

# **COLD-FORMED STEEL BACK-TO-BACK HEADER ASSEMBLY TESTS**

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# COLD-FORMED STEEL BACK-TO-BACK HEADER ASSEMBLY TESTS

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The following publication has been developed for the American Iron and Steel Institute (AISI) which is comprised of representatives of steel producers in the US, Canada and Mexico. In the production of this publication, due diligence has been exercised in consulting a wide range of pertinent authorities and experiences. Efforts have been made to present accurate, reliable and useful information. AISI acknowledges the principal author of this publication, Kevin Bielat, Jay Crandall, P.E., Nader Elhadj, P.E., and Shawn McKee of the NAHB Research Center.

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## INTRODUCTION

The purpose of this test program was to investigate the structural capacity and performance of built-up headers typically used in cold-formed steel framing. The configuration of the headers tested was limited to doubled, back-to-back C-sections assembled in accordance with the *Prescriptive Method for Residential Cold-Formed Steel Framing* (Prescriptive Method) [1]. Currently, allowable spans of header assemblies are typically determined by doubling the allowable capacity of a single C-section (one of the two member built-up header assembly) as calculated in accordance with the *Specification for the Design of Cold-Formed Steel Structural Members* (AISI Design Specification) [2]. This conservative assumption and simplified design approach under-estimates the actual performance of the header assembly resulting in an uneconomical design and unnecessarily short header spans, particularly with thin deep sections. The findings of this study demonstrate that much greater header spans are possible with improved design rules. Benefits realized from built-up header assemblies are as follows:

- back-to back webs stiffen and support each other against web crippling at concentrated loads;
- back-to-back webs, of thin deep sections, stiffen and support each other against conditions where high shear loads exist; and,
- back-to-back headers produce a doubly-symmetric section which has a coinciding centroid and shear center, thus minimizing torsional stability concerns associated with singly-symmetric C-sections.

The major goal of the testing program is to support the development of more economical header designs for cold-formed steel framing. The results are intended to be implemented in future editions of the Prescriptive Method.

## LITERATURE REVIEW

A literature review of similar work was performed prior to testing. Little information pertaining to the benefits of back-to-back headers was found in the literature.

N. Hetrakul and W. Yu studied 73 I-beam specimens subjected to a combination of partial edge loading and bending moment [3]. The purpose of the work was to develop an interaction formula to predict the effect of the bending moment on web crippling strength of I-beams (double C-sections) having unreinforced webs. In 1992, Chen and Fang performed an experimental investigation of back-to-back I-beams connected by both resistance spot welding and arc-welding. Their study showed that both the stability and ultimate strength of these beams were different with respect to the two separate welding methods. The beams connected with the arc-welding approach were considerably stronger and more stable [4]. Neither of these reports addressed the objectives of this study.

## EXPERIMENTAL APPROACH

A total of 24 back-to-back header assemblies were constructed and tested in accordance with Table 1. Each header consisted of two C-sections fastened back-to-back with two #10 screws spaced 24 inches on center. The top and bottom tracks were fastened to the flanges of the C-sections with two #8 screws spaced at 24 inches on center (one through each flange). A detail of the built-up header assembly is shown in Figure 1. Representative header spans for the tests were selected from the header tables in the Prescriptive Method.

The header test specimens represent common construction practices. All steel used in the tests had a specified minimum tensile strength of 33 ksi. Actual mechanical properties were verified by tensile tests in accordance with ASTM A370-92 [5]. Base steel thicknesses were also determined following ASTM 90-93 [6]. The dimensions of all steel members used in the tests conformed to the Prescriptive Method requirements with the exception of some members falling below the minimum base steel thickness. The cold-formed steel members were supplied by two manufacturers

