## Capacity Of Nail & Screw Connections

Capacity of nail and screw connections is performed using; (1) Standard NDS code provisions (11.4) for combined withdrawal and lateral load, and (2) General Dowel Equations per Technical Report 12 to determine reference lateral capacity, including gap between members.

Angle (alpha) between wind uplift force and main member (main truss top chord) is equal to 90 degrees minus the slope of the main truss (24.6 degrees), or 65.4 degrees.

Calculation of adjusted withdrawal capacity (W') is based on the assumption that nail or screw is perpendicular to the main truss top chord, which is very nearly the case for installation angle around 30 degrees.

Calculation of adjusted lateral capacity (Z') must be based on requirements (NDS 11.3.9) for load inclined with respect to the fastener axis.

As shown in Figure 11E of the NDS code, thickness of each member (Ts, Tm) is to be taken as projected length of fastener in each member (Ls, Lm)

For this calculation, projected length of fastener in valley truss (Ls for "side" member) is taken as length of fastener in the valley truss.

For installation parameters specified on design plans (S4.1), effective thickness (Ts) of side member (valley truss) is then 1.44 inches. Effective thickness of main member (Tm) is 1.54 inches.

Fastener Properties

Nail diameter (0.135") is taken as the same diameter listed in calculations by engineer for builder. Yield strength is taken as 100,000 psi, per standard NDS guidelines.

Screw diameter (0.152" root diameter) is taken as standard per NDS for the 10 gage screw specified on design plans. Per standard NDS recommendations, yield strength is then 90,000 psi and pullout strength is 163 pounds per inch of thread penetration.

However, diameter of wood screw listed on product sheet attached to calculations by engineer for builder show a much smaller diameter (0.138") which would result in much lesser uplift capacity.

Further information about properties of as-installed nails and screws should be obtained.

Capacity For Installation Parameters Per Design Plans (S4.1)

Uplift capacity of nail and screw connection is calculated for design parameters specified in the detail on plan sheet S4.1; 30-degree installation angle and 1-1/4 inches top-of-nail height.

Per equation 11.4-2, calculated design capacity for combined withdrawal and lateral load is 80 pounds per nail and 271 pounds per screw.

For 2 nails, calculated capacity of 160 pounds is much less than maximum required capacities for 6 on 12 roof slope (322 lbs Exp B & 395 lbs Exp C) per calculations in this report. Capacity is also lower than maximum required capacities for 7 on 12 roof slope (222 lbs Exp B & 274 lbs Exp C).

Calculated screw capacity (271 lbs) is 56% greater than capacity of 2-12d nails (160 lbs).

However, withdrawal strength of screw in valley truss may control capacity.

Sensitivity To Changes Of Installation Parameters

For nail and screw connections, determination of design capacity (to resist design uplift force applied by valley truss) must consider sensitivity to changes of the following parameters;

1. Top-of-nail (screw) height (above base of valley truss)
2. Installation angle (with respect to vertical axis of valley truss)

General dowel equations per Technical Report 12 are used to calculate "reference" lateral (shear) capacity values. Side member thickness is taken as length of nail or screw in the valley truss (side member). Penetration into main truss takes the gap into account. Reference withdrawal capacity is calculated using NDS-2005.

Equations from NDS-2005 for combined lateral and withdrawal load are used to determine uplift capacity. Standard load duration factor for wind is applied to each reference value.

Table 1 - Design Uplift Capacity

Design uplift capacity of nail and screw connection (one each) is shown below for various values of the two basic design parameters;

Nail: 12d sinker (0.135" dia; 3.25" length; Fy = 100,000 psi)
Screw: 10 gage (0.152" root dia, 3.50" length; Fy = 90,000 psi)

Load Duration Factor = 1.6

| Top-Of-Nail Height | Installation Angle | Gap | Nail Design Uplift Capacity | Screw Design Uplift Capacity |
|---|---|---|---|---|
| 1.08 in | 25 deg | 0.28 in | 89 lbs | 360 lbs |
| ### 1.08 in | 30 deg | 0.27 in | 86 lbs | 321 lbs |
| 1.08 in | 35 deg | 0.25 in | 84 lbs | 287 lbs |
| 1.08 in | 40 deg | 0.23 in | 82 lbs | 260 lbs |
| 1.08 in | 45 deg | 0.21 in | 81 lbs | 239 lbs |
| | | | | |
| 1.25 in | 25 deg | 0.29 in | 82 lbs | 340 lbs |
| +++ 1.25 in | 30 deg | 0.26 in | 80 lbs | 307 lbs |
| 1.25 in | 35 deg | 0.24 in | 78 lbs | 279 lbs |
| 1.25 in | 40 deg | 0.21 in | 77 lbs | 256 lbs |
| 1.25 in | 45 deg | 0.17 in | 76 lbs | 240 lbs |
| | | | | |
| 1.50 in | 25 deg | 0.28 in | 72 lbs | 311 lbs |
| 1.50 in | 30 deg | 0.24 in | 71 lbs | 286 lbs |
| 1.50 in | 35 deg | 0.20 in | 70 lbs | 266 lbs |
| 1.50 in | 40 deg | 0.16 in | 69 lbs | 250 lbs |
| 1.50 in | 45 deg | 0.10 in | 67 lbs | 240 lbs |

