n, is given by

AISI S100 Eq. C3.1.1-1:

$$M_n = S_e F_y$$ Eqn. 2-

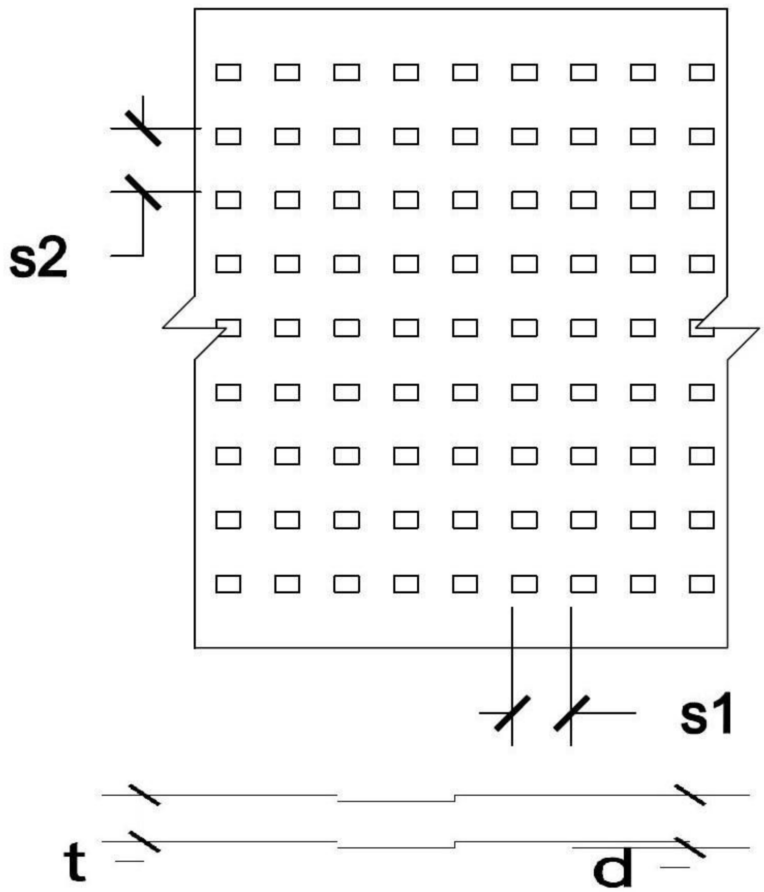

Figure 2.3: Dimensions for Knurls.

Table 2.4: Knurl Dimensions.

Section	t	d	s1	s2
362S125-18	0.0171	0.0190	0.116	0.116
600S125-18	0.0187	0.0211	0.116	0.116
Note:	All dimension in inches			

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2.2.1 Distortional Buckling

Distortional buckling is a new flexural limit state in the section C3.1.4 of the 2007

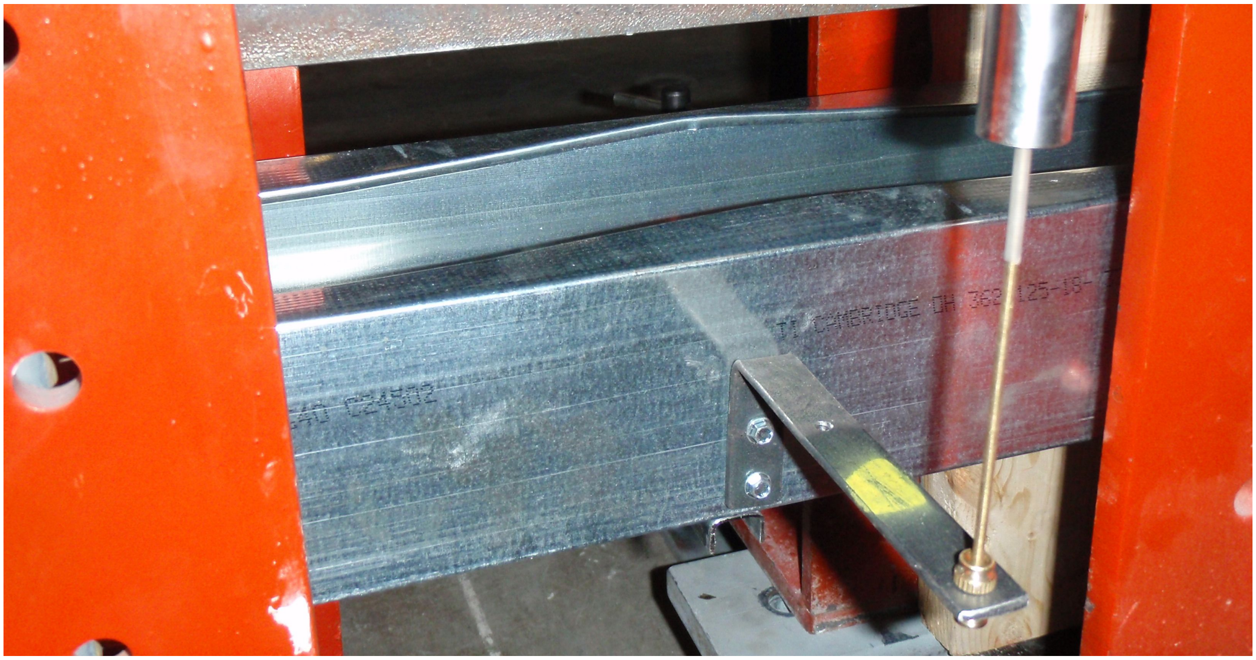

Figure 2.4: Distortional Buckling Observed in the Flange of a Specimen.

edition of the AISI S100 and effects shapes with a lipped flange stiffener, such as C-sections or Z-sections. Distortional buckling falls between local buckling and overall buckling. Local buckling involves the buckling of only a single element of the cross section, while overall buckling is a distortion of the section as a whole. Distortional buckling, in contrast, involves buckling of both the flange and its stiffener as single unit. This is often observed as a sine wave forming in the flange. Figure 2.4 is a photo of distortional buckling observed in this investigation. Distortional buckling is computed from equation (*Eq*. C3.1.4-2) from the AISI *Specification*:

$$M_n = \left(1 - 0.22\left(\frac{M_{crd}}{M_y}\right)^{0.5}\right)\left(\frac{M_{crd}}{M_y}\right)^{0.5} M_y \qquad \text{Eqn. 2-2}$$

where

$$M_y = S_{fy} F_y$$

where

S_{fy} = Elastic section modulus of full unreduced section relative to extreme fiber in first yield

$$M_{crd} = S_f F_d$$

where

S_f = Elastic section modulus of full unreduced section relative to extreme compression fiber

F = Elastic distortional buckling stress calculated in accordance with Section C3.1.4(b)

2.2.3 Direct Strength Method

Rather than a limit state, the direct strength method is a method of analysis used for calculations allowed per Appendix I of AISI S100. Direct strength is a finite strip analysis, where a member's cross section is divided into a series of thin strips. Each of these strips is evaluated individually, and then are superimposed to form an overall capacity for the member as a whole. Direct strength calculations look at both elastic distortional buckling states.

2.3 Test Specimens

In order to determine the nominal flexural strength of the studs, specimens were assembled to test in bending. Specimens were constructed of two 8'-0" long C-studs assembled in an open box configuration with their flanges toward the center of the specimen. This box section was assembled to provide a more laterally stable specimen than a single stud could, as well as allowing for loading through the shear center of the specimen, which is very difficult to do for a single stud. If loads were not applied to the shear center of the section, an extra torsional component would have to be considered as well. The test was designed so that the failure mode would be flexure. Studs were assembled so that the width of the specimen would be 5½ inches, which was based on

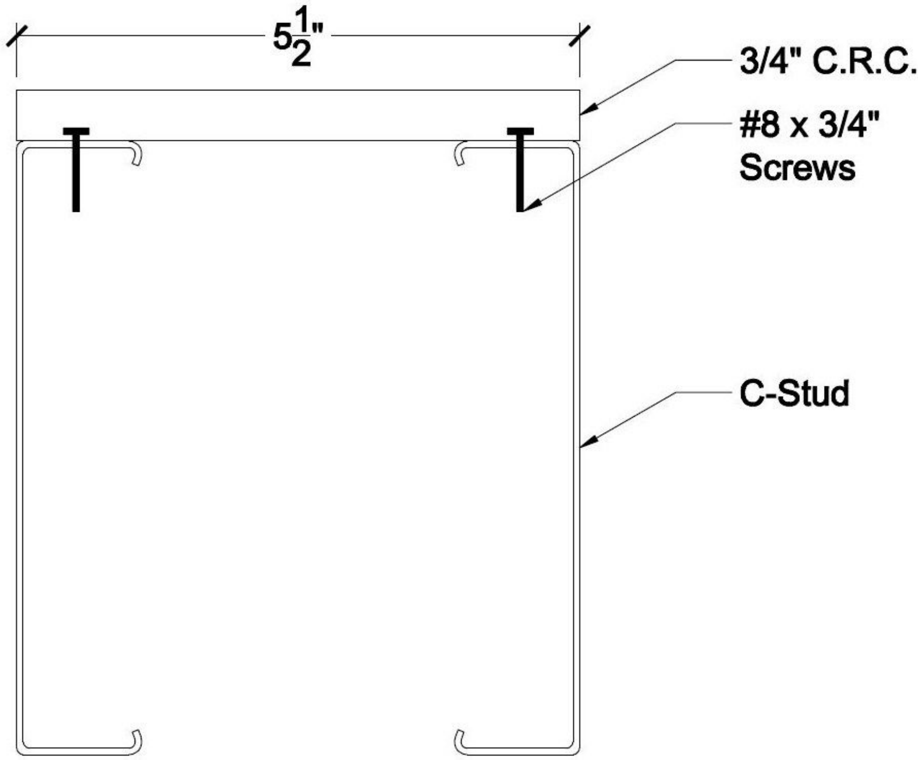

Figure 2.5: Typical Specimen Section.

the available material for bracing the ends (Figure 2.5).

Pieces of ¾” wide cold-rolled channel (CRC) were used to brace the flanges against distortional buckling as well as maintaining a consistent spacing along it's span. During the testing of the first three specimens of each size, despite the braces, distortional buckling of the flange was seen. In order to help prevent this, the spacing for the CRCs was changed for a second set of specimens. For the first set, channels were spaced at midpoints between loads and reactions and at midpoint of the span on the bottom flange, and at midpoints between loads and reactions as well as near the point of load application (Figure 2.6). The second set of specimens were constructed with channels placed at 12 inches on center along both top and bottom flanges (Figure 2.7). This spacing was chosen to represent the way gypsum board is often attached in the field, using screws at a maximum of 12 inches on both sides of the stud.

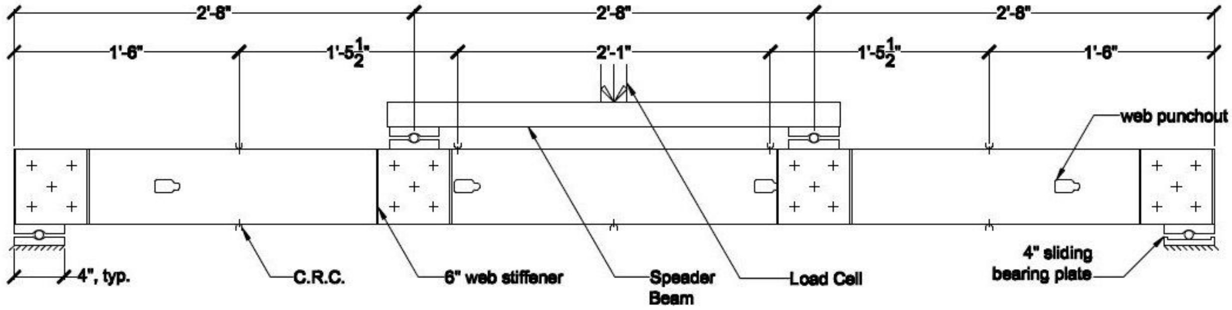

Figure 2.6: Test set up for 6-inch Specimens 6-A, 6-B, 6-C.

To prevent web crippling, each specimen was braced with web stiffeners at the end supports and points of load application (Figure 2.8). Segments of cold-formed studs, with length equal to the depth of the specimen and oriented perpendicular to the specimen, were used as web stiffeners, which were attached to the specimens with five screws. For the first three specimens tested of each size, the stiffeners were made from the same size of stud that was being tested. In the second set of tests, all web stiffeners were cut from 3⅝" studs, and stiffeners at the point of load application were also extended approximately ⅛" above the top flange, to allow load to be transfered directly to the web thus avoiding buckling of the flange from local stresses at the bearing plates (Figure 2.9). This change was made because in the first set of three tests it was discovered that loading directly on the flanges may have been causing a concentration of stresses leading to premature flange buckling. In this case, 6 screws were used per stiffener, to ensure full load transfer from the stiffener to the specimen web.