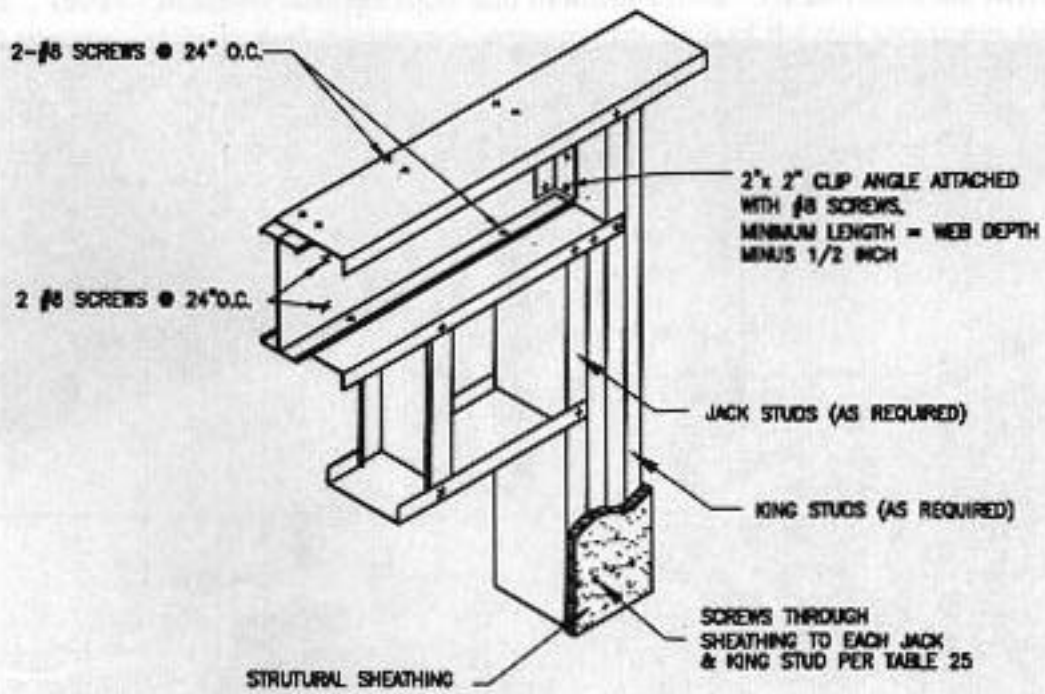
**TABLE 1**  
**Header Test**

| <b>HEADER CONFIGURATION</b> | <b>MEASURED DIMENSIONS<sup>1</sup></b> | <b>SPAN (INCHES)</b> | <b>NUMBER OF TESTS</b> |
|-----------------------------|--|----------------------|------------------------|
| 2-2x4x33                    | 1 5/8" x 3 1/2"                        | 47                   | 3                      |
| 2-2x4x43                    | 1 5/8" x 3 1/2"                        | 57                   | 3                      |
| 2-2x8x33                    | 1 5/8" x 8"                            | 36                   | 3                      |
| 2-2x8x43                    | 1 5/8" x 8"                            | 80                   | 3                      |
| 2-2x10x43                   | 1 5/8" x 10"                           | 67                   | 3                      |
| 2-2x10x54                   | 1 5/8" x 10"                           | 104                  | 3                      |
| 2-2x12x43                   | 1 5/8" x 12"                           | 57                   | 3                      |
| 2-2x12x68                   | 1 5/8" x 12"                           | 104                  | 3                      |

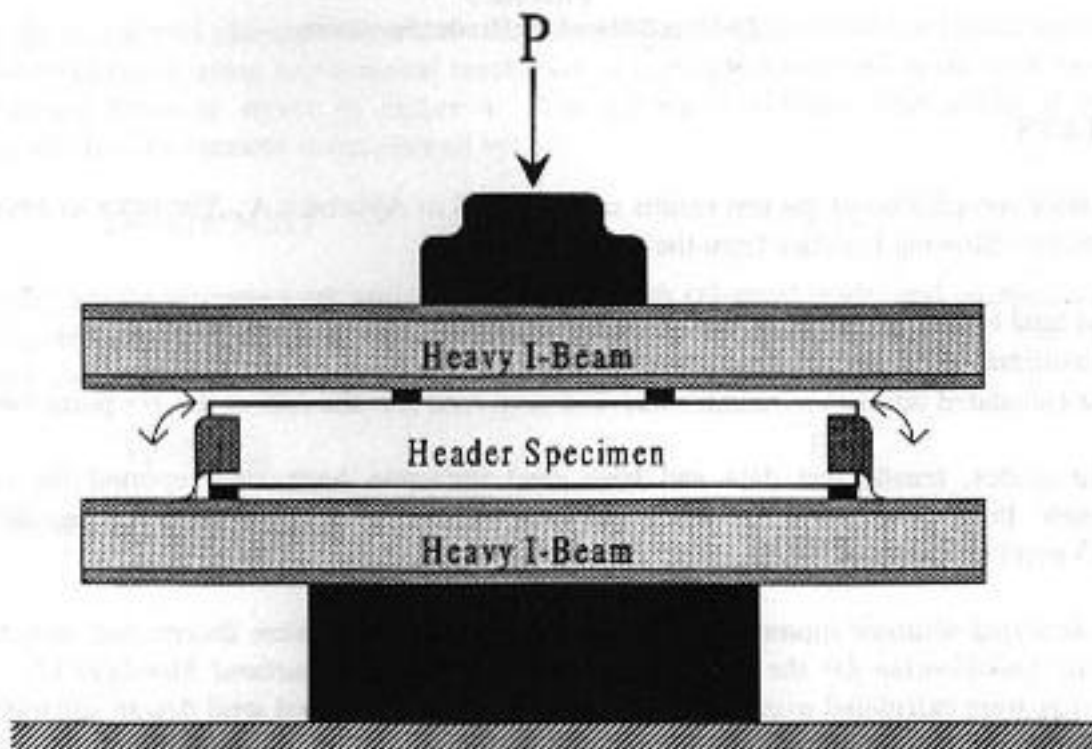
Notes:

1. All return lips were 1/2 inch. Dimensions were verified within a tolerance of  $\pm 1/16$  inch.

The header assemblies were tested using a universal testing machine. A heavy steel I-beam and 1.5-inch-wide steel bearing plates were used to apply a two-point concentrated load on the header samples. The ends of the header were supported on 1.5-inch-wide steel plates, representing a minimum typical bearing width (i.e. 1 1/2 inches). The test set-up is illustrated in Figure 2. The load was applied at a load rate of 1/20 inch per minute until the headers failed. Deflections at the midpoint of the header were measured during the full range of loads until failure. The ends of the header were restrained against weak axis rotation and lateral movement as shown in Figure 3. Rotation was allowed in the plane of bending to model a simply supported beam with pinned ends. Rollers were not used at the reactions or concentrated load points because of the intent to replicate conditions in actual use.



