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# Experimental Evaluation of the Strength and Behaviour of 16- and 18-gauge Cold Formed Steel Top Track Systems

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research report

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## PREFACE

This report was developed by the University of New Brunswick for the Canadian Sheet Steel Building Institute, the Steel Framing Alliance and the Prescriptive Methods Subcommittee of the AISI Committee on Framing Standards. The objective of this project was experimental determination of the strength and stiffness of load bearing top track assemblies.

This project involved tests on 60 assemblies, including track and 2x4 wood on a 3-5/8 inch stud wall, standard track on 3-5/8 inch stud wall, track and 2x6 wood on 6-inch stud wall, standard track on 6-inch stud wall and deep leg track on 3-5/8 inch stud wall. Based on the rather limited structural capacities, it was concluded that it was not worth pursuing the development of a design methodology or including details and span-load tables in the AISI *Standard for Cold-Formed Steel Framing – Prescriptive Method for One and Two Family Dwellings* for the tested assemblies.

Research Team
Steel Framing Alliance

# EXPERIMENTAL EVALUATION OF THE STRENGTH AND BEHAVIOUR OF 16- AND 18-GAUGE COLD FORMED STEEL TOP TRACK SYSTEMS - 92 MM AND 152 MM, 16”- and 24”-SPANS (W & W/O 2X4 AND 2X6 WOOD TOP PLATES)

**A Study Conducted at the University of New Brunswick Structural Engineering Laboratory under the Supervision of J. L. Dawe, PhD, P.Eng.**

**Submitted to: CSSBI; attn.: Steve Fox, PhD, P.Eng.**

**September 2005**

## 1.0 INTRODUCTION

### 1.1 Background

This research project was proposed by the Canadian Sheet Steel Building Institute on behalf of the Steel Framing Alliance in order to continue research and the development of standards for cold-formed steel framing. The American Iron and Steel Institute has published the *Standard for Cold-Formed Steel Framing – Prescriptive Method for One and Two Family Dwellings* which provides member selection tables and construction methods that can be used to design and construct a residential home. One of the requirements in this standard is for in-line framing, where the roof framing must line up with a wall stud below to provide a direct load path. This requirement can be waived if there is a load distribution member provided to transfer the load from the roof framing to the wall studs.

It is common practice in residential framing to use roof trusses at 24 in. spacing and wall studs at 16 in spacing. In this situation a load distribution member is needed for the building to be constructed in accordance with the prescriptive method. At the present time the prescriptive method does not provide any selection tables for these load distribution members. Therefore, if a builder wants to use steel framing that is not in-line, an engineer would be needed to design this structural load distribution member. The steel industry wants to remove this limitation and provide prescriptive member selection tables and construction details for load-bearing top track configurations to be used within the limitations of the prescriptive method.

### 1.2 Objectives

The following objectives were proposed by the Steel Framing Alliance. The objectives of this research include the experimental determination of the strength and stiffness of the following load bearing top track assemblies:

A. Track and 2x4 wood on 3-5/8 inch (92 mm) stud wall
B. Standard Track on 3-5/8 inch (92mm) stud wall
C. Track and 2x6 wood on 6 inch (152 mm) stud wall
D. Standard Track on 6 inch (152 mm) stud wall
E. Deep leg track on 3-5/8 inch (92 mm) stud wall

### 1.3 Scope

Research began with a literature review of topics pertaining to both cold-formed steel and top-load bearing tracks. Current standards for steel-frame residential housing and cold-formed steel were also examined.

Testing was performed on sixty specimens which were separated into 5 groups, based upon their composition including the type of track and whether the specimen was coupled with wood. Each group (A, B, C, D and E) consisted of 16- and 18-gauge tracks on 16 and 24 inch spans. All specimens were tested using a 100 000 kg Baldwin Universal Testing Machine and deflections were measured using linear strain converters (LSCs) placed underneath bearing points.

A theoretical analysis was completed, using formulae from the North American Specification for the Design of Cold Formed Steel Structural Members. The analytical results were compared with experimental results. Examination of the effects of uplift was beyond the scope of this research.

### 1.4 Outline

Part 2 of this report summarizes a recent NAHB study. In Part 3, the experimental program is outlined, while in Part 4 the results from tests are presented in written and in tabular form. Finally, Part 5 contains a summary and conclusion to the report as well as several recommendations. The terms, “Ult.” and “Max.” as well as ‘ultimate” and “maximum” are used synonymously in this report.

## 2.0 NAHB Report

In March 2003, the National Association of Home Builders (NAHB) completed a study entitled “Cold-formed Steel Top Load Bearing Tracks”. At the time of testing, little evidence of research on top-load bearing tracks was found, although it did note that different configurations for the top track had been developed by Australians and a company known as Mitek (NAHB 2003).

The NAHB study tested three configurations of tracks – a deep-leg track, a standard track with a wood top plate, and a J-Track. All tests were performed with a 24” spacing, and loads at the centre of each span. Prescriptive Method tables were drawn up based on the results obtained. It was determined that the most applicable section for general residential construction was the combination of a 20 gauge standard track and a 2x4 wood top plate (NAHB 2003).