All specimens were also braced against torsional buckling at the end reactions

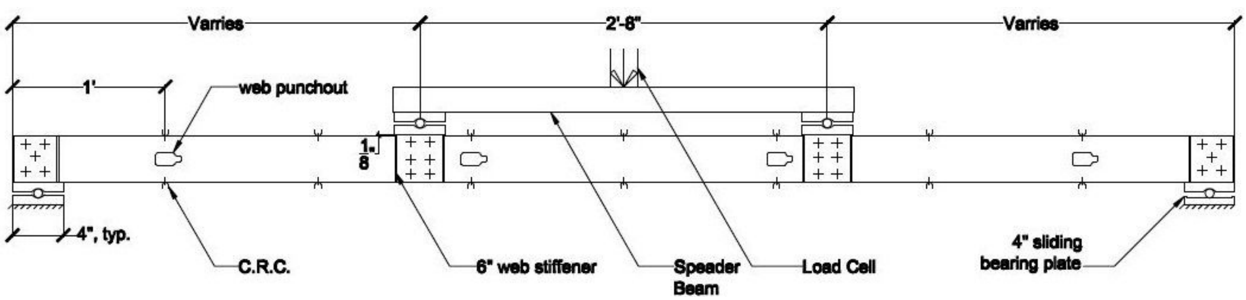

Figure 2.7: Test set up for 3⅝-in specimen showing web stiffeners extending above specimen for 3-D & 3-E.

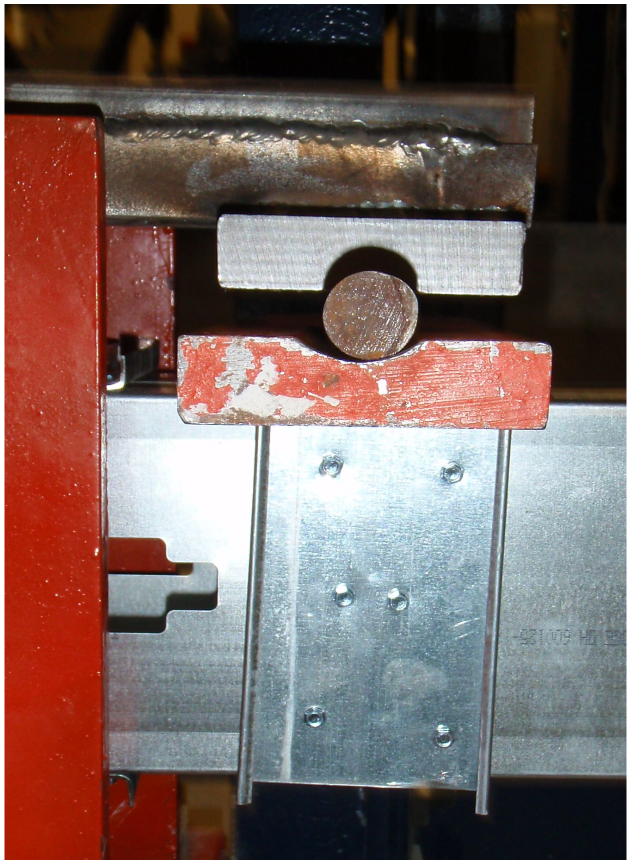

Figure 2.8: Web stiffener at load application.

with dimensional 2x lumber blocking (3”x5½”x1½” for the 3⅝” specimens and 5½”x5½”x1½” for the 6” specimens) (Figure 2.10) for restraint and to prevent torsional buckling at the ends.

2.4 Test Setup

Specimens were tested in a simple span condition with two concentrated loads located at third points (2'-8”) of the beam, creating a constant moment region with zero shear in the central span between the loads, so the specimens could be tested in pure flexure without having to account for any interaction between shear and flexure. Third points were selected for loading because they provided a reasonably large constant moment region and provided balanced loading. Loads were applied to the specimens

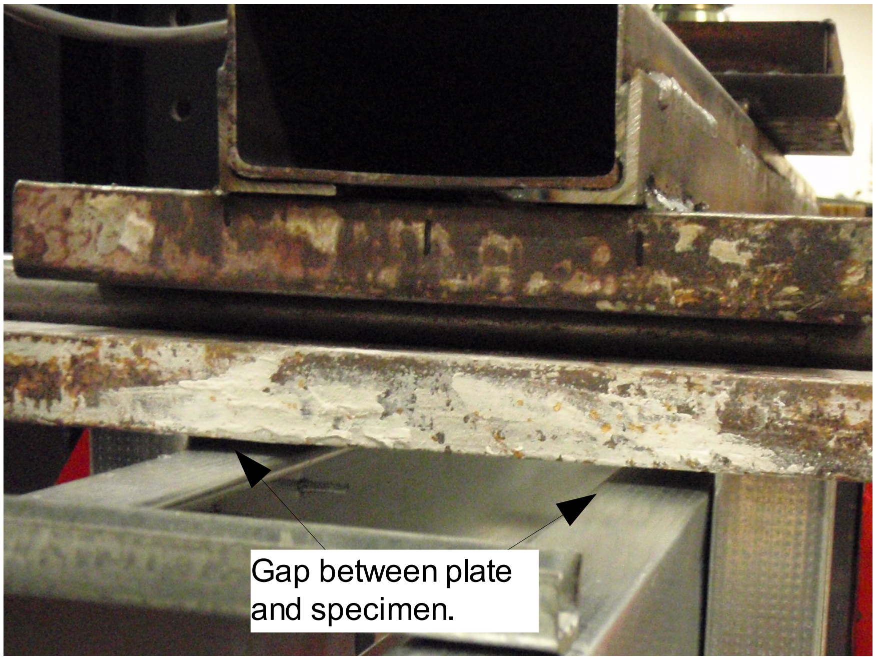

Figure 2.9: Load being applied to web stiffeners, showing gap above specimen.

at the location of the web stiffeners with 4” wide steel plates, to help prevent web crippling. Bearing plates at the end reactions were also 4” wide, and one support was a sliding bearing plate to allow for longitudinal movement of the specimen.

To prevent lateral displacements for the center of the span between load points, four large, hot rolled steel brackets were arranged with wooden shims to restrain the specimen laterally while still allowing it to deflect vertically. These braces were located at 8 inches from load points (Figure 2.11).

During shipping, several of the 3⅝” studs had become damaged at one end. For the last test, there were no undamaged 8'-0” long studs remaining so damaged studs had to be used. In order to prevent the preexisting damage from affecting the results, the damaged end was excluded from the test, along with an equal length of the other end (to preserve symmetry). Figure 2.12 show this shortened specimen being tested.

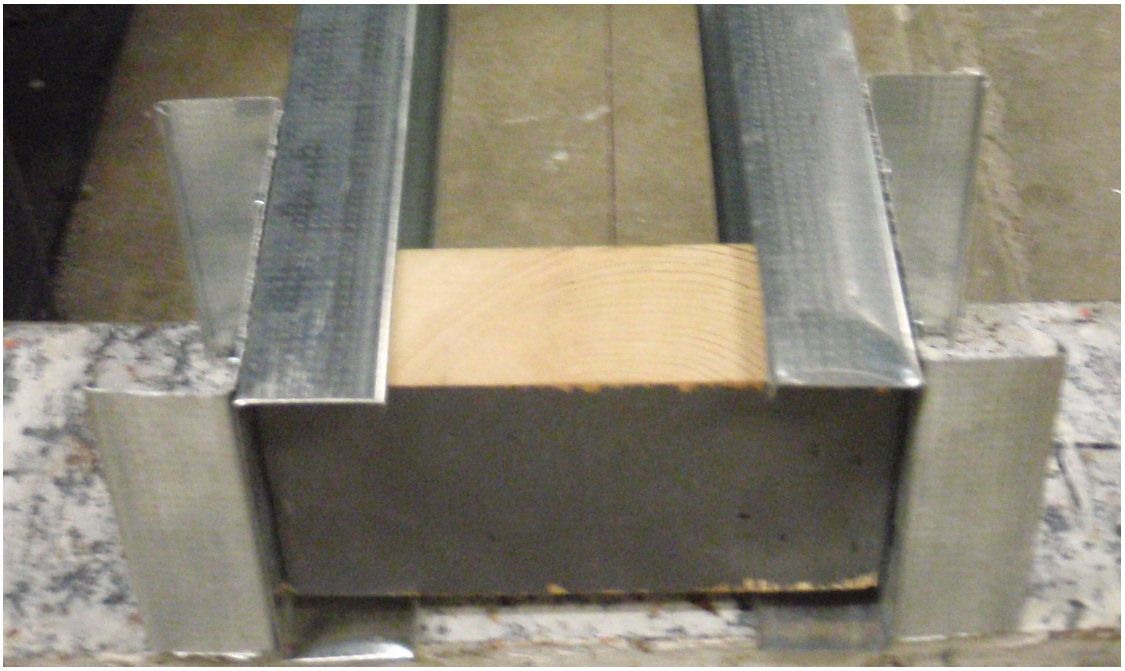

Figure 2.10: Wood blocking and web stiffeners at end reaction of a 3⅝" specimen.

2.5 Test Procedures

Tests were completed on an MTS Flextest GT unit, with a 22-kip actuator and load cell. Time, load, and stroke displacement were measured and recorded through a MultiPupose TestWare (MPT) program written to control the actuator. Additionally, a linear variable differential transformer (LVDT) was applied at midspan to measure deflection at this point. This data was also continually recorded through the MPT software.

The actuator was run in a displacement-controlled manner at a rate of 0.1 inch per minute. Each specimen was loaded until it would take no more load.

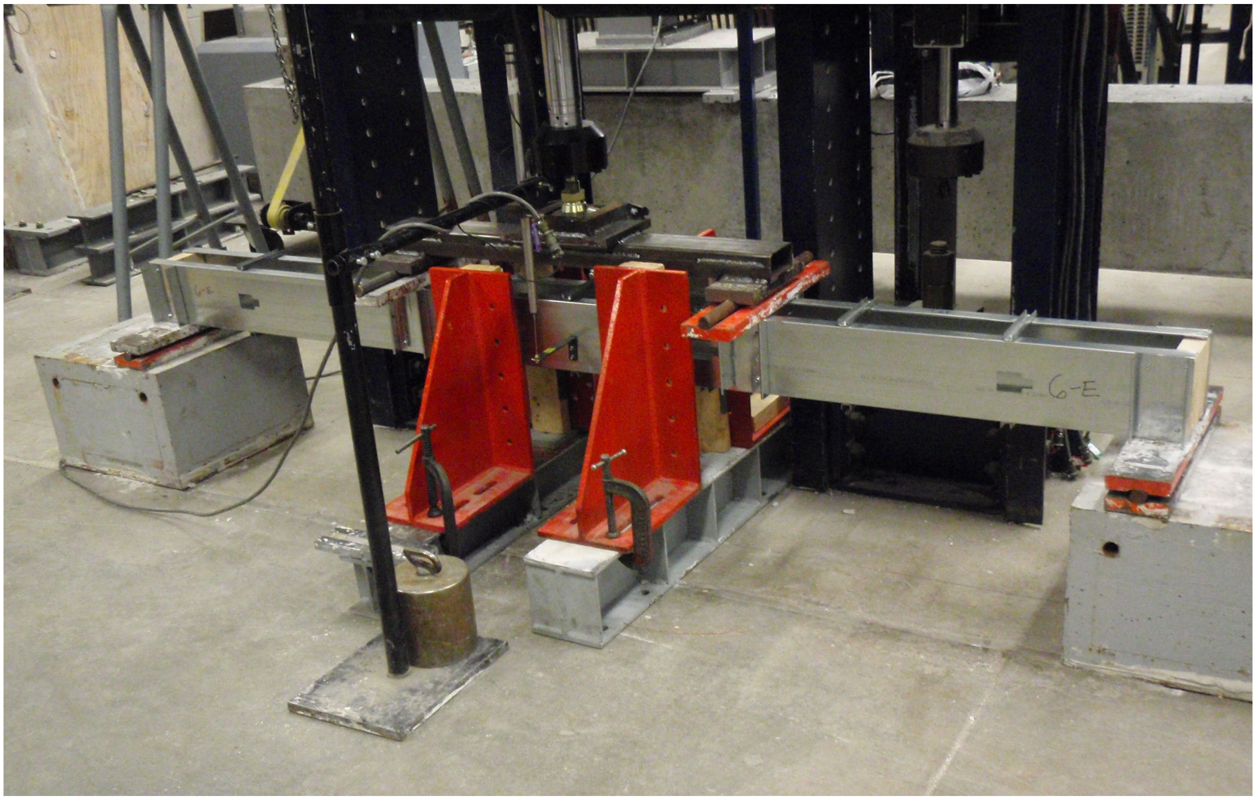

Figure 2.11: Test specimen being loaded.

