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AISI Standard for Cold-Formed Steel Framing – Truss Design, 2004 Edition

American Iron and Steel Institute

AISI/COFS/TRUSS-2004

American Iron and Steel Institute

AISI STANDARD

Standard for Cold-Formed Steel Framing – Truss Design, 2004 Edition

Revision of AISI/COFS/TRUSS-2002

Endorsed by:

Steel Framing Alliance™

DISCLAIMER

The material contained herein has been developed by the American Iron and Steel Institute Committee on Framing Standards. The Committee has made a diligent effort to present accurate, reliable, and useful information on cold-formed steel framing design and installation. The Committee acknowledges and is grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject. Specific references are included in the *Commentary*.

With anticipated improvements in understanding of the behavior of cold-formed steel framing and the continuing development of new technology, this material may eventually become dated. It is anticipated that AISI will publish updates of this material as new information becomes available, but this cannot be guaranteed.

The materials set forth herein are for general purposes only. They are not a substitute for competent professional advice. Application of this information to a specific project should be reviewed by a design professional. Indeed, in many jurisdictions, such review is required by law. Anyone making use of the information set forth herein does so at their own risk and assumes any and all liability arising there from.

2nd Printing – May 2005

PREFACE

The American Iron and Steel Institute (AISI) Committee on Framing Standards (COFS) has developed this *Standard For Cold-Formed Steel Framing-Truss Design* [*Truss Standard*] to provide technical information and specifications on cold-formed steel truss construction.

The Committee acknowledges and is grateful for the contributions of the numerous engineers, researchers, producers and others who have contributed to the body of knowledge on the subjects. The Committee wishes to also express their appreciation for the support and encouragement of the Steel Framing Alliance.

All terms in this *Truss Standard* written in italics are defined in this *Truss Standard* or the AISI *Standard for Cold-Formed Steel Framing – General Provisions*. Any listed definitions identified with [*reference*/year] are defined in the referenced document and listed to ease use of this *Truss Standard*.

This 2nd Printing incorporates the Errata to the Standard for Cold-Formed Steel Framing – Truss Design [Errata], dated May 6, 2005.

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TABLE OF CONTENTS

STANDARD FOR COLD-FORMED STEEL FRAMING – TRUSS DESIGN

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STANDARD FOR COLD-FORMED STEEL FRAMING – TRUSS DESIGN

A. GENERAL

A1 Scope

The design of cold-formed steel *trusses* for load carrying purposes in buildings shall be in accordance with the *North American Specification for the Design of Cold-Formed Steel Structural Members* [*Specification*] and the *Standard for Cold-Formed Steel Framing-General Provisions* [*General Provisions*] except as modified by the provisions of this *Truss Standard*. This *Truss Standard* shall also apply to manufacturing, quality criteria, installation and testing as they relate to the design of cold-formed steel *trusses*.

This *Truss Standard* does not intend to preclude the use of other materials, assemblies, structures or designs not meeting the criteria herein, when they demonstrate equivalent performance for the intended use to those specified in this *Truss Standard*.

Where there is a conflict between this *Truss Standard* and other reference documents the requirements contained within the *Truss Standard* shall govern.

This *Truss Standard* shall include Sections A through G inclusive.

A2 Definitions

Building Designer. Also referred to as *design professional* and registered building designer, but hereinafter referred to as *building designer*, is an individual or organization responsible for the overall building design in accordance with the statutes and regulations governing the professional registration and certification of architects or engineers of the jurisdiction where the building will be located.

Chord Member. A structural member that forms the top or bottom component of a *truss*.

Gusset Plate. A structural member used to facilitate the connection of *truss chord* or *web members* at a *heel*, *ridge*, or *panel point*.

Hat-Shape. A singly-symmetric shape consisting of at least two vertical webs and a horizontal stiffened flange which is used as a *chord member* in a *truss*.

Heel. The connection region between the top and bottom *truss chords* of a non-parallel *chord truss*.

Nominal Load. Magnitude of the load specified by the *applicable building code*. [*AISC/AISI Terminology*/2004]

Panel Point. The connection region between a *web* and *chord member*.

Ridge. The connection region between two top *chord members* at the junction of two upward sloping roof surfaces.

Static Load. A load or series of loads that are supported by or are applied to a structure so gradually that forces caused by change in momentum of the load and structural elements can be neglected and all parts of the system at any instant are essentially in equilibrium.

Truss Designer. Also referred to as *truss* engineer, design engineer and registered engineer, but hereinafter referred to as *truss designer*, is an individual or organization responsible for the design of cold formed steel *trusses*.

Truss Manufacturer. An individual or organization engaged in the manufacturing of site-built or in-plant *trusses*.

Web Member. A structural member in a *truss* that is connected to the top and bottom *chords*, but is not a *chord member*.

Z-Shape. A point-symmetric or non-symmetric section that is used as a *chord member* in a *truss*.

A3 Referenced Documents

The following documents are referenced in this *Truss Standard*:

1. AISI, *North American Specification for the Design of Cold-Formed Steel Structural* Members, 2001 Edition with 2004 Supplement, American Iron and Steel Institute, Washington, DC.
2. AISI, *Standard for Cold-Formed Steel Framing - General Provisions,* 2004 *Edition*, American Iron and Steel Institute, Washington, DC.
3. AISI, "Stub-Column Test Method for Effective Area of Cold-Formed Steel Columns", in the 2002 edition of the *AISI Cold-Formed Steel Design Manual*, American Iron and Steel Institute, Washington, DC.
4. AISI, "Test Methods for Mechanically Fastened Cold-Formed Steel Connections", in the 2002 edition of the *AISI Cold-Formed Steel Design Manual*, American Iron and Steel Institute, Washington, DC.
5. ASCE 7-02, *Minimum Design Loads for Buildings and Other Structures*, American Society of Civil Engineers, Reston, VA.

B. DESIGN RESPONSIBILITIES

The professional design responsibilities defined by this *Truss Standard* are not intended to preclude alternate provisions as agreed upon by the parties involved.

B1 Truss Designer

The *truss designer's* responsibility shall be in accordance with the statutes and regulations governing the professional registration and certification of design professionals of the jurisdiction where the *truss* is to be incorporated into the building project.

The *truss designer* shall make available, upon request, comprehensive design calculations, including the following:

(a) loads and load combinations considered
(b) axial forces, moments, and shears resulting from the applied loads and load combinations
(c) design assumptions

The *truss* design drawings shall include, as a minimum, the following:

(a) slope, depth, span, and spacing of the *truss*
(b) bearing locations and minimum bearing lengths
(c) design loading(s)
(d) nominal reaction forces and direction
(e) location of all *truss* connections
(f) *gusset plate* locations, sizes, and material specifications
(g) fastener type, size, quantities, and locations
(h) shape and material specification for each component
(i) maximum nominal compressive force in all *truss* members
(j) locations of required permanent *truss* member bracing
(k) connection requirements for:
  (1) *truss*-to-*truss* girder
  (2) *truss* ply-to-ply
  (3) field assembly of *trusses*
(l) calculated deflection ratio and/or maximum deflection for live and total load

B2 Building Designer

The *building designer's* responsibility includes, but not limited to, foundation design, structural member sizing, load transfer, bearing conditions, and the structure's compliance with applicable codes.

The *building designer* shall specify the following:

(a) design loads in accordance with Section C
(b) roof profile and geometry
(c) bearing conditions
(d) temperature and moisture environment for the intended end use
(e) any special requirements or considerations to be taken in the *truss* design

The *building designer* shall provide for the following in the design and detailing of the building:

(a) horizontal, vertical, or other *truss* deflection due to design loads

(b) *truss* movement due to temperature changes
(c) *truss* supports and anchorage accommodating horizontal, vertical, or other reactions or displacements
(d) permanent *truss* bracing to resist wind, seismic, and any other lateral forces acting perpendicular to the plane of the *truss*
(e) permanent lateral bracing as specified by the *truss designer*

C. LOADING

The loads and load combinations to be used in the design of cold-formed steel *trusses* shall be determined by the *building designer* in accordance with the *applicable building code*. In the absence of an *applicable building code*, the loads, and combinations of loads shall be in accordance with accepted engineering practice for the geographical area under consideration as specified by the appropriate sections of ASCE 7.

C1 Construction Loads

Construction load used in design shall be determined by the building designer in accordance with the local building code and construction practices. In the absence of such a governing code, the *building designer* shall determine the construction load.

C2 Other Loads

The *building designer* shall specify any applicable loads in addition to those in this chapter.

D. TRUSS DESIGN

The members and connections of a *truss* must possess adequate strength to safely support the design loads. Except as modified or supplemented in this *Truss Standard*, strength determinations shall be in accordance with the *Specification*.