## 3.0 EXPERIMENTAL PROGRAM

### 3.1 Introduction

According to the CFS Code, framing must be in-line so that roof trusses are aligned with studs in the supporting stud wall or, otherwise, the building must be designed and approved by an accredited engineer. Another option is to use approved members to transfer roof truss loads to the wall studs. The main objective of this research was to investigate how standard light gauge steel tracks behave when used as top load-bearing tracks.

Specimens were tested in the research presented herein to determine maximum permissible loadings on such load-bearing top tracks. Five series of tests, constructed of different sizes of track and with or without wood members, were conducted with load spacing of 16 and 24 inches.

### 3.2 Specimen Identification

Specimens were designated according to their count number, objective letter, stud spacing, and gauge thickness. Therefore, for example, 3A24-18 indicates the third specimen tested according to the first objective (composite A-track and 2x4 wood on 3-5/8" stud) with a 24 inch stud spacing and 18-gauge steel thickness.

### 3.3 Fabrication

Each specimen was constructed as a frame consisting of three 8-inch long studs spaced at 16 or 24 inches and supporting a top track as described in objective A, B, C, D, or E. The assembly was completed by attaching a bottom track of the same specified size as the top track. Studs and track were connected with #8 hexagonal self-drilling screws. Standard 2x4 pieces of lumber were attached as required to top tracks using 3-inch long galvanized common nails. Stud spacing was either 610 mm (24") or 406 mm (16"). Typical specimens are diagrammatically illustrated in Figures 3.1 and 3.2.

The three types of top track employed in this research included 3-5/8 inch standard track, 6 inch standard track, and 3-5/8 inch deep leg track. Table 3.1 lists the different test groups, the type of track used, and other fabrication details. The dimensions of all tracks and studs used are given in Tables 3.1, 3.2, and 3.3.

**Table 3.1 – Fabrication Details of Test Specimens**

| Objective | Specimen | Gauge | Spacing | Top Track | Wood Top Plate |
|---|---|---|---|---|---|
| A | A16-16 | 16 | 16” | 92 mm (3 5/8”) | Yes |
| | A16-18 | 18 | 16” | 92 mm (3 5/8”) | Yes |
| | A24-16 | 16 | 24” | 92 mm (3 5/8”) | Yes |
| | A24-18 | 18 | 24” | 92 mm (3 5/8”) | Yes |
| B | B16-16 | 16 | 16” | 92 mm (3 5/8”) | No |
| | B16-18 | 18 | 16” | 92 mm (3 5/8”) | No |
| | B24-16 | 16 | 24” | 92 mm (3 5/8”) | No |
| | B24-18 | 18 | 24” | 92 mm (3 5/8”) | No |
| C | C16-16 | 16 | 16” | 152 mm (6”) | Yes |
| | C16-18 | 18 | 16” | 152 mm (6”) | Yes |
| | C24-16 | 16 | 24” | 152 mm (6”) | Yes |
| | C24-18 | 18 | 24” | 152 mm (6”) | Yes |
| D | D16-16 | 16 | 16” | 152 mm (6”) | No |
| | D16-18 | 18 | 16” | 152 mm (6”) | No |
| | D24-16 | 16 | 24” | 152 mm (6”) | No |
| | D24-18 | 18 | 24” | 152 mm (6”) | No |
| E | E16-16 | 16 | 16” | 92 mm (3 5/8”)-DL | No |
| | E16-18 | 18 | 16” | 92 mm (3 5/8”)-DL | No |
| | E24-16 | 16 | 24” | 92 mm (3 5/8”)-DL | No |
| | E24-18 | 18 | 24” | 92 mm (3 5/8”)-DL | No |

DL – Deep Leg (Std. leg otherwise); 18 ga. ≡ 1.22 mm; 16 ga. ≡ 1.52 mm

**Table 3.2 – Track Dimensions**

| Designation | a(mm) | b(mm) |
|---|---|---|
| 3 $^{5}/_{8}$” | 29.97 | 92.58 |
| 6” | 29.97 | 152.91 |
| DL | 50.80 | 92.58 |

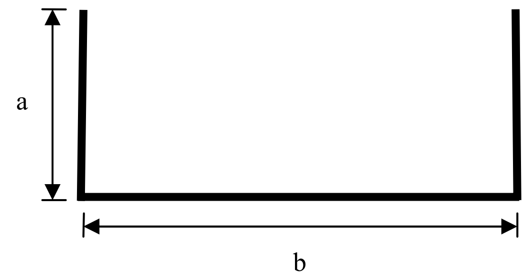
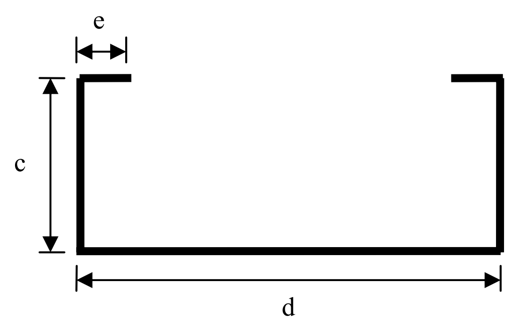



**Table 3.3 – Stud Dimensions**

| Designation | c(mm) | d(mm) | e(mm) |
|---|---|---|---|
| 3 $^{5}/_{8}$” | 41.28 | 92.08 | 12.7 |
| 6” | 41.28 | 152.40 | 12.7 |




### 3.4 Experimental Set-up

Typical test set-ups are illustrated in Figures 3.1 and 3.2 which show the locations of the point-applied loads for the 16 inch and 24 inch stud spacing configurations. Figure 3.3 is a photograph of a typical set-up in the Baldwin UTM.