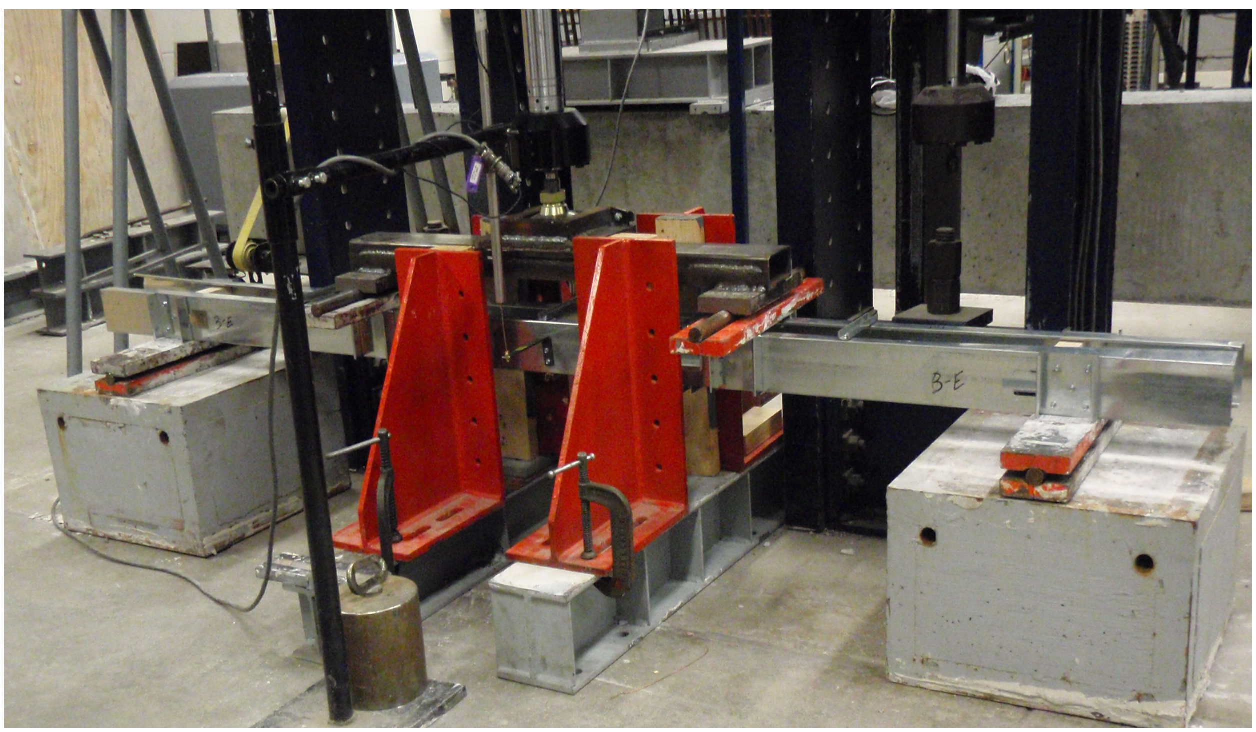

Figure 2.12: Shortened 3⅝" Specimen being tested.

3.0 Test Results and Evaluation of Data

3.1 General

This section contains the test results of this investigation, and a discussion of those results. Ten total specimens were tested (five from 3⅝" studs and five from 6" studs) and were loaded until local or distortional buckling reduced the resistance to the point that they would not take any more load. All of the specimens failed in a similar manner; by flange local buckling. In some cases, after the flange local buckling was observed, buckling of th web below the flange buckle was noted (Figures 3.1 and 3.2). After each specimen was tested, the tested ultimate moment capacity was computed for the specimen as a whole. The nominal flexural strength was also calculated using *AISI S100-07* and the CFS software. These two values were then compared to determine the accuracy of the specification equations for embossed-flanged studs.

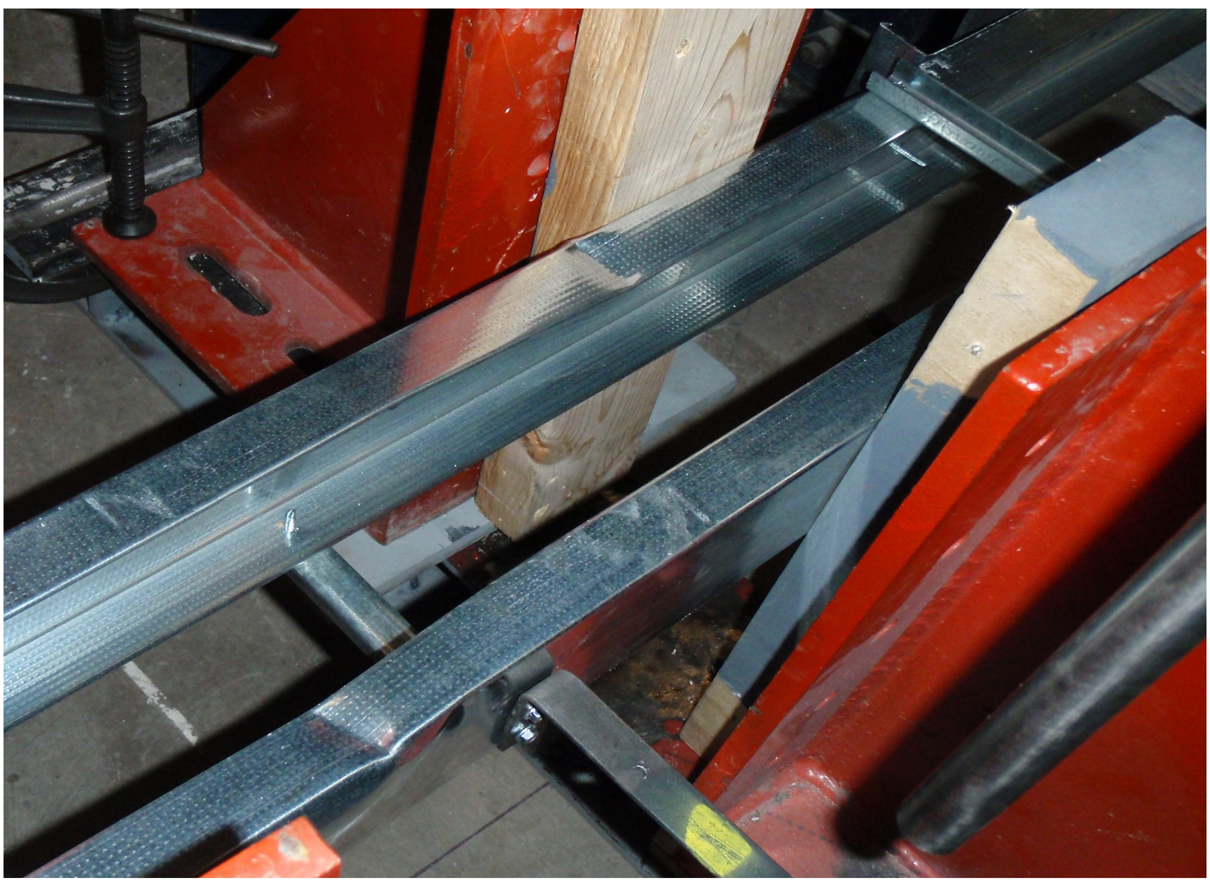

Figure 3.1: Typical Failure in a 3⅝" beam.

Figure 3.2: Typical Failure of a 6" specimen.

As can be seen in figures 2.6 and 2.7, the load application points were very close to the web punchouts. In 60% of the tests conducted, failure occurred at these punchouts. To maintain consistency between tests, the load points were not altered throughout this trial. The punchouts were considered for the calculation of the nominal flexural strength. Failure by buckling at these locations is as expected since the section properties for bending are most critical at the punchouts.

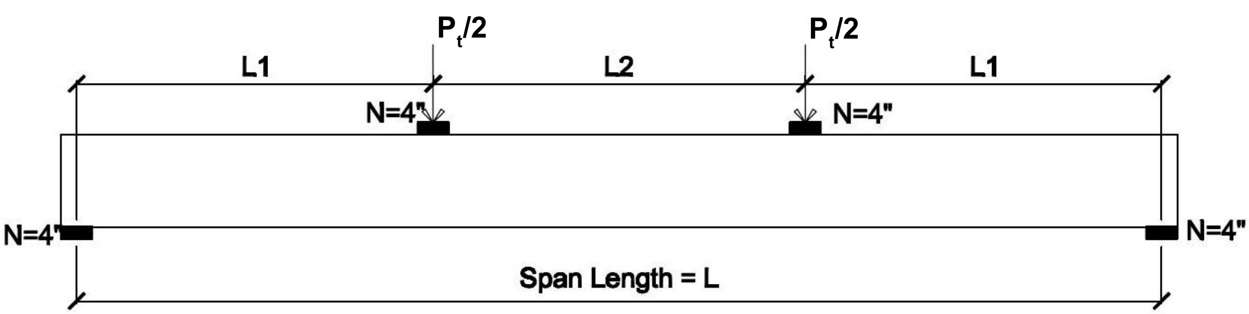

Figure 3.3: Typical Loading Configuration.

3.2 3⅝ inch Specimens

3.2.1 Results

Table 3.1 summarizes the results obtained for the 3⅝" specimens. The first column shows the test yield stress, F_y found in the tensile tests. The next columns show the configuration of the the test, referencing the dimensions shown in Figure 3.3. The max load is the total read from the load cell plus the weight of the bearing plates and spreader beam, consisting of both point loads applied to the overall specimen. The displacement shown was recorded by the load cell, and represents the displacement at the point of load application.

Table 3.1: 3⅝" Specimen Configuration and Test Loads

Specimen	F_y (ksi)	Span L	Loading Dimensions L1	Loading Dimensions L2	Max. Load P_t (lbs.)	Disp. @ Max. Load
3 A	51	7'-8"	2'-6"	2'-8"	396.88	0.513
3 B	51	7'-8"	2'-6"	2'-8"	396.72	0.503
3 C	51	7'-8"	2'-6"	2'-8"	404.27	0.495
3 D	51	7'-8"	2'-6"	2'-8"	388.16	0.495
3 E*	51	6'-6"	1'-11"	2'-8"	494.61	0.411

Note: P_t=Total test load (at load cell) including weight of plates and spreader beam
*-This sample was shortened due to damage at its ends
Ref. Figure3.3 for loading dimensions.

Figure 3.4 shows a graph of the force and displacement of one of the 3⅝" test specimens, representative of all the 3⅝" specimens. The graph starts at 100 pounds due to the weight of the plates and spreader beam on the specimen prior to the beginning of the test. The two peaks on this graph likely represent the two different studs that comprise the specimen buckling at slightly different loads due to an imperfect distribution of the load between the two studs. The predicted displacement is also displayed. This was calculated using the section properties as calculated using CFS. As can be seen once the predicted line is adjusted for initial take up, the displacements were slightly higher than predicted. This is likely due to some deflection being caused by shear, and not due to bending alone as the deflection equation assumes.

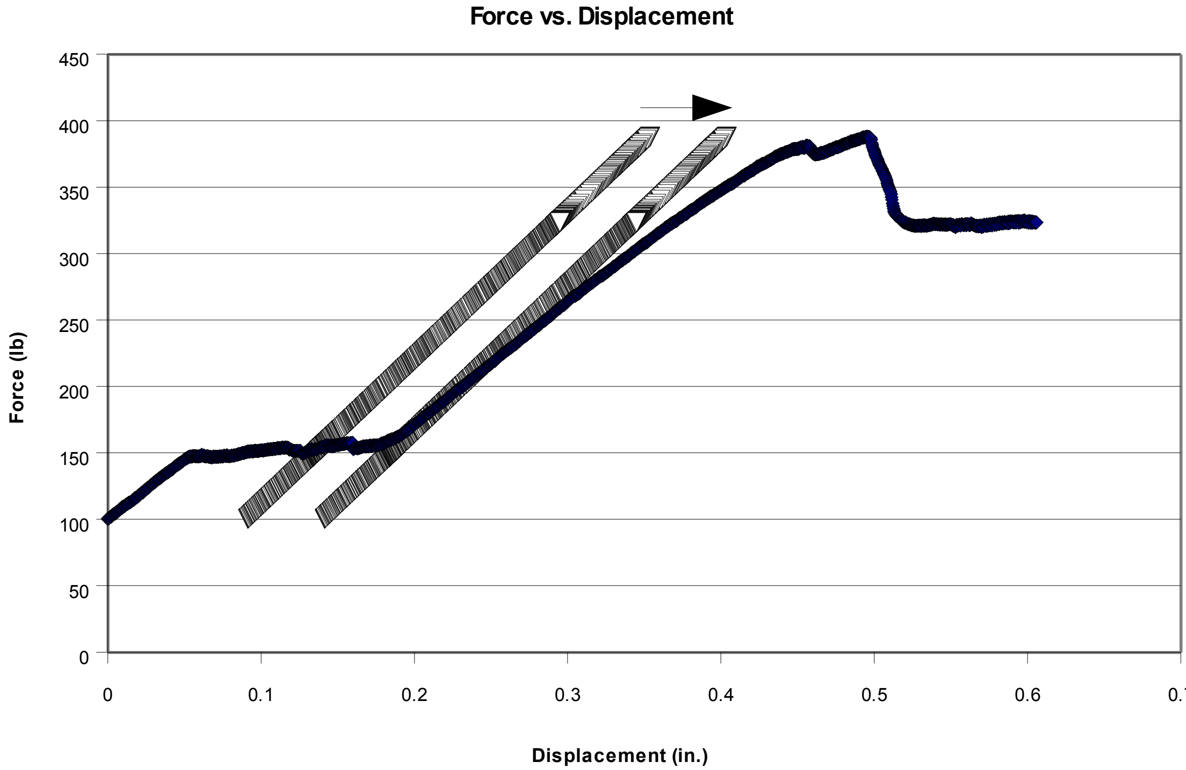

Figure 3.4: Force-Displacement Graph for 3⅝" Specimen 3D.

