Special Seismic and Blast Design

Cold-Formed Steel Connection Strength

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End connections of cold-formed steel (CFS) framing are major components of the structural system. Evaluation of connection strength for design purposes is mostly done through laboratory tests to obtain the ASD strength and the LRFD strength. For special seismic and blast design, other levels of design strength are needed by the engineer – primarily the nominal strength. Some design codes even allow the use of an increased nominal strength or an increased expected strength. A Static Increase Factor (SIF) and a Dynamic Increase Factor (DIF) can be applied to the nominal and expected strength, respectively, to attain greater strength of the connection for special design purposes. This article provides a summary of the strength demand for CFS connections in special seismic and blast design, and how engineers can calculate the different levels of strength from the connection test data.

Seismic Design

Special seismic design requirements are mandated in AISI S213-07 *North American Standard for Cold-Formed Steel Framing – Lateral Design*, Section C1.1 "Seismic Requirements", which are applicable to the design of CFS shear walls or systems using diagonal strap bracing that resists wind, seismic, or other in-plane lateral loads. Section C1.1 further directs the designer to Section C5, the "Special Seismic Requirements" section, if the Response Modification Coefficient (R) of the shear wall system is greater than 3 or the Seismic Design Category of the structure is D through F.

Section C5 contains the provisions allowing nominal strength of material to be used in the design of members and/or connections. Section C5.1, "Shear Walls", and Section C5.2, "Diagonal Strap Bracing", present the provisions for design of connections, chord studs and anchorage, and foundations when using a shear wall or diagonal strap bracing lateral force resistance systems. Section C5.2.2.2 states:

All members in the load path and uplift and shear anchorage thereto from the diagonal strap bracing member to the foundation shall have the ***nominal strength*** *to resist the expected yield strength $A_gR_yF_y$, of the diagonal strap bracing member(s), except the* ***nominal strength*** *need not exceed the following, as applicable:*

(a) In the United States and Mexico: Amplified seismic load.

(b) In Canada: Maximum anticipated seismic loads calculated with R_dR_o = 1.0.

Blast Design

Standard 10 of the new 2012 Department of Defense UFC 4-010-01 *DoD Minimum Antiterrorism Standards for Buildings*, outlines the design of window and skylight systems under blast pressure loading. Provisions are given for a static or dynamic method of analysis and design for window and skylight opening framing and connections. Section B-3.1 allows the use of nominal strength when performing a *static* analysis of structural elements which support windows and skylights. These elements include jamb, header, and sill members along with connections between them and connections to the primary structure. The code states:

"Use strength design with load factors of 1.0 and ***strength reduction factors of 1.0*** *for all methods of analysis referenced herein."*

The UFC design code provides an alternative design method utilizing the *dynamic* material properties of the window glazing, framing members, connections, and supporting structural elements. Section B-3.1.1 "Dynamic Analysis" states:

Any of the glazing, framing members, connections, and supporting structural elements may be designed using dynamic analysis to prove the window or skylight systems will provide performance equivalent to or better than the hazard rating associated with the applicable level of protection as indicated in Table 2-1. Dynamic analysis guidance is presented in PDC TR 10-02. The design loading for dynamic analyses will be the appropriate pressures and impulses from the applicable explosive weights

Table 1: Static and dynamic increase factors for cold-formed steel.

	Static Increase Factor (SIF) or Average Strength Factor (ASF)	Dynamic Increase Factor (DIF)	
		Bending/ Shear	Tension/ Compression
ASCE/SEI Standard 59-11	1.1	1.1	1.1
ASCE Design of Blast-Resistant Buildings in Petrochemical Facilities (2010)	1.21	1.1	1.1
UFC 3-340-02 (2008)	1.21	1.1	1.1

at the actual standoff distances at which the windows are sited. The design loading will be applied over the areas tributary to the element being analyzed.

The dynamic method of analysis and design of framing members incorporates strength increase factors that enhance the nominal and expected strength of materials. A Static Increase Factor (SIF) can be applied to the nominal strength of a material, while a Dynamic Increase Factor (DIF) can be applied to the expected strength of a material. Note that the Static Increase Factor (SIF) is sometimes called the Average Strength Factor (ASF).

Documents such as the UFC 3-340-02 *Structures to Resist the Effects of Accidental Explosions*, the ASCE Publication *Design of Blast-Resistant Buildings in Petrochemical Facilities*, and the ASCE/SEI Standard 59-11 *Blast Protection of Buildings* describe Static and Dynamic Increase Factors and the uses of each. Since the nominal strength is typically taken as the lower bound minimum yield strength of the material, the Static Increase Factor (SIF) is applied to the nominal strength to account for higher yield strength of installed components than minimum specified yield strength values. The resulting value is the "Expected Strength". Beyond the use of this expected strength level, ASCE and the UFC code states that the Dynamic Increase Factor (DIF) is to be applied to the expected strength to account for strain rate effects from a rapid blast loading. The resulting value is the "Dynamic Strength". *Table 1* shows suggested increase factors to be used for CFS design as recommended by the ASCE publications and the DoD UFC 3-340-02.

