SBC ASSOCIATION

Research Report

MWFRS Method v/s Components and Cladding Method for Truss Uplift Connection Design for Wind

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This research report is based on practical scientific research (literature review, testing, analysis, etc.). This research report complies with the following sections of the building code:

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Introduction:

ASCE/SEI 7-10, Minimum Design Loads of Buildings and Other Structures, lists two methods for calculating wind pressures: Main Wind Force Resisting System (MWFRS) and Components & Cladding (C&C). Choosing which method to use when designing uplift connections for trusses can raise a number of questions for building designers, code officials and truss designers. This report will provide information to assist the building designer in deciding upon the appropriate analysis method for uplift due to wind loading.

This article should prove to be of relevance to building designers, building code officials and truss designers regarding which analysis method, MWFRS or C&C, should be used in wind load calculations for the design of uplift connections for trusses.

Key Definitions:

Main Wind Force Resisting System (MWFRS) One of the three methods outlined by *ASCE 7* for calculating wind pressures. MWFRS pertains to a structural frame or an assemblage of structural elements working together to transfer wind loads acting on the entire structure to the ground. The system typically receives wind loading from more than one surface.

Components and Cladding (C&C): Second method outlined by *ASCE 7* for calculating wind pressures. Cladding elements receive wind loads directly. Examples are roof coverings and wall coverings. Components receive wind loads either directly or from the cladding and then transfer the loads to the main wind force resisting system. Fasteners and purlins are examples of components. C&C elements are exposed to higher wind pressures than MWFRS elements and must be designed accordingly.

Building Designer: Owner of the Building or the person that contracts with the Owner for the design of the Framing Structural System and/or who is responsible for the preparation of the Construction Documents. When mandated by the Legal Requirements, the Building Designer shall be a Registered Design Professional.

Truss Design Drawing: Written, graphic and pictorial depiction of an individual truss.

Truss Design Engineer: Person who is licensed to practice engineering as defined by the Legal Requirements of the Jurisdiction in which the Building is to be constructed and who supervises the preparation of the Truss Design Drawings.

Truss Designer: Person responsible for the preparation of the Truss Design Drawings.

Truss Manufacturer: Person engaged in the fabrication of Trusses.

Background:

Regardless of design method, before designing individual trusses in a roof system, the truss designer needs as much loading information as possible from the building designer who is responsible for producing the structural design documents and for providing all the information necessary to develop the design of the trusses. In the case of projects not requiring the services of a licensed professional building designer, the owner or the owner's agent is responsible for providing the required information for permitting as well as for the actual design. Although the International Building Code (*IBC*) and the International Residential Code (*IRC*) require all applicable design loads to be listed by the building designer in the structural design documents, this information is often lacking or not available to the truss designer at the time of design.

The *IRC* design scope for wind is limited in Section R301.2.1.1 as follows:

- *IRC* 2015 – where design is not required in accordance with Figure R301.2(4)B. This is generally all areas with an ultimate wind speed of 130 mph(V_{ult}) or less except in the New England states where wind speeds up to 140 mph are allowed.
- *IRC* 2012 – less than 110 mph (Basic wind speed, V_{asd}) or where design is not required in accordance with Figure R301.2(4)B
- *IRC* 2006 and 2009 – less than 100 mph in hurricane prone regions and less than 110 mph elsewhere.

- *IRC* 2000 and 2003 – less than 110 mph.

The default Exposure Category in the *IRC* is "B", but adjustments for Exposure Categories C & D as well as mean roof heights up to 60 feet are allowed. The truss designer must rely on the building designer to provide accurate site-specific wind information per Table R301.2(1):

- Basic (V_{asd}) or Ultimate (V_{ult}) Wind speed (3 second gust) and whether or not the structure is in a hurricane-prone region
- Exposure Category
- Plus: mean roof height (if not given, 15 feet would be typical for a one-story, 25 feet would be typical for a two-story)

Generally, the following design criteria for structures within the scope of the *IRC* can be used. Always verify any assumptions made with the building design where they are not shown on the construction documents:

- Importance Factor (I) = 1.0
- Enclosure Category = Enclosed
- Topographic Factor (K_{ZT}) = 1.0
- Directionality Factor (K_D) = 0.85

By definition, a truss is an assemblage of structural elements, which would put it into the MWFRS category. But a truss also receives wind load directly from the roof sheathing (i.e., cladding) and therefore acts as a component, which puts the truss into the C&C category. Roof trusses can be found in the Commentary for *ASCE 7* as examples of both MWFRS and C&C.

Truss Uplift Analysis:

Selecting a method of wind load analysis depends on whether you are designing uplift connections for an individual truss member (e.g. web, top chord, etc.) or to the entire truss as both MWFRS and Component and Cladding methods can apply, depending on the situation (see Figure 1). By definition, a truss is an assemblage of structural elements, which would put it into the MWFRS category. The minimum uplift connection forces are provided in Table R802.11 of the *IRC* and Table 2308.10.1 of the *IBC* for rafters and trusses used in conventional light-frame construction. Both of these tables are developed using the MWFRS method as indicated by the reference in Footnote to Figure 6-2 of *ASCE 7-05* and Chapter 28 of *ASCE 7-10*.

Table R802.11 of the 2006 and 2009 IRC states:

> The uplift connection requirements are based on wind loading on end zones as defined in Figure 6-2 of ASCE 7. Connection loads for connections located a distance of 20% of the least horizontal dimension of the building from the corner of the building are permitted to be reduced by multiplying the table connection value by 0.7 and multiplying the overhang load by 0.8.