3.2.2 Evaluation

Table 3.2 shows the values of the maximum load resisted by each stud within the given specimen based on the test results. From this, the tested moment capacity was calculated for a single stud. The third column is the calculated nominal flexural

Table 3.2: Nominal Flexural Capacity Comparison, 3⅝"

Specimen	P_t (lbs.)	M_t (k-in.)	M_n (k-in.)	M_t/M_n
3 A	198.44	2.977	2.976	1.00
3 B	198.36	2.975	2.976	1.00
3 C	202.13	3.032	2.976	1.02
3 D	194.08	2.911	2.976	0.98
3 E	247.30	2.844	2.976	0.96
Note:	P_t = Total test load applied to single stud. M_t = Maximum test moment per stud. M_n = Computed nominal flexural strength for one member			

strength. Using the CFS software, checking both elastic and distortional buckling, it was found that the governing limit state for this size stud was elastic buckling based on the effective section modulus. A detailed report of the CFS calculations is included in Appendix A. Finally, the ratio of the bending moment based on the test load to the calculated nominal flexural strength is shown.

3.3 6 inch Specimens

3.3.1 Results

Table 3.3 summarizes the results of the bending tests on the 6" specimens. The yield stress found in the coupon test is shown. The loading configuration, again referencing Figure 3.3, is in the next columns. The maximum load shown in the table is the total load applied by the load cell including the weight of the bearing plates and spreader beam to the overall specimen. The displacement recorded in the table represents the the displacements at points of load application.

Table 3.3: 6" Specimen Configuration and Test Loads

Specimen	F_y (ksi)	Span L	Loading Dimensions L1	Loading Dimensions L2	Max. Load P_t (lbs.)	Disp. @ Max. Load
6 A	51.5	7'-8"	2'-6"	2'-8"	706.39	0.444
6 B	51.5	7'-8"	2'-6"	2'-8"	716.09	0.442
6 C	51.5	7'-8"	2'-6"	2'-8"	702.12	0.415
6 D	51.5	7'-8"	2'-6"	2'-8"	745.71	0.396
6 E	51.5	7'-8"	2'-6"	2'-8"	736.83	0.363
Note:	P_t = Total test load (at load cell) including weight of plates and spreader beam. Ref. Figure 3.3 for loading dimensions.					

The graph shown in Figure 3.5 is a representative sample force-displacement graph for one of the 6" specimens. Again, the graph starts at 100 pounds due to the spreader beams and load plates. This graph has a single peak, signaling that both members experienced flange buckling simultaneously. This graph also show the predicted displacement curve. For this specimen, more adjustment for take up was necessary, and the actual deflections were again slightly higher than predicted. This is also likely due to the deflection for shear not being considered in the calculated deflections.

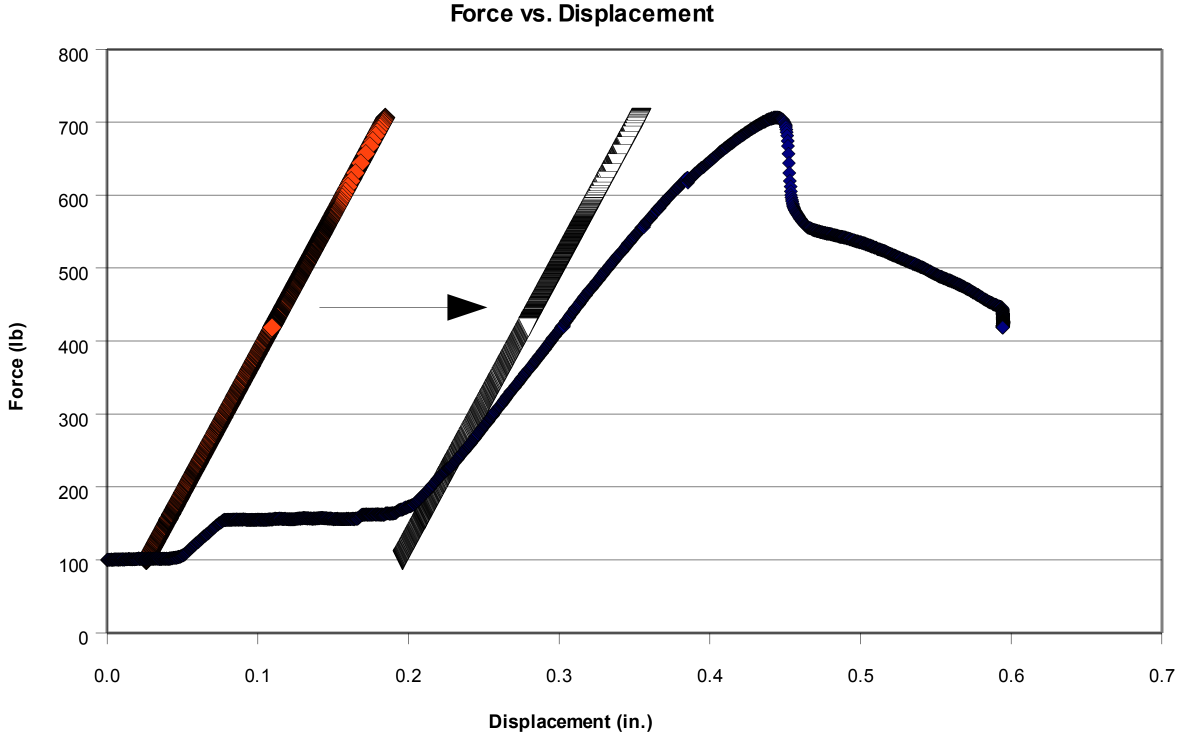

Figure 3.5: Moment-Displacement Graph for 6" Specimen 6A.

3.3.2 Evaluation

Table 3.4 shows the maximum load applied to a single stud in each of the 6”

Table 3.4: Nominal Flexural Strength Comparison, 6”

Specimen	P_t (lbs.)	M_t (k-in.)	M_n (k-in.)	M_t/M_n
6 A	353.20	5.298	5.570	0.95
6 B	358.05	5.371	5.570	0.96
6 C	351.06	5.266	5.570	0.95
6 D	372.86	5.593	5.570	1.00
6 E	368.41	5.526	5.570	0.99

Note: P_t = Total test load for one member.
M_t = Maximum moment for each member
M_n = Computed nominal flexural strength for one stud.

specimens. This was used to calculate the tested bending capacity of a single stud, shown in the next column. The nominal flexural strength as calculated per AISI S100 is also shown. For the 6” studs, it was found that the distortional buckling calculated by the direct strength method was the governing limit state. Member properties output from CFS for both analysis based on effective width at imitation of yielding and distortional buckling and direct strength methods is included in Appendix A. The ratio of the bending moment based on the test load to calculated nominal flexural strength is presented in Table 3.4, as well. It can be seen in the table, that the decreased spacing of the cold-rolled channels appears to have increased the bending capacity of the specimens.

4.0 Conclusions and Recommendations

4.1 Conclusions

Statistical significance tests were conducted on the data obtained from this study. For both sizes of stud, it was tested if the presence of flange embossing resulted in an average moment capacity for the stud below the nominal flexural strength computed by the provisions of the *AISI S100-07*.

For the 3⅝" studs, a significance (α) of 0.220 was found. Typically, an α of 0.1 or less indicates a degree of statistical significance, meaning that with an α of 0.220, there is not evidence that the average flexural strength of the studs is less than the computed nominal flexural strength. Based on these results, it is recommended that the *AISI Specification* provisions may be appropriate for the determination of both section properties and nominal flexural strength.

For the 6" studs, an α of 0.033 was found. Since this is significantly below the 0.1 threshold, it shows that there is statistically significant evidence of an average moment capacity lower than the nominal flexural strength. The average ratio of tested moment capacity to nominal flexural strength was .971.

If only specimens 6-D and 6-E (from the second set of tests, with the closer spacing of bracing) are considered, a significance test gives an α of 0.4006, indicating no evidence of a decreased average nominal flexural strength.

4.2 Recommendations for Additional Research

Based upon the findings of this investigation, additional testing should be done with 6" studs with bracing at 1'-0" o.c.

References

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(AISI 2007b), *North American Standard for Cold-Formed Steel Framing—General Provisions* AISI S200-07, AMERICAN IRON AND STEEL INSTITUTE, Washington D.C., 2007.

(AISI 2007c), *North American Standard for Cold-Formed Steel Framing—Product Data* AISI S201-07, AMERICAN IRON AND STEEL INSTITUTE, Washington D.C., 2007.

(AISI 2007d), *North American Standard for Cold-Formed Steel Framing—Wall Stud Standard* AISI S211-07, AMERICAN IRON AND STEEL INSTITUTE, Washington D.C., 2007.

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Yu, Wei-Wen. (2000). *Cold-Formed Steel Design (3rd ed.).* John Wiley and Sons, Inc., New York City, 1-38.

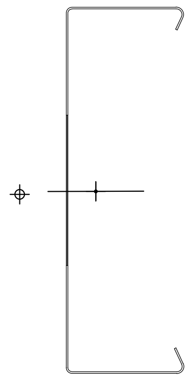
Appendix A

This appendix contains the full report outputs from RSG Software's CFS program, version 6.0.2 (RSG 2009). The first report is for the 3⅝ inch studs, evaluated according to Chapter C of the *AISI S100-07*. The second is for the 6 inch studs, also evaluated per Chapter C. The final report is for the 6 inch studs, evaluated with the direct strength method from Appendix 1 of the AISI S100.

Section: 362S125.sct
Channel 6x1.25x0.5-25 Gage

Roger LaBoube
Missouri S&T

Rev. Date: 5/7/2009 9:06:10 AM
By: Roger LaBoube



Section Inputs

Material: A875 SS Grade 40
No strength increase from cold work of forming.

Modulus of Elasticity, E	29500	ksi
Yield Strength, Fy	50	ksi
Tensile Strength, Fu	59	ksi
Warping Constant Override, Cw	0	in^6
Torsion Constant Override, J	0	in^4

Stiffened Channel, Thickness 0.017 in
Placement of Part from Origin:

X to center of gravity	0	in
Y to center of gravity	0	in

Outside dimensions, Open shape

	Length (in)	Angle (deg)	Radius (in)	Web	k Coef.	Hole Size (in)	Distance (in)
1	0.2810	295.000	0.053000	None	0.000	0.0000	0.1405
2	1.2190	180.000	0.053000	Single	0.000	0.0000	0.6095
3	3.6560	90.000	0.039000	Cee	0.000	1.5000	1.8280
4	1.2190	0.000	0.043000	Single	0.000	0.0000	0.6095
5	0.2500	-115.000	0.057000	None	0.000	0.0000	0.1250

Section: 362S125.sct
Channel 6x1.25x0.5-25 Gage

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Full Section Properties

Area	0.10797 in^2	Wt.	0.00036711 k/ft	Width	6.3513 in
Ix	0.21747 in^4	rx	1.4192 in	Ixy	-0.00078 in^4
Sx(t)	0.11835 in^3	y(t)	1.8376 in	α	0.225 deg
Sx(b)	0.11959 in^3	y(b)	1.8184 in		
		Height	3.6560 in		
Iy	0.01813 in^4	ry	0.4098 in	Xo	-0.7641 in
Sy(l)	0.06086 in^3	x(l)	0.2979 in	Yo	-0.0310 in
Sy(r)	0.02058 in^3	x(r)	0.8812 in	jx	1.9895 in
		Width	1.1791 in	jy	0.0378 in
I1	0.21748 in^4	r1	1.4192 in		
I2	0.01813 in^4	r2	0.4098 in		
Ic	0.23560 in^4	rc	1.4772 in	Cw	0.045634 in^6
Io	0.29875 in^4	ro	1.6634 in	J	0.00001040 in^4

Net Section Properties

Ix	0.21269 in^4	rx	1.6059 in	Area	0.082473 in^2
Sx(t)	0.11556 in^3	y(t)	1.8405 in	Ixy	-0.00069 in^4
Sx(b)	0.11715 in^3	y(b)	1.8155 in	Ic	0.22802 in^4
Iy	0.01533 in^4	ry	0.4312 in		
Sy(l)	0.03958 in^3	x(l)	0.3874 in		
Sy(r)	0.01937 in^3	x(r)	0.7917 in		

Fully Braced Strength - 2007 North American Specification - US (ASD)

Material Type: A875 SS Grade 40, Fy=50 ksi

Compression		Positive Moment		Positive Moment	
Pao	0.9687 k	Maxo	1.7817 k-in	Mayo	0.5740 k-in
Ae	0.034872 in^2	Ixe	0.14287 in^4	Iye	0.01523 in^4
		Sxe(t)	0.05951 in^3	Sye(l)	0.03962 in^3
Tension		Sxe(b)	0.11381 in^3	Sye(r)	0.01917 in^3
Ta	2.4329 k				
		Negative Moment		Negative Moment	
		Maxo	1.8845 k-in	Mayo	0.4795 k-in
Shear		Ixe	0.14780 in^4	Iye	0.00989 in^4
Vay	0.1235 k	Sxe(t)	0.11302 in^3	Sye(l)	0.01761 in^3
Vax	0.6053 k	Sxe(b)	0.06294 in^3	Sye(r)	0.01602 in^3

Stiffened Channel element 2 w/t exceeds 60.
Stiffened Channel element 3 w/t exceeds 200.
Stiffened Channel element 4 w/t exceeds 60.

