International Design Codes and Manual Design Aids

Prof Dr Ben Schafer
Johns Hopkins University

Session 2: Resources for the Engineering & Design of Light Steel Framing
Overview

• CFS Strength Design Glossary
• International CFS Design Codes
  – Eurocode
  – North America
  – Others
• Manual Design Aids/Resources
  – Engineering examples
  – Basic load and span tables
  – Detailed technical notes
  – Supplementary notes and information
CFS Strength Design Glossary

- Local Buckling
  - Winter’s Equation
  - Post-buckling Capacity
- Distortional Buckling
- Global Buckling
- Effective Width
- Effective Area
- Effective Stiffness
- Direct Strength
CFS Strength Design Glossary

• Local Buckling
  – Winter’s Equation
  – Post-buckling Capacity
• Distortional Buckling
• Global Buckling
• Effective Width
• Effective Area
• Effective Stiffness
• Direct Strength

\[ P_y > P_n > P_{cr\ell} \]

(not like flexural buckling, where no post-buckling exists)
CFS Strength Design Glossary

• Local Buckling
  – Winter’s Equation
  – Post-buckling Capacity

• Distortional Buckling

• Global Buckling

• Effective Width

• Effective Area

• Effective Stiffness

• Direct Strength

\[ P_y > P_n > P_{crd} \]

(some post-buckling which is good, but not as much as in local buckling.)
CFS Strength Design Glossary

- Local Buckling
  - Winter’s Equation
  - Post-buckling Capacity
- Distortional Buckling
- Global Buckling
- Effective Width
- Effective Area
- Effective Stiffness
- Direct Strength

\[ P_n < P_{cre} \]

(no post-buckling in global Buckling modes.)
CFS Strength Design Glossary

- Local Buckling
  - Winter’s Equation
  - Post-buckling Capacity
- Distortional Buckling
- Global Buckling
- Effective Width
- Effective Area
- Effective Stiffness
- Direct Strength

Bulk of most CFS codes is finding the effective width so you can get the effective area and the effective stiffness.
CFS Strength Design Glossary

• Local Buckling
  – Winter’s Equation
  – Post-buckling Capacity

• Distortional Buckling

• Global Buckling

• Effective Width

• Effective Area

• Effective Stiffness

• Direct Strength

New design alternative to effective width available in many codes:

Direct Strength:

input

\[ P_{cr\ell}, P_{crd}, P_{cre}, P_y \]

output

\[ P_n, EI_{eff} \]
International Design Standards

AISI

North American Specification for the Design of Cold-Formed Steel Structural Members

2007 EDITION

Approved in Canada by the Canadian Standards Association CSA S130-07

Endorsed in Mexico by CANACERO

Eurocode

EN 1993-1-3 : 2004

04 July 2004

UDC

Descriptors:

English version

Eurocode 3 : Design of steel structures

Part 1-3: General rules
Supplementary rules for cold-formed members and sheeting

The improvements made on the version dated 1 March 2004 are marked
(improvements made on the original Project Team draft until 29 February 2004 are marked in the "dirty" version dated 1 March 2004)

Stage 34

CEN

European Committee for Standardisation
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

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## Comparisons

<table>
<thead>
<tr>
<th>AISI</th>
<th>Eurocode</th>
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<tbody>
<tr>
<td>• High Complexity</td>
<td>• Unbelievable complexity</td>
</tr>
<tr>
<td>• Developed in an industry-academic cooperative since the 1950’s</td>
<td>• Mostly from German and Swedish standards as opposed to British (BS)</td>
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<tr>
<td>• Includes standards for light steel framing</td>
<td>• No standards specific to light steel framing</td>
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<tr>
<td>• Includes Direct Strength Method for handling essentially any shape</td>
<td>• Design methods focus on effective width without any alternatives</td>
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<td>• Has a test-based method for novel situations</td>
<td>• Has a test-based method for novel situations</td>
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<td>• Open process easy for anyone to be involved in</td>
<td>• Unclear how to participate in the process</td>
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Around the world?