A distribution beam was used to transfer equal loads from the load head to the points of load application of each specimen. Reaction plates measuring approximately 18x50x250 mm were placed between each point of load application of the distribution beam and the test specimen. A W200x36 steel section was utilized as a support reaction beam for the majority of specimens. Due to various laboratory demands, it was necessary to replace this beam with a C230x30 steel section for all specimens under Objective C with the exception of specimen 1C16-16.

As shown in Figure 3.3, load cells were placed between two of the specimen supports and the platen of the UTM while a ball and socket joint was used to support the specimen at the third support point. Linear strain converters (LSCs) were used to measure deflections. Two LSCs were placed so as to measure downward movement of the distribution beam and another was positioned on the platen to track its progress upward. Steel restraints were placed at either end of the specimen to prevent in-plane and lateral movement.

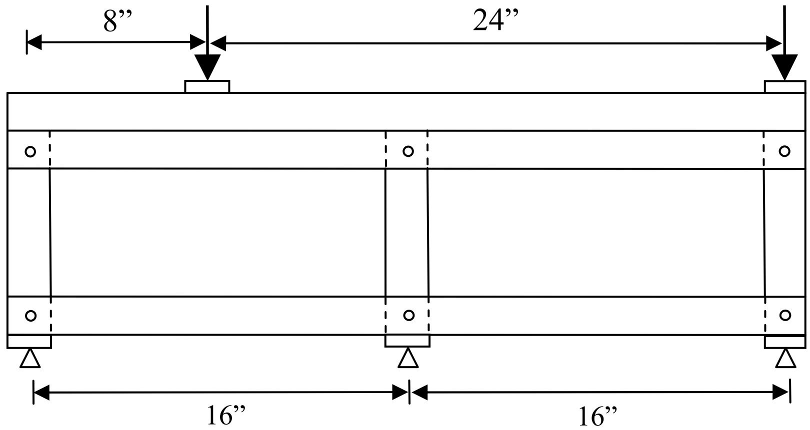



**Figure 3.1 – Typical Test Setup of 16 Inch Specimen**

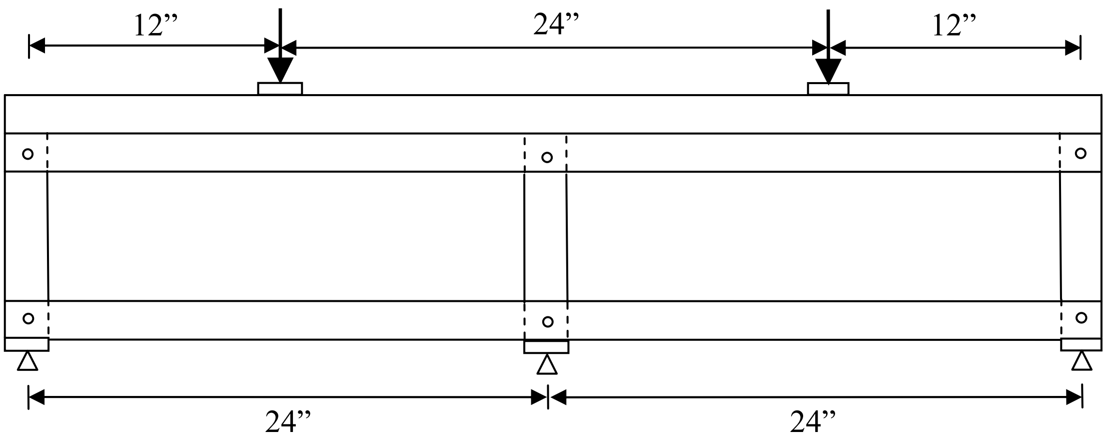



**Figure 3.2 – Typical Test Setup of 24 Inch Specimen**

**Figure 3.3 – Typical Test Setup Showing Placement of LSCs and Load Cells**

### 3.5 Test Procedure

Specimens were mounted on the reaction beam and the loading ram was lowered to contact the specimen with a low-level holding force. Specimens were then cyclically loaded at approximately 10% of the estimated total load to settle in the instrumentation and specimen. Typically, load was applied to a specimen at a nominal rate of 1 kN/min and gradually increased to ultimate capacity and beyond to ensure that ultimate had indeed been reached.