Calculation Details - 2007 North American Specification - US (ASD)

Axial Tension Strength
Ag=0.10797 in^2, Fy=50 ksi
Tn=5.3986 k NAS Eq. C2-1
Ωt=1.67, ϕt=0.9

An=0.082473 in^2, Fu=59 ksi
Tn=4.8659 k NAS Eq. C2-2

Ωt=2, ϕt=0.75

Shear Strength
Stiffened Channel element 2
Aw=0.017903 in^2, Fv=27.182 ksi — NAS Eq. C3.2.1-3
Vn=0.48665 k at 180 deg
Ωv=1.6, ϕv=0.95
Stiffened Channel element 3
qs=1
Aw=0.06018 in^2, Fv=3.2835 ksi — NAS Eq. C3.2.1-4a
Vn=0.1976 k at 90 deg
Ωv=1.6, ϕv=0.95
Stiffened Channel element 4
Aw=0.017728 in^2, Fv=27.45 ksi — NAS Eq. C3.2.1-3
Vn=0.48665 k at 0 deg
Ωv=1.6, ϕv=0.95

Axial Compression Strength
Effective width calculations for part 1: Stiffened Channel
Element 1: Unstiffened, w=0.17112 in
f1=50 ksi, f2=50 ksi
ψ=1 — NAS Eq. B3.2-1
k=0.43 — NAS Eq. B3.2-3
λ=0.66483 — NAS Eq. B2.1-4
λ<0.673 (fully effective) — NAS Eq. B2.1-1
Element 2: Check for lip stiffener reduction
S=31.091 — NAS Eq. B4-7
Ia=1.9555e-5 in^4 — NAS Eq. B4-8
Is=5.8434e-6 in^4
ds=0.051134 in (lip ineffective width=0.11999 in) — NAS Eq. B4-6
k=2.7605 — NAS Table B4-1
Element 2: Partially stiffened, w=1.0531 in
f=50 ksi, k=2.7605
λ=1.6148 — NAS Eq. B2.1-4
ρ=0.53489 — NAS Eq. B2.1-3
b=0.56331 in (ineffective width=0.48981 in) — NAS Eq. B2.1-2
b1=0.084163 in, b2=0.47915 in
Element 3: Treat as two unstiffened elements
f1=50 ksi, f2=50 ksi
ψ=1 — NAS Eq. B3.2-1
k=0.43 — NAS Eq. B3.2-3
λ=3.9706 — NAS Eq. B2.1-4
ρ=0.2379 — NAS Eq. B2.1-3
b=0.24313 in (ineffective width=0.77887 in) — NAS Eq. B2.1-2
f1=50 ksi, f2=50 ksi
ψ=1 — NAS Eq. B3.2-1
k=0.43 — NAS Eq. B3.2-3
λ=3.9551 — NAS Eq. B2.1-4
ρ=0.23878 — NAS Eq. B2.1-3
b=0.24307 in (ineffective width=0.77493 in) — NAS Eq. B2.1-2
Element 5: Unstiffened, w=0.13384 in
f1=50 ksi, f2=50 ksi
ψ=1 — NAS Eq. B3.2-1
k=0.43 — NAS Eq. B3.2-3

λ=0.52	NAS Eq. B2.1-4
λ<0.673 (fully effective)	NAS Eq. B2.1-1
Element 4: Check for lip stiffener reduction	
S=31.091	NAS Eq. B4-7
Ia=1.9368e-5 in^4	NAS Eq. B4-8
Is=2.7998e-6 in^4	
ds=0.019348 in (lip ineffective width=0.1145 in)	NAS Eq. B4-6
k=2.3036	NAS Table B4-1
Element 4: Partially stiffened, w=1.0428 in	
f=50 ksi, k=2.3036	
λ=1.7505	NAS Eq. B2.1-4
ρ=0.49948	NAS Eq. B2.1-3
b=0.52088 in (ineffective width=0.52197 in)	NAS Eq. B2.1-2
b1=0.037648 in, b2=0.48323 in	
Ae=0.034872 in^2, Fy=50 ksi	
Pn=1.7436 k	NAS Eq. C4.1-1
Ωc=1.8, ϕc=0.85	

Positive Flexural Strength about X-axis

Effective width calculations for part 1: Stiffened Channel	
Element 1: No compressive stress (fully effective)	
Element 2: No compressive stress (fully effective)	
Element 3: Treat as two unstiffened elements	
f1=48.75 ksi, f2=27.546 ksi	
ψ=0.56504	NAS Eq. B3.2-1
k=0.63865	NAS Eq. B3.2-2
λ=3.2045	NAS Eq. B2.1-4
ρ=0.29064	NAS Eq. B2.1-3
b=0.29587 in (ineffective width=0.72213 in)	NAS Eq. B2.1-2
Element 5: Unstiffened, w=0.13384 in	
f1=47.882 ksi, f2=45.355 ksi	
ψ=0.94723	NAS Eq. B3.2-1
k=0.44903	NAS Eq. B3.2-2
λ=0.49797	NAS Eq. B2.1-4
λ<0.673 (fully effective)	NAS Eq. B2.1-1
Element 4: Check for lip stiffener reduction	
S=31.146	NAS Eq. B4-7
Ia=1.9335e-5 in^4	NAS Eq. B4-8
Is=2.7998e-6 in^4	
ds=0.019381 in (lip ineffective width=0.11446 in)	NAS Eq. B4-6
k=2.3047	NAS Table B4-1
Element 4: Partially stiffened, w=1.0428 in	
f=49.823 ksi, k=2.3047	
λ=1.747	NAS Eq. B2.1-4
ρ=0.50034	NAS Eq. B2.1-3
b=0.52177 in (ineffective width=0.52107 in)	NAS Eq. B2.1-2
b1=0.037778 in, b2=0.48399 in	
Center of gravity shift: y=-0.56017 in	
Sxe=0.05951 in^3, Fy=50 ksi	
Mnx=2.9755 k-in	NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.95	

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Negative Flexural Strength about X-axis
Effective width calculations for part 1: Stiffened Channel
Element 1: Unstiffened, w=0.17112 in
f1=47.956 ksi, f2=44.653 ksi
ψ=0.93113 NAS Eq. B3.2-1
k=0.45471 NAS Eq. B3.2-2
λ=0.63316 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 2: Check for lip stiffener reduction
S=31.148 NAS Eq. B4-7
Ia=1.9521e-5 in^4 NAS Eq. B4-8
Is=5.8434e-6 in^4
ds=0.051225 in (lip ineffective width=0.1199 in) NAS Eq. B4-6
k=2.7619 NAS Table B4-1
Element 2: Partially stiffened, w=1.0531 in
f=49.819 ksi, k=2.7619
λ=1.6115 NAS Eq. B2.1-4
ρ=0.53582 NAS Eq. B2.1-3
b=0.56429 in (ineffective width=0.48883 in) NAS Eq. B2.1-2
b1=0.084459 in, b2=0.47983 in
Element 3: Treat as two unstiffened elements
f1=48.807 ksi, f2=27.043 ksi
ψ=0.55408 NAS Eq. B3.2-1
k=0.64647 NAS Eq. B3.2-2
λ=3.1994 NAS Eq. B2.1-4
ρ=0.29106 NAS Eq. B2.1-3
b=0.29747 in (ineffective width=0.72453 in) NAS Eq. B2.1-2
Element 5: No compressive stress (fully effective)
Element 4: No compressive stress (fully effective)

Center of gravity shift: y=0.53274 in
Sxe=0.062942 in^3, Fy=50 ksi
Mnx=3.1471 k-in NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.95

Positive Flexural Strength about Y-axis
Effective width calculations for part 1: Stiffened Channel
Element 1: Unstiffened, w=0.17112 in
f1=49.102 ksi, f2=44.551 ksi
ψ=0.9073 NAS Eq. B3.2-1
k=0.4634 NAS Eq. B3.2-2
λ=0.63465 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 2: Stiffened, w=1.0531 in
f1=45.594 ksi, f2=-20.689 ksi
ψ=0.45377 NAS Eq. B2.3-1
k=13.052 NAS Eq. B2.3-2
λ=0.70916 NAS Eq. B2.1-4
ρ=0.97266 NAS Eq. B2.1-3
be=1.0243 in NAS Eq. B2.1-2
ho=1.219 in, bo=0.281 in, ho/bo=4.3381
b1=0.29658 in NAS Eq. B2.3-6
b2=0.40802 in NAS Eq. B2.3-7
Compression width=0.72441 in

Ineffective width=0.019802 in
Element 3: No compressive stress (fully effective)
Element 5: Unstiffened, w=0.13384 in
f1=48.935 ksi, f2=45.375 ksi

ψ=0.92725	NAS Eq. B3.2-1
k=0.45611	NAS Eq. B3.2-2
λ=0.49949	NAS Eq. B2.1-4
λ<0.673 (fully effective)	NAS Eq. B2.1-1

Element 4: Stiffened, w=1.0428 in
f1=45.199 ksi, f2=-20.437 ksi

ψ=0.45217	NAS Eq. B2.3-1
k=13.029	NAS Eq. B2.3-2
λ=0.69982	NAS Eq. B2.1-4
ρ=0.97973	NAS Eq. B2.1-3
be=1.0217 in	NAS Eq. B2.1-2
ho=1.219 in, bo=0.25 in, ho/bo=4.876	
b1=0.29596 in	NAS Eq. B2.3-6
b2=0.40761 in	NAS Eq. B2.3-7
Compression width=0.71813 in	
Ineffective width=0.014556 in	

Center of gravity shift: x=-0.0029523 in
Sye=0.01917 in^3, Fy=50 ksi
Mny=0.95852 k-in NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.9

Negative Flexural Strength about Y-axis
Effective width calculations for part 1: Stiffened Channel
Element 1: No compressive stress (fully effective)
Element 2: Stiffened, w=1.0531 in
f1=40.872 ksi, f2=-44.336 ksi

ψ=1.0847	NAS Eq. B2.3-1
k=26.291	NAS Eq. B2.3-2
λ=0.47309	NAS Eq. B2.1-4
ρ=1	NAS Eq. B2.1-3
be=1.0531 in	NAS Eq. B2.1-2
ho=1.219 in, bo=3.656 in, ho/bo=0.33342	
b1=0.25782 in	NAS Eq. B2.3-3
b2=0.52656 in	NAS Eq. B2.3-4
Compression width=0.50516 in	
b1+b2 > compression width (fully effective)	

Element 3: Treat as two unstiffened elements
f1=44.716 ksi, f2=44.716 ksi

ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=3.7549	NAS Eq. B2.1-4
ρ=0.25071	NAS Eq. B2.1-3
b=0.25623 in (ineffective width=0.76577 in)	NAS Eq. B2.1-2

f1=44.716 ksi, f2=44.716 ksi

ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=3.7402	NAS Eq. B2.1-4
ρ=0.25164	NAS Eq. B2.1-3
b=0.25617 in (ineffective width=0.76183 in)	NAS Eq. B2.1-2

Element 5: No compressive stress (fully effective)
Element 4: Stiffened, w=1.0428 in
f1=40.549 ksi, f2=-43.828 ksi
ψ=1.0809 NAS Eq. B2.3-1
k=26.182 NAS Eq. B2.3-2
λ=0.46758 NAS Eq. B2.1-4
ρ=1 NAS Eq. B2.1-3
be=1.0428 in NAS Eq. B2.1-2
ho=1.219 in, bo=3.656 in, ho/bo=0.33342
b1=0.25554 in NAS Eq. B2.3-3
b2=0.52142 in NAS Eq. B2.3-4
Compression width=0.50116 in
b1+b2 > compression width (fully effective)

Center of gravity shift: x=0.17416 in
Sye=0.016017 in^3, Fy=50 ksi
Mny=0.80084 k-in NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.9