D1 Materials

Sheet steel materials utilized in steel *truss* construction shall comply with the requirements for structural members defined in the *General Provisions* or the *Specification.*

D2 Corrosion Protection

Truss members, including *gusset plates*, shall have corrosion protection as required by the *General Provisions*.

D3 Analysis

In lieu of a rigorous analysis to define joint flexibility, the following analysis model assumptions shall be used:

(a) *Chord members* are continuous, except members are assumed to have pinned connections at the *heel*, *ridge*, other pitch breaks, and intermediate splices.

(b) *Web members* are assumed to have pinned connections at each end.

Use of a specific joint stiffness other than the complete rotational freedom of a pin for a connection shall be permitted if the connection is designed for the forces resulting from a structural analysis with this specific joint stiffness.

D4 Member Design

D4.1 Properties of Sections

For *C-shapes* and other simple cross section geometries, the properties of sections shall be determined in accordance with conventional methods of structural design. Properties shall be based on full cross section properties, except where use of a reduced cross section or effective design width is required by the *Specification.* For other cross section geometries, properties shall be based on tests in accordance with Section G1.

D4.2 Compression Chords

The compression *chord* shall be evaluated for combined axial load and bending using Section C5.2.1 of the *Specification*.

D4.2.1 For axial load strength determination, the effective length, KL, shall be permitted to be determined by rational analysis and/or testing. In the absence of such analysis or test, the following design assumptions shall be used:

(a) For *C-shapes* the x-axis is the axis of symmetry. L_x shall be equal to the distance between *panel points*, and C_m shall be taken as 0.85, unless an analysis is performed to justify another value. When the *chord* is continuous over at least one intermediate *panel point* between the *heel* and *ridge* and when sheathing is directly attached to the *chord*, K_x shall be permitted to be equal to 0.75. Otherwise, K_x shall be taken as unity. As an alternative, L_x shall be the distance between points of contraflexure with C_m and K_x taken as unity. When sheathing is attached to the *chord*, L_y shall be equal to the distance between sheathing connectors and K_y shall be permitted to be equal to 0.75. When purlins are attached to the *chord*, L_y shall be the distance between purlins with K_y equal to unity. L_t shall be equal to the distance between *panel points*. When the *chord* is continuous over at least one intermediate *panel point* between the *heel* and *ridge* and when sheathing is directly attached to the *chord*, K_t shall be permitted to be equal to 0.75. Otherwise, K_t shall be taken as unity. As an alternate, L_t shall be the distance between points of contraflexure with K_t taken as unity.

(b) For *hat-shapes* the x-axis is the axis of symmetry. When sheathing is attached to the *chord*, L_x shall be equal to the distance between sheathing connectors and K_x shall be permitted to be equal to 0.75. When purlins are attached to the *chord*, L_x shall be the distance between purlins with K_x equal to unity. L_y shall be equal to the distance between *panel points*, and C_m shall be taken as 0.85, unless an analysis is performed to justify another value. When the *chord* is continuous over at least one intermediate *panel point* between the *heel* and *ridge* and when sheathing is directly attached to the *chord*, K_y shall be permitted to be equal to 0.75. Otherwise, K_y shall be taken as unity. As an alternative, L_y shall be the distance between points of contraflexure with C_m and K_y taken as unity. L_t shall be equal to the distance between sheathing connectors or purlin spacing. When the *chord* is continuous over at least one intermediate *panel point* between the *heel* and *ridge* and when sheathing is directly attached to the *chord*, K_t shall be permitted to be equal to 0.75. Otherwise, K_t shall be taken as unity. As an alternate, L_t shall be the distance between the points of contraflexure with K_t taken as unity.

(c) For *Z-shapes* the x-axis is out of the plane of the *truss*, L_x shall be equal to the distance between *panel points*, and C_m shall be taken as 0.85, unless an analysis is performed to justify another value. When the *chord* is continuous over at least one intermediate *panel point* between the *heel* and *ridge* and when sheathing is directly attached to the *chord*, K_x shall be permitted to be equal to 0.75. Otherwise, K_x shall be taken as unity. As an alternative, L_x shall be the distance between points of contraflexure with C_m and K_x taken as unity. When sheathing is attached to the *chord*, L_y shall be equal to the distance between sheathing connectors and K_y shall be permitted to be equal to 0.75. When purlins are attached to the *chord*, L_y shall be the distance between purlins with K_y equal to unity. Where the member depth is less than 6 inches, L_t shall be equal to the distance between sheathing connectors or purlin spacing. For *Z-shapes* where the member depth is greater than or equal to 6 inches, L_t shall be equal to the distance between *panel points*. When the *chord* is continuous over at least one intermediate *panel point* between the *heel* and *ridge* and when sheathing is directly attached to the *chord*, K_t shall be permitted to be equal to 0.75. Otherwise, K_t shall be taken as unity. As an alternative, L_t shall be equal to the distance between points of contraflexure with K_t taken as unity.

D4.2.2 For bending strength determination, the effective length, KL, shall be permitted to be determined by rational analysis and/or testing. In the absence of such analysis or test, the following design assumptions shall be used:

(a) When sheathing is attached to the compression flange, M_n for the compression chord shall be permitted to be taken as S_eF_y in accordance with Section C3.1.1 of the *Specification*.

(b) When purlins are attached to the compression flange between *panel points*, $M_n = M_c$ in accordance with Section C3.1.2.1 of the *Specification* with KL_y and KL_t for *C-shapes* and *Z-shapes* and KL_x and KL_t for *hat-shapes* taken as the distance between purlins.

(c) When sheathing or purlins are attached to the tension flange and the compression flange is laterally unbraced, M_n shall be taken as M_c in accordance with Section C3.1.2 of the *Specification*. For continuous span *chords* M_n in the region of the *panel point* shall be determined with KL_y and KL_t for *C-shapes* and *Z-shapes* and KL_x and KL_t for *hat-shapes* taken as the distance between the *panel point* and the point of contraflexure and C_b shall be taken as unity. For simple and continuous span *chords*, M_n in the mid-span region shall be determined with the effective length taken as the distance between *panel points* and C_b shall be computed in accordance with Section C3.1.2.1 of the *Specification*.

D4.2.3 When a C-section compression *chord* is subject to concentrated load at a *panel point*, the interaction of axial compression, bending and web crippling shall be considered as follows:

For ASD:

$$\frac{P}{P_{no}} + \frac{M}{M_{nxo}} + \frac{R}{R_n} \le \frac{1.49}{\Omega} \qquad (Eq.\ D4.2.3\text{-}1)$$

Where:

P = required compressive axial strength for ASD
M_x = required flexural strength for ASD
R = required concentrated load strength for ASD
P_{no} = *nominal* axial strength computed at $f = F_y$
M_{nxo} = *nominal* flexural strength computed at $f = F_y$
R_n = *nominal* interior one-flange web crippling strength
Ω = factor of safety, 1.95

For LRFD:

$$\frac{\overline{P}}{P_{no}} + \frac{\overline{M}_x}{M_{nxo}} + \frac{\overline{R}}{R_n} \le 1.49\phi \qquad (Eq.\ D4.2.3\text{-}2)$$

Where:

$\overline{P}$ = required compressive axial strength for LRFD
$\overline{M}_x$ = required flexural strength for LRFD
$\overline{R}$ = required concentrated load strength for LRFD
P_{no} = *nominal* axial strength computed at $f = F_y$
M_{nxo} = *nominal* flexural strength computed at $f = F_y$
R_n = *nominal* interior one-flange web crippling strength
ϕ = 0.85

D4.3 Tension Chords

The tension chord shall be evaluated for combined axial load and bending using Section C5.1.1 of the *Specification*. The axial load shall be permitted to be taken as acting through the centroid of the section.

D4.4 Compression Web Members

Compression *web members* shall be evaluated for combined axial load and bending using Section C5 of the *Specification*.

(a) For a C-shaped compression web member that is attached through its web element, the interaction of axial compression and out-of-plane bending shall be determined by the following interaction equation,

For ASD:
$$\frac{\Omega_c RP}{P_n} + \frac{\Omega_b C_{my} RPe}{M_{ny}\alpha_y} \le 1.0 \quad (Eq.\ D4.4\text{-}1)$$

For LRFD:
$$\frac{R\overline{P}}{\phi_c P_n} + \frac{C_{my} R\overline{P}e}{\phi_b M_{ny}\alpha_y} \le 1.0 \quad (Eq.\ D4.4\text{-}2)$$

Where:

$$R = -\left(\frac{L/r}{173}\right)^2 + \frac{L/r}{88} - 0.22 \ge 0.6 \quad (Eq.\ D4.4\text{-}3)$$

L = unbraced length of the compression *web member*

r = radius of gyration of the full section about the minor axis

P_n = nominal axial strength based on Section C4.1 of the *Specification*. Only flexural buckling need be considered.

e = eccentricity of compression force with respect to the centroid of the full section of the *web*

P, Ω_b, Ω_c, C_{my}, M_{ny} and α_y shall be defined in accordance with Section C5.2.1 of the *Specification*.

