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Multi-axis treatment of typical light-frame wood roof-to-wall metal connectors in design

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ABSTRACT

Proper selection of metal roof-to-wall connectors is needed to provide a cost-effective load path to transfer uplift loads on a roof system down to the supporting walls and transfer lateral loads into and out of the roof diaphragm of light frame wood structures. Structural engineers, architects and builders rely upon published design values in catalogs, software, and websites provided by individual manufacturers to aid in the appropriate selection of connectors once the determination has been made for the required capacities of the connector. To date, the *state-of-the-practice* for dealing with multi-axis loads in these connectors is to use a linear unity equation based on uni-axis design values. However, no significant validation of this practice is to be found in the literature. This study experimentally examines three very common connector types under both bi-axis and tri-axis loads and helps to understand the behavior of such connectors under multi-axis loads. After testing over 350 connections and performing detailed analyses, the currently used design equation is found to be inefficient (has the least usable design space compared to other considered design equations) and overly conservative. Based on the criteria of efficiency, performance and safety, a design space using either the linear unity equation or by simply taking a 25% reduction on all allowable loads is proposed. The proposed design space for the three types of connectors is shown to have a high level of safety and adequate performance while providing up to 2.5 times the usable design space as compared with the current practice.

1. Introduction

Metal connectors are extensively used to establish roof-to-wall and wall-to-foundation connections in light frame wood structures. Metal connectors replace or complement traditional nail fasteners and can be effective in withstanding extreme seismic and wind events. If properly installed, the connectors serve to establish a continuous load path in both residential and commercial structures. A disconnected load path is seen as one of the leading causes for roof uplift failure during intense windstorms and hurricanes. If metal connectors are to provide efficient yet effective solutions for establishing robust load paths, it is important that one understands their behavior in both uni-axis and multi-axis conditions. Appropriate yet straightforward design guidelines can then be developed to accommodate this behavior. Current practice is to obtain the design capacity of the connector and the proper method of installation in manuals provided by each manufacturer. Manufacturers apply AC13 – acceptance criteria [1] approved in 2006 by the International Code Council Evaluation Services (ICC-ES) – for joist hangers and similar devices to determine design capacities. These criteria are specifically defined to develop allowable vertical capacities of a connector where the allowable design capacity is the smallest value taken from:

a. Lowest vertical ultimate load divided by three if only three tests are conducted and each load does not vary by more than 20% from the average vertical load. Alternately, if six or more tests are conducted, the design capacity may be taken as the average of the ultimate vertical load divided by three. The same procedure is also currently used to calculate the capacity of roof-to-wall connectors when subjected to lateral loads even though lateral capacities are not explicitly addressed in AC13.
b. The average load corresponding to a 3.2 mm (0.125 in.) vertical displacement.
c. The NDS (National Design Specification) [2] prescribed allowable design load for the connected wood members or the nail fasteners.

Although AC13 was originally intended to determine design values for hangers subjected to gravity loads, these design values are used with possible adjustments for wind and seismic loads.

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