### 3.6 Specimen Properties

Eight steel tensile coupons, cut from stock pieces used to fabricate the specimens, were tested in a 20 000 kg Instron® testing machine according to standard ASTM specifications. Yield stress levels are listed in Table 3.5

**Table 3.5 – Yield Stress for 16- and 18-gauge Material**

| Coupon | Gauge | Yield (MPa) | Coupon | Gauge | Yield (MPa) |
|---|---|---|---|---|---|
| E | 16 | 350 | I | 18 | 320 |
| F | 16 | 335 | J | 18 | 385 |
| G | 16 | 390 | K | 18 | 340 |
| H | 16 | 400 | L | 18 | 315 |
| Ave. = 354 MPa | | | | | |

## 4.0 EXPERIMENTAL RESULTS

### 4.1 General

Ultimate loads and corresponding deflections and failure mechanisms are presented. It is important to note that the loads listed are for individual equal point loads as opposed to the total load on a specimen.

All figures listed are placed at the end of the corresponding section – figures of specimens tested under Objective A would be located after a discussion of test results for this objective. Graphs of load vs. deflection for each Specimen Group are also located at the end of each corresponding objective. A summary table of loads and deflections for all specimens tested is provided at the end of this section.

## 4.2 OBJECTIVE A

### *4.2.1 Specimen Group A16-16*

Specimen 1A16-16 developed a slight bowing of the top track leg over its length and subsequently failed at ultimate due to tensile fracturing of the wood at mid-span. The specimen continued to deform without taking additional load as local buckling of the track legs developed at the central support in the compression zone followed by failure of the wood in the tension zone at this negative moment location. The ultimate failure of specimen 2A16-16 and 3A16-16 also occurred as a result of tension failure of the wood at mid-span followed by tensile fracturing of the wood and leg local buckling at the central support as the deformation increased and the load dropped off. The photograph in Figure 4.1, taken after failure, illustrates a typical failure mode for this specimen group.

### *4.2.2 Specimen Group A16-18*

At approximately 60% of the ultimate load, the legs of Specimen 1A16-18 began to buckle locally in the negative moment region of the central support. At ultimate, the wood failed in tensile flexure above the centre stud as shown in Figure 4.2. As deformation continued, cracking of the wood and bearing failure of the steel track occurred directly beneath the mid-span point load. Specimen 3A16-18 and 4A16-18 failed in a similar manner.

The shear connection between the wood and top track for specimen 2A16-18 was varied and consisted of steel plates fastened to the wood and steel track as shown in Figure 4.3. This specimen failed almost identically to specimen 1A16-18, although the shear connection was less efficient, and there was separation of the wood from the steel as indicated in Figure 4.4. For graphing purposes, specimen 2A16-18 was excluded as the shear connection was fundamentally different from that of the other specimens in this group.

### *4.2.3 Specimen Group A24-16*

Specimens 1A24-16, 2A24-16, and 3A24-16 reached ultimate load and failed by tension fracturing of the wood top plate in the flexural tension zone of a preferential span along with leg buckling of the top track near the middle support. Visible local buckling at the center support was not as pronounced as that of the 16 inch specimens in this group. A typical specimen failure is shown in Figure 4.5.

### *4.2.4 Specimen Group A24-18*

In this group, the usual specimen installation was used for specimen 1A24-18 and 2A24-18 while specimen 3A24-18 was tested with the bottom track clamped directly to the reaction beam as shown in Figure 4.6. This procedure was used to evaluate any effect that may have resulted from using three individual supports as opposed to supporting the specimen along the full length of the bottom track. It was determined that this resulted in no significant difference in specimen behaviour or strength

Typically, the legs of the steel top track showed signs of local buckling deformation in the compression zone of the negative bending moment at the central support at approximately 75% of the ultimate load. Fracturing of the wood in the tension zone at this location resulted in ultimate failure. As deformation continued, the track at a load point distorted as the legs of the track splayed and the web developed a simultaneous depression across its width. This was accompanied by cracking of the wood at this location.

**Figure 4.1 – Failed specimen, Group A16-16**

**Figure 4.2 – Flexural failure of Specimen 1A16-18**

**Figure 4.3 –Specimen 2A16-18 with shear plates**

**Figure 4.4 –Note wood/track separation**

**Figure 4.5 – Failed Specimen, 1A24-16**

**Figure 4.6 – Clamped Specimen, 3A24-18**

## 4.3 OBJECTIVE B

### *4.3.1 Specimen Group B16-16*

At approximately 90% of the ultimate load, the specimens began to buckle at mid-span under the point load followed by top track buckling near the central support. Figure 4.7 shows specimen 2B16-16 after failure. Both this deformation and the midspan deflection were more pronounced than those of Group A16-16, which was composed of similar specimens but with the addition of a wood top plate. The wood, when attached to the steel, prevented such excessive deflections.

### *4.3.2 Specimen Group B16-18*

Specimens in this group first began to show signs of failure at the middle support, where buckling of the top track occurred. This took place at approximately 90% of the ultimate load. As the buckling at the middle support became more prominent, deflection under the midspan load became more noticeable. Group B16-18 withstood ultimate loads that were slightly less than group B16-16, which was to be expected as a lighter gauge steel section was used.

### *4.3.3 Specimen Group B24-16*

As with other groups under Objective B, specimens in this group failed primarily by buckling of the middle support accompanied by significant deformation at midspan load point. Buckling became noticeable at around 95% of the ultimate load, with permanent deflection of the centre spans occurring shortly thereafter. Figure 4.8 shows specimen 2B24-16 after reaching ultimate as it is still deflecting with significant deformation evident at the centres of both spans.

