

## Design Nailed and Wood Screwed Connections with Spreadsheet

### Course Content

#### INTRODUCTION

The complete design of a wood structure includes the design of connections between the various structural members. The integrity of the load path depends on the strength of the attachment between pieces. Nails and screws are commonly used to connect sheathing and decking to light wood structural members and nails or spikes are commonly used to connect structural members together. Codes give prescriptive nailing requirements for various common connections, but it is useful to have a basis for design for the many other situations that arise. Nails (to include spikes in this discussion) and screws may be loaded in withdrawal, laterally, or in a combination of the two.

Specific loads can be assigned to nailed or screwed connections based on several variables. Load calculations are quite complex and lend themselves well to the use of a spreadsheet. This course discusses the design of nailed and wood screwed connections and includes the Excel© 2003 spreadsheet, NAILSCREW©, with seven examples of its use. The spreadsheet is designed for stand alone use for many common situations requiring only information provided in the following discussion or the spreadsheet itself. It is assumed that the student is familiar with the use of spreadsheets. Traditional (English) units and the allowable stress design (ASD) approach are used.

The design of wood member connections is complicated, in part, because of the variability of wood. Dozens of species are used for structures, and the relevant properties vary within and between species. Also, the structural properties within a single piece of wood vary significantly depending on the direction of the grain.

Engineering properties of wood products intended for structural use are readily available. The American Forest & Paper Association has published several manuals including the National Design Standard ANSI/AF&PA NDS-2001 (Reference 1) that provide information relevant for wood structural design, including connector design. Technical information for “engineered” lumber products such as laminated veneer lumber (LVL) and I joists is available from manufacturers. References used for this course are given at the end of this discussion. These and similar sources provide additional useful information.

#### WOOD PROPERTIES RELEVANT TO CONNECTOR DESIGN

The following is a brief description of several properties or descriptors of wood that are relevant to nail and screw design.

**Species** – The species refers to the biological kind of tree from which the wood is obtained. Most wood used for structural purposes is called “softwood” which means it comes from cone bearing (coniferous) trees. This includes several sub-species of pine and fir as well as dozens of other commonly used species. Less commonly used is “hardwood” lumber which comes from leaf bearing (deciduous) trees. Examples of these are oak and maple. The terms “softwood” and “hardwood” can be misleading because

some “softwoods” such as southern yellow pine are harder than some “hardwoods” such as cottonwood. Nearly all wood used for structures in the U.S.A. comes from trees that grow by adding layers (rings) to the outside of the tree (exogenous growth). The rate of this ring growth varies from season to season and from species to species. The density of the wood depends to a large extent on the nature of the growth.

Density/Specific Gravity – Weight density is arguably the most important wood property affecting connector design. Weight density is expressed in the number of pounds per cubic foot of dry wood. It is converted into specific gravity, G, by dividing by the weight density of water as illustrated following. Wood that weighs 40 lbs/ft<sup>3</sup> dry has a specific gravity of .64 as shown below.

$$G = 40 \text{ lbs/ft}^3 / 62.4 \text{ lbs/ft}^3 = .64$$

Published specific gravities usually are an average for an entire species and are typically given to two significant digits. The National Design Specification publication (Ref. 1, p.74) is one source of values. The spreadsheet, NAILSCREW©, provides a table of specific gravities for some common species.

Grade – Agencies have been organized to provide grading rules for commercially useful wood species. Based on these rules, lumber is sorted into grades with reliable structural properties. Even within one grade of one species there may be a large range in any given engineering property so the assigned design values are conservative.