Member Check - 2007 North American Specification - US (ASD)

```
Material Type: A875 SS Grade 40, Fy=50 ksi
Design Parameters:
Lx        0.0000 ft     Ly        0.0000 ft     Lt        0.0000 ft
Kx        1.0000        Ky        1.0000        Kt        1.0000
Cbx       1.0000        Cby       1.0000        ex        0.0000 in
Cmx       1.0000        Cmy       1.0000        ey        0.0000 in
Braced Flange: None     Red. Factor, R: 0       Stiffness, kϕ: 0 k

Loads:             P          Mx         Vy         My         Vx
                 (k)      (k-in)        (k)     (k-in)        (k)
Entered      0.00000     0.0000    0.00000     0.0000    0.00000
Applied      0.00000     0.0000    0.00000     0.0000    0.00000
Strength     0.96866     1.7817    0.12350     0.5740    0.60534

Effective section properties at applied loads:
Ae      0.107973 in^2   Ixe      0.21747 in^4   Iye      0.01813 in^4
                        Sxe(t)   0.11835 in^3   Sye(l)   0.06086 in^3
                        Sxe(b)   0.11959 in^3   Sye(r)   0.02058 in^3

Interaction Equations
NAS Eq. C5.2.1-1  (P, Mx, My)  0.000 + 0.000 + 0.000 = 0.000 <= 1.0
NAS Eq. C5.2.1-2  (P, Mx, My)  0.000 + 0.000 + 0.000 = 0.000 <= 1.0
NAS Eq. C3.3.1-1     (Mx, Vy)     Sqrt(0.000 + 0.000)= 0.000 <= 1.0
NAS Eq. C3.3.1-1     (My, Vx)     Sqrt(0.000 + 0.000)= 0.000 <= 1.0

Stiffened Channel element 2 w/t exceeds 60.
Stiffened Channel element 3 w/t exceeds 200.
Stiffened Channel element 4 w/t exceeds 60.
```

Calculation Details - 2007 North American Specification - US (ASD)

Axial Compression Strength
(KL/r)x=0, (KL/r)y=0

$\sigma x=\infty$	NAS C3.1.2.1-11
$\sigma y=\infty$	NAS C3.1.2.1-8
$\sigma t=\infty$	NAS C3.1.2.1-9
Fe=∞	
Fy=50 ksi	
λc=0	NAS C4.1-4
Fn=50 ksi	NAS C4.1-2
Effective width calculations for part 1: Stiffened Channel	
Element 1: Unstiffened, w=0.17112 in	
f1=50 ksi, f2=50 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=0.66483	NAS Eq. B2.1-4
λ<0.673 (fully effective)	NAS Eq. B2.1-1
Element 2: Check for lip stiffener reduction	
S=31.091	NAS Eq. B4-7
Ia=1.9555e-5 in^4	NAS Eq. B4-8
Is=5.8434e-6 in^4	
ds=0.051134 in (lip ineffective width=0.11999 in)	NAS Eq. B4-6
k=2.7605	NAS Table B4-1
Element 2: Partially stiffened, w=1.0531 in	
f=50 ksi, k=2.7605	
λ=1.6148	NAS Eq. B2.1-4
ρ=0.53489	NAS Eq. B2.1-3
b=0.56331 in (ineffective width=0.48981 in)	NAS Eq. B2.1-2
b1=0.084163 in, b2=0.47915 in	
Element 3: Treat as two unstiffened elements	
f1=50 ksi, f2=50 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=3.9706	NAS Eq. B2.1-4
ρ=0.2379	NAS Eq. B2.1-3
b=0.24313 in (ineffective width=0.77887 in)	NAS Eq. B2.1-2
f1=50 ksi, f2=50 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=3.9551	NAS Eq. B2.1-4
ρ=0.23878	NAS Eq. B2.1-3
b=0.24307 in (ineffective width=0.77493 in)	NAS Eq. B2.1-2
Element 5: Unstiffened, w=0.13384 in	
f1=50 ksi, f2=50 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=0.52	NAS Eq. B2.1-4
λ<0.673 (fully effective)	NAS Eq. B2.1-1
Element 4: Check for lip stiffener reduction	
S=31.091	NAS Eq. B4-7
Ia=1.9368e-5 in^4	NAS Eq. B4-8
Is=2.7998e-6 in^4	
ds=0.019348 in (lip ineffective width=0.1145 in)	NAS Eq. B4-6
k=2.3036	NAS Table B4-1
Element 4: Partially stiffened, w=1.0428 in	
f=50 ksi, k=2.3036	
λ=1.7505	NAS Eq. B2.1-4

ρ=0.49948 NAS Eq. B2.1-3
b=0.52088 in (ineffective width=0.52197 in) NAS Eq. B2.1-2
b1=0.037648 in, b2=0.48323 in

Ae=0.034872 in^2
Pn=1.7436 k NAS C4.1-1
Ωc=1.8, ϕc=0.85

Flexural Strength about X-axis
σy=∞ NAS C3.1.2.1-8
σt=∞ NAS C3.1.2.1-9
Ctf=1 NAS C3.1.2.1-12
Not subject to lateral-torsional buckling - same as fully braced strength

Flexural Strength about Y-axis
σx=∞ NAS C3.1.2.1-11
σt=∞ NAS C3.1.2.1-9
Ctf=1 NAS C3.1.2.1-12
Not subject to lateral-torsional buckling - same as fully braced strength

Compression and Bending Interaction
αx=1 NAS C5.2.1-4
αy=1 NAS C5.2.1-5

Effective section at applied loads
Effective width calculations for part 1: Stiffened Channel
Element 1: No compressive stress (fully effective)
Element 2: No compressive stress (fully effective)
Element 3: No compressive stress (fully effective)
Element 5: No compressive stress (fully effective)
Element 4: No compressive stress (fully effective)

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Missouri S&T

Rev. Date: 5/7/2009 9:07:41 AM
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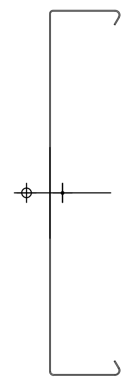

Section Inputs

Material: A653 HSLAS Grade 50
Apply strength increase from cold work of forming.

Modulus of Elasticity, E	29500	ksi
Yield Strength, Fy	51.5	ksi
Tensile Strength, Fu	60.8	ksi
Warping Constant Override, Cw	0	in^6
Torsion Constant Override, J	0	in^4

Stiffened Channel, Thickness 0.0186 in
Placement of Part from Origin:

X to center of gravity	0	in
Y to center of gravity	0	in

Outside dimensions, Open shape

	Length (in)	Angle (deg)	Radius (in)	Web	k Coef.	Hole Size (in)	Distance (in)
1	0.2810	300.000	0.063000	None	0.000	0.0000	0.1405
2	1.2190	180.000	0.063000	Single	0.000	0.0000	0.6095
3	6.0310	90.000	0.047000	Cee	0.000	1.5000	3.0155
4	1.2190	0.000	0.043000	Single	0.000	0.0000	0.6095
5	0.2810	-120.000	0.063000	None	0.000	0.0000	0.1405