***4.3.4 Specimen Group B24-18***

Specimens in this group followed the same failure pattern and failure shape as those in Specimen Group B24-16. At approximately 80% of the ultimate load, buckling on either side of the middle support became visible. As for Specimen Group B24-16, deformation occurred in both spans following buckling at the middle support.

**Figure 4.7 – Specimen 2B16-16**

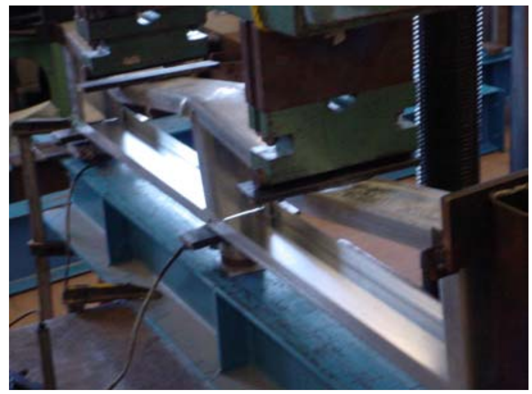


**Figure 4.8 – Failure of Specimen 2B24-16**

## 4.4 OBJECTIVE C

***4.4.1 Specimen Group C16-18***

Specimens in this group showed initial signs of failure at the middle support, where buckling was evident at approximately 70% of the ultimate load. As loading continued, tension cracks appeared in the wood at midspan beneath the load at around 75% of the maximum load. The tension cracks grew as the specimen approached ultimate and cracking developed in the compression zone at the central support.

***4.4.2 Specimen Group C16-16***

Specimens in this group reacted similarly to those tested previously in Specimen Group C16-16. At approximately 80% of the maximum load specimens began to show noticeable signs of buckling near the middle support. As this buckling became more distinct, a tension crack began to form in the wood at midspan and above the middle support as ultimate was approached. Figure 4.9 shows specimen 2C16-16 near the end of testing.

**Figure 4.9 – Deformation of Specimen 2C16-16**

**Figure 4.10 – Preferential Span Deflection, Specimen 2C24-18**

### *4.4.3 Specimen Group C24-16*

Specimens in this group first began to buckle in the legs of the top track at the middle support at approximately 85% of the ultimate for 2C24-16 and 3C24-16 and at approximately 65% of the ultimate for 1C24-16. Once the track began to buckle, the wood top plate began carrying more of the load until tension cracks ultimately appeared and the specimen failed. Tension fracturing of the wood developed at the midspan loads and above the middle support.

### *4.4.4 Specimen Group C24-18*

Specimens in this group, which consisted of lighter gauge steel, began buckling at the middle support at around 50% of the ultimate load. Ultimate capacity was determined by cracking of the wood shortly after the legs of the steel top track began to buckle. The wood fractured in the flexural tension zones at the middle support and at each point load. As is often the case for symmetrical test specimens, as ultimate load is approached, accentuated preferential deformation occurs under one of the two symmetrical loads. This is evident in Figure 4-10 for example. As can be understood, this is not indicative of unequal loads being applied throughout the test, but rather that near ultimate, the randomly weaker of the two spans shows significantly more deformation.

## 4.5 OBJECTIVE D

### *4.5.1 Specimen Group D16-16*

The track legs of the specimens in this group began to buckle at the middle support before any significant deformation was noted at the midspan. As the support buckling progressed, deflections at midspan became more pronounced and ultimate capacity became imminent. Severe deformation occurred at the middle support as shown in Figure 4.11.

Figure 4.11-Buckling at Central Support

Figure 4.12-Failure of 18-ga. track

### *4.5.2 Specimen Group D16-18*

The specimens in this group acted in a manner very similar to those of Group D16-16. Buckling was noted at the middle support followed by deformation at midspan as load increased. Near ultimate, severe deformations of the top track developed at the central support as can be seen in Figure 4.12.

### *4.5.3 Specimen Group D24-16*

Failure of specimens in this group was initiated by buckling of the top track at the middle support, followed by bending at mid-span below each load point. The midspan deflection was noticeable in both spans, although one was usually more prominent than the other.

At approximately 95% of the ultimate load, the specimens yielded after which followed by ductile behaviour and a slight load increase as deformations became significantly noticeable. An example of a failed specimen, 3D24-16, is shown in Figure 4.13. Buckling of the top track legs was especially noticeable in this specimen.

**Figure 4.13 – Failure of Specimen 3D24-16**

### *4.5.4 Specimen Group D24-18*

Failure was initiated at the middle support where the legs of the top track began to buckle in the flexural compression zone. For the specimen group in general, buckling first became noticeable at about 90% of the ultimate load. Once buckling had commenced, deformation became evident at the mid-spans.

## 4.6 OBJECTIVE E

### *4.6.1 Specimen Group E16-16*

Specimens in this group began to fail at about 95% of the ultimate load by local buckling of the top track legs at the middle support. The buckling became increasingly prominent as loading continued, with larger buckles forming on the unloaded side of the middle stud. At this point, the specimens reached their ultimate load. As testing continued past this point, deformation at midspan increased and the legs of the top track began to bow inward.