**FIGURE 1**  
Detail of a Built-up Header Assembly



**FIGURE 2**  
Header Test Apparatus



**FIGURE 3**  
**End Condition of the Header Specimens**

## **RESULTS**

A detailed compilation of the test results can be found in Appendix A. The table in Appendix A reports the following key data from the tests:

- the total load at  $L/240$  deflection (a typical building code deflection limit);
- the ultimate load and standard deviation; and
- the calculated ultimate moment, shear, and load (i.e. the sum of the 1/3-point loads).

Failure modes, tensile test data and base steel thickness were also reported for each test specimen. In all cases, the failure mode was local buckling of the compression flange initiated at the 1/3-point concentrated loads.

The calculated ultimate moment and calculated ultimate shear were determined in accordance with the *Specification for the Design of Cold-Formed Steel Structural Members* [2]. Section properties were calculated using AISIWIN Version 1.0 cold-formed steel design software [7]. A sample calculation can be found in Appendix B. Table 2 shows calculated ultimate shear and moment values. These values are based on average yield stresses and base steel thicknesses measured for each of the best specimens (see Appendix A). The composite action of the track members connected to the header was neglected in determining the calculated capacities. The capacity of a

single C-section was doubled to estimate the shear and moment capacity of the built-up section. In addition, the top flanges (compression flanges) were considered to be laterally supported at the 1/3-point concentrated loads.

**TABLE 2**  
**Calculated moment and Shear values**

| HEADER SPECIMEN | SPAN INCHES | CALULATED ULTIMATE MOMENT (FT-LBS) | CALULATED ULTIMATE SHEAR (LBS) |
|-----------------|-------------|------------------------------------|--------------------------------|
| 2-2x4x33        | 47          | 1,917                              | 1,343                          |
| 2-2x4x43        | 57          | 2,473                              | 2,986                          |
| 2-2x8x33        | 36          | 4,964                              | 854                            |
| 2-2x8x43        | 80          | 6,772                              | 1,923                          |
| 2-2x10x43       | 67          | 8,552                              | 1607                           |
| 2-2x10x54       | 104         | 12,369                             | 3,070                          |
| 2-2x12x43       | 57          | 12,972                             | 1,623                          |
| 2-2x12x68       | 104         | 22,776                             | 5,827                          |

Using the calculated ultimate shear and moments of Table 2, the calculated ultimate load,  $P_u$ , may be determined using conventional mechanics of a simply supported beam with two, equal, concentrated loads as shown in Figure 4. The estimated ultimate load produced from the calculated ultimate moment is determined by:

$$P_u = [6 \cdot M_u / L] \quad \text{Eq.1}$$

$P_u$  and  $M_u$  are the ultimate total load (i.e. the sum of both 1/3-point loads) and ultimate calculated moment, respectively, and  $L$  is the clear span length of the header assembly. The estimated ultimate load produced from the maximum shear equation is determined by:

$$P_u = [2 \cdot V_u] \quad \text{Eq.2}$$

$V_u$  is the ultimate calculated shear.

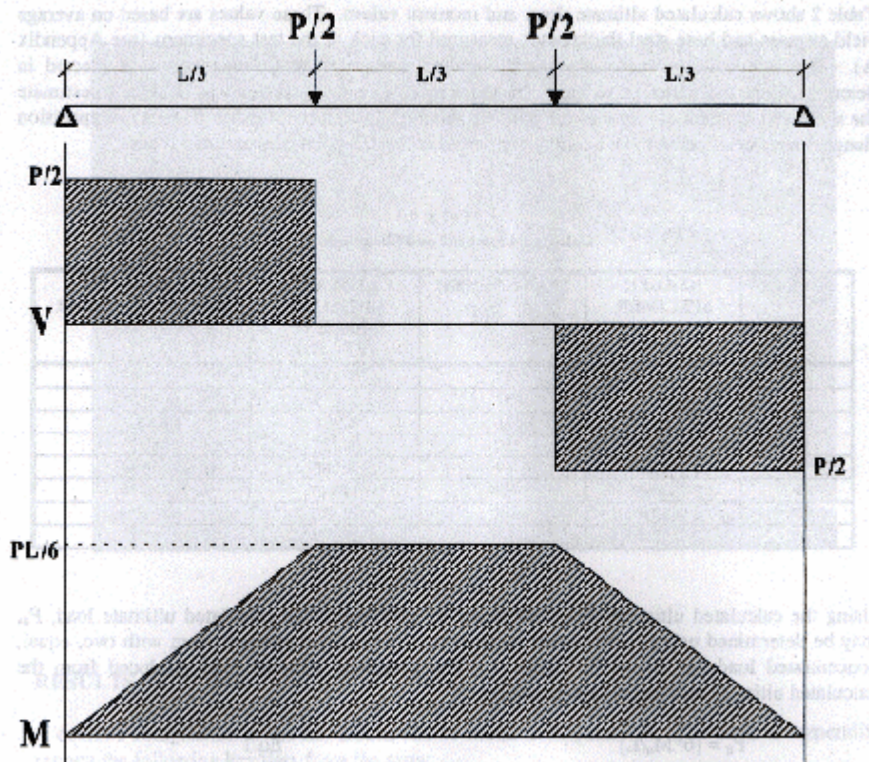


FIGURE 4  
Simply Supported Beam with 2-Point Loading

FIGURE 4  
Simply Supported Beam with 2-Point Loading

The test results demonstrate that the calculated values consistently underestimate the tested capacities, particularly for thin deep sections. As shown in the test data in Table 3, the tested ultimate load is greater than the calculated ultimate capacity, with shear controlling the design, by a factor ranging from 1.41 to 4.30. The following factors contributed to the large ratio of tested ultimate load to calculated ultimate load (shear controlled):