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Fully Braced Strength - 2007 North American Specification - US (ASD)

```
Material Type: A653 HSLAS Grade 50, Fy=51.5 ksi
Compression              Positive Moment          Positive Moment
Pao       1.1302 k       Maxo      3.8093 k-in    Mayo      0.6789 k-in
Ae      0.039500 in^2    Ixe      0.49304 in^4    Iye      0.01992 in^4
                         Sxe(t)   0.12352 in^3    Sye(l)   0.07833 in^3
Tension                  Sxe(b)   0.24175 in^3    Sye(r)   0.02201 in^3
Ta        4.0625 k
                         Negative Moment          Negative Moment
                         Maxo      3.8267 k-in    Mayo      0.5370 k-in
Shear                    Ixe      0.49478 in^4    Iye      0.01077 in^4
Vay       0.0970 k       Sxe(t)   0.24210 in^3    Sye(l)   0.01990 in^3
Vax       0.7285 k       Sxe(b)   0.12409 in^3    Sye(r)   0.01741 in^3

Stiffened Channel element 3 w/t exceeds 200.
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Calculation Details - 2007 North American Specification - US (ASD)

Axial Tension Strength
Ag=0.16154 in^2, Fy=51.5 ksi
Tn=8.3191 k — NAS Eq. C2-1
Ωt=1.67, ϕt=0.9

An=0.13364 in^2, Fu=60.8 ksi
Tn=8.125 k — NAS Eq. C2-2
Ωt=2, ϕt=0.75

Shear Strength
Stiffened Channel element 2
Aw=0.018824 in^2, Fv=30.9 ksi — NAS Eq. C3.2.1-2
Vn=0.58167 k at 180 deg
Ωv=1.6, ϕv=0.95
Stiffened Channel element 3
qs=1
Aw=0.10981 in^2, Fv=1.4132 ksi — NAS Eq. C3.2.1-4a
Vn=0.15518 k at 90 deg
Ωv=1.6, ϕv=0.95
Stiffened Channel element 4
Aw=0.018899 in^2, Fv=30.9 ksi — NAS Eq. C3.2.1-2
Vn=0.58397 k at 0 deg
Ωv=1.6, ϕv=0.95

Axial Compression Strength
Effective width calculations for part 1: Stiffened Channel
Element 1: Unstiffened, w=0.13966 in
f1=51.5 ksi, f2=51.5 ksi
ψ=1 — NAS Eq. B3.2-1
k=0.43 — NAS Eq. B3.2-3
λ=0.50332 — NAS Eq. B2.1-4
λ<0.673 (fully effective) — NAS Eq. B2.1-1
Element 2: Check for lip stiffener reduction
S=30.635 — NAS Eq. B4-7
Ia=2.5046e-5 in^4 — NAS Eq. B4-8
Is=3.1858e-6 in^4

ds=0.017765 in (lip ineffective width=0.1219 in)	NAS Eq. B4-6
k=2.1559	NAS Table B4-1
Element 2: Partially stiffened, w=1.0121 in	
f=51.5 ksi, k=2.1559	
λ=1.6289	NAS Eq. B2.1-4
ρ=0.531	NAS Eq. B2.1-3
b=0.53741 in (ineffective width=0.47466 in)	NAS Eq. B2.1-2
b1=0.034179 in, b2=0.50323 in	
Element 3: Treat as two unstiffened elements	
f1=51.5 ksi, f2=51.5 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=7.928	NAS Eq. B2.1-4
ρ=0.12263	NAS Eq. B2.1-3
b=0.26978 in (ineffective width=1.9301 in)	NAS Eq. B2.1-2
f1=51.5 ksi, f2=51.5 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=7.9424	NAS Eq. B2.1-4
ρ=0.12242	NAS Eq. B2.1-3
b=0.2698 in (ineffective width=1.9341 in)	NAS Eq. B2.1-2
Element 5: Unstiffened, w=0.13966 in	
f1=51.5 ksi, f2=51.5 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=0.50332	NAS Eq. B2.1-4
λ<0.673 (fully effective)	NAS Eq. B2.1-1
Element 4: Check for lip stiffener reduction	
S=30.635	NAS Eq. B4-7
Ia=2.5142e-5 in^4	NAS Eq. B4-8
Is=3.1858e-6 in^4	
ds=0.017697 in (lip ineffective width=0.12197 in)	NAS Eq. B4-6
k=2.1564	NAS Table B4-1
Element 4: Partially stiffened, w=1.0161 in	
f=51.5 ksi, k=2.1564	
λ=1.6351	NAS Eq. B2.1-4
ρ=0.52929	NAS Eq. B2.1-3
b=0.53779 in (ineffective width=0.47827 in)	NAS Eq. B2.1-2
b1=0.034072 in, b2=0.50372 in	

Ae=0.0395 in^2, Fy=51.5 ksi	
Pn=2.0343 k	NAS Eq. C4.1-1
Ωc=1.8, φc=0.85	

Positive Flexural Strength about X-axis
Effective width calculations for part 1: Stiffened Channel

Element 1: No compressive stress (fully effective)	
Element 2: No compressive stress (fully effective)	
Element 3: Stiffened, w=5.9038 in	
f1=50.705 ksi, f2=-25.469 ksi	
ψ=0.5023	NAS Eq. B2.3-1
k=13.786	NAS Eq. B2.3-2
λ=3.7285	NAS Eq. B2.1-4
ρ=0.25238	NAS Eq. B2.1-3

be=1.49 in NAS Eq. B2.1-2
ho=6.031 in, bo=1.219 in, ho/bo=4.9475
b1=0.42543 in NAS Eq. B2.3-6
b2=0.56638 in NAS Eq. B2.3-7
Compression width=3.9299 in
Ineffective width=2.938 in
Element 5: Unstiffened, w=0.13966 in
f1=49.981 ksi, f2=48.42 ksi
ψ=0.96878 NAS Eq. B3.2-1
k=0.44163 NAS Eq. B3.2-2
λ=0.48927 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 4: Check for lip stiffener reduction
S=30.671 NAS Eq. B4-7
Ia=2.5114e-5 in^4 NAS Eq. B4-8
Is=3.1858e-6 in^4
ds=0.017717 in (lip ineffective width=0.12195 in) NAS Eq. B4-6
k=2.1571 NAS Table B4-1
Element 4: Partially stiffened, w=1.0161 in
f=51.38 ksi, k=2.1571
λ=1.633 NAS Eq. B2.1-4
ρ=0.52988 NAS Eq. B2.1-3
b=0.53839 in (ineffective width=0.47767 in) NAS Eq. B2.1-2
b1=0.034148 in, b2=0.50424 in

Center of gravity shift: y=-0.97671 in
Sxe=0.12352 in^3, Fy=51.5 ksi
Mnx=6.3615 k-in NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.95

Negative Flexural Strength about X-axis
Effective width calculations for part 1: Stiffened Channel
Element 1: Unstiffened, w=0.13966 in
f1=49.979 ksi, f2=48.417 ksi
ψ=0.96874 NAS Eq. B3.2-1
k=0.44165 NAS Eq. B3.2-2
λ=0.48926 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 2: Check for lip stiffener reduction
S=30.671 NAS Eq. B4-7
Ia=2.5017e-5 in^4 NAS Eq. B4-8
Is=3.1858e-6 in^4
ds=0.017785 in (lip ineffective width=0.12188 in) NAS Eq. B4-6
k=2.1565 NAS Table B4-1
Element 2: Partially stiffened, w=1.0121 in
f=51.38 ksi, k=2.1565
λ=1.6267 NAS Eq. B2.1-4
ρ=0.53159 NAS Eq. B2.1-3
b=0.538 in (ineffective width=0.47406 in) NAS Eq. B2.1-2
b1=0.034256 in, b2=0.50375 in
Element 3: Stiffened, w=5.9038 in
f1=50.653 ksi, f2=-25.601 ksi
ψ=0.50543 NAS Eq. B2.3-1
k=13.834 NAS Eq. B2.3-2

λ=3.72 NAS Eq. B2.1-4
ρ=0.25292 NAS Eq. B2.1-3
be=1.4932 in NAS Eq. B2.1-2
ho=6.031 in, bo=1.219 in, ho/bo=4.9475
b1=0.42596 in NAS Eq. B2.3-6
b2=0.5659 in NAS Eq. B2.3-7
Compression width=3.9217 in
Ineffective width=2.9298 in
Element 5: No compressive stress (fully effective)
Element 4: No compressive stress (fully effective)

Center of gravity shift: y=0.97108 in
Sxe=0.12409 in^3, Fy=51.5 ksi
Mnx=6.3906 k-in NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.95

Positive Flexural Strength about Y-axis
Effective width calculations for part 1: Stiffened Channel
Element 1: Unstiffened, w=0.13966 in
f1=50.419 ksi, f2=46.444 ksi
ψ=0.92116 NAS Eq. B3.2-1
k=0.45831 NAS Eq. B3.2-2
λ=0.48239 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 2: Stiffened, w=1.0121 in
f1=46.855 ksi, f2=-10.754 ksi
ψ=0.22952 NAS Eq. B2.3-1
k=10.176 NAS Eq. B2.3-2
λ=0.71512 NAS Eq. B2.1-4
ρ=0.96817 NAS Eq. B2.1-3
be=0.97985 in NAS Eq. B2.1-2
ho=1.219 in, bo=0.281 in, ho/bo=4.3381
b1=0.3034 in NAS Eq. B2.3-6
b2=0.49353 in NAS Eq. B2.3-7
Compression width=0.82314 in
Ineffective width=0.026201 in
Element 3: No compressive stress (fully effective)
Element 5: Unstiffened, w=0.13966 in
f1=50.419 ksi, f2=46.444 ksi
ψ=0.92116 NAS Eq. B3.2-1
k=0.45831 NAS Eq. B3.2-2
λ=0.48239 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 4: Stiffened, w=1.0161 in
f1=46.855 ksi, f2=-10.982 ksi
ψ=0.23438 NAS Eq. B2.3-1
k=10.23 NAS Eq. B2.3-2
λ=0.71605 NAS Eq. B2.1-4
ρ=0.96747 NAS Eq. B2.1-3
be=0.98301 in NAS Eq. B2.1-2
ho=1.219 in, bo=0.281 in, ho/bo=4.3381
b1=0.30393 in NAS Eq. B2.3-6
b2=0.49243 in NAS Eq. B2.3-7
Compression width=0.82314 in

Ineffective width=0.026776 in

Center of gravity shift: x=-0.0037342 in
Sye=0.022014 in^3, Fy=51.5 ksi
Mny=1.1337 k-in NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.9

Negative Flexural Strength about Y-axis
Effective width calculations for part 1: Stiffened Channel
Element 1: No compressive stress (fully effective)
Element 2: Stiffened, w=1.0121 in
f1=39.563 ksi, f2=-44.706 ksi
ψ=1.13 NAS Eq. B2.3-1
k=27.586 NAS Eq. B2.3-2
λ=0.39912 NAS Eq. B2.1-4
ρ=1 NAS Eq. B2.1-3
be=1.0121 in NAS Eq. B2.1-2
ho=1.219 in, bo=6.031 in, ho/bo=0.20212
b1=0.24505 in NAS Eq. B2.3-3
b2=0.50603 in NAS Eq. B2.3-4
Compression width=0.47515 in
b1+b2 > compression width (fully effective)
Element 3: Treat as two unstiffened elements
f1=44.251 ksi, f2=44.251 ksi
ψ=1 NAS Eq. B3.2-1
k=0.43 NAS Eq. B3.2-3
λ=7.3489 NAS Eq. B2.1-4
ρ=0.132 NAS Eq. B2.1-3
b=0.29039 in (ineffective width=1.9095 in) NAS Eq. B2.1-2
f1=44.251 ksi, f2=44.251 ksi
ψ=1 NAS Eq. B3.2-1
k=0.43 NAS Eq. B3.2-3
λ=7.3623 NAS Eq. B2.1-4
ρ=0.13177 NAS Eq. B2.1-3
b=0.2904 in (ineffective width=1.9135 in) NAS Eq. B2.1-2
Element 5: No compressive stress (fully effective)
Element 4: Stiffened, w=1.0161 in
f1=39.897 ksi, f2=-44.706 ksi
ψ=1.1205 NAS Eq. B2.3-1
k=27.312 NAS Eq. B2.3-2
λ=0.40439 NAS Eq. B2.1-4
ρ=1 NAS Eq. B2.1-3
be=1.0161 in NAS Eq. B2.1-2
ho=1.219 in, bo=6.031 in, ho/bo=0.20212
b1=0.24659 in NAS Eq. B2.3-3
b2=0.50803 in NAS Eq. B2.3-4
Compression width=0.47915 in
b1+b2 > compression width (fully effective)

Center of gravity shift: x=0.28289 in
Sye=0.017412 in^3, Fy=51.5 ksi
Mny=0.89672 k-in NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.9

Member Check - 2007 North American Specification - US (ASD)

Material Type: A653 HSLAS Grade 50, Fy=51.5 ksi
Design Parameters:

Lx	0.0000 ft	Ly	0.0000 ft	Lt	0.0000 ft
Kx	1.0000	Ky	1.0000	Kt	1.0000
Cbx	1.0000	Cby	1.0000	ex	0.0000 in
Cmx	1.0000	Cmy	1.0000	ey	0.0000 in
Braced Flange: None		Red. Factor, R: 0		Stiffness, kφ: 0 k	

Loads:	P (k)	Mx (k-in)	Vy (k)	My (k-in)	Vx (k)
Entered	0.00000	0.0000	0.00000	0.0000	0.00000
Applied	0.00000	0.0000	0.00000	0.0000	0.00000
Strength	0.82051	3.5728	0.09699	0.6789	0.72853

Effective section properties at applied loads:

Ae	0.161535 in^2	Ixe	0.77950 in^4	Iye	0.02160 in^4
		Sxe(t)	0.25855 in^3	Sye(l)	0.10043 in^3
		Sxe(b)	0.25845 in^3	Sye(r)	0.02288 in^3

Interaction Equations
NAS Eq. C5.2.1-1 (P, Mx, My) 0.000 + 0.000 + 0.000 = 0.000 <= 1.0
NAS Eq. C5.2.1-2 (P, Mx, My) 0.000 + 0.000 + 0.000 = 0.000 <= 1.0
NAS Eq. C3.3.1-1 (Mx, Vy) Sqrt(0.000 + 0.000)= 0.000 <= 1.0
NAS Eq. C3.3.1-1 (My, Vx) Sqrt(0.000 + 0.000)= 0.000 <= 1.0

Stiffened Channel element 3 w/t exceeds 200.

Calculation Details - 2007 North American Specification - US (ASD)

Axial Compression Strength
(KL/r)x=0, (KL/r)y=0
σx=∞ NAS C3.1.2.1-11
σy=∞ NAS C3.1.2.1-8
σt=∞ NAS C3.1.2.1-9
Fe=∞
Fy=51.5 ksi
λc=0 NAS C4.1-4
Fn=51.5 ksi NAS C4.1-2
Effective width calculations for part 1: Stiffened Channel
Element 1: Unstiffened, w=0.13966 in
f1=51.5 ksi, f2=51.5 ksi
ψ=1 NAS Eq. B3.2-1
k=0.43 NAS Eq. B3.2-3
λ=0.50332 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 2: Check for lip stiffener reduction
S=30.635 NAS Eq. B4-7
Ia=2.5046e-5 in^4 NAS Eq. B4-8
Is=3.1858e-6 in^4
ds=0.017765 in (lip ineffective width=0.1219 in) NAS Eq. B4-6
k=2.1559 NAS Table B4-1

Element 2: Partially stiffened, w=1.0121 in