### *4.6.2 Specimen Group E16-18*

These were the first tests performed for this research project, and as such were done on an exploratory basis to determine the procedures for testing. The first two specimens were tested with only one point load. This was later changed to the two-point loading configuration because the stud most remote from the load point had a tendency to lift off the support as the ultimate load was approached.

The setup for specimen 1E16-18 and 2E16-18 is shown in Figure 4.14. A bearing failure initiated under the point load at approximately 50% of the ultimate load. Near ultimate load, the far stud started to lift off of the support and local buckles formed on the legs of the bottom track near the centre stud. A failed specimen for this configuration is shown in Figure 4.14.

Specimens 3E16-18 to 5E16-18 were tested using the two load point configuration, as used for all other tests. The initiation of bearing failure was first noticed at approximately 50% of the ultimate load at the location of the mid-span load point. This was followed by the start of local buckling in the legs of the top track near the centre stud. Each leg of the top track had two buckles start to form symmetrically around the centre stud. A failed specimen is shown in Figure 4.15.


**Figure 4.14: Failed Specimen 1E16-18**

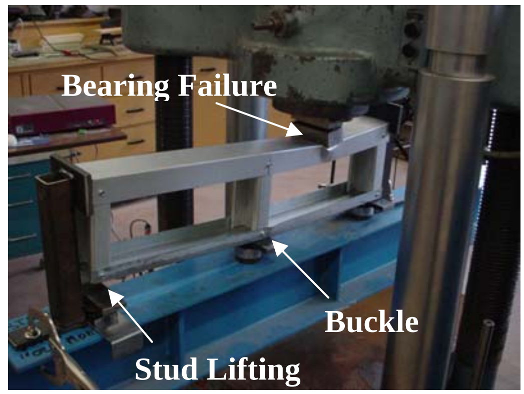



**Figure 4.15 – Failed Specimen 4E16-18**

***4.6.3 Specimen Group E24-16***

At approximately 65% of the ultimate load, specimens in this group began showing signs of buckling around the centre stud. As the load increased, the buckles became more visible, similar to other tests in this group. As the buckling increased, the track began to deform at midspan, causing the legs to bow inwards. The specimens began to buckle even more, eventually failing in this manner.

Specimen 1E24-16 tended to have more pronounced deformation in one span as opposed to the other while the second and third specimens tested seemed to deflect an equal amount in both spans. Although all specimens in this group tended to bow in the top of the track, this was more visible in Specimen 3E24-16.

***4.6.4 Specimen Group E24-18***

The legs of the top track began to buckle at the centre support at roughly 65% of the maximum load. As the load on the specimens was increased, this buckling became more evident. In fact, large buckles were present in the top track before any deformation was noticeable at midspan. As Figure 4.16 shows, specimens in this group deformed locally predominantly under the point loads. Typically the span would bend at the support, and bending would be evident throughout the span. In this case, and to a larger extent most specimens in Objective E, the majority of each span deflected only slightly, with the majority of deformation occurring immediately below the loading points.

**Figure 4.16 – Bearing Failures, Specimen Group E24-18**

## 4.7 SUMMARY AND ANALYSIS

Below are summary tables listing the values of ultimate load for each specimen, as well as the deflection at the value of ultimate load. The loads listed are for a single point load corresponding to one-half the total load applied to each specimen.

**Table 4.1 – Test Results, Objective A**

| Objective A | | | | |
|---|---|---|---|---|
| Specimen | Ult. Load (kN) | Deflection (mm) | Ave. Ult. Load (kN) | Ave. Deflection (mm) |
| 1A16-16 | 22.90 | 8.03 | 24.94 | 10.77 |
| 2A16-16 | 23.46 | 7.49 | | |
| 3A16-16 | 28.45 | 16.79 | | |
| 1A16-18 | 23.46 | 7.97 | 22.32 | 8.93 |
| 2A16-18 | 22.90 | 7.40 | | |
| 3A16-18 | 20.61 | 11.41 | | |
| 1A24-16 | 15.77 | 13.05 | 17.68 | 18.28 |
| 3A24-16 | 19.50 | 22.82 | | |
| 4A24-16 | 17.77 | 18.96 | | |
| 1A24-18 | 13.33 | 11.20 | 13.05 | 13.25 |
| 2A24-18 | 13.65 | 10.90 | | |
| 4A24-18 | 12.18 | 17.64 | | |

**Table 4.2 – Test Results, Objective B**

| Objective B | | | | |
|---|---|---|---|---|
| Specimen | Ult. Load (kN) | Deflection (mm) | Ave. Ult. Load (kN) | Ave. Deflection (mm) |
| 1B16-16 | 7.98 | 17.90 | 8.04 | 17.39 |
| 2B16-16 | 7.98 | 21.23 | | |
| 3B16-16 | 8.17 | 13.05 | | |
| 1B16-18 | 7.25 | 10.04 | 5.90 | 10.60 |
| 2B16-18 | 5.27 | 16.41 | | |
| 3B16-18 | 5.18 | 5.35 | | |
| 1B24-16 | 4.25 | 4.71 | 4.25 | 18.39 |
| 2B24-16 | 4.25 | 7.34 | | |
| 3B24-16 | 4.25 | 6.34 | | |
| 1B24-18 | 2.80 | 10.74 | 2.81 | 10.83 |
| 2B24-18 | 2.79 | 10.58 | | |
| 3B24-18 | 2.83 | 11.18 | | |