Moisture Content – Wood may contain varying amounts of water. It may be in “cells” (open pores) that would otherwise contain air or it may be in the cell walls. Moisture content (M.C.) is expressed as a percentage and is calculated by dividing the weight of water present in a specimen by the weight of the dry specimen. It could vary from above 100% to 0%. A sample that weighs 40 grams and is completely dried to 35 grams had a moisture content of:

$$(40 \text{ grams} - 35 \text{ grams}) / 35 \text{ grams} = 14\% \text{ moisture content.}$$

Lumber is typically dried in air or by kiln from the “green” condition when it is harvested to a “dry” condition for use. A typical range of moisture content for “dry” structural lumber as used is about 6% to 19% with 19% M.C. serving as the break point between dry and wet lumber. (Ref. 2, p. 186). The moisture content of wood changes in response to its environment. This is associated with volume changes that differ in different directions within the wood. The effects of moisture content and its possible variation throughout the life of a structure require careful consideration. It may affect the selection of connector material (zinc plated, galvanized, stainless steel, etc.) as well as the design value per connector. Adjustments to design values for a variety of reasons including damp or wet conditions of use are discussed later.

Grain – The grain of wood refers to the make-up and orientation of the cells that compose the material. The configuration of most of the cells can be compared to a bundle of straws standing upright. The grain direction is not always in perfect alignment with the length of a piece of lumber (cross grain) and may be interrupted by various other defects (knots, splits, etc.). These strength reducing characteristics are accounted for in the grading of the lumber.

A nail or screw placed in the face or edge of a piece of lumber is in “side grain”; a nail or screw in the end of a piece of lumber is in “end grain.” More load can be carried in side grain than in end grain. Withdrawal loading is not allowed in end grain. Figure 1 illustrates various aspects of grain and load direction. The red loads shown are parallel to the surfaces of the structural member but are at different angles to the grain. For nails and screws of diameter less than 1/4” the angle of load to grain is immaterial. For all connectors of diameters of 1/4” and over the angle of load to grain is a design factor. The yellow loads shown are at angles to the wood surface.

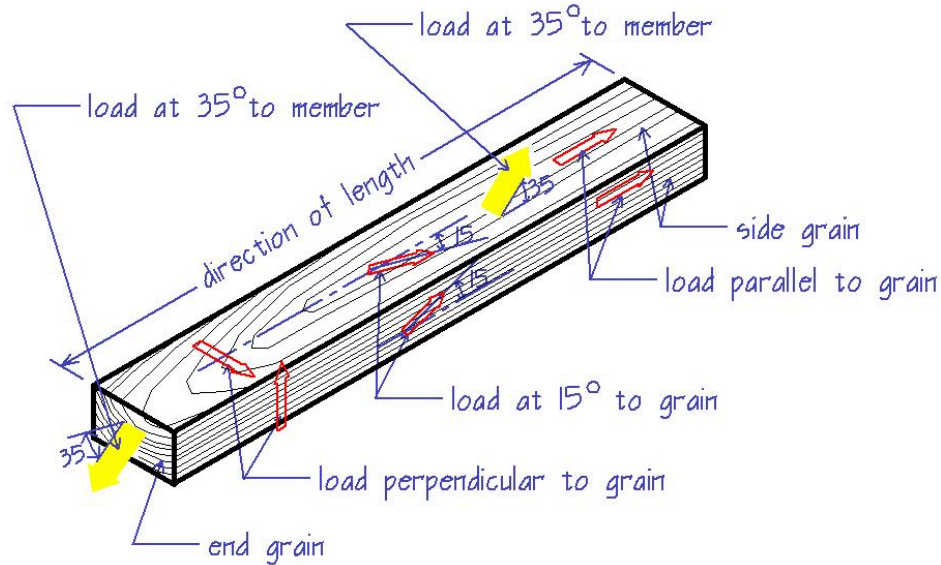


Figure 1. Wood Grain and Load Directions

Engineering Properties - The wood strength parameter that controls nail and screw lateral loading is the “dowel bearing strength”,  $F_e$ , in psi, which relates to the allowable bearing stress of the wood. For connectors of less than 1/4” diameter,  $F_e$  is a function of the specific gravity,  $G$ , of the wood as follows (Ref. 1, p.73):

$$F_e = 16600G^{1.84}$$

Thus, for a 16 penny common nail ( $D = .162''$ ) in wood of  $G = .64$

$$F_e = 16600(.64)^{1.84} = 7300 \text{ psi.}$$

For larger diameter connectors the dowel bearing strength is a function of angle of load to grain and the connector diameter. Diameters over 1/4” are not common for nails and screws, and are not discussed in this course. (For a discussion of larger diameter connectors see courses on bolts and lag screws by this author.)