1. local buckling of the top (compression) flange at the concentrated load points initiated all failures, not web crippling or overall bending;
2. web height to thickness ( $h/t$ ) ratio effects are limited when webs brace each other (back-to-back members); and
3. span length.

**TABLE 3**  
**Summary Data and Analysis of Specimens**

| HEADER SPECIMEN | SPAN (INCH) | H/T RATIO | TESTED ULTIMATE LOAD (LBS) <sup>1</sup> | CALULATED ULTIMATE LOAD (LBS) <sup>2</sup> | LOAD INCREASE RATIO |
|-----------------|-------------|-----------|---|--|---------------------|
| 2-2x4x33        | 47          | 115       | 3,899                                   | 2,687 shear                                | 1.45                |
| 2-2x4x43        | 57          | 86        | 3,822                                   | 3,124 bending                              | 1.22                |
| 2-2x8x33        | 36          | 238       | 7,341                                   | 1,707 shear                                | 4.30                |
| 2-2x8x43        | 80          | 181       | 6,141                                   | 3,846 shear                                | 1.60                |
| 2-2x10x43       | 67          | 226       | 9,111                                   | 3,214 shear                                | 2.83                |
| 2-2x10x54       | 104         | 183       | 8,673                                   | 6,139 shear                                | 1.41                |
| 2-2x12x43       | 57          | 277       | 11,723                                  | 3,246 shear                                | 3.27                |
| 2-2x12x68       | 104         | 169       | 21,413                                  | 11,654 shear                               | 1.84                |

Note:

1. Values are based on an average of three tests per specimen.
2. Calculated values are based on twice the capacity of a single C-section designed according to the AISI Design Specification. The controlling load effect according to design calculations is noted.

The span length is critical in affecting whether shear or bending controls the design of a header. Shorter spans are typically controlled by shear while longer spans are typically controlled by bending. The fact that the spans were not varied for each member size creates a difficulty in completely analyzing the data without additional testing. As seen in Figure 4, the maximum moment and maximum shear just about coincide at the load points resulting in a potential combined stress problem. Combined bending and shear may have contributed to the failure of the header specimens. Therefore, as the span lengths varied, the relationship between the ratio of predicted bending to predicted shear failure also changed. This partially explains why the specimens with larger h/t ratios and shorter spans had higher load increase ratios and specimens with smaller h/t ratios and longer spans had lower load increase ratios. This trend is demonstrated in the data by comparing the two 2x8x33 and the two 2x10x54 header specimens.

Local buckling of the compression flange was the major visible mode of failure for all specimens. As the section sizes and spans increased so did the concentrated load at the 1.5-inch-wide load bearing plates. This increased the local buckling effects and initiated failure in the compression flange before yielding in the tension flange or lateral-torsional buckling of the whole member was experienced. However, local buckling of the top flange initiated a bending type of failure even in the short span specimens. As expected, the h/t shear reductions for the individual members using the AISI Specification were offset by the composite effects of the back-to-back header assembly. This is evident in the data in Table 3 because the “load increase ratios” are largest for header assemblies with the largest h/t ratios.

As seen in Table 3, moment controlled the calculated design capacity in only the 2-2x4x43 mil header assembly. This is due to the relatively long span with a low h/t ratio. This member also had the smallest h/t ratio and the smallest load increase ratio.

As previously stated, failure was initiated by local buckling of the compression flange due deformation of the flange under concentrated load applied through the 1.5-inch-wide bearing plates. Therefore, it is unclear that adding traditional web stiffeners at the load points (with typical construction practices and tolerances) would have dramatically improved performance such that the failure mode may have been yielding or lateral torsional buckling. Greater distribution of the load (using more than a two-point load) may have improved tested capacities. The 1.22 load increase ratio for the 2x4x43 test specimen could be due to the fact that the calculated values did not include composite action from the tracks attached to the top and bottom of the header flanges. Therefore, one could conclude that the bending capacity is predicted rather well and that a small load increase factor (e.g., 20 percent) may be appropriate when the headers are attached to track members on the top and bottom flange. However, since the failure mode was local buckling initiated, it is difficult to substantiate such a system effect from these tests. In summary, the local buckling failure mode indicates that other factors play a much less significant role than steel thickness and local buckling due to deformation in the flange caused by concentrated loads for the condition of these tests.

