not include the tapered portion at the point. NDS•Appendix L contains dimensions for lag screws.

[NDS•9.2.1]

$$W = 1800(G)^{\frac{3}{2}} D^{\frac{3}{4}} L_p \quad \text{unadjusted withdrawal design value (lb) for a lag screw}$$

where,

G = specific gravity of the lumber receiving the lag screw tip
D = the diameter of the lag screw shank (in)
L_p = the depth of penetration (in) of the lag screw into the member receiving the tip, less the tapered length of the tip

The allowable withdrawal design strength of a lag screw is greater when the screw is installed in the side rather than the end grain of a member. However, unlike the treatment of nails, the withdrawal strength of lag screws installed in the end grain may be calculated by using the C_{eg} adjustment factor with the equation above.

The design shear value Z for a lag screw is typically determined by using the following tables from NDS•9:

- Table 9.3A. Lag screw, single-shear (two-member) connections with the same species of lumber for both members.
- Table 9.3B. Lag screw and metal plate-to-wood connections.

The yield equations in NDS•9.3 may be used for conditions not represented in the design value tables for Z. Regardless of the method used to determine the Z value for a single lag screw, the value must be adjusted as described in Section 7.3.2.

It is also worth mentioning that the NDS provides an equation for determining the allowable shear design value when a lag screw connection is loaded in combined withdrawal and shear (see NDS•9.3.5, Equation 9.3-6). The equation does not, however, appear to apply to typical uses of lag screws in residential construction.

7.3.6 System Design Considerations

As with any building code or design specification, the NDS provisions may or may not address various conditions encountered in the field. Earlier chapters made several recommendations regarding alternative or improved design approaches. Similarly, some considerations regarding wood connection design are in order.

First, as a general design consideration, “crowded” connections should be avoided. If too many fasteners are used (particularly nails), they may cause splitting during installation. When connections become “crowded,” an alternative fastener or connection detail should be considered. Basically, the connection detail should be practical and efficient.

Second, while the NDS addresses “system effects” within a particular joint (i.e., element) that uses multiple bolts or lag screws (i.e. the group action factor C_g), it does not include provisions regarding the system effects of multiple joints in an assembly or system of components. Therefore, some consideration of system effects is given below based on several relevant studies related to key connections in a home that allow the dwelling to perform effectively as a structural unit.

Sheathing Withdrawal Connections

Several recent studies have focused on roof sheathing attachment and nail withdrawal, primarily as a result of Hurricane Andrew (HUD, 1999a; McClain, 1997; Cunningham, 1993; Mizzell and Schiff, 1994; and Murphy, Pye, and Rosowsky, 1995); refer to Chapter 1. The studies identify problems related to predicting the pull-off capacity of sheathing based on single nail withdrawal values and determining the tributary withdrawal load (i.e., wind suction pressure) on a particular sheathing fastener. One clear finding, however, is that the nails on the interior of the roof sheathing panels are the critical fasteners (i.e., initiate panel withdrawal failure) because of the generally larger tributary area served by these fasteners. The studies also identified benefits to the use of screws and deformed shank nails. However, use of a standard geometric tributary area of the sheathing fastener and the wind loads in Chapter 3, along with the NDS withdrawal values (Section 7.3.3), will generally result in a reasonable design using nails. The wind load duration factor should also be applied to adjust the withdrawal values since a commensurate reduction is implicit in the design withdrawal values relative to the short-term, tested, ultimate withdrawal capacities (see Section 7.3).

It is interesting, however, that one study found that the lower-bound (i.e., 5th percentile) sheathing pull-off resistance was considerably higher than that predicted by use of single-nail test values (Murphy, Pye, and Rosowsky, 1995). The difference was as large as a factor of 1.39 greater than the single nail values. While this would suggest a withdrawal system factor of at least 1.3 for sheathing nails, it should be subject to additional considerations. For example, sheathing nails are placed by people using tools in somewhat adverse conditions (i.e., on a roof), not in a laboratory. Therefore, this system effect may be best considered as a reasonable “construction tolerance” on actual nail spacing variation relative to that intended by design. Thus, an 8- to 9-inch nail spacing on roof sheathing nails in the panel’s field could be “tolerated” when a 6-inch spacing is “targeted” by design.

Roof-to-Wall Connections

A couple of studies (Reed, et al., 1996; Conner, et al., 1987) have investigated the capacity of roof-to-wall (i.e., sloped rafter to top plate) connections using conventional toenailing and other enhancements (i.e., strapping, brackets, gluing, etc.). Again, the primary concern is related to high wind conditions, such as experienced during Hurricane Andrew and other extreme wind events; refer to Chapter 1.

First, as a matter of clarification, the toenail reduction factor C_{tn} does not apply to *slant-nailing* such as those used for rafter-to-wall connections and floor-to-wall connections in conventional residential construction (Hoyle and Woeste, 1989). Toenailing occurs when a nail is driven at an angle in a direction parallel-