While this note is not included in the 2012 and 2015 versions, the basis of the table remains unchanged. The 2015 version includes wind speeds in terms of Ultimate Design Wind Speed (V_{ult}) rather than the Basic Design Wind speed (V_{asd}) as found in earlier versions.

Table 2308.10.1 of the 2012 *IBC* states:

> The uplift connection requirements are based upon wind loading on end zones as defined in Figure 28.6.3 of ASCE 7.1 Connection loads for connections located a distance of 20 percent of the least horizontal dimension of the building from the corner of the building are permitted to be reduced by multiplying the table connection value by 0.7 and multiplying the overhang load by 0.8.

As a truss also receives wind load directly from the roof sheathing (i.e., cladding) and therefore acts as a component, it can also be considered part of the C&C category. This crossover is illustrated in C26 of the Commentary for *ASCE 7*, which lists roof trusses as examples of both MWFRS and C&C (bold added to definitions to emphasize key concepts):

> **COMPONENTS AND CLADDING**: … Examples of components include fasteners, purlins, girts, studs, roof decking, and **roof trusses. … The engineer needs to use appropriate loadings for design of components, which may require certain components to be designed for more than one type of loading, for example, long-span roof trusses should be designed for loads associated with MWFRS, and individual members of trusses should also be designed for component and cladding loads**…

> **MAIN WIND-FORCE RESISTING SYSTEM (MWFRS):** … Structural elements such as cross-bracing, shear walls, **roof trusses,** and roof diaphragms are part of the Main Wind-Force Resisting System (MWFRS) when they assist in transferring overall loads…

Further, in the frequently asked section of "Guide to the Use of the Wind Load Provisions of ASCE 7-02" By Kishor C. Mehta and James M. Delahay the following question and answer are posed regarding the design of a gable truss:

> 16. *When is a gable truss in a house part of the MWFRS? Should it also be designed as a C&C? What about individual members of a truss?*
>
> Roof trusses are considered to be components since they receive load directly from the cladding. However, since a gable truss receives wind loads from more than one surface, which is part of the definition for MWFRS, an argument can be made that the total load on the truss is more accurately defined by the MWFRS loads. A common approach is to design the members and internal connections of the gable truss for C&C loads, while using the MWFRS loads for the anchorage and reactions. When designing shear walls or cross-bracing, roof loads can be considered an MWFRS.
>
> In the case where the tributary area on any member exceeds 700 ft^2, Section 6.5.12.1.3 permits it to be considered a MWFRS. Even when considered a MWFRS under this provision, the top chord members of a gable truss would have to follow rules of C&C if they receive load directly from the roof sheathing.

Combined Analysis:
The truss industry uses a combined analysis, incorporating both the MWFRS and C&C method, to generate wind uplift and downward pressure loading conditions. MWFRS applies to the assembly of multiple parts, while C&C covers an individual part. SBCA recommends this hybrid approach. Most two-dimensional software analysis programs offer a choice of wind analysis methods when applying wind loads.

Using this combined analysis, truss or rafter uplift connections, at the plate line or as attached to a header, beam or girder, should be designed for wind load using the MWFRS analysis method, and individual truss or rafter members should be designed using the C&C analysis method. Similarly, gable frame uplift connections should be designed for wind uplift loads using the MWFRS analysis method, while individual members of the gable frame should be designed using the wind applied downward pressure loads developed through the C&C analysis method.

MWFRS	C&C
Truss Uplift Connection	Individual Truss Member
Gable Frame Uplift Connection	Individual Member of a Gable Frame for Downward Pressure Loading Conditions
Rafter Uplift Connection	Roof Covering, Wall Covering

Figure 1: Examples Using the MWFRS and C&C Analysis Methods

Issues to Watch:

Regardless of the design method used, the truss designer needs as much loading information as possible from the building designer in order to design the trusses. The building designer is responsible for providing the structural design documents and all of the load and dimension information necessary to design the trusses. If a project does not require a licensed professional building designer, the owner or the owner's agent is responsible for providing this information. Although the *IBC* and *IRC* require all applicable design loads to be listed by the building designer in the structural design documents, this information is often lacking or not available to the truss designer at the time of design. Problems can arise if the end reactions on the truss designer's or truss design engineer's truss design drawings are different than the building designer's calculation of roof-to-wall anchorage forces. If this occurs, the issue falls under the building designer's scope of responsibility per *ANSI/TPI 1-2007* and *AISI S214-07* to resolve any differences in the reaction forces.

Conclusion:

Based on the recommendations of the *IRC*, *IBC* and *ASCE 7*, truss uplift connections should be designed utilizing the MWFRS wind loading analysis method. Individual truss members and their connections should be designed with the C&C method. While this combined method of analysis is recommended and widely used throughout the truss industry, ultimately it is the responsibility of the building designer to determine the method(s) to be used.

References:

IRC International Residential Code 2009, ICC IRC-2009; International Code Council.

IBC International Building Code 2012, ICC IbC-2011; International Code Council.

ASCE 7-10 Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7-10, American Society of Civil Engineers. Copyright 2010.

NDS National Design Specifications for Wood Construction with Commentary, *ANSI/AWC NDS-2012*; American Wood Council; Approval Date: Aug. 15, 2011.

American National Standard: National Design Standard for Metal Plate Connected Wood Truss Construction, *ANSI/TPI 1 – 2014*; Truss Plate Institute; Revision of *ANSI/TPI 1 – 2007*.

Guide to the Use of the Wind Load Provisions of ASCE 7-02, By Kishor C. Mehta and James M. Delahay