## CONCLUSIONS

The following conclusions are supported by the findings of this work:

- The practice of designing built-up header members by doubling single-member capacities results in very conservative spans.
- The largest increases in tested capacity relative to predicted capacity were realized for the back-to-back header specimens made from individual members with high h/t ratios and shorter spans (i.e. the single member design capacity was controlled by shear).
- The smallest increases in tested capacity relative to predicted capacity were realized for the back-to-back headers with longer spans and smaller h/t ratios (i.e., the single member design capacity was controlled by bending).
- The consistent failure mode in all tests was related to local buckling of the top (compression flange) at the concentrated load points.
- Greater tested capacities would undoubtedly have been achieved with a more uniform load distribution rather than the load created by the 2-point load apparatus, particularly for longer header spans that are intended for use in a 24 inch on-center framing system.

## RECOMMENDATIONS

Although the results are very promising, more testing and analysis of the data is needed to develop an accurate design procedure for the built-up header assemblies. The following recommendations are suggested for future tests and analysis:

- use larger load bearing plates to minimize local buckling effects and isolate other failure modes (i.e. bending, shear, etc.), although this would not be representative of a repetitive member framing system;
- brace the compression flange every 24 inches if the span is over 48 inches;
- a wider range of span lengths should be tested for each specimen size;
- test each specimen for shear and bending failures separately;
- developed improved h/t relationships for built-up sections; and
- investigate a design approach using a true back-to-back section model in lieu of doubling the capacity of a single member model.

These additional tests would create a comprehensive data set from which improved design rules could be created and developed for use in the AISI Design Specification for back-to-back headers constructed from C-sections. The potential design and construction cost savings are clearly evidenced in the findings of this study.