• Americas
  – U.S./Canada/Mexico have AISI as a joint Spec.
  – Brazil has a customized version of AISI

• Europe
  – Eurocode, with national annex documents

• Other Countries..
  – Custom version of British standard most common
  – Custom version of AISI standard also common
  – Australia/New Zealand follow AISI closely
  – Wholesale adoption of AISI or Eurocode
  – China now working on its own in many respects
Overview

• CFS Strength Design Glossary

• International CFS Design Codes
  – Eurocode
  – North America
  – Others

• Manual Design Aids/Resources
  – Engineering examples
  – Basic load and span tables
  – Detailed technical notes
  – Supplementary notes and information
Engineering Examples

Recent textbooks
• Yu and LaBoube – Cold-Formed Steel Design [to the AISI Specification]
• Dubina, Ungureanu and Landolfo – Design of Cold-Formed Steel Structures [to Eurocode]

AISI-D100 Design Manual
• Best source of complete examples
• Presented in a format most-like hot-rolled steel design, best starting place

CFS-NEES Model Building
• www.ce.jhu.edu/cfsnees building example

Building archetypes for this study
Part I
Dimensions and Properties I-1 – I-132

Part II
Beam Design II-1 - II-196

Part III
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Part IV
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**For Use With the 2007 Edition of the North American Specification for the Design of Cold-Formed Steel Structural Members**

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BEAM DESIGN**

For Use With the 
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**Table II-12b** LRFD - Combined Shear and Bending - Z-Sections With Lips
SECTION 4 – EXAMPLE PROBLEMS

Example II-1: Four Span Continuous C-Purlins Attached to Through Fastened Roof - LRFD

Dead Load = 15 PLF, Roof Live Load = 90 PLF, Wind Uplift = 90 PLF

Figure 1 - Spans and Loading
Note: Lap dimensions are to connection points of purlins

Figure 2 - Reactions, Shears and Moments
Note: Moments and forces are from unfactored nominal loads
Interior Span:

In the region of negative moment between the left lap and the inflection point:

Calculate the design lateral-torsional buckling strength per Section C3.1.2.1(a).

Determine the nominal strength using the distance from the inflection point to the lap as the unbraced length using Section C3.1.2.1(a).

\[ L_y = L_t = 7.44 - 2.75 = 4.69 \text{ ft or } 56.3 \text{ in.} \]

\[ C_b = 1.67 \text{ (Conservatively assumes linear moment diagram in this region.)} \]

\[
\sigma_{ey} = \frac{\pi^2 29500}{[(1.0)(56.3)/0.890]^2} = 72.8 \text{ ksi} \quad \text{(Eq. C3.1.2.1-8)}
\]

\[
\sigma_t = \frac{1}{0.881(3.90)^2} \left[ (11300)(0.00102) + \frac{\pi^2 (29500)(11.9)}{[(1.0)(56.3)]^2} \right] = 82.4 \text{ ksi} \quad \text{(Eq. C3.1.2.1-9)}
\]

\[
F_e = \frac{(1.67)(3.90)(0.881)}{2.29} \sqrt{(72.8)(82.4)} = 194 \text{ ksi} \quad \text{(Eq. C3.1.2.1-4)}
\]

\[ 2.78F_y = (2.78)(55) = 153 \text{ ksi} \]

Since \( F_e > 2.78 F_y \), the section is not subject to lateral-torsional buckling.
Calculate the design distortional buckling strength per Section C3.1.4(b).

Since there is no distortional restraint of the bottom flange, take $F_d/\beta$ from Table II-7.