### Installation parameters per original calculations (2-12-07)
+++ Installation parameters per design plans (S4.1)

Uplift Capacity; General Results

For each top-of-nail (screw) height, uplift capacity is reduced as installation angle increases. Rate of reduction, which is not constant, is greatest for the wood screw.

For each installation angle, uplift capacity for the 12d nail decreases modestly as top-of-nail height increases. Up to installation angle of 40 degrees, uplift capacity for the wood screw decreases. However, capacity increases slightly for the 45-degree angle.

Uplift Capacity; General Approach For Design

- ☑ For a conservative design, without load testing, allowable capacity should be based on lowest calculated capacity values for an expected range of "normal" installation tolerances.

As explained elsewhere in this report, the use of "average" values for all connections of a valley set is not appropriate since individual connections must have capacity to resist design wind uplift force applied to the tributary area for one connection.

- ➡ If one connection fails, progressive failure ("zipper" effect) might occur as uplift load from the failed connection is redistributed to adjacent connections.

To account for installation tolerances, a reasonable approach would be to consider that installation angle could easily be as high as 40 degrees and top-of-nail height could be 1-1/2 inches or more, at the same time. Measurements of actual installations (if practical) might allow for more liberal limits.

Uplift Capacity Of Nail Connection

For 12d nail, with installation angle of 40 degrees and top-of-nail height of 1-1/2 inches, design capacity is 69 pounds per nail. This is 14% less than capacity (80 lbs) for plan-specified installation parameters.

Compared to condition without a gap (between valley truss and main truss), capacity is about 30% less.

- ➡ For two 12d nails, and stated conditions of installation, allowable uplift capacity of 138 pounds (69 lbs per nail) is grossly inadequate.

Of course, calculated uplift capacity is based on the lack of any splits or other damage to wood members. As shown by inspection results of as-built valley trusses (reported by others), nail installation tends to cause wood damage to a significant number of connections.

Uplift Capacity For Screw Connection

Wood screw has much greater capacity than the nail due to much greater unit withdrawal capacity (163 lbs/inch compared to 42 lbs/inch), longer length of penetration and the greater influence of withdrawal strength on combined capacity.

For all conditions, one wood screw has much greater capacity than two nails.

For plan-specified parameters, uplift capacity of one 10 gage wood screw (307 lbs) is 92% greater than uplift capacity for two 12d nails (160 lbs).

However, as previously explained, design properties of as-installed wood screws may provide much less uplift capacity, based on indications from calculations prepared by engineer for builder.

Actual capacity of wood screw connection may be governed by upper part of the screw, in the valley truss. Since there are no code provisions to calculate capacity of the upper part, use of capacity values for the lower part (in main member) must be used carefully (if at all).

Steel Strength Of Wood Screw

Per NDS 11.2.2.3, strength of screw must be checked for withdrawal force, using the net "root" section, which requires use of "root" diameter per Table L3 in Appendix L.

Per 10.2.3, adjustment factors for wood construction are not applicable for screw.

For standard 10 gage screw per Table L3, root diameter is 0.152 inches. Section area is then 0.0181 square inches.

As explained in the code, steel strength is not a requirement of standard industry material specifications. Therefore, a conservative approach is warranted.

Using minimum tension yield strength of 55,000 psi per Federal Specification FF-S-111D, and applying typical factor of 0.60 to obtain for design allowable stress, tension strength of the screw is 599 pounds. Although this capacity is greater than withdrawal capacity of the screw, it is close enough to warrant explicit checking.

For valley truss connections, tension strength of screw should be specified on design plans, with a requirement that the supplier provide test data to certify strength.

Withdrawal Strength In Valley Truss

NDS code does not include provisions to calculate withdrawal strength of the upper part of nail or screw from "side" member.

However, for nail installed through side member as for a "standard" toenail connection, a reasonable assumption (to be verified) is that withdrawal strength of the upper part of nail (from side member) is at least equal to withdrawal capacity of a standard toenail (without gap between members). For 12d nail, standard toenail capacity is 81 pounds (162 lbs for 2 nails).

Logic of applying the same assumption to a wood screw, considered as a nail with full diameter of the screw, is complicated by the need to determine "standard" withdrawal capacity from main member (as toenail).

- ☑ Load testing is therefore recommended as the conservative method for obtaining uplift capacity of screw in valley truss.