**Table 4.3 – Test Results, Objective C**

| Objective C | | | | |
|---|---|---|---|---|
| Specimen | Ult. Load (kN) | Deflection (mm) | Ave. Ult. Load (kN) | Ave. Deflection (mm) |
| 1C16-18 | 31.12 | 14.68 | 32.07 | 13.06 |
| 2C16-18 | 31.61 | 13.26 | | |
| 3C16-18 | 33.48 | 11.24 | | |
| 1C16-16 | 38.63 | 15.85 | 38.20 | 15.33 |
| 2C16-16 | 40.56 | 16.95 | | |
| 3C16-16 | 35.42 | 13.18 | | |
| 1C24-18 | 16.20 | 7.54 | 15.65 | 10.83 |
| 2C24-18 | 17.00 | 14.35 | | |
| 3C24-18 | 13.74 | 10.59 | | |
| 1C24-16 | 22.57 | 13.36 | 21.58 | 15.38 |
| 2C24-16 | 18.51 | 16.89 | | |
| 3C24-16 | 23.66 | 15.88 | | |

**Table 4.4 – Test Results, Objective D**

| Objective D | | | | |
|---|---|---|---|---|
| Specimen | Ult. Load (kN) | Deflection (mm) | Ave. Ult. Load (kN) | Ave. Deflection (mm) |
| 1D16-16 | 8.72 | 25.95 | 8.84 | 18.47 |
| 2D16-16 | 8.83 | 10.35 | | |
| 3D16-16 | 8.97 | 19.11 | | |
| 1D16-18 | 5.85 | 16.27 | 5.84 | 16.65 |
| 2D16-18 | 5.86 | 18.98 | | |
| 3D16-18 | 5.81 | 14.70 | | |
| 1D24-16 | 4.72 | 20.56 | 4.90 | 18.08 |
| 2D24-16 | 5.15 | 20.96 | | |
| 3D24-16 | 4.82 | 18.88 | | |
| 1D24-18 | 2.60 | 11.90 | 2.54 | 13.03 |
| 2D24-18 | 2.55 | 11.28 | | |
| 3D24-18 | 2.46 | 15.91 | | |

**Table 4.5 – Test Results, Objective E**

| Objective E | | | | |
|---|---|---|---|---|
| Specimen | Ult. Load (kN) | Deflection (mm) | Ave. Ult. Load (kN) | Ave. Deflection (mm) |
| 1E16-16 | 17.20 | 5.62 | 17.21 | 6.58 |
| 2E16-16 | 17.10 | 5.99 | | |
| 3E16-16 | 17.33 | 8.13 | | |
| 3E16-18 | 11.68 | 4.60 | 11.70 | 4.49 |
| 4E16-18 | 12.05 | 4.42 | | |
| 5E16-18 | 11.36 | 4.44 | | |
| 1E24-16 | 11.86 | 7.30 | 11.54 | 6.73 |
| 2E24-16 | 11.33 | 6.90 | | |
| 3E24-16 | 11.42 | 5.98 | | |
| 1E24-18 | 6.65 | 19.76 | 6.70 | 9.72 |
| 2E24-18 | 6.70 | 4.07 | | |
| 3E24-18 | 6.74 | 5.33 | | |

**General**

Although specimens failed at a variety of loads, one failure mechanism that was common to all specimens involved buckling of the legs of the top track at the middle support. For specimens without a wood top plate (Objectives B, D and E), this was a primary failure mode. Large deflections at mid-span were also common. For specimens with a wood top plate attached (Objectives A and C), the primary mode of failure, along with track leg buckling, was tension failure of the wood in flexural tension zones, both at mid-span and above the centre support.

**Gauge**

As expected, 16-gauge specimens developed higher capacities than 18-gauge specimens. Table 4.6 lists average test results for 16- and 18-gauge specimens grouped according to objective and span length. Differences in strength between gauges ranged from 19% for specimens in Objective C with 16” span, to 77% for specimens in Objective D with 24” span. In general, there was a greater difference between gauges in specimens with a 24” span than those with a 16” span.

**Table 4.6 – Comparison of Load Capacity by Gauge**

| Objective | Span | 16 Ga. | 18 Ga. | Ratio (16 ga./18 ga.) |
|---|---|---|---|---|
| A (92 mm track+2x4) | 16 | 24.94 | 22.32 | 1.12 |
| | 24 | 17.68 | 13.05 | 1.35 |
| B (92 mm track only) | 16 | 8.04 | 5.90 | 1.36 |
| | 24 | 4.25 | 2.81 | 1.51 |
| C (152 mm track+2x6) | 16 | 38.20 | 32.07 | 1.19 |
| | 24 | 21.58 | 15.65 | 1.38 |
| D (152 mm track only) | 16 | 8.84 | 5.84 | 1.51 |
| | 24 | 4.49 | 2.54 | 1.77 |
| E (92 mm deep leg track) | 16 | 17.21 | 11.70 | 1.47 |
| | 24 | 11.54 | 6.70 | 1.72 |

**Span**

Table 4.7 shows a comparison between 16" spans and 24" spans, grouped by objective and gauge. As would be expected, specimens with 16" spans reached a higher average load than their 24" counterparts. Differences in capacity ranged from 41% to 130%. On average, 16" span specimens had 1.83 times the ultimate capacity of 24" span specimens.