From Table II-7, for the 9CS2.5x059,

\[ F_d/\beta = 41.2 \text{ ksi} \]

\[ L_{cr} = 25.8 \text{ in.} \]

The unbraced length for distortional buckling, $L_m$, is taken as the distance between the end of the lap and the inflection point.

\[ L_m = 56.3 \text{ in. (from above)} \]

\[ L = \min(L_{cr}, L_m) \]

\[ = \min(25.8, 56.3) = 25.8 \text{ in.} \]

The moments at the ends of the segment are:

\[ M_1 = 0.0 \text{ kip-ft at the inflection point} \]
\[ M_2 = 6.54 \text{ kip-ft at the lap} \]

\[ \beta = 1.0 \leq 1 + 0.4(\frac{L}{L_m})^{0.7} \left(1 - \frac{M_1}{M_2}\right)^{0.7} \leq 1.3 \quad (Eq. \ C3.1.4-11) \]

\[ = 1.0 \leq 1 + 0.4\left(\frac{25.8}{56.3}\right)^{0.7} \left(1 - \frac{0.0}{6.54}\right)^{0.7} \leq 1.3 \]

\[ = 1.0 \leq 1.23 \leq 1.3 \text{ therefore, use } \beta = 1.3 \]

\[ F_d = \beta \left(\frac{F_d}{\beta}\right) \]

\[ = 1.23(41.2) = 50.7 \text{ ksi} \]
Calculate the design distortional buckling strength per Section C3.1.4.

\[ M_y = S_{fy}F_y \]
\[ = (2.29)(55) = 126 \text{ kip-in.} \]  

\[ M_{crd} = S_{t}F_d \]  
\[ = 2.29(50.7) = 116 \text{ kip-in.} \]

\[ \lambda_d = \sqrt{\frac{M_y}{M_{crd}}} \]  
\[ = \sqrt{\frac{126}{116}} = 1.04 > 0.673 \text{ therefore,} \]

\[ M_n = \left( 1 - 0.22 \left( \frac{M_{crd}}{M_y} \right)^{0.5} \right) \left( \frac{M_{crd}}{M_y} \right)^{0.5} M_y \]
\[ = (1 - 0.22(1/1.04))(1/1.04)(126) = 95.5 \text{ kip-in. or } 7.96 \text{ kip-ft} \]

\[ \phi_b M_n = (0.90)(7.96) = 7.16 \text{ kip-ft} > 6.54 \text{ kip-ft OK} \]

*Equation C3.1.4-2*

Calculate the design strength based on the initiation of yielding using Section C3.1.1(a).

\[ M_n = S_{e}F_y = (1.89)(55) = 104 \text{ kip-in. or } 8.66 \text{ kip-ft} \]  

\[ \phi_b M_n = (0.95)(8.66) = 8.23 \text{ kip-ft} > 6.54 \text{ kip-ft OK} \]  

*Equation C3.1.1-1*
SSMA/SFIA

• Example of associations of allied CFS stud producers in the USA.
  – www.ssma.com
  – www.steelframingassociation.org

• Product technical catalogs provide member properties, and *basic load and span tables* completed to the American standards – great for understanding possibilities and limitations of current run-of-the-mill CFS products
Technical Guide for Cold-Formed Steel Framing Products

The data in this guide is based upon the 2007 American Iron and Steel Institute's S100-07 "North American Specification for the Design of Cold-Formed Steel Structural Members" and meets the requirements of the IBC 2009 Building Code, as well as the 2011 California Building Code.

Complies with the 2009 IBC and 2007 NASPEC

General Product Information

Thickness Table

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* Minimum thickness represents some of the design thickness and is the minimum acceptable thickness delivered to the job site based upon Section A2.4 of the A570-07 Specification.

