to-grain at the end of a member (i.e., a wall stud toenail connection to the top or bottom plate that may be used instead of end nailing). Slant nailing occurs when a nail is driven at an angle, but in a direction perpendicular-to-grain through the side of the member and into the face grain of the other (i.e., from a roof rafter or floor band joist to a wall top plate). Though a generally reliable connection in most homes and similar structures built in the United States, even a well-designed slant-nail connection used to attach roofs to walls will become impractical in hurricane-prone regions or similar high-wind areas. In these conditions, a metal strap or bracket is preferrable.

Based on the studies of roof-to-wall connections, five key findings are summarized as follows (Reed et al., 1996; Conner et al., 1987):

1. In general, it was found that slant-nails (not to be confused with toe-nails) in combination with metal straps or brackets do not provide directly additive uplift resistance.
2. A basic metal twist strap placed on the interior side of the walls (i.e., gypsum board side) resulted in top plate tear-out and premature failure. However, a strap placed on the outside of the wall (i.e., structural sheathing side) was able to develop its full capacity without additional enhancement of the conventional stud-to-top plate connection (see Table 7.1).
3. The withdrawal capacity for single joints with slant nails was reasonably predicted by NDS with a safety factor of about 2 to 3.5. However, with multiple joints tested simultaneously, a system factor on withdrawal capacity of greater than 1.3 was found for the slant-nailed rafter-to-wall connection. A similar system effect was not found on strap connections, although the strap capacity was substantially higher. The ultimate capacity of the simple strap connection (using five 8d nails on either side of the strap–five in the spruce rafter and five in the southern yellow pine top plate) was found to be about 1,900 pounds per connection. The capacity of three 8d common slant nails used in the same joint configuration was found to be 420 pounds on average, and with higher variation. When the three 8d common toenail connection was tested in an assembly of eight such joints, the average ultimate withdrawal capacity per joint was found to be 670 pounds with a somewhat lower variation. Similar “system” increases were not found for the strap connection. The 670 pounds capacity was similar to that realized for a rafter-to-wall joint using three 16d box nails in Douglas fir framing.
4. It was found that the strap manufacturer’s published value had an excessive safety margin of greater than 5 relative to average ultimate capacity. Adjusted to an appropriate safety factor in the range of 2 to 3 (as calculated by applying NDS nail shear equations by using a metal side plate), the strap (a simple 18g twist strap) would cover a multitude of high wind conditions with a simple, economical connection detail.
5. The use of deformed shank (i.e., annular ring) nails was found to increase dramatically the uplift capacity of the roof-to-wall connections using the slant nailing method.

Heel Joint in Rafter-to-Ceiling Joist Connections

The heel joint connection at the intersection of rafters and ceiling joists have long been considered one of the weaker connections in conventional wood roof framing. In fact, this highly stressed joint is one of the accolades of using a wood truss rather than conventional rafter framing (particularly in high-wind or snow-load conditions). However, the performance of conventional rafter-ceiling joist heel joint connections should be understood by the designer since they are frequently encountered in residential construction.

First, conventional rafter and ceiling joist (cross-tie) framing is simply a “site-built” truss. Therefore, the joint loads can be analyzed by using methods that are applicable to trusses (i.e., pinned joint analysis). However, the performance of the system should be considered. As mentioned earlier for roof trusses (Section 5.6.1 in Chapter 5), a system factor of 1.1 is applicable to tension members and connections. Therefore, the calculated shear capacity of the nails in the heel joint (and in ceiling joist splices) may be multiplied by a system factor of 1.1, which is considered conservative. Second, it must be remembered that the nail shear values are based on a deformation limit and generally have a conservative safety factor of three to five relative to the ultimate capacity. Finally, the nail values should be adjusted for duration of load (i.e., snow load duration factor of 1.15 to 1.25); refer to Section 5.2.4 of Chapter 5. With these considerations and with the use of rafter support braces at or near mid-span (as is common), reasonable heel joint designs should be possible for most typical design conditions in residential construction.

Wall-to-Floor Connections

When wood sole plates are connected to wood floors, many nails are often used, particularly along the total length of the sole plate or wall bottom plate. When connected to a concrete slab or foundation wall, there are usually several bolts along the length of the bottom plate. This points toward the question of possible system effects in estimating the shear capacity (and uplift capacity) of these connections for design purposes.

In recent shear wall tests, walls connected with pneumatic nails (0.131-inch diameter by 3 inches long) spaced in pairs at 16 inches on center along the bottom plate were found to resist over 600 pounds in shear per nail (HUD, 1999b). The bottom plate was Spruce-Pine-Fir lumber and the base beam was Southern Yellow Pine. This value is about 4.5 times the adjusted allowable design shear capacity predicted by use of the NDS equations. Similarly, connections using 5/8-inch-diameter anchor bolts at 6 feet on center (all other conditions equal) were tested in full shear wall assemblies; the ultimate shear capacity per bolt was found to be 4,400 pounds. This value is about 3.5 times the adjusted allowable design shear capacity per the NDS equations. These safety margins appear excessive and should be considered by the designer when evaluating similar connections from a practical “system” standpoint.