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## **APPENDIX A**

# Header Test Results and Comparisons

Deflection L/ 240

| Test            | Span (Inches) | Measured Dimensions | Test Ultimate Load <sup>1</sup> (lbs) | Standard Deviation (lbs) | Allowable Deflection (in) | Load at Allowable Deflection (lbs) | ht ratio | Measured Base Metal Thickness <sup>2</sup> (in) | Measured Yield Stress Fy <sup>2</sup> (ksi) | Measured Ultimate Stress Fu <sup>2</sup> (ksi) | Percent Elongation (2" gauge length) | Calculated Ultimate Moment (ft-lb) | Calculated Ultimate Shear (lbs) | Calculated Ultimate Load (lbs) | Ratio Tested To Calculated Ultimate Load | Controls Calculated Design |
|-----------------|---------------|---------------------|---------------------------------------|--------------------------|---------------------------|------------------------------------|----------|---|---|--|--------------------------------------|------------------------------------|---------------------------------|--------------------------------|--|----------------------------|
| 2x4x3 test 1a   | 47            | 1-5/8"x3-1/2"       | 4,076                                 |                          | 0.1958                    | X                                  | 115      | 0.0327  | 48.93                                       | 55.96  | 23%                                  | 1,917                              | 1,343                           | 2,687                          | 1.52                                     | SHEAR                      |
| 2x4x3 test 1b   | 47            | 1-5/8"x3-1/2"       | 3,774                                 |                          | 0.1958                    | X                                  | 117      | 0.0321  | 50.16                                       | 58.26  | 27%                                  | 1,917                              | 1,343                           | 2,687                          | 1.40                                     | SHEAR                      |
| 2x4x3 test 1c   | 47            | 1-5/8"x3-1/2"       | 3,648                                 |                          | 0.1958                    | X                                  | 115      | 0.0326  | 49.39                                       | 58.26  | 20%                                  | 1,917                              | 1,343                           | 2,687                          | 1.43                                     | SHEAR                      |
| Test 1 average  | 47            | 1-5/8"x3-1/2"       | 3,899                                 | 157.41                   | 0.1958                    | X                                  | 115      | 0.0325  | 49.49                                       | 57.50  | 23%                                  | 1,917                              | 1,343                           | 2,687                          | 1.45                                     | SHEAR                      |
| 2x4x3 test 2a   | 57            | 1-5/8"x3-1/2"       | 3,774                                 |                          | 0.2375                    | X                                  | 86       | 0.0433  | 47.86                                       | 53.18  | 27%                                  | 2,473                              | 2,986                           | 3,124                          | 1.21                                     | MOMENT                     |
| 2x4x3 test 2b   | 57            | 1-5/8"x3-1/2"       | 3,848                                 |                          | 0.2375                    | X                                  | 86       | 0.0434  | 47.47                                       | 53.46  | 26%                                  | 2,473                              | 2,986                           | 3,124                          | 1.23                                     | MOMENT                     |
| 2x4x3 test 2c   | 57            | 1-5/8"x3-1/2"       | 3,844                                 |                          | 0.2375                    | 2,595                              | 86       | 0.0432  | 49.07                                       | 53.47  | 27%                                  | 2,473                              | 2,986                           | 3,124                          | 1.23                                     | MOMENT                     |
| Test 2 average  | 57            | 1-5/8"x3-1/2"       | 3,822                                 | 41.62                    | 0.2375                    | 2,595                              | 86       | 0.0433  | 48.13                                       | 53.37  | 27%                                  | 2,473                              | 2,986                           | 3,124                          | 1.22                                     | MOMENT                     |
| 2x6x3 test 8a   | 36            | 1-5/8"x8"           | 7,726                                 |                          | 0.1500                    | 7,430                              | 240      | 0.0323  | 53.68                                       | 56.53  | 25%                                  | 4,964                              | 854                             | 1,707                          | 4.53                                     | SHEAR                      |
| 2x6x3 test 8b   | 36            | 1-5/8"x8"           | 6,898                                 |                          | 0.1500                    | 5,722                              | 236      | 0.0328  | 52.87                                       | 56.14  | 28%                                  | 4,964                              | 854                             | 1,707                          | 3.92                                     | SHEAR                      |
| 2x6x3 test 8c   | 36            | 1-5/8"x8"           | 7,598                                 |                          | 0.1500                    | 7,598                              | 238      | 0.0325  | 53.30                                       | 56.13  | 23%                                  | 4,964                              | 854                             | 1,707                          | 4.45                                     | SHEAR                      |
| Test 8 average  | 36            | 1-5/8"x8"           | 7,341                                 | 560.23                   | 0.1500                    | 6,917                              | 238      | 0.0326  | 53.28                                       | 56.27  | 25%                                  | 4,964                              | 854                             | 1,707                          | 4.30                                     | SHEAR                      |
| 2x6x43 test 7a  | 80            | 1-5/8"x8"           | 5,682                                 |                          | 0.3333                    | 4,652                              | 182      | 0.0424  | 51.95                                       | 55.95  | 27%                                  | 6,772                              | 1,923                           | 3,846                          | 1.48                                     | SHEAR                      |
| 2x6x43 test 7b  | 80            | 1-5/8"x8"           | 6,464                                 |                          | 0.3333                    | 5,030                              | 179      | 0.0431  | 51.04                                       | 55.88  | 26%                                  | 6,772                              | 1,923                           | 3,846                          | 1.68                                     | SHEAR                      |
| 2x6x43 test 7c  | 80            | 1-5/8"x8"           | 6,276                                 |                          | 0.3333                    | 5,750                              | 181      | 0.0427  | 51.58                                       | 56.27  | 24%                                  | 6,772                              | 1,923                           | 3,846                          | 1.63                                     | SHEAR                      |
| Test 7 average  | 80            | 1-5/8"x8"           | 6,141                                 | 408.19                   | 0.3333                    | 5,111                              | 181      | 0.0427  | 51.52                                       | 55.97  | 26%                                  | 6,772                              | 1,923                           | 3,846                          | 1.60                                     | SHEAR                      |
| 2x10x43 test 4a | 67            | 1-5/8"x10"          | 8,246                                 |                          | 0.2792                    | X                                  | 227      | 0.0428  | 49.90                                       | 54.56  | 27%                                  | 8,552                              | 1,607                           | 3,214                          | 2.57                                     | SHEAR                      |
| 2x10x43 test 4b | 67            | 1-5/8"x10"          | 8,378                                 |                          | 0.2792                    | X                                  | 225      | 0.0433  | 49.25                                       | 54.57  | 26%                                  | 8,552                              | 1,607                           | 3,214                          | 2.61                                     | SHEAR                      |
| 2x10x43 test 4c | 67            | 1-5/8"x10"          | 10,710                                |                          | 0.2792                    | 8,239                              | 227      | 0.0429  | 50.33                                       | 54.87  | 26%                                  | 8,552                              | 1,607                           | 3,214                          | 3.33                                     | SHEAR                      |
| Test 4 average  | 67            | 1-5/8"x10"          | 9,111                                 | 1386.06                  | 0.2792                    | 8,239                              | 226      | 0.0430  | 49.83                                       | 54.87  | 26%                                  | 8,552                              | 1,607                           | 3,214                          | 2.83                                     | SHEAR                      |
| 2x10x54 test 6a | 104           | 1-5/8"x10"          | 8,766                                 |                          | 0.4333                    | 7,926                              | 181      | 0.0536  | 68.10                                       | 70.90  | 14%                                  | 12,369                             | 3,070                           | 6,139                          | 1.41                                     | SHEAR                      |
| 2x10x54 test 6b | 104           | 1-5/8"x10"          | 8,856                                 |                          | 0.4333                    | 7,630                              | 181      | 0.0536  | 68.10                                       | 70.90  | 7%                                   | 12,369                             | 3,070                           | 6,139                          | 1.44                                     | SHEAR                      |
| 2x10x54 test 6c | 104           | 1-5/8"x10"          | 8,396                                 |                          | 0.4333                    | 6,345                              | 189      | 0.0514  | 66.98                                       | 68.84  | 13%                                  | 12,369                             | 3,070                           | 6,139                          | 1.37                                     | SHEAR                      |
| Test 6 average  | 104           | 1-5/8"x10"          | 8,673                                 | 243.79                   | 0.4333                    | 7,300                              | 183      | 0.0529  | 67.72                                       | 70.21  | 11%                                  | 12,369                             | 3,070                           | 6,139                          | 1.41                                     | SHEAR                      |
| 2x12x43 test 3a | 57            | 1-5/8"x12"          | 11,670                                |                          | 0.2375                    | X                                  | 280      | 0.0419  | 66.48                                       | 66.48  | 10%                                  | 12,972                             | 1,623                           | 3,246                          | 3.61                                     | SHEAR                      |
| 2x12x43 test 3b | 57            | 1-5/8"x12"          | 12,900                                |                          | 0.2375                    | X                                  | 276      | 0.0425  | 66.48                                       | 66.48  | 15%                                  | 12,972                             | 1,623                           | 3,246                          | 3.97                                     | SHEAR                      |
| 2x12x43 test 3c | 57            | 1-5/8"x12"          | 10,600                                |                          | 0.2375                    | 8,096                              | 275      | 0.0427  | 66.17                                       | 66.17  | 13%                                  | 12,972                             | 1,623                           | 3,246                          | 3.27                                     | SHEAR                      |
| Test 3 average  | 57            | 1-5/8"x12"          | 11,723                                | 1,150.93                 | 0.2375                    | 8,096                              | 277      | 0.0424  | 66.37                                       | 66.37  | 13%                                  | 12,972                             | 1,623                           | 3,246                          | 3.61                                     | SHEAR                      |
| 2x12x68 test 5a | 104           | 1-5/8"x12"          | 21,270                                |                          | 0.4333                    | 17,710                             | 170      | 0.0684  | 65.13                                       | 70.77  | 18%                                  | 22,776                             | 5,827                           | 11,654                         | 1.83                                     | SHEAR                      |
| 2x12x68 test 5b | 104           | 1-5/8"x12"          | 22,920                                |                          | 0.4333                    | 16,440                             | 168      | 0.0691  | 62.98                                       | 68.97  | 19%                                  | 22,776                             | 5,827                           | 11,654                         | 1.97                                     | SHEAR                      |
| 2x12x68 test 5c | 104           | 1-5/8"x12"          | 20,050                                |                          | 0.4333                    | 19,340                             | 168      | 0.0688  | 65.17                                       | 69.25  | 19%                                  | 22,776                             | 5,827                           | 11,654                         | 1.72                                     | SHEAR                      |
| Test 5 average  | 104           | 1-5/8"x12"          | 21,413                                | 1,440.36                 | 0.4333                    | 17,830                             | 169      | 0.0688  | 64.39                                       | 69.66  | 19%                                  | 22,776                             | 5,827                           | 11,654                         | 1.84                                     | SHEAR                      |