** The tables in this guide are calculated based on inside corners and based on this table.

General Notes for all Tables

1. Where ASI S100-07 Specification is referenced, it is the "North American Specification for the Design of Cold-Formed Steel Structural Members."
2. The strength increase from cold work of forming has been incorporated for flexural strength per section A7.2 of ASI S100-07 Specification.
3. The effective moment of inertia for deflection is calculated at a stress which results in a section modulus such that the stress times the section modulus at that stress is equal to the allowable moment. ASI S100-07 specification procedure 1 for serviceability determination has been used. Increases in the effective moment of inertia (Ie) may be possible at lower stress levels. Any modified values would be required to be calculated by a qualified engineer.
4. Various members may be manufactured with yield strengths of 36 or 50 ksi per square inch (ksi). The yield strength used for calculations is indicated in the table.
5. For members available in both 33 and 50 ksi, the specifier must clearly indicate which yield strength is required. For example, 3625162.54 (50ksi).
6. When provided, factory punchouts shall be located along the centerline of the webs of the members and will have a minimum center-to-center spacing of 24 inches. Punchouts for members greater than 2.5 inches deep are a maximum of 1.5 inches wide x 1 inch long. Members with depths of 1.25 and 2.5 inches and smaller are a maximum of 1/4 inches wide x 1 inch long.
7. Allowable flexural strength values in the tables are based upon the minimum of local, distortional and lateral-torsional buckling. Distortional buckling strength is based on a k-factor = 0. Higher values may be obtained when sheathing is applied to the wall resulting in a higher k-factor value.
# Combined Axial and Lateral Load Tables

## 15 psf Lateral Load

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## 15 psf Lateral Load

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<th>16</th>
<th>18</th>
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<td>2.75</td>
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### Note

See Combined Axial and Lateral Load Tables on page 41.
Overview

• CFS Strength Design Glossary
• International CFS Design Codes
  – Eurocode
  – North America
  – Others
• Manual Design Aids/Resources
  – Engineering examples
  – Basic load and span tables
  – Detailed technical notes
  – Supplementary notes and information
• Group of structural engineers dedicated to improving the practice of CFS design

• American attendees at conference deeply involved in group including current and past President’s and Technical Manager of CFSEI.

• Produce Technical Notes, peer reviewed by structural engineers in the field, on a variety of topics with particular importance to design

• Open to international membership and participation, excited about collaboration with you
- Durability and Corrosion
  - D200-12 Protection for framing
  - D100-08 Protection for fasteners
- Fastners and Connection Hardware
  - F101-12 Screws for CFS
  - 562 Power Actuated Fasteners
- Component Assemblies
  - 551f Specifying Pre-Eng CFS Trusses
- General Topics
  - G500-11 Inspection Guidelines
  - G101-08, G103-11a Distortional buckling design
  - G100-07 Design by testing
- Wall Systems
  - W102-12 Curtain Wall Design
  - W104-10 Top Track Load Dist.
  - W500-12 Construction Bracing
- Floor Systems
  - J100-11 Floor Joists
- Roof Systems
- Thermal, Fire, and Acoustic
  - T100-12 Fire assemblies
  - T101-09 Acoustic recommendations
- Lateral Systems
  - L202-12, 558b-1 Diaphragm Design
  - L001-10 Strap Braced Walls

more…
FIRE RATED ASSEMBLIES OF COLD-FORMED STEEL CONSTRUCTION

Summary: Cold-formed steel has been widely used in commercial buildings, especially in non-load bearing (partitions) and curtain wall applications. Cold-formed steel sections are increasingly used as primary structural members, such as beams and columns, or as load-bearing walls or partitions in commercial and residential construction. In most cases, these members are expected to be fire resistant where they are part of a compartment wall or aisle, or where they support other floors. The purpose of this Tech Note is to provide the user with a comprehensive list of resources summarizing available tested fire rated steel assemblies, building code requirements, test methods and applicable references.

Disclaimer: Designs cited herein are not intended to preclude the use of other materials, assemblies, structures or designs when those other designs and materials demonstrate equivalent performance for the intended use. CFSEI documents are not intended to exclude the use and implementation of any other design or construction techniques.

INTRODUCTION

Building codes frequently require steel framed assemblies to have a fire resistance rating that is based on tests conducted in accordance with a recognized standard test. Fire rating of an assembly is a measurement which indicates how long the assembly will resist the spread of fire while maintaining structural integrity. Fire resistance ratings are expressed by the number of hours that a wall or other assembly can maintain its integrity while containing the fire, smoke, and temperature of a working fire.

The thickness of fire protection needed depends upon the exposure condition and the occupancy classification and hence is intended to limit the heat that enters the space.