$\overline{P}$, ϕ_c, ϕ_b shall be defined in accordance with Section C5.2.1 of the *Specification*

When computing the design strength, the effective lengths, K_xL_x, K_yL_y and K_tL_t, shall be taken as the distance between the centers of the member's end connection patterns.

(b) For other compression *web members* that are concentrically loaded, the axial compression load shall be permitted to be taken as acting through the centroid of the section.

(c) For other compression members that are not concentrically loaded, proper regard for eccentricity shall be considered.

D4.5 Tension Web Members

For tension *web members*, which are symmetrically loaded, the axial tension load shall be permitted to be taken as acting through the centroid of the section. For other tension members that are not symmetrically loaded, proper regard for eccentricity shall be considered.

D4.6 Eccentricity in Joints

An analysis using multiple nodes or an analysis using single nodes that includes proper regard for the effects of eccentricity shall be performed.

Chord shear and moments in joints shall include the following considerations:

(a) When the *web member* lap length is greater than or equal to 75% of the *chord member* depth, the *chord* shall be investigated for combined bending and shear in accordance with Equation C3.3.1-2 of the *Specification*. For C-section *trusses* when screws are used as the connector, a minimum of four screws shall be used in the *web* to *chord* connection and the screws shall be uniformly distributed in the lapped area.

(b) When the *web member* lap length is less than 75% of the *chord member* depth, the *chord* shall be investigated for combined bending and shear in accordance with Equation C3.3.1-1 of the *Specification*.

Along the length of the *chord*, at the mid-point between the intersecting *web members* at a joint, shear shall be evaluated by Section C3.2 of the *Specification*. The shear buckling coefficient shall be based on either Equation C3.2-4 or C3.2-5 with "a" taken as the smaller of the distance between the fastener groups, or center-to-center of the *web members*.

D5 Connection Design

D5.1 Fastening Methods

Appropriate fastening systems shall be approved by the *truss designer*. Screw, bolt, and weld connections shall be designed in accordance with the *Specification*. For connections using other fastener types, design values shall be determined by testing in accordance with Section F1 of the *Specification*.

For other fastening methods, appropriate manufacturers specifications shall be followed.

D5.2 Coped Connections for C-Sections

Coping shall be permitted at *ridge* and *heel* connections in accordance with the *truss* design.

(a) At a coped *heel* connection with a coped flange and a bearing stiffener having a moment of inertia (I_{min}) greater than or equal to of 0.161 in.^{4} (67,000 mm^4), the shear strength shall be calculated in accordance with *Specification* Section C3.2 and reduced by the following factor, R:

$$R = 0.976 - \frac{0.556c}{h} - \frac{0.532d_c}{h} \leq 1.0 \qquad (Eq.\ D5.2\text{-}1)$$

with the following applicable limitations:

$h/t \leq 200$, $0.10 < c/h < 1.0$ and $0.10 < d_c/h < 0.4$

(b) At a coped *heel* connection with a coped flange where a bearing stiffener having a moment of inertia (I_{min}) less than 0.161 in.^{4} (67,000 mm^4), the computed strength at the *heel* is governed by web crippling in accordance with *Specification* Section C3.4 and shall be reduced by the following factor, R:

$$R = 1.036 - \frac{0.668c}{h} - \frac{0.0505d_c}{h} \le 1.0 \qquad (Eq.\ D5.2\text{-}2)$$

with the following applicable limitations:

$h/t \le 200$, $0.10 < c/h < 1.0$ and $0.10 < d_c/h < 0.4$

Where:

c = length of cope

d_c = depth of cope

I_{min} is computed with respect to an axis parallel to the web of the *chord*.

D6 Serviceability

Serviceability requirements, as defined in the *Specification*, shall be determined by the *building designer* or building code. When computing *truss* deflections, it shall be permitted to use the full cross-sectional area of the *truss* members.

E. QUALITY CRITERIA FOR STEEL TRUSSES

E1 Quality Assurance

These quality criteria for the manufacturing of steel *trusses* shall be used in conjunction with a quality assurance procedure. *Truss manufacturers* shall establish filing methods that document the proper application of quality assurance procedures throughout the manufacturing and inspection process.

E2 Truss Design

A *truss* design submittal, which has been prepared by a *truss designer*, shall be provided for each *truss* manufactured.

E3 Steel

Sheet steel materials utilized in steel *truss* construction, including *truss* members and *gusset plates*, shall be of the grade, thickness, coating, size, and shape specified by the *truss* design. *Truss* steel of a higher grade, thickness, or coating of the same size and shape shall not be prohibited from being substituted for the grade, thickness, or coating as specified. Changes in size and/or shape shall require the approval of the *truss designer* and review by the *building designer* to demonstrate equivalency.

E4 Member Identification

Truss chord and *web members* shall be identified in accordance with the Product Identification requirements for framing members defined in the *General Provisions*.

E5 Special Marking

Trusses shall be marked to document the orientation of parallel *chord trusses*, locations of special bearing conditions and permanent bracing. Alternatively, it shall be acceptable for the *truss designer* to provide this information to the contractor by means of indications on the *truss* designs, *truss* drawing/erection plans and/or special detail drawings.

E5.1 Parallel Chord Trusses

Parallel *chord trusses* shall be clearly marked in a manner that permits visual verification of proper installation.

E5.2 Bearing Locations

Trusses having bearing locations other than at the end of *heel* locations shall have bearing points clearly marked in a manner that permits verification during and after installation.

E5.3 Lateral Bracing

All *truss chord* and *web members* that require permanent lateral bracing to prevent lateral buckling (such as but not limited to top *chords* of piggyback *trusses*, long compression *webs*, and bottom *chords* at cantilevers) shall be clearly marked to identify the need for field bracing during and after installation.

E6 Gusset Plates

Gusset plates shall be installed in accordance with the *truss* design. The placement of *gusset* *plates* shall not interfere with other design aspects or function of the *truss*.

E7 Fasteners

Fasteners used in the manufacture of steel *trusses* shall be of the type and minimum size specified by the *truss designer*. Fasteners shall be installed in accordance with the *General Provisions* or as specified by the *truss designer*.

E8 Assembly

Trusses shall have steel members that are accurately cut, in accordance with the *truss* design, so that the assembled *truss* has close fitting steel members. The maximum gap between *web members* shall not exceed ½ inch (12.7 mm) unless approved by the *truss designer*. The location of *chords*, *webs*, and joints shall be as specified in the *truss* design.

Truss dimensions which vary from the *truss* design shall not exceed the tolerances shown in Table E8. Inaccuracies exceeding these allowable tolerances shall be acceptable upon approval and follow-up documentation by the *truss designer*. Any shop modifications or repairs shall be documented by the *truss designer*.

Table E8
Manufacturing Tolerances For Finished Truss Units

Length[1]	Variance from Design Dimensions
Up to 30 ft (9.14 m)	½ inch (12.7 mm)
Over 30 feet (9.14 m)	¾ inch (19.1 mm)
Height[2]	**Variance from Design Dimensions**
Up to 5 feet (1.52 m)	¼ inch (6.4 mm)
Over 5 feet (1.52 m)	½ inch (12.7 mm)

1 Length, for manufacturing tolerance purposes, is the overall length of the *truss* unit, excluding overhangs, and extensions.
2 Height, for manufacturing tolerances purpose, is the overall height of the *truss* unit measured from the top of the top *chord* to the bottom of the bottom *chord* at the highest point of the *truss*, excluding projections above the top *chord* and below the bottom *chord*, overhangs, and extensions.

E9 Camber

Truss camber, if any, shall be provided, as specified in the *truss* design.

F. TRUSS INSTALLATION AND BRACING

F1 Installation Tolerances

F1.1 Straightness

Trusses shall not be installed with an overall bow or bow in any *chord* or panel which exceeds the lesser of L/200 or 2 inches (50.4 mm), where L is the length of the *truss*, *chord*, or panel in inches.

F1.2 Plumbness

Trusses shall not be installed with a variation from plumb (vertical tolerance) at any point along the length of the *truss* from top to bottom which exceeds 1/50 of the depth of the *truss* at that point or 2 inches (50.4 mm) whichever is less, unless *trusses* are specifically designed to be installed out of plumb.