Notes:

1. The failure mode was local buckling of the compression flange at one of the two concentrated loads for all tests.
2. Measured yield stress, ultimate stress, percent elongation and thickness represent the average of three coupon samples taken from the lot of the specified material.
3. The 2x12x43 section ht ratio exceeds 260. Therefore, a thickness of 0.0451" was used for calculation purposes due to limitations in the analysis software.
4. All return lips were 1/2 inch. Dimensions were verified to be within a tolerance of +/- 1/16 inch.



## Back-to-Back Header Assembly



## **APPENDIX B**

## 2x8x33 Header Bending Calculations

Given:

Section properties are taken from Section Properties table

|      |                        |               |                        |               |                          |
|------|------------------------|---------------|------------------------|---------------|--------------------------|
| Sx=  | 0.556 in <sup>3</sup>  | E=            | 29,500,000 psi         | Sf=           | 0.811725 in <sup>3</sup> |
| Fy=  | 53,300 psi             | punchout=     | 1.5 in                 | rx=           | 2.9415 in                |
| h=   | 8 in                   | R=            | 0.09375 in             | ry=           | 0.5499 in                |
| t=   | 0.0326 in              | K=            | 1                      | ro=           | 3.141 in                 |
| Fyc= | 53,300 psi             | L=            | 12 in                  | J=            | 0.000138 in <sup>4</sup> |
| Pi=  | 3.14159                | A=            | 0.3889 in <sup>2</sup> | G=            | 11,300,000               |
| psi  |                        |               |                        |               |                          |
| Cw=  | 1.5257 in <sup>6</sup> | Ixx (gross) = | 3.2469 in <sup>4</sup> | Ycg (gross) = | 4                        |

### C3 Flexural Members

Find Allowable Bending Moment (Ma)

$$Ma = Mn/Safety$$

$$Safety = 1.67$$

$$Ma = Mn/1.67$$

Mn is the smallest of C3.1.1, C3.1.2 and C3.1.3

C3.1.1 Nominal Section Strength  
Based on initiation of yielding

$$Mn = SeFy$$

$$Mn = 30,167.80 \text{ in-lb}$$

$$18064.55$$

$$1505.379$$

C3.1.2 Lateral Buckling Strength

$$Mn = ScMc/Sf$$

For  $Me > .5My$

$$Mc = My(1 - My/4Me)$$

$$My = SfFy$$

$$My = 43,264.94 \text{ in-lb}$$

$$Me = CbroA(OeyOt)^{.5}$$

$$Cb = 1 \text{ (M for unbraced length is larger than M @ ends)}$$

$$Oey = \frac{\pi^2 E}{(KxLx/rx)^2}$$

$$Oey = 611,400.76 \text{ psi}$$

$$Ot = \frac{1}{Aro^2} (GJ + \pi^2 Ecw / (KtLt)^2)$$

$$Ot = 804,401.80 \text{ psi}$$

$$Me = 856,653.87 \text{ in-lb}$$

$$Mc1 = My(1 - My/4Me)$$

$$Mc1 = 42,718.67 \text{ in-lb}$$

For  $Me \leq .5My$

$$Mc2 = Me$$

$$Mc2 = 856,653.87 \text{ in-lb}$$

$$Mc = 42,718.67 \text{ in-lb}$$

$$M_n = 29,786.90 \text{ in-lb}$$

C3.1.3 Beams having one flange through – fastened to Deck or Sheathing  
Does not apply

