# Technical Q & A

## Factors that Affect the Capacity of a Toe-Nailed Connection

by Jim Vogt, P.E.

Learn what is necessary to ensure that nailed connections can resist uplift requirements.

Toe-nailed connections are a common means of attaching wood joists, rafters and trusses to the top of a supporting wood wall or beam. Depending on the application, these connections must often provide resistance to uplift from wind and/or certain multi-span gravity load conditions, as well as resistance to lateral loads from wind and seismic forces. The building codes provide minimum fastening requirements for various connection scenarios that meet the "Conventional Light-Frame Construction" provisions of the code. There are many applications, however, in which toe-nailed connections are used in wood construction that are beyond the scope of the Conventional Light-Frame Construction provisions of the code. For these instances, a basic understanding of the factors affecting the withdrawal and lateral resistance of fasteners can be helpfulin determining whether or not this type of connection is viable.



Figure 1.

### Question

*I'm looking for information that will help me understand the load resisting capacity of a nailed connection. We typically attach the truss heels to the top plates of the walls with a toe-nailed connection. What do we need to keep in mind to ensure that these nailed connections can resist the uplift requirements provided on the Truss Design Drawing?*

### Answer

The resistance provided by a toe-nailed connection is governed by several factors including proper installation, lumber species, length of penetration, and type of nail.

**Proper Installation:**

To get the most out of a toe-nailed connection, it is important to toe-nail correctly. Figure 1 illustrates proper toe-nailing of a truss to the wood top plates of a bearing wall. The dimensions shown are only meant to serve as an approximate guide. *Note:* Toe-nailing through a metal connector plate of a truss does not adversely affect the uplift capacity of the connection provided the truss plate and lumber are not damaged during installation.

**Species of Lumber:**

The species of wood that the nail is driven into also affects the amount of resistance provided by a toe-nailed connection. More specifically, nail resistance to withdrawal and lateral forces is directly related to the specific gravity (SG) of the wood. For example, a toe-nailed connection into Southern Pine (SG = 0.55) will provide greater resistance than the same connection into Spruce-Pine-Fir (SG = 0.42).

**Length of Penetration:**

The withdrawal and lateral resistance provided by a nail depends, in part, on the length of penetration into the wood member. The greater the penetration, the greater the resistance.

### at a glance

- Toe-nailed connections are a common means of attaching wood joists, rafters and trusses to the top of a supporting wood wall or beam.
- Many applications go beyond the scope of the Conventional Light-Frame Construction provisions of the code.
- The resistance provided by a toe-nailed connection is governed by several factors including proper installation, lumber species, length of penetration, and type of nail.

B8 of the 2006 edition of BCSI provides the uplift and lateral load capacities for toe-nailed connections consisting of three, four or five nails for various types and species of wood.

**Type of Nail:**

The type of nail used in a toe-nailed connection also influences capacity. The larger the diameter of the nail shank, the greater the resistance to withdrawal and lateral loads. For this reason, common wire nails provide greater resistance than the same size (i.e., penny-weight) of box or sinker nails. The type of nail shank will also influence nail holding capacity. Deformed shanks (i.e., ring- or screw-shank) typically provide greater withdrawal resistance than smooth shank nails.

When installing toe-nails, use care to avoid splitting the wood. The Building Designer typically provides nail spacing and minimum end and edge distances. In lieu of such guidance, a well accepted rule is to limit the total number of toe-nails to three (total, including both sides) for full bearing on a 2x4 top plate (i.e., 3-1/2") and five (total, including both sides) for full bearing on a 2x6 top plate (i.e., 5-1/2"). (See Figure 1.)

When using toe-nails to attach the top or bottom chord of a truss to the side of a girder truss or wood beam, the number of nails used is generally limited to a maximum of three toe-nails for 2x4 chords and four toe-nails for 2x6 chords.

The National Design Specification® (NDS®) for Wood Construction, published by the American Forest & Paper Association (AF&PA) provides the engineering basis for toe-nail and slant-nail connections when used to resist withdrawal and lateral loads. In addition to the factors mentioned above, the load carrying capacity of a toe-nailed connection is also affected by the duration that the load is applied to the connection, the moisture content of the wood (at the time the connection is made as well as in-service), the sustained temperature of the wood and whether or not the nails are driven into the end-grain of the supporting member. The NDS provides a detailed review of the affect each of these factors has on the allowable withdrawal and lateral resistance capacity of a nailed connection. In addition, B8 of the 2006 edition of Building Component Safety Information (BCSI) provides the uplift and lateral load capacities for toe-nailed connections consisting of three, four or five nails for various types and species of wood (see **Support Docs** at **www.sbcmag.info** for Chapter 8 of BCSI). The information provided in each of these documents can be used to determine if a toe-nailed connection has adequate capacity to resist the applied loads. SBC

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Truss Publications, Inc.

6300 Enterprise Lane • Suite 200 • Madison, WI 53719
608/310-6706 phone • 608/271-7006 fax
www.sbcmag.info • admgr@sbcmag.info