f=51.5 ksi, k=2.1559
λ=1.6289 NAS Eq. B2.1-4
ρ=0.531 NAS Eq. B2.1-3
b=0.53741 in (ineffective width=0.47466 in) NAS Eq. B2.1-2
b1=0.034179 in, b2=0.50323 in
Element 3: Treat as two unstiffened elements
f1=51.5 ksi, f2=51.5 ksi
ψ=1 NAS Eq. B3.2-1
k=0.43 NAS Eq. B3.2-3
λ=7.928 NAS Eq. B2.1-4
ρ=0.12263 NAS Eq. B2.1-3
b=0.26978 in (ineffective width=1.9301 in) NAS Eq. B2.1-2
f1=51.5 ksi, f2=51.5 ksi
ψ=1 NAS Eq. B3.2-1
k=0.43 NAS Eq. B3.2-3
λ=7.9424 NAS Eq. B2.1-4
ρ=0.12242 NAS Eq. B2.1-3
b=0.2698 in (ineffective width=1.9341 in) NAS Eq. B2.1-2
Element 5: Unstiffened, w=0.13966 in
f1=51.5 ksi, f2=51.5 ksi
ψ=1 NAS Eq. B3.2-1
k=0.43 NAS Eq. B3.2-3
λ=0.50332 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 4: Check for lip stiffener reduction
S=30.635 NAS Eq. B4-7
Ia=2.5142e-5 in^4 NAS Eq. B4-8
Is=3.1858e-6 in^4
ds=0.017697 in (lip ineffective width=0.12197 in) NAS Eq. B4-6
k=2.1564 NAS Table B4-1
Element 4: Partially stiffened, w=1.0161 in
f=51.5 ksi, k=2.1564
λ=1.6351 NAS Eq. B2.1-4
ρ=0.52929 NAS Eq. B2.1-3
b=0.53779 in (ineffective width=0.47827 in) NAS Eq. B2.1-2
b1=0.034072 in, b2=0.50372 in

Ae=0.0395 in^2
Pn=2.0343 k NAS C4.1-1
Ωc=1.8, ϕc=0.85

Distortional buckling for part 1 elements 1 to 2
Af=0.025459 in^2, Ixf=7.4089e-5 in^4, Iyf=0.0033733 in^4, Ixyf=0.00025013 in^4
Xo=0.50084 in, Yo=-0.021024 in, Cwf=1.4997e-8 in^6, Jf=2.9359e-6 in^4
hx=-0.66201 in, ho=6.031 in
Lcr=13.911 in NAS C4.2-13
kϕfe=0.0074568 k NAS C3.1.4-13
kϕwe=0.0057647 k NAS C4.2-11
kϕ=0 k
kϕfg=0.00075985 in^2 NAS C3.1.4-15
kϕwg=0.0034684 in^2 NAS C4.2-12
Fd=3.1269 ksi NAS C4.2-10
Pcrd=0.50511 k NAS C4.2-5

Py=8.3191 k	NAS C4.2-4
λ=4.0583	NAS C4.2-3
Pn=1.4769 k	NAS C4.2-2

Flexural Strength about X-axis

σy=∞	NAS C3.1.2.1-8
σt=∞	NAS C3.1.2.1-9
Cb=1	NAS C3.1.2.1-6

Not subject to lateral-torsional buckling - same as fully braced strength

Distortional buckling for part 1 elements 4 to 5
Af=0.025459 in^2, Ixf=7.4089e-5 in^4, Iyf=0.0033733 in^4, Ixyf=-0.00025013 in^4
Xo=0.50084 in, Yo=0.021024 in, Cwf=1.4997e-8 in^6, Jf=2.9359e-6 in^4
hx=-0.66201 in, ho=6.031 in

Lcr=12.592 in	NAS C3.1.4-12
kϕfe=0.010651 k	NAS C3.1.4-13
kϕwe=0.010775 k	NAS C3.1.4-14
kϕ=0 k	
kϕfg=0.0009273 in^2	NAS C3.1.4-15
kϕwg=0.00070066 in^2	NAS C3.1.4-16
Fd=13.161 ksi	NAS C3.1.4-10
Mcrd=3.4133 k-in	NAS C3.1.4-5
My=13.22 k-in	NAS C3.1.4-4
λ=1.968	NAS C3.1.4-3
Mn=5.9665 k-in	NAS C3.1.4-2

Flexural Strength about Y-axis

σx=∞	NAS C3.1.2.1-11
σt=∞	NAS C3.1.2.1-9
Ctf=1	NAS C3.1.2.1-12

Not subject to lateral-torsional buckling - same as fully braced strength

Compression and Bending Interaction

αx=1	NAS C5.2.1-4
αy=1	NAS C5.2.1-5

Effective section at applied loads
Effective width calculations for part 1: Stiffened Channel
Element 1: No compressive stress (fully effective)
Element 2: No compressive stress (fully effective)
Element 3: No compressive stress (fully effective)
Element 5: No compressive stress (fully effective)
Element 4: No compressive stress (fully effective)

Section: 600S125.sct
Channel 6x1.25x0.5-25 Gage

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Missouri S&T

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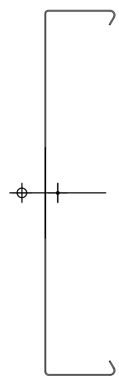

Section Inputs

Material: A653 HSLAS Grade 50
Apply strength increase from cold work of forming.

Modulus of Elasticity, E	29500	ksi
Yield Strength, Fy	51.5	ksi
Tensile Strength, Fu	60.8	ksi
Warping Constant Override, Cw	0	in^6
Torsion Constant Override, J	0	in^4

Stiffened Channel, Thickness 0.0186 in
Placement of Part from Origin:
X to center of gravity 0 in
Y to center of gravity 0 in
Outside dimensions, Open shape

	Length (in)	Angle (deg)	Radius (in)	Web	k Coef.	Hole Size (in)	Distance (in)
1	0.2810	300.000	0.063000	None	0.000	0.0000	0.1405
2	1.2190	180.000	0.063000	Single	0.000	0.0000	0.6095
3	6.0310	90.000	0.047000	Cee	0.000	1.5000	3.0155
4	1.2190	0.000	0.043000	Single	0.000	0.0000	0.6095
5	0.2810	-120.000	0.063000	None	0.000	0.0000	0.1405

Direct Strength Parameters
Prequalified Section: Yes
Compression: Pcrl/Py = 0.00000 Pcrd/Py = 0.00000
Positive Mx: Mcrl/My = 0.16156 Mcrd/My = 0.21748
Negative Mx: Mcrl/My = 0.16156 Mcrd/My = 0.21748
Positive My: Mcrl/My = 0.00000 Mcrd/My = 0.00000
Negative My: Mcrl/My = 0.00000 Mcrd/My = 0.00000

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Fully Braced Strength - 2007 North American Specification - US (ASD)

Material Type: A653 HSLAS Grade 50, Fy=51.5 ksi

Compression		Positive Moment		Positive Moment	
Pao	1.1302 k	Maxo	3.3355 k-in	Mayo	0.6789 k-in
Ae	0.039500 in^2	Ixe	0.32622 in^4	Iye	0.01992 in^4
		Sxe(t)	0.10820 in^3	Sye(l)	0.07833 in^3
Tension		Sxe(b)	0.10816 in^3	Sye(r)	0.02201 in^3
Ta	4.0625 k				
		Negative Moment		Negative Moment	
		Maxo	3.3355 k-in	Mayo	0.5370 k-in
Shear		Ixe	0.32622 in^4	Iye	0.01077 in^4
Vay	0.0970 k	Sxe(t)	0.10820 in^3	Sye(l)	0.01990 in^3
Vax	0.7285 k	Sxe(b)	0.10816 in^3	Sye(r)	0.01741 in^3

Stiffened Channel element 3 w/t exceeds 200.

Calculation Details - 2007 North American Specification - US (ASD)

Axial Tension Strength
Ag=0.16154 in^2, Fy=51.5 ksi
Tn=8.3191 k — NAS Eq. C2-1
Ωt=1.67, ϕt=0.9

An=0.13364 in^2, Fu=60.8 ksi
Tn=8.125 k — NAS Eq. C2-2
Ωt=2, ϕt=0.75

Shear Strength
Stiffened Channel element 2
Aw=0.018824 in^2, Fv=30.9 ksi — NAS Eq. C3.2.1-2
Vn=0.58167 k at 180 deg
Ωv=1.6, ϕv=0.95
Stiffened Channel element 3
qs=1
Aw=0.10981 in^2, Fv=1.4132 ksi — NAS Eq. C3.2.1-4a
Vn=0.15518 k at 90 deg
Ωv=1.6, ϕv=0.95
Stiffened Channel element 4
Aw=0.018899 in^2, Fv=30.9 ksi — NAS Eq. C3.2.1-2
Vn=0.58397 k at 0 deg
Ωv=1.6, ϕv=0.95

Axial Compression Strength
Effective width calculations for part 1: Stiffened Channel
Element 1: Unstiffened, w=0.13966 in
f1=51.5 ksi, f2=51.5 ksi
ψ=1 — NAS Eq. B3.2-1
k=0.43 — NAS Eq. B3.2-3
λ=0.50332 — NAS Eq. B2.1-4
λ<0.673 (fully effective) — NAS Eq. B2.1-1
Element 2: Check for lip stiffener reduction
S=30.635 — NAS Eq. B4-7
Ia=2.5046e-5 in^4 — NAS Eq. B4-8
Is=3.1858e-6 in^4

ds=0.017765 in (lip ineffective width=0.1219 in)	NAS Eq. B4-6
k=2.1559	NAS Table B4-1
Element 2: Partially stiffened, w=1.0121 in	
f=51.5 ksi, k=2.1559	
λ=1.6289	NAS Eq. B2.1-4
ρ=0.531	NAS Eq. B2.1-3
b=0.53741 in (ineffective width=0.47466 in)	NAS Eq. B2.1-2
b1=0.034179 in, b2=0.50323 in	
Element 3: Treat as two unstiffened elements	
f1=51.5 ksi, f2=51.5 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=7.928	NAS Eq. B2.1-4
ρ=0.12263	NAS Eq. B2.1-3
b=0.26978 in (ineffective width=1.9301 in)	NAS Eq. B2.1-2
f1=51.5 ksi, f2=51.5 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=7.9424	NAS Eq. B2.1-4
ρ=0.12242	NAS Eq. B2.1-3
b=0.2698 in (ineffective width=1.9341 in)	NAS Eq. B2.1-2
Element 5: Unstiffened, w=0.13966 in	
f1=51.5 ksi, f2=51.5 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=0.50332	NAS Eq. B2.1-4
λ<0.673 (fully effective)	NAS Eq. B2.1-1
Element 4: Check for lip stiffener reduction	
S=30.635	NAS Eq. B4-7
Ia=2.5142e-5 in^4	NAS Eq. B4-8
Is=3.1858e-6 in^4	
ds=0.017697 in (lip ineffective width=0.12197 in)	NAS Eq. B4-6
k=2.1564	NAS Table B4-1
Element 4: Partially stiffened, w=1.0161 in	
f=51.5 ksi, k=2.1564	
λ=1.6351	NAS Eq. B2.1-4
ρ=0.52929	NAS Eq. B2.1-3
b=0.53779 in (ineffective width=0.47827 in)	NAS Eq. B2.1-2
b1=0.034072 in, b2=0.50372 in	
Ae=0.0395 in^2, Fy=51.5 ksi	
Pn=2.0343 k	NAS Eq. C4.1-1
Ωc=1.8, ϕc=0.85	

Positive Flexural Strength about X-axis

Sxe=0.10816 in^3, Fy=51.5 ksi	
Mnx=5.5703 k-in	NAS 1.2.2-9
Ωb=1.67, ϕb=0.9	

Negative Flexural Strength about X-axis

Sxe=0.10816 in^3, Fy=51.5 ksi	
Mnx=5.5703 k-in	NAS 1.2.2-9
Ωb=1.67, ϕb=0.9	

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Positive Flexural Strength about Y-axis
Effective width calculations for part 1: Stiffened Channel
Element 1: Unstiffened, w=0.13966 in
f1=50.419 ksi, f2=46.444 ksi
ψ=0.92116 NAS Eq. B3.2-1
k=0.45831 NAS Eq. B3.2-2
λ=0.48239 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 2: Stiffened, w=1.0121 in
f1=46.855 ksi, f2=-10.754 ksi
ψ=0.22952 NAS Eq. B2.3-1
k=10.176 NAS Eq. B2.3-2
λ=0.71512 NAS Eq. B2.1-4
ρ=0.96817 NAS Eq. B2.1-3
be=0.97985 in NAS Eq. B2.1-2
ho=1.219 in, bo=0.281 in, ho/bo=4.3381
b1=0.3034 in NAS Eq. B2.3-6
b2=0.49353 in NAS Eq. B2.3-7
Compression width=0.82314 in
Ineffective width=0.026201 in
Element 3: No compressive stress (fully effective)
Element 5: Unstiffened, w=0.13966 in
f1=50.419 ksi, f2=46.444 ksi
ψ=0.92116 NAS Eq. B3.2-1
k=0.45831 NAS Eq. B3.2-2
λ=0.48239 NAS Eq. B2.1-4
λ<0.673 (fully effective) NAS Eq. B2.1-1
Element 4: Stiffened, w=1.0161 in
f1=46.855 ksi, f2=-10.982 ksi
ψ=0.23438 NAS Eq. B2.3-1
k=10.23 NAS Eq. B2.3-2
λ=0.71605 NAS Eq. B2.1-4
ρ=0.96747 NAS Eq. B2.1-3
be=0.98301 in NAS Eq. B2.1-2
ho=1.219 in, bo=0.281 in, ho/bo=4.3381
b1=0.30393 in NAS Eq. B2.3-6
b2=0.49243 in NAS Eq. B2.3-7
Compression width=0.82314 in
Ineffective width=0.026776 in

Center of gravity shift: x=-0.0037342 in
Sye=0.022014 in^3, Fy=51.5 ksi
Mny=1.1337 k-in NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.9

Negative Flexural Strength about Y-axis
Effective width calculations for part 1: Stiffened Channel
Element 1: No compressive stress (fully effective)
Element 2: Stiffened, w=1.0121 in
f1=39.563 ksi, f2=-44.706 ksi
ψ=1.13 NAS Eq. B2.3-1
k=27.586 NAS Eq. B2.3-2
λ=0.39912 NAS Eq. B2.1-4
ρ=1 NAS Eq. B2.1-3

be=1.0121 in	NAS Eq. B2.1-2
ho=1.219 in, bo=6.031 in, ho/bo=0.20212	
b1=0.24505 in	NAS Eq. B2.3-3
b2=0.50603 in	NAS Eq. B2.3-4
Compression width=0.47515 in	
b1+b2 > compression width (fully effective)	
Element 3: Treat as two unstiffened elements	
f1=44.251 ksi, f2=44.251 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=7.3489	NAS Eq. B2.1-4
ρ=0.132	NAS Eq. B2.1-3
b=0.29039 in (ineffective width=1.9095 in)	NAS Eq. B2.1-2
f1=44.251 ksi, f2=44.251 ksi	
ψ=1	NAS Eq. B3.2-1
k=0.43	NAS Eq. B3.2-3
λ=7.3623	NAS Eq. B2.1-4
ρ=0.13177	NAS Eq. B2.1-3
b=0.2904 in (ineffective width=1.9135 in)	NAS Eq. B2.1-2
Element 5: No compressive stress (fully effective)	
Element 4: Stiffened, w=1.0161 in	
f1=39.897 ksi, f2=-44.706 ksi	
ψ=1.1205	NAS Eq. B2.3-1
k=27.312	NAS Eq. B2.3-2
λ=0.40439	NAS Eq. B2.1-4
ρ=1	NAS Eq. B2.1-3
be=1.0161 in	NAS Eq. B2.1-2
ho=1.219 in, bo=6.031 in, ho/bo=0.20212	
b1=0.24659 in	NAS Eq. B2.3-3
b2=0.50803 in	NAS Eq. B2.3-4
Compression width=0.47915 in	
b1+b2 > compression width (fully effective)	

Center of gravity shift: x=0.28289 in	
Sye=0.017412 in^3, Fy=51.5 ksi	
Mny=0.89672 k-in	NAS Eq. C3.1.1-1
Ωb=1.67, ϕb=0.9	