$$M_n = 29,786.90$$

$$M_a = 17,836.47 \text{ in-lb}$$
$$M_a = 1,486.37 \text{ ft-lb}$$

### C3.2 Strength for Shear (unpunched)

Compute the depth of the flat portion of the web (H)

$$H = h - 2(R + t) = 7.7473$$

$$H/t = 237.64724$$

Calculate  $1.38(Ekv/Fy)^{.5}$

$$k_v = 5.34$$

$$1.38(Ekv/Fy)^{.5} = 75.023465$$

$$\text{If } H/t \leq 75.023465 \text{ lb}$$

$$V_{a1} = .38t^2(kvFyE)^{.5} \leq .4Fyht$$

$$V_{a1} = 1,170.21 \text{ lb}$$

$$\text{If } H/t > 75.023465 \text{ lb}$$

$$V_{a2} = .53Ekvt^3/H$$

$$V_{a2} = 373.37 \text{ lb}$$

$$V_a = 373.4 \text{ lb}$$

### ICBO method for calculating Shear (punched)

Calculate reduction factor

$$q_s = 1 - 1.1(a/d)$$

$$q_s = 0.79375$$

$$V_a = 296.4 \text{ lb}$$

### Header Comparisons:

Span = 36 in

$$V_{u2} = 2 * V_a * 1.44$$

$$V_{u2} = 853.53 \text{ lb}$$

$$M_{a2} = 2 * M_a * 1.67$$

$$M_{a2} = 4964.48 \text{ ft-lb}$$

$$P_{uv} = 2 * V_{u2}$$

$$P_{uv} = 1707.06 \text{ lb}$$

$$P_{um} = 6 * M_{u2} / L$$

Pum = 9928.97 lb

**Pu = 1707.06 lb**

**1986 AISU Specification w/1989 Addenda**

**Date: 7/7/97**

**NAHB Research Center**

Section Designation:

Input Properties:

|                  |          |                        |           |
|------------------|----------|------------------------|-----------|
| Web Height =     | 8.000 in | Steel Thickness =      | 0.0326 in |
| Top Flange =     | 1.625 in | Inside Corner Radius = | 0.0938 in |
| Bottom Flange =  | 1.625 in | Yield Stress, Fy =     | 53.3 ksi  |
| Stiffening Lip = | 0.500 in |                        |           |
| Punchout width = | 1.500 in | Punchout Length =      | 4.000 in  |

Output Properties:

Effective Section Properties, Strong Axis

|  |                        |
|--|------------------------|
| Neutral Axis from Top Fiber (Ycg)      | 4.7091 in              |
| Moment of Inertia for Deflection (Ixx) | 3.2469 in <sup>4</sup> |
| Section Modulus (Sxx)                  | 0.5660 in <sup>3</sup> |
| Allowable Bending Moment (Ma)          | 1505.45 Ft-lb          |

Gross Section Properties of Full Section, Strong Axis

|  |                        |
|--|------------------------|
| Neutral Axis from Top Fiber (Ycg)      | 4.0000 in              |
| Moment of Inertia for Deflection (Ixx) | 3.3652 in <sup>4</sup> |
| Cross Sectional Area (A)               | 0.3889 in <sup>2</sup> |
| Radius of Gyration (Rx)                | 2.9415 in              |

Section Properties, Weak Axis

|  |                        |
|--|------------------------|
| Gross Neutral Axis (Xcg) From Web Face     | 0.3454 in              |
| Gross Moment of Inertia (Iyy)              | 0.1176 in <sup>4</sup> |
| Radius of Gyration (Rx)                    | 0.5499 in              |
| Effective Section Modulus (Syy)            | 0.0734 in <sup>3</sup> |
| Effective Neutral Axis (Xcg) from Web Face | 0.7789 in              |
| Allowable Moment (May)                     | 195.20 Ft-lb           |

Other Section Property Data

|  |                        |
|--|------------------------|
| Net Area at Punchouts                    | 0.3400 in <sup>2</sup> |
| Member weight per Foot of Length         | 1.2590 lb/ft           |
| Allowable Shear Force in Web (Unpunched) | 373.37 lb              |
| Allowable Shear Force in Web (Punched)   | 296.36 lb              |
| Pao for use in Interaction Equation C5-2 | 3791 lb                |

Torsional Properties

|  |                        |
|--|------------------------|
| Dist. from Shear Center to Neutral Axis (Xo) | -0.9546 in             |
| St. Venant Torsion Constant (J x 1000)       | 0.1378 in <sup>4</sup> |
| Warping Constant (Cw)                        | 1.5257 in <sup>6</sup> |
| Radii of Gyration (Ro)                       | 3.1410 in              |
| Torsional Flexural Constant (Beta)           | 0.9076                 |

**\*\*\*WEB DEPTH-TO-THICKNESS RATIO EXCEEDS 200\*\*\***

## **APPENDIX C**

## METRIC CONVERSIONS

1 mil = 1/1000 inch

1 kip = 1000 lbs = 4.448 kN

1 inch = 1000 mils = 25.40 mm