F1.3 Top Chord Bearing Trusses

For top *chord* bearing *trusses* a maximum gap tolerance between the inside of the bearing and the first diagonal or vertical *web* shall be specified in the design.

F2 Permanent Bracing

Permanent *truss* bracing shall be designed and specified by the *building designer* for the structural safety of the building. It shall be the responsibility of the *building designer* to integrate the *truss* member bracing requirements indicated in the *truss* design drawing into the building permanent bracing system and then to indicate size, location, and attachments for all permanent bracing. The design and location of all bracing shall be such that they work together with other structural parts of the building (such as shear walls, portal frames, bearing walls, columns, beams, etc.) to achieve total structural integrity.

Permanent *truss* bracing shall provide out-of-plane support to the *truss* at the top *chord* plane, bottom *chord* plane, and *web member* plane, as required by design.

F2.1 Top and Bottom Chord Planes

Top and bottom *chord* plane permanent bracing shall be designed to resist lateral movement of the top *chord*.

Sheathing, metal panels, or other approved materials used to act as permanent bracing shall be designed to act as a diaphragm.

Purlins used to act as permanent bracing shall be adequately attached to the top and bottom *chords* and to a diagonal brace or diaphragm. Purlin spacing shall be considered in determining the design buckling strength of the top *chord*.

F2.2 Web Member Plane

Web member plane bracing shall be designed to hold the *trusses* in a vertical position and to provide permanent bracing to shorten the buckling length of *web members*, as specified by the design.

F3 Field Assembly

Any requirements for field assembly of *trusses* shall be specified by the *truss designer*. The installer is responsible for the proper field assembly.

F4 Delivery, Handling and Installation

Care shall be exercised at all times to avoid damage through handling during storage, delivery, unloading, and erection of *trusses*. The installer shall ensure that handling and installation procedures do not reduce the load carrying capacity of the *truss*. The installer shall obtain proper guidance from the *truss designer* prior to repairing damaged *trusses*.

G. TEST METHODS

Tests, when required as defined below, shall be conducted under the supervision of a registered professional engineer in accordance with this *Truss Standard*.

(a) For cold-formed steel *truss* components (*chord* and *web members*) for which the nominal strength cannot be computed according to this *Truss Standard* or its specific references, performance tests shall be performed in accordance with Section G1.

(b) For cold-formed steel *truss* connections for which the nominal strength can not be computed according to this *Truss Standard* or its specific references, performance tests shall be performed in accordance with the AISI *Test Methods for Mechanically Fastened Cold-Formed Steel Connections.*

(c) For cold-formed steel *trusses* for which the nominal strength can be computed according to this *Truss Standard* and its specific references or determined on the basis of component performance tests in accordance with Section G1, and when it must be demonstrated that the strength is not less than the nominal resistance specified in this *Truss Standard* or its specific references confirmatory tests shall be performed in accordance with Section G2.

(d) For cold-formed steel *trusses* for which the nominal strength can not be computed according to this *Truss Standard* and its specific references or determined on the basis of component performance tests in accordance with Section G1, performance tests shall be performed in accordance with Section G3.

G1 Component Structural Performance Load Test

G1.1 Flexural Test

Flexural tests shall be performed to define the positive or negative flexural strength of the cross section of a *truss* member for *static load*.

G1.1.1 Number of Test Specimens

The minimum number of test specimens shall be in accordance with the Section F1 of the *Specification*.

G1.1.2 Materials

The test specimens shall be representative of those intended for use in the final product. Physical and material properties of the steel shall be determined according to Section F3 of the *Specification*.

G1.1.3 Test Apparatus

The test apparatus and procedures employed shall produce a failure consistent with the purpose.

G1.1.4 Load and Deflection Measuring Devices

The load measuring device or devices used shall be capable of measuring loads to an accuracy of $\pm 2\%$ of the design load.

The deflection measuring devices, if employed, shall avoid magnification of deflection readings due to a movement of supports during loading. When deflection measuring systems that do not compensate for support settlement are used, measurement of support displacement under load is needed to obtain an accurate load-deflection response. Deflection readings and measuring devices shall have an accuracy of 0.01 inches (0.25 mm).

G1.1.5 Loading Procedures

Load shall be applied and load measurements shall be taken. The maximum loading rate shall not exceed a corresponding applied stress rate of 3 ksi (20.7 MPa) of gross cross-sectional area per minute.

G1.1.6 Interpretation of Test Results

Evaluation of the test results shall be made in accordance with Section F1, Tests for Determining Structural Performance, of the *Specification.*

G1.1.7 Report

The report shall identify the testing laboratory, laboratory address, laboratory personnel involved in the conduct of the test, and the registered professional engineer in responsible charge.

The report shall consist of a description of all specimen components, including drawings defining actual and nominal geometry, material specifications, material properties test results describing the actual physical properties of each component, and the sources of supply. Differences between the actual and the nominal dimensions and material properties shall be noted in the report. The report shall also indicate those modifications made to the test apparatus and any deviations made to the test procedure and their influence on the results of the test.

The test report shall also contain a sketch or photograph of the test setup, the latest calibration date and accuracy of the equipment used, the signature and engineering seal of the registered professional engineer responsible for the test, and a tabulation of all raw and evaluated test data.

All graphs resulting from the test evaluation procedure shall be included in the test report.

G1.2 Compression Test

Compression tests shall be performed to define the compressive strength, excluding overall buckling, of a *truss* member for *static load*. The AISI *Stub-Column Test Method for Effective Area of Cold-Formed Steel Columns* shall be considered as an acceptable test method. Alternative tests methods shall be acceptable, when approved by the *truss designer*.

G2 Full-Scale Confirmatory Load Test

G2.1 Test Specimen

For the purpose of this test, a test specimen shall be considered to consist of a full-scale *truss* assembly representative of those intended for use in the final product.

G2.2 Number of Test Specimens

A single confirmatory load test shall be considered as meeting the required minimum number of test specimens.

G2.3 Materials

The materials contained within the test specimen shall be representative of those intended for use in the final product. Physical and material properties of the steel shall be determined according to Section F3 of the *Specification*.

G2.4 Fabrication

Fabrication of the test specimen shall be representative of that intended for the finished product.

G2.5 Test Apparatus

A test shall consist of a single *truss*, pair of t*russes*, or multiple *trusses*.

A single *truss* shall be tested in either a vertical position (normal or inverted) or in a horizontal position. A pair of *trusses* or multiple *trusses* shall be tested in a vertical position (normal or inverted).

The self-weight of the *truss* shall be included in the total load applied to *trusses* that are tested in a vertical position to compensate for the effect of dead loads and gravity.

Reaction supports shall provide sufficient clearance above the ground or restraint frame to allow for normal displacements, ease of loading, instrumentation, and provide room for observations and measurements. Supports shall have adequate strength and stiffness to resist deformations during tests.

Support reaction hardware shall be typical of that planned for use in the completed structure or as required to satisfy the intent of the tests.

Lateral support shall be provided beneath a single *truss* when tested horizontally to keep the test *truss* flat and to minimize any adverse lateral displacement caused by gravity. Lateral support shall be provided for single, paired, or multiple *trusses* when tested vertically to minimize adverse lateral displacement and prevent buckling of the assembly. Where lateral support is used, it shall not interfere with the free in-plane displacement of the *truss* or *truss* assembly. The components of the test *truss* shall not be laterally supported in a manner that will exceed that intended in a representative installation.

When loads are applied using dead weight, such as sand, masonry units, or water, the dead load material shall be positioned to prevent arching action.

When loads are applied using water, the water shall be compartmentalized into cells to prevent a non-uniform load as the *truss* deflects.

G2.6 Load and Deflection Measuring Devices

When multiple *trusses* are tested as an assembly, load-measuring devices shall be located beneath each *truss* support. The load measuring device or devices used shall be capable of measuring loads to an accuracy of ± 2% of the design load.

The deflection measuring devices, if employed, shall avoid magnification of deflection readings due to a movement of supports during loading. When deflection-measuring systems that do not compensate for support settlement are used, measurement of support displacement under load is needed to obtain an accurate load-deflection response. Deflection readings and measuring devices shall have an accuracy of the greater of ± 2% of design load deflection or 0.01 inches (0.25 mm).

G2.7 Loading Procedures

Each of the increments of test load shall not exceed 1/5 of the nominal load.

When a test to confirm design deflections is required, the test load shall be applied up to the nominal load. This load shall be held for no less than 5 minutes, at which time deflection readings shall be recorded. When testing *trusses* in pairs, the deflections of two *trusses* at corresponding locations shall be permitted to be averaged. Support displacement under load shall be measured to obtain an accurate load-deflection response when deflection-measuring systems that do not compensate for support settlement are used.