FIRE RESISTANCE REQUIREMENTS

Gypsum wallboard and its derivatives provide the necessary fire protection in interior walls, such that one or two layers of fire-resistant boards will provide the 1 or 2-hour fire protection (See Figures 1 and 2). IBC and IRC outline the minimum fire rating requirements of steel framed assemblies. Furthermore, some localities in the US, in particular large cities such as New York or Los Angeles, have their own codes which are often more restrictive than the IBC and IRC requirements. Fire rating requirements are described in the chapters sections of the IBC and IRC as shown in Table 1.

METHODS OF FIRE PROTECTING COLD-FORMED STEEL SECTIONS

The methods of fire protecting load-bearing and non-load bearing cold-formed steel sections can be broadly defined as follows:

1. Plaster or flat protection to floors, walls, and ceilings by single or multi-layer gypsum boards or similar fire protecting boards.
2. Board protection to columns and beams in the form of a box around the section.
3. Sprayed protection to columns and beams around the profiles of the section.

TABLE 1: Applicable IBC and IRC Sections for Fire Rated Steel Assemblies

<table>
<thead>
<tr>
<th>Building Code</th>
<th>Fire Resistance Requirement for Building Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>International Building Code (IBC)</td>
<td>Chapters 4, 5, 6 and 7</td>
</tr>
<tr>
<td>International Residential Code (IRC)</td>
<td>Sections R310.1 and R301.3</td>
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</table>
Steel Framing Alliance

- Provides collection of resource documents in key areas related to utilizing cold-formed steel framing

<table>
<thead>
<tr>
<th>ENERGY</th>
<th>CYCLE TIME</th>
<th>HEIGHT ADVANTAGES</th>
<th>INSURANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUILD ENERGY EFFICIENT STEEL BUILDINGS</td>
<td>MOVE TENANTS IN FASTER</td>
<td>BUILD BIGGER AND TALLER</td>
<td>CONSTRUCTION INSURANCE SAVE BIG $$$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SEISMIC</th>
<th>GREEN BUILDING</th>
<th>TERMITES</th>
<th>FIRE RESISTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>BE PREPARED FOR A “BIG ONE”</td>
<td>REDUCE, REUSE AND RECYCLE MATERIALS</td>
<td>PROTECT YOUR INVESTMENT FROM THE START</td>
<td>NON-COMBUSTIBLE SOLUTIONS</td>
</tr>
</tbody>
</table>
INTRODUCTION
THERMAL DESIGN AND CODE COMPLIANCE FOR COLD-FORMED STEEL WALLS

BACKGROUND AND OBJECTIVES
In the early 1990s cold-formed steel (CFS) began making gains in the residential construction market. In response, the American Iron and Steel Institute (AISI) sponsored ground-breaking research to develop recommendations for the design of walls constructed from cold-formed steel. The 1995 AISI Thermal Design Guide for Exterior Walls resulted from this early work.

The 1995 AISI Design Guide has been the industry’s primary reference source on the thermal design of cold-formed steel walls since its release. Although the research in the original guide is still valid, the residential framing environment has undergone significant changes, mostly relating to recent research findings and the adoption of more stringent energy efficiency requirements, in the past decade. The need to update the 1995 design guide is driven by these six industry changes:

1. Wider use of the performance approach for achieving code compliance;
2. Availability of new test and research data;
3. An on-going shift in codes and standards away from clear wall assembly factors to more accurate and detailed framing factors;
4. The move from R-11 to R-13 as the code minimum cavity insulation in walls;
5. A better understanding of how to calculate an assembly's U-Factor and effective R-Value; and
6. Climate zone designations used in codes and standards have changed since the 1990s.

With any type of wall framing, heat flows directly through the cavity AND directly through the frame. Both heat flow paths must be considered when taking a whole-wall performance approach.
Conclusions

• Certainly some new terminology to learn
• AISI Specification provides the greatest flexibility and the deepest set of codified rules and procedures
• Numerous resources for learning (Google…)
  – Textbooks, e.g., Yu, Cold-Formed Steel Design
  – AISI-D100 Design Manual
  – SSMA or SFIA Catalogs
  – CFSEI
  – Steel Framing Alliance
  – More