**Table 4.7 – Comparison of Load Capacity (kN) by Span**

| Objective | Gauge | 16" Span | 24" Span | Ratio (16"/24") |
|---|---|---|---|---|
| A | 16 | 24.94 | 17.68 | 1.41 |
| | 18 | 22.32 | 13.05 | 1.71 |
| B | 16 | 8.04 | 4.25 | 1.89 |
| | 18 | 5.90 | 2.81 | 2.10 |
| C | 16 | 38.20 | 21.58 | 1.77 |
| | 18 | 32.07 | 15.65 | 2.05 |
| D | 16 | 8.84 | 4.90 | 1.80 |
| | 18 | 5.84 | 2.54 | 2.30 |
| E | 16 | 17.21 | 11.54 | 1.49 |
| | 18 | 11.70 | 6.70 | 1.75 |

## Wood Top Plate

Objectives A and C were nominally identical in fabrication to Objectives B and D, respectively, except for the addition of a wood top plate on the former. The wood top plate carried a portion of the load previously carried by the steel track alone, thus resulting in a stronger structure. Table 4.8 includes information on the failure loads of these specimens, as well as the difference in capacity between the standard steel track specimen and its wood top plate counterpart.

In general, the strength of these specimens was largely dependent upon the capacity of the wood as opposed to the steel with the wood carrying most of the load. The 24” spans and the 18-gauge specimens benefited the most from the addition of the wood top plate, as it significantly increased their ultimate load. On the other hand, shorter spans and thicker steel specimens did not benefit by as large a percentage increase in ultimate from the addition of the wood due to their already high strength.

**Table 4.8 – Effects of Wood Top plate**

| Track | Top Plate | | Without Top Plate | | Ratio (With/Without) |
|---|---|---|---|---|---|
| 3 5/8” | A16-16 | 24.94 | B16-16 | 8.04 | 3.10 |
| | A16-18 | 22.32 | B16-18 | 5.90 | 3.78 |
| | A24-16 | 17.68 | B24-16 | 4.25 | 4.16 |
| | A24-18 | 13.05 | B24-18 | 2.81 | 4.64 |
| 6” | C16-16 | 38.20 | D16-16 | 8.84 | 4.32 |
| | C16-18 | 32.07 | D16-18 | 5.84 | 5.49 |
| | C24-16 | 21.58 | D24-16 | 4.90 | 4.40 |
| | C24-18 | 15.65 | D24-18 | 2.54 | 6.16 |

**Deep Leg Track**

Specimens in Objectives B and E were constructed using a 3 5/8" track, but those in Objective E had longer legs. The extra steel in the deep legs caused these specimens to be stronger by increasing the moment of inertia along the bending axis, as shown in Table 4.9. Differences in strength between specimens ranged from 98% for 18-gauge specimens with a 16" span, to 172% for 16-gauge specimens with a 24" span. On average, deep leg tracks developed about 2.30 times the capacity of that of specimens with a standard leg length.

**Table 4.9 –Load Capacity (kN) for Standard and Deep Leg Tracks**

| Specimen | Std. Leg | Deep Leg | DL/SL |
|---|---|---|---|
| 16-16 | 8.04 | 17.21 | 2.14 |
| 16-18 | 5.90 | 11.70 | 1.98 |
| 24-16 | 4.25 | 11.54 | 2.72 |
| 24-18 | 2.81 | 6.70 | 2.38 |

## 6.0 SUMMARY AND CONCLUSIONS

### *6.1 Summary*

This study was conducted for the Canadian Sheet Steel Building Institute to contribute to the knowledge and understanding of cold-formed steel framing related to top track capacity and behaviour. Sixty specimens were tested corresponding to twelve under each of the five main objectives, A, B, C, D, and E. Consideration was given to 16-gauge and 18-gauge tracks with spans of 16 and 24 inches. The use of a wood top plate and a deep leg track to improve strength was investigated.

### *6.2 Conclusions*

The following conclusions were drawn as a result of this research:

1. In all categories, specimens with heavier gauge steel tracks developed higher capacities than those of lighter gauge steel;
2. For the same gauge metal, shorter spans (16”) developed greater capacities at lower deflections than did longer spans (24”);
3. Specimens with a wood top plate were considerably stronger with less deflection than those without. Specimens weaker in flexure (18-gauge or 24” spans) were aided most by the addition of a wood top plate;
4. The longer legs of the deep leg track allowed it to resist significantly more load than a standard track. Deformations occurred locally at the load points rather than over the spans indicating a higher resistance to flexure than to local crippling. Despite this, the deeper leg track specimens developed, on average, 2.3 times the strength of standard leg track specimens.

**References**

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