The test load shall be applied up to the nominal load times 1.65 (factor of safety) and held for no less than 5 minutes and then the confirmatory test shall be considered complete.

G2.8 Interpretation of Test Results

The confirmatory test shall be deemed successful if the test specimen complies with the loading requirements in Section G2.7. When a test to confirm design deflections is required, the test shall be deemed successful if the measured deflections of the test specimen do not exceed the design (dead plus live load) deflection limit.

G2.9 Report

The report shall identify the testing laboratory, laboratory address, laboratory personnel involved in the conduct of the test, and the registered professional engineer in responsible charge.

The report shall consist of a description of all specimen components, including drawings defining actual and nominal geometry, material specifications, material properties test results describing the actual physical properties of each component, and the sources of supply. Differences between the actual and the nominal dimensions and material properties shall be noted in the report. The report shall also indicate those modifications made to the test apparatus and any deviations made to the test procedure and their influence on the results of the test.

The test report shall also contain a sketch or photograph of the test setup, the latest calibration date and accuracy of the equipment used, the signature and engineering seal of the registered professional engineer responsible for the test, and a tabulation of all raw and evaluated test data.

All graphs resulting from the test evaluation procedure shall be included in the test report.

G3 Full-Scale Structural Performance Load Test

G3.1 Test Specimen

For the purpose of this test, a test specimen shall be considered to consist of a full-scale *truss* assembly representative of those intended for use in the final product.

G3.2 Number of Test Specimens

Performance testing of two identical test specimens shall be considered as meeting the required minimum number of test specimens.

G3.3 Materials

The materials contained within the test specimen shall be representative of those intended for use in the final product. Physical and material properties of the steel shall be determined according to Section F3 of the *Specification*.

G3.4 Fabrication

Fabrication of the test specimen shall be representative of that intended for the finished product.

G3.5 Test Apparatus

A test shall consist of a single *truss*, pair of *trusses* or multiple *trusses*.

A single *truss* shall be tested in either a vertical position (normal or inverted) or in a horizontal position. A pair of *trusses* or multiple *trusses* shall be tested in a vertical position (normal or inverted).

The self-weight of the *truss* shall be included in the total load applied to *trusses* that are tested in a vertical position to compensate for the effect of dead loads and gravity.

Reaction supports shall provide sufficient clearance above the ground or restraint frame to allow for normal displacements, ease of loading, instrumentation, and provide room for observations and measurements. Supports shall have adequate strength and stiffness to resist deformations during tests.

Support reaction hardware shall be typical of that planned for use in the completed structure or as required to satisfy the intent of the tests.

Lateral support shall be provided beneath a single *truss* when tested horizontally to keep the test *truss* flat and to minimize any adverse lateral displacement caused by gravity. Lateral support shall be provided for single, paired or multiple *trusses* when tested vertically to minimize adverse lateral displacement and prevent buckling of the assembly. Where lateral support is used, it shall not interfere with the free in-plane displacement of the *truss* or *truss* assembly. The components of the test *truss* shall not be laterally supported in a manner that will exceed that intended in a representative installation.

When loads are applied using dead weight, such as sand, masonry units, or water, the dead load material shall be positioned to prevent arching action.

When loads are applied using water, the water shall be compartmentalized into cells to prevent a non-uniform load as the *truss* deflects.

G3.6 Load and Deflection Measuring Devices

When multiple *trusses* are tested as an assembly, load-measuring devices shall be located beneath each *truss* support. The load measuring device or devices used shall be capable of measuring loads to an accuracy of ± 2% of the design load.

The deflection measuring devices, if employed, shall avoid magnification of deflection readings due to a movement of supports during loading. When deflection-measuring systems that do not compensate for support settlement are used, measurement of support displacement under load is needed to obtain an accurate load-deflection response. Deflection readings and measuring devices shall have an accuracy of 0.01 inches (0.25 mm).

G3.7 Loading Procedures

Each of the increments of test load shall not exceed 1/5 of the design load.

When a test to confirm design deflections is required, the test load shall be applied up to the design load. This load shall be held for no less than 5 minutes, at which time deflection readings shall be recorded. When testing *trusses* in pairs, the deflections of two *trusses* at corresponding locations shall be permitted to be averaged. Support displacement under load shall be measured to obtain an accurate load-deflection response when deflection-measuring systems that do not compensate for support settlement are used.

The test load shall be applied up to the design load times the factor of safety and held for no less than 5 minutes and then the performance test shall be considered complete.

The factor of safety for the performance test shall be 2.0 when two specimens are tested or shall be determined in accordance with Section F1 of the *Specification* with β_0 equal to 2.0 when three or more specimens are tested.

G3.8 Interpretation of Test Results

The performance test shall be deemed successful if the test specimen complies with the loading requirements in Section G3.7. When a test to confirm design deflections is required, the test shall be deemed successful if the measured deflections of the test specimen do not exceed the design (dead plus live load) deflection limit.

G3.9 Report

The report shall identify the testing laboratory, laboratory address, laboratory personnel involved in the conduct of the test and the registered professional engineer in responsible charge.

The report shall consist of a description of all specimen components, including drawings defining actual and nominal geometry, material s, material properties test results describing the actual physical properties of each component, and the sources of supply. Differences between the actual and the nominal dimensions and material properties shall be noted in the report. The report shall also indicate those modifications made to the test apparatus and any deviations made to the test procedure and their influence on the results of the test.

The test report shall also contain a sketch or photograph of the test setup, the latest calibration date and accuracy of the equipment used, the signature and engineering seal of the registered professional engineer responsible for the test, and a tabulation of all raw and evaluated test data.

All graphs resulting from the test evaluation procedure shall be included in the test report.

American Iron and Steel Institute

AISI STANDARD

Commentary on the Standard for Cold-Formed Steel Framing – Truss Design, 2004 Edition

Endorsed by:

Steel Framing Alliance™

DISCLAIMER

The material contained herein has been developed by the American Iron and Steel Institute Committee on Framing Standards. The Committee has made a diligent effort to present accurate, reliable, and useful information on cold-formed steel framing design and installation. The Committee acknowledges and is grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject. Specific references are included in this *Commentary*.

With anticipated improvements in understanding of the behavior of cold-formed steel framing and the continuing development of new technology, this material may eventually become dated. It is anticipated that AISI will publish updates of this material as new information becomes available, but this cannot be guaranteed.

The materials set forth herein are for general purposes only. They are not a substitute for competent professional advice. Application of this information to a specific project should be reviewed by a design professional. Indeed, in many jurisdictions, such review is required by law. Anyone making use of the information set forth herein does so at their own risk and assumes any and all liability arising there from.

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PREFACE

This *Commentary* is intended to facilitate the use, and provide an understanding of the background, of the AISI *Standard for Cold-Formed Steel Framing - Truss Design*. The *Commentary* illustrates the substance and limitations of the various provisions of the *Truss Standard*.

In the *Commentary*, sections, equations, figures, and tables are identified by the same notation as used in the *Truss Standard*.

The Committee greatly acknowledges the assistance and guidance of the Steel Truss and Component Association (STCA) and the Wood Truss Council of America (WTCA) in the preparation of this document.

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TABLE OF CONTENTS

COMMENTARY ON THE STANDARD FOR COLD-FORMED STEEL FRAMING – TRUSS DESIGN

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COMMENTARY ON THE STANDARD FOR COLD-FORMED STEEL FRAMING – TRUSS DESIGN

A. GENERAL

A1 Scope

This *Truss Standard* applies to the design, quality assurance, installation and testing of cold-formed steel *trusses* used for load carrying purposes in buildings. The *Truss Standard* does not preclude the use of other cold-formed steel members, assemblies, structures, or designs when they demonstrate equivalent performance for the intended use to those specified in the *Truss Standard*.

Cold-formed steel *trusses* are planar structural components. Structural performance depends on the *trusses* being installed vertically, in-plane, and at specific spacing, and being properly fabricated and braced. The *Truss Standard* describes the materials used in a cold-formed steel *truss*, as well as design, fabrication, and bracing procedures for *truss* members.

This *Truss Standard* is intended to serve as a supplement to the AISI *North American Specification for the Design of Cold-Formed Steel Structural Members* [*Specification*] (AISI, 2004a) [*Specification*]. This *Truss Standard* is also intended to be used in conjunction with the AISI *General Provisions for Construction with Cold-Formed Steel Framing* (AISI, 2004b).

A2 Definitions

Many of the terms in the *Truss Standard* are self-explanatory. Only definitions of terms not self-explanatory or not defined in the referenced documents are provided in the *Truss Standard.*

A3 Referenced Documents

The referenced documents pertain to various aspects of cold-formed steel design and behavior. All of the documents that are listed in this section are referenced in the *Truss Standard.*

B. DESIGN RESPONSIBILITIES

The *Truss Standard* defines the professional design responsibilities of the individuals and organizations involved in the preparation, submittal, review, and approval of a cold-formed steel *truss*. Alternate provisions, as agreed upon by the involved parties are permitted.