Dowel bearing strength for plywood is based on the specific gravity of the wood; the dowel bearing strength of Oriented Strand Board is based on a  $G$  of .5 (Ref. 1, p.75).

ADJUSTMENT FACTORS TO ALLOWABLE STRESSES

References give basic allowable stresses for wood based on species and grade. The stresses are subject to adjustment by multiplying by various factors that have been found relevant to load carrying capacity. A brief description of the factors follows.

Load Duration Factor - The capacity of wood to support a given load depends on how long the load will be in place. Greater loads can be carried if the duration of loading is brief. Consideration must be given to all load combinations to determine the controlling situation. The addition of a load of short duration may not control the design since the allowable stresses can be increased as is illustrated below. The equation for calculating duration factor is (after Ref. 2, p.8):

$$C_D = (1.7512)(T^{-.04635}) + .29575 \quad \text{where T is time in seconds.}$$

The factors given in Table 1 are used for commonly encountered situations.

Table 1. Load Duration Factors,  $C_D$  \* (Ref. 3, p.8)

Maximum Load Duration	$C_D$	Typical Design Load
Permanent	.9	Dead Load
10 years	1.0	Occupancy Live Load
2 months	1.15	Snow Load (when appropriate)
7 days	1.25	Construction Load
10 minutes	1.6	Wind/Earthquake/Impact

\*Not applied to compression stress perpendicular to grain,  $F_{C\perp}$ , or modulus of elasticity, E (Ref.1, p.26).

Using the information from Table 1 and the wood of allowable tensile stress ( $F_t$ ) of 600 psi with snow load controlling:

$$F_e = 1.15 (600) = 690 \text{ psi}$$

Assume, however, the following loads:

- Dead Load = 200 pound and
- Occupancy Live Load = 300 pounds and
- Wind Load = 200 pounds

The dead load, which might be alone, has an allowable stress of  $(.9)(600) = 540$  psi. The dead load plus the occupancy live load has an allowable stress of  $(1)(600) = 600$  psi. The total load has an allowable stress of  $(1.6)(600) = 960$  psi since the total load is of short duration because of the wind. The controlling load can be found by taking the largest of the following ratios:  $200/.9 = 220$ ,  $(200 + 300)/1.0 = 500$ ,  $(200 + 300 + 200)/1.6 = 450$ . Thus, dead load plus occupancy live load control. Wind load may be neglected in this instance and  $C_D = 1.0$ .

Moisture and Temperature Factors – Two additional factors that may affect connection strength are given in Table 2. The wet service factor,  $C_M$ , depends on the moisture content of the wood at the time of fabrication and in use. The temperature

factor,  $C_t$ , depends on both temperature and the in-use moisture condition. For temperatures below 100F,  $C_t = 1.0$ .

Table 2. Moisture and Temperature Factors (Ref. 3, pp.6-10)

Moisture Content		$C_M$		$C_t$	
At Fabrication	In Use	Screws	Nails*	$100 < T \leq 125$	$125 < T \leq 150$
$\leq 19\%$	$\leq 19\%$	1.0	1.0	.8	.7
$> 19\%$	$\leq 19\%$	.4 lateral 1.0 withdrawal	.7 .25	.8	.7
$\leq 19\%$	$> 19\%$	.7 lateral 1.0 withdrawal	.7 .25	.7	.5
$> 19\%$	$> 19\%$	.7 lateral .7 withdrawal	.7 1.0	.7	.5

\* $C_M = 1.0$  for threaded or hardened nails all conditions

Pressure treatments with preservatives or fire retardant chemicals may require allowable stress adjustments. That information should be obtained from the treatment company.

End Grain and Toe Nail Factors – Nails and screws have smaller capacity in end grain than in side grain. This is accounted for by applying the end grain factor,  $C_{eg}$ . For lateral loads  $C_{eg} = .67$ ; withdrawal in end grain is not permitted. A toe nail factor,  $C_{tn}$  of .83 applies to lateral loads and a factor of .67 applies to withdrawal loads. A toe nail connection is shown in Figure 2.