How to Determine the Connection Design Strength?

Figure 1 shows two examples of CFS curtain wall framing connections. CFS connections are usually tested according to AISI Test Standard S905-08 *Test Methods for Mechanically Fastened Cold-Formed Steel Connections* or ICC-ES AC261 *Acceptance Criteria for Connectors Used with Cold-Formed Steel Structural Members*. A connection is typically tested to failure, and the load obtained from the test is considered the "Ultimate Strength" of the connection. Chapter F of the AISI S100-07 specification permits the calculation of the LRFD strength of the connection as the ultimate strength of the test multiplied by a calculated test resistance factor (φ_t). The test resistance factor (φ_t) is typically less than the strength resistance factor (φ) from the main specification. To determine the nominal strength of the connection for use in seismic or blast design, it is recommended to use the factor φ rather than φ_t and apply it to the LRFD strength. Selection of the appropriate φ from AISI S100-07 should depend on the observed mode of failure of the connection during the test. Once the nominal strength of the connection is determined, its expected strength and dynamic strength can be calculated using the appropriate SIF and DIF as explained above. *Figure 2* is a diagram depicting the various levels of connection strength and the factor relationship between them.

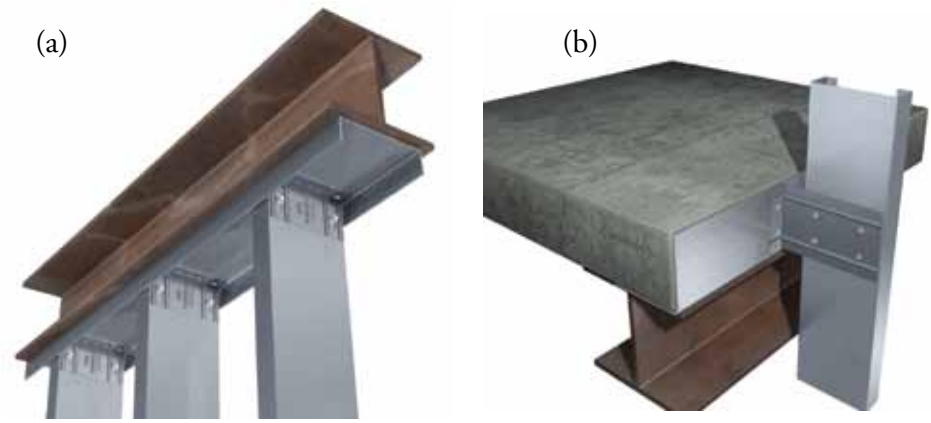

Figure 1: Cold-formed steel curtain wall framing connection; (a)sliding connection (b) fixed connection.

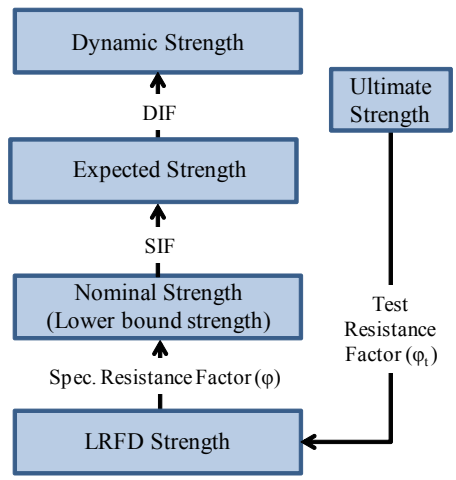

Figure 2: Strength relationship diagram.

Sample Calculations

The VertiClip® SL600 connector (*Figure 1a*) is used at the top of the curtain wall to connect CFS studs to the floor slab or beam, and to provide a sliding connection to isolate the wall from the vertical deflection of the floor system. The connector was tested under load in the out-of-plane horizontal direction. The observed modes of failure of the connector were bending then rupture:

Test ultimate strength		= 4250 lbs
Calculated φ_t using Chapter F of the AISI S100-07		= 0.633
LRFD strength	= 4250 x 0.633	= 2690 lbs
Appropriate φ from AISI S100-07, Section C3.1		= 0.9
Nominal strength	= 2690 / 0.9	= 2990 lbs
Expected strength	= 2990 x 1.21	= 3620 lbs
Dynamic strength	= 3620 x 1.1	= 3980 lbs

This data is applicable to the connector only. Attachment of the connector to stud framing and to the floor should be evaluated in a similar way. Also, it should be noted that engineers tend to use the ultimate strength of the connector as a measure of its dynamic strength. This example shows that this assumption is reasonable (difference about 7%) but un-conservative at the same time.▪