B1 Truss Designer

To aid the *truss designer* in the preparation of a design submittal, a comprehensive list of pertinent design information is provided in the *Truss Standard*. It should be noted that even when Load and Resistance Factor Design (LRFD) is used to design the trusses, the *Truss Standard* specifies that *nominal* (unfactored) reactions and member forces be shown on the *truss* design drawings. This is intended to avoid confusion and facilitate the design of other portions of the structure, particularly when load factors other than those used for the design of the cold-formed steel trusses are prescribed by the applicable code for those other portions.

B2 Building Designer

The *building designer* has broad responsibility for the overall building design in accordance with the statutes and regulations governing the professional registration and certification of architects or engineers of the state where the building will be located. The *Truss Standard* aids in defining information to be provided to the *truss designer*, as well as the design responsibility of the *building designer*.

It is imperative that the *building designer* considers the effect that *truss* deflections may have on the performance of the building. Also, the *truss designer* needs to consider the use of lateral *bracing* to preclude out-of-plane buckling of a truss or an element of the truss, that is a *chord* or *web member*. The *building designer* is responsible to ensure that an adequate load path and anchorage of the *bracing* is provided.

C. LOADING

The *Truss Standard* does not establish the appropriate loading requirements for which a *truss* should be designed. In most cases, these loads are adequately covered by the applicable building code or standard. In the absence of such a code, the loads, forces, and combinations of loads should be in accordance with accepted engineering practice for the geographical area under consideration as specified by the appropriate sections of the American Society of Civil Engineers' *Minimum Design Loads for Buildings and Other Structures* (ASCE 7, 2002).

D. TRUSS DESIGN

The provisions contained in this section of the *Truss Standard* address the various design aspects related to *truss* strength. The strength determinations required by the *Truss Standard* are in accordance with the allowable stress design method given by the *Specification*, except where additional research studies have indicated an alternative approach is warranted.

D3 Analysis

The structural analysis requirements contained in the *Truss Standard* are based on available information pertaining to the behavior of cold-formed steel C-section *truss* assemblies (Harper, 1995; LaBoube and Yu, 1998). These requirements do not preclude the use of more rigorous analysis or design assumptions as determined by rational analysis and/or testing.

D4 Member Design

D4.1 Properties of Sections

The *Specification* has been shown to be a highly reliable for determining the design cross-section properties of *C-shapes* and other simple geometries. However, recent proprietary research has shown that for more complex shapes utilizing longitudinal stiffeners, the *Specification* provisions may not provide an accurate estimate of the load-carrying capacity. In the absence of an analytical solution for these more complex shapes, tests in accordance with Section F1 of the *Specification* are necessary.

D4.2 Compression Chords

When subjected to gravity load, the compression *chord* may experience the combined effects of bending and axial compression. The design for combined load effects is governed by Section C5.2.1 of the *Specification*.

Engineering design specifications recognize the need for using rational analysis and/or test to define an effective length factor. The *Truss Standard* permits the use of either rational analysis and/or testing.

Based on research on C-section *trusses* conducted at the University of Missouri-Rolla (UMR), (Harper, 1995; Ibrahim, 1998) it was determined that the unbraced lengths, L_x and L_t , may be taken as equal to the distance between the panel points. It was also discovered that when sheathing is attached to the *chord* and when the compression *chord* is continuous over at least one intermediate panel point, and is continuous from the heel to the ridge, or breakpoint of a *truss*, L_y, may be taken as the distance between sheathing connectors. Engineering judgment indicates that when sheathing is not attached to the top *chord* L_y may be taken as the distance between panel points.

The UMR research also determined that for a sheathed C-section *truss* when the compression *chord* is continuous over at least one intermediate panel point, and is continuous from the heel to the ridge, or breakpoint of a *truss* K_x, K_y, and K_t may be taken as 0.75. For other compression *chords*, based on engineering judgment, K_x, K_y, and K_t should be taken as unity.

An alternative design assumption for *chords* in compression, based on engineering practice and judgment, is to assume that the effective length be taken as the distance between two adjacent points of contraflexure. In such case, the effective length factor and C_m should be taken as unity.

The required effective length factors and unbraced lengths given in the *Truss Standard* for hat shapes are based on engineering judgment. The *Z-shape* requirements are based on proprietary testing.

Consistent with the *Specification*, the end moment coefficient, C_m, should be taken as 0.85, unless a more rigorous analysis is performed to justify another value.

Requirements in the *Truss Standard* for the evaluation of the bending strength are based on engineering judgment.

Ibrahim et al. (1998), determined that when a C-section compression *chord* is subject to concentrated load at a panel point, the interaction of axial compression, bending and *web* crippling must be considered. The researchers proposed the following interaction equation:

$$\frac{P}{P_{no}} + \frac{M}{M_{nxo}} + \frac{R}{R_n} \leq \frac{1.49}{\Omega} \qquad (Eq.\ D4.2.3\text{-}1)$$

Where:

P = compression axial load

M = bending moment

R = concentrated load

P_{no} = nominal axial strength computed at $f = F_y$

M_{nxo} = nominal flexural strength computed at $f = F_y$

R_n = nominal interior one-*flange web* crippling strength

Ω = factor of safety, 1.95

The values of P and M are to be determined by structural analysis for the panel point in question, where as R is the applied concentrated load at the panel point. The nominal capacities are to be computed using the *Specification*. Based on a statistical analysis consistent with load and resistance factor design, the factor of safety was determined. The *Truss Standard* also includes a similar equation applicable to the LRFD method.

D4.3 Tension Chords

The design requirements prescribed by the *Truss Standard* for tension *chords* is based on experience and engineering judgment.

D4.4 Compression Web Members.

The behavior of a compression *web member* is a function of the connection of the *web member* to the *chord*. For example, when *C-shaped chord* and *web members* are employed, a common connection detail is to attach the respective members back-to-back through their *webs*. Such a connection detail creates in the *web member* an eccentric loading condition. In such case, the *web member* should be evaluated for combined axial load and bending using Section C5 of the *Specification*.

Researchers at the University of Missouri-Rolla (Rieman, 1996; Ibrahim et al., 1998) determined that for a *C-shaped* compression *web member* that is attached through its *web* element, the interaction of axial compression and out-of-plane bending may be determined by the following ASD interaction equation,

$$\frac{\Omega_c RP}{P_n} + \frac{\Omega_b C_{my} RPe}{M_{ny}\alpha_y} \le 1.0 \qquad (\textit{Eq. } \text{D4.4-1})$$

Where:

$$R = -\left(\frac{L/r}{173}\right)^2 + \frac{L/r}{88} - 0.22 \ge 0.6 \qquad (\textit{Eq. } \text{D4.4-2})$$

L = unbraced length of the compression web member

r = radius of gyration of the full section about the minor axis

P_n = nominal axial strength based on Section C4.1 of the *Specification*. Only flexural buckling need be considered.

e = eccentricity of compression force with respect to the centroid of the full section of the *web*

The parameter R is an experimentally determined reduction imposed on the axial load. The equation is a fit to the average test data, which is a common practice in cold-formed steel research. To recognize the lower limit on the tested L/r ratio, the *Truss Standard* stipulates R ≥ 0.6. The intent of R is to recognize the increased significance of the bending effect, compared to the axial effect for longer length *web members*. Unique to the application of the interaction equation is the determination of the nominal axial strength based on flexural buckling alone. Research showed that the minor axis bending, which resulted from the eccentrically applied axial load, created a member deflection which enabled only flexural buckling. Thus, the behavior of the *web member* was determined predominately by bending resulting from the eccentric load. The parameters P, Ω_b, Ω_c, C_{my}, M_{ny} and α_y are defined in accordance with Section C5.2.1 of the *Specification*. The *Truss Standard* also includes a similar equation applicable to the LRFD method.

For compression *web member* cross sections other than a *C-shape* attached through its *web* element, which has symmetry of loading, the axial compression load may be taken as acting through the centroid of the section.

When computing the design strength, the effective lengths, K_xL_x, K_yL_y and K_tL_t, may be taken as the distance between the center of the member's end connection patterns. This assumption is consistent with the analysis approach used by UMR researchers (Rieman, 1996; Ibrahim et al., 1998).

D4.5 Tension Web Members

Tension *web members* may experience a reduction in load-carrying capacity when subjected to combined axial load and bending. For *C-shaped* sections, this may be attributed to the dominant behavior being that of bending resulting from the eccentric load. However, testing has not documented that the combined loading compromises the integrity of the tension member. Therefore, for a tension *web member* connected to the *web* element of a *chord member*, or connected to a gusset plate, the *Truss Standard* permits the axial tension load to be taken as acting through the centroid of the *web member's* cross section.

D4.6 Eccentricity in Joints

The *Truss Standard* does not specify the use of a multiple or single node structural analysis model to account for the effects of eccentricity in joints. The *truss* stiffness will differ based on whether a multiple or single node analysis is performed. When a multiple node analysis is used, a node should be placed at each *web* location where the centerline of the *web* meets the centerline of the *chord*. When performing a single node analysis, additional design considerations may be necessary. For example, eccentricity created by the spatial relationship of the *webs* and the *chord* at a joint may generate additional moments, shears, and/or axial forces. Such moments and forces may be directly reflected in a multiple node analysis model. Thus, when using a single node analysis model, a secondary analysis and design check of the joint, or a load test may be required to justify the design.

The *Truss Standard* defines a *web member* lap length as 75% of the *chord member* depth. This minimum lap length is assumed, based on engineering judgment, to serve as a *web* shear stiffener for the *chord*. The *chord* segment between the assumed stiffeners is to be investigated for combined bending and shear, where a stiffened shear panel is assumed, in accordance with Equation C3.3.1-2 of the *Specification*. For *truss* configurations having the *web member* lap length less that 75% the *chord member's* depth, the *chord* is to be investigated for combined bending and shear in accordance with Equation C3.3.1-1 of the *Specification.*

Along the length of the *chord*, at the mid-point between the intersecting *web members*, shear is to be evaluated by Section C3.2 of the *Specification*. The shear buckling coefficient is taken to be consistent with the assumed shear panel condition at the segments ends as defined by Section C3.2 of the *Specification*.

Based on experience, when screws are used as the connector, a minimum of four screws should be used in a *web* to *chord* connection and the screws should be equally distributed in their group.

D5 Connection Design

D5.1 Fastening Methods

Although the common fastening system used by the industry is the self-drilling screw. The *Truss Standard* permits the use of bolts, welds, rivets, clinches, and other technologies as *approved* by the *truss designer*. Screw, bolt, and weld connections are to be designed in accordance with the *Specification*. If other fastener types, such as rivets, clinches, rosettes, adhesives, etc., are to be used in the fabrication of the *truss*, the design values are to be determined by tests, and the design strength determined in accordance with Section F1 of the *Specification.*

For the design of connecting elements, such as plates, gussets, and brackets, reference is made to the *Specification* and to Section J4 of the American Institute of Steel Construction's *Load and Resistance Design Specification for Structural Steel Buildings* (AISC, 1993).

D5.2 Coped Connections for C-Sections

The design engineer should give special attention to the heel and ridge connections of the *truss* to ensure structural integrity of the *truss.*

At the ridge, coped members may be reinforced to prevent *web* buckling of the *chord member*. Attachment of a track section of the same thickness as the *chord member*, thus creating a box section, and having a length equal to the depth of the *chord member* has been shown to provide adequate reinforcement (Ibrahim, 1998). Lateral *bracing* is also important to stabilize the ridge from overall buckling. At the heel, a *web* stiffener may be needed to preclude *web* crippling (Koka, 1997).

At a heel connection, UMR research (Koka, 1997) determined that coping reduces both the shear buckling and *web* crippling strength of the bottom *chord* coped member. The UMR research proposed that when a coped *flange* had a bearing stiffener with a minimum moment of inertia (I_{min}) of 0.161 in.^{4} (67,000 mm^4), the shear strength could be calculated in accordance with *Specification*) Section C3.2, but required a reduction as defined by the following factor, R:

$$R = 0.976 + \frac{0.556c}{h} - \frac{0.532d_c}{h} \le 1.0 \qquad (Eq.\ D5.2\text{-}1)$$

The cited limits in the *Truss Standard* reflect the scope of the experimental study and apply only to connections where the bottom *chord* is coped.

When a bearing stiffener not having the minimum moment of inertia is used, *web* crippling controlled the heel connection strength (Koka, 1997). Therefore, the *Truss Standard* requires that the computed end-one-*flange web* crippling strength at the heel, as determined by *Specification* Section C3.4 be reduced by the following factor:

$$R = 1.036 + \frac{0.668c}{h} - \frac{0.0505d_c}{h} \le 1.0 \qquad (Eq.\ D5.2\text{-}2)$$

The cited limits in the *Truss Standard* reflect the scope of the experimental study.

Where c = length of cope and d_c = depth of cope as illustrated in Figure D5.2-1. I_{min} of the stiffener is computed with respect to an axis parallel to the *web* of the bottom *chord*.

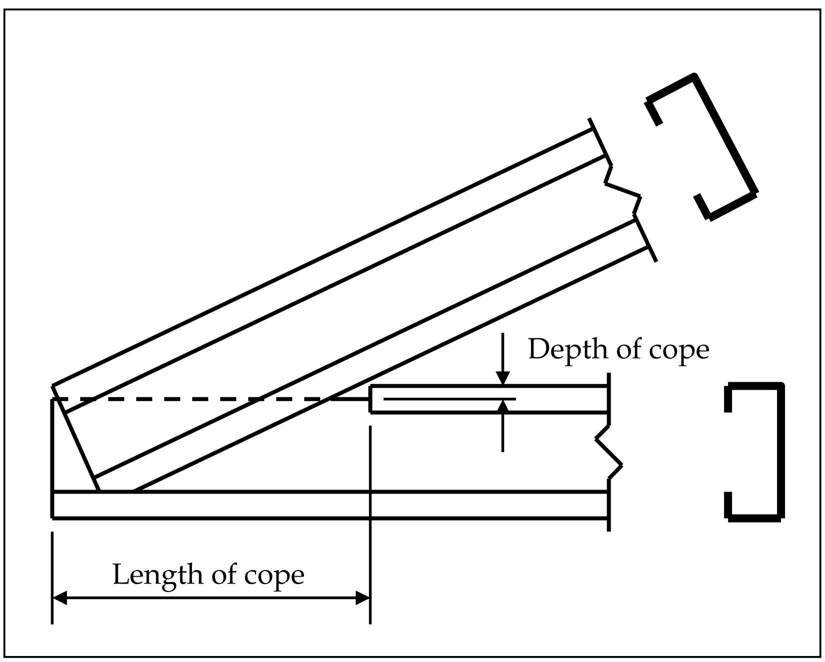

Figure D5.2-1: Definition of Truss Coping Dimensions

D6 Serviceability

Serviceability limits are to be chosen based on the intended function of the structure, and should be evaluated based on realistic loads and load combinations as determined by the *building designer*. Because serviceability limits depend on the function of the structure and the perception of the occupant, it is not possible to specify general limits in the *Truss Standard*. As a guide to the designer, the maximum allowable deflection of the *chord* of a *truss* resulting from gravity load, excluding dead load, may be taken as the following:

Span/360 for plaster ceilings
Span/240 for flexible type ceilings
Span/180 for no finished ceiling
Span/480 for floor systems

Although the use of a deflection limit has been used to preclude vibration problems in the past, some floor systems may require explicit consideration of the dynamic characteristics of the floor system.

Truss serviceability is evaluated at design load. When computing *truss* deflections, the *Truss Standard* permits the use the full cross-sectional area of the *truss* members. The use of full areas is warranted because a *truss* system is a highly indeterminate structural system, and local buckling of an individual member does not appreciably affect the stiffness of the *truss* at design load.

E. QUALITY CRITERIA FOR STEEL TRUSSES

The practices defined herein have been adopted by the *Truss Standard* as commonly accepted practice. In the absence of other instructions in the contract documents, the provisions of Section E are the quality standard for the manufacturing processes of steel *trusses* to be used in conjunction with an in-plant quality assurance procedure and a *truss* design.

F. TRUSS INSTALLATION & BRACING

Cold-formed steel *trusses* are planar structural components. The structural performance depends on the *trusses* being installed vertically, in-plane, at specified spacing, and being properly braced. The installer is responsible for receipt, storage, erection, installation, field assembly, and *bracing*. The practices defined herein have been adopted by the *Truss Standard* as commonly accepted practice.

F2 Permanent Bracing

Permanent *bracing* ensures that the *truss* is an integral part of the roof and building structure. For additional guidance refer to the Light Gage Steel Engineers Association (LGSEA) Tech Note 551e, *Design Guide for Permanent Bracing of Cold-Formed Steel Trusses* (LGSEA, 1998). Permanent *bracing* may include diagonal *bracing*, cross *bracing*, and lateral *bracing*. Sheathing may also be used to provide stability, but reliance on sheathing material must be documented in the structural submittal.

Lateral *bracing*, which may be required by the *truss* design to reduce the buckling length of *chord* or *web members* of a *truss*, is part of the *truss* design and is the only *bracing* specified on the *truss* design drawings. This *bracing* must be sufficiently anchored or restrained by diagonal *bracing* to prevent its movement. Effective lateral *bracing* should restrain lateral and rotational movements of the compression member in question. Single sided *bracing* may not be fully effective to restrain such movements for concentrically loaded members having large h/t ratios. It is suggested that for compression members having depths less than four inches and thickness greater than or equal to 0.033 inches (0.84mm), the single sided brace will be effective. For compression members that do not conform to these limits, single sided lateral *bracing* should be considered as ineffective for buckling restraint, and *bracing* should be provided on both *flanges*.

Sheathing, metal panels, or other *approved* materials used as permanent *bracing* is to be designed to act as a *diaphragm*. Where metal roofing materials are used to act as a *diaphragm* they are to be properly lapped and connected in accordance with the specification of the *building designer*.

When purlins are used to act as permanent *bracing*, an adequate attachment of the purlins to a diagonal brace or *diaphragm* is necessary to provide a load path for the brace forces.

Bottom *chord* plane permanent *bracing* is required to maintain the *truss* design spacing and to provide lateral support to the bottom *chord* to resist buckling forces in the event of stress reversal due to wind uplift or unequal roof or floor loads.

For multiple bearing *trusses* or cantilever conditions, portions of the bottom *chord* become compression members and must be braced laterally to resist buckling in the same manner as the top *chord* of simple span *trusses*.

Permanent diagonal *bracing* and associated continuous lateral braces are not required when the bottom *chords* of *trusses* are braced by engineered horizontal *diaphragms*, for example, properly attached gypsum wallboard sheathing.

The *building designer* is responsible for specifying how the permanent lateral *bracing* is to be anchored or restrained to prevent lateral movement if all *truss* members, so braced, buckle together. Such *bracing* may be accomplished by anchorage to solid walls, diagonal *bracing* in the plane of the *web members*, or other equivalent means.

F4 Delivery, Handling And Installation

Care needs to be exercised at all times to avoid damage through handling during storage, delivery, unloading, and erection of *trusses*. Field installation of the *trusses*, including considerations such as proper handling, safety precautions, temporary and permanent *bracing*, and other safeguards or procedures, is not the responsibility of the *truss* fabricator, *truss designer*, or the metal components manufacturer. During installation each *truss* must be temporarily braced. The installer must ensure that handling and installation procedures do not reduce the load-carrying capacity of the *truss*.

All *trusses* should be securely braced, both during erection and after permanent installation. Because individual *trusses* are designed only as structural components, the function of *bracing* is to cause all elements of the roof system to act as a unit to resist applied loads.

Temporary *bracing* is used during erection to hold the *trusses* until permanent *bracing*, sheathing, and ceilings are in place. Construction loads, for example stacked roofing material, must never be placed on unbraced *trusses* because *trusses* are laterally unstable until adequate *bracing* is installed. For guidance on temporary *bracing* during construction, refer to the LGSEA Tech Note 551d, *Design Guide for Construction Bracing of Cold-Formed Steel Trusses* (LGSEA, 1996) and the American Institute of Steel Construction's Steel Design Guide Series #10 on *Erection Bracing of Low-Rise Structural Steel Buildings* (AISC, 1997).

G. TEST METHODS

Design calculations require the application of *approved* materials and cross section properties. In such cases where calculations are used to define the structural performance of a *truss* assembly, the structural performance may be verified by full-scale test. However, when the structural performance cannot be determined by calculation, the structural performance must be determined by test. This *Truss Standard* provides guidance for both component and full-scale load tests.

G1 Component Structural Performance Load Test

The load test procedures contained in the *Truss Standard* may be used to confirm or define the design methodology for a *chord member* or a *web member* of a *truss* assembly. This test protocol is intended for use in the testing of *truss* assembly components fabricated using cold-formed steel structural members.

Because the flexural strength of a *truss* member may be bending (yielding or buckling), shear, web crippling, or combinations thereof, this test protocol defines what should be considered in regard to a test, it does not define for the testing agency how to do the test. This leaves the selection of the test fixture and loading medium to the discretion of the testing agency. For details of test apparatus and procedures that have been used for such purposes, but in no way should be regarded as mandatory, see Hetrukul and Yu (1978), LaBoube and Yu (1978a, 1978b, 1982), and Yu (2000).

This protocol also outlines the procedures to be followed to define the compression strength of a *truss* component for static load. Because the compression strength of a *truss* component may be local buckling or overall column buckling, this procedure defines what to do in regard to performing a test, it does not tell the testing agency how to do the test. This leaves the selection of the test fixture and loading medium to the discretion of the testing agency.

Load tests can be hazardous to the individuals performing or observing the tests, and also can damage the testing fixtures or the structure housing the test setup due to a sudden release of stored energy at failure. Care should be exercised in the preparation of the test setup to ensure that the failure of a test specimen will not result in a secondary collapse of a structural element not involved in the test.

The number of similar components that should be tested will vary with the desired precision and reliability of the information to be obtained and with the purpose of the test.

Loads may be measured using one or more of the following devices. Pressure gages or load cells can be incorporated into a hydraulic loading system. These devices must be calibrated with the jacks or cylinders at different positions of piston travel to ensure a true loading history.

Deflection readings may be taken in a variety of ways. One of the simplest methods is by the use of a taut wire or monofilament line stretched between supports in combination with a mirror-scale located at the desired deflection measuring points. When the taut wire method is used, care must be taken to ensure that the wire will remain under tension during the entire test. This can be accomplished by incorporating a spring into the line or by letting one end run over a pulley with a weight attached to the line. Deflections are read on a scale with a mirror backing. The mirror-scale deflection-measuring device is read by visually lining up the top of the wire with its image on the mirror and then reading the scale.

Other commonly used deflection measuring devices are such things as direct reading micrometer dial gages, optical levers used to read scales attached to the *truss*, linearly variable differential transformers (LVDT), or a combination of flexible wire attached at deflection points and monitored remotely through a system of pulleys attached to dial gages.

G2 Full-Scale Confirmatory Load Test

This test protocol is intended for use in the testing of *truss* assemblies fabricated using cold-formed steel structural members and connections. A confirmatory test is performed with the intent of verify structural performance as defined by calculations in accordance with a recognized specification and/or standard. Because design was in accordance with a specification or standard, all that is needed is that the tested specimen demonstrates strength not less than the applicable calculated strength.

The test protocol does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this protocol to establish appropriate safety and health practices and determine the applicability of regulatory limitation prior to use.

A full-scale *truss* test is the test of a structural system. It is generally accepted that a factor of safety of 1.5 is for overload and nothing above it should be expected in an in-situ test since the other uncertainties may already have been used up. If the test is done under laboratory conditions, 1.65 is a reasonable factor of safety since fabrication and erection uncertainties are minimized. This factor of 1.65 is consistent with the recommendations of the Steel Joist Institute.

This protocol outlines the procedures to be followed in the static load testing of load carrying *truss* assemblies. While the procedure tells what to do, it does not tell the testing agency how to do it. This leaves the selection of the test fixture and loading medium to the discretion of the testing agency.

Full-scale load tests of any large size specimen such as a *truss* can be hazardous to the individuals performing or observing the tests, and also can damage the testing fixtures or the structure housing the test setup due to a sudden release of stored energy at failure. Care should be exercised in the preparation of the test setup to ensure that the failure of a test specimen will not result in a secondary collapse of a structural element not involved in the test.

The test fixture and load application means should be designed with adequate strength and stiffness to ensure that it is the test specimen that is being tested and not the test fixture.

In a single *truss* test, frequently the support at one end will allow rotation but not translation (a rocker) and the other will allow both rotation and translation (a roller) so as not to induce additional unintentional secondary stresses into the test *truss* as it deforms under load.

The loading devices should result in the desired *truss*-loading situation regardless of whether uniform, concentrated, or a combination of both. The loading system should be such as to allow the application of loads during the test to approximate the overall intended in-service load distribution. Care should be taken to avoid eccentrically applied loads unless this type of loading is desired.

G3 Full-Scale Performance Load Test

This test protocol is intended for use in the testing of truss assemblies fabricated using cold-formed steel structural members and connections where calculation of the safe strength cannot be made in accordance with recognized calculation design specifications or standards.

The *Specification* addresses the design of the individual cold-formed steel members and connections. A *truss* is an indeterminate structural system, which therefore possesses a degree of reliability that differs from a member or connection. Galambos (1988) recommended a value of 2.0 for β_o to recognize the reliability for a structural system.

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