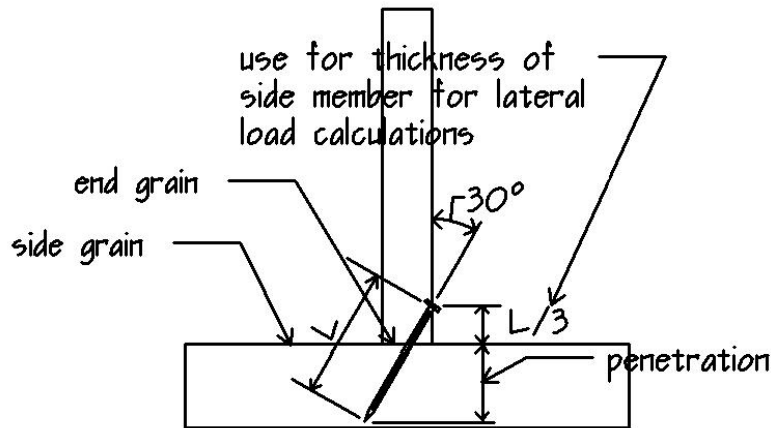


Figure 2. Toe Nail Connection (after Ref.1, p.67)

Penetration Depth Factor (Ref. 1, pp. 96, 97) - For both laterally loaded nails and screws a minimum depth of penetration,  $p$ , into equal to 10 times the diameter,  $D$ , is required for the full design value. Otherwise, the penetration depth factor,  $C_d = p/10D$ . The minimum penetration for any design value is  $6D$ . In a two member connection, this

penetration is into the main member; in a three member connection, it is into the far side member. Penetration depth factor does not apply to withdrawal loads which are calculated per inch of penetration.

Diaphragm Factor (Ref. 2, p. 148) - For laterally loaded nails loaded in diaphragm action as in shear walls or in floor or roof decks acting as deep shallow horizontal beams a diaphragm factor,  $C_{di} = 1.10$  is applied.

COMBINING FACTORS

All factors relevant to a design situation are used. Thus, several factors may be multiplied for a given condition. If, for example, a nail used in a shear wall has a basic allowable lateral load of 120 pounds and is subject to both wind load and moisture the allowable stress is:

$$(120 \text{ psi})(1.10)(1.60)(.7) = 148 \text{ pounds}$$

The 1.10 is the diaphragm factor, the 1.60 is  $C_D$  from Table 1 and the .7 is  $C_M$  from Table 2. If conditions are called “normal,” the adjustments factors that are entered by the spreadsheet user are all 1.0.

NAIL AND SCREW SPACING

The general rule for nail and screw spacing is to space them far enough apart and far enough from ends and edges to prevent splitting. Recommended minimum spacings to achieve this are given in Table 3. In the table, D is the nail or screw diameter. Note that pilot holes, to be discussed later, may be used.

Table 3. Minimum Nail and Screw Spacings (Ref. 2, pp. 139, 149)

	With Wood Side Members		With Steel Side Members	
	not pre-bored	pre-bored	not pre-bored	pre-bored
Edge Distance	2.5D	2.5D	2.5D	2.5D
End Distance	15D tension load    grain 10D compression load    grain	10D 5D	10D tension load    grain 5D compression load    grain	5D 3D
In A Row	15D    to grain 10D ⊥ to grain	10D 5D	10D    to grain 5D ⊥ to grain	5D 2.5D
Between Rows	5D in a line 2.5D staggered	3D 2.5D	3D in a line 2.5D staggered	2.5D 2.5D

Figures 3 and 4 illustrate spacing dimensions. In Figure 3, “a” is end spacing, “b” is spacing in a row, “c” is edge spacing, and “d” is spacing between rows for both the main and side members. The load is parallel to grain for both members. In Figure 4, “a” is end spacing, “b” is spacing in a row, “c” is edge spacing, and “d” is spacing between rows for the side member. For the main member, “a” is edge spacing, “b” is spacing in a row, and “d” is spacing between rows. A “row” is a line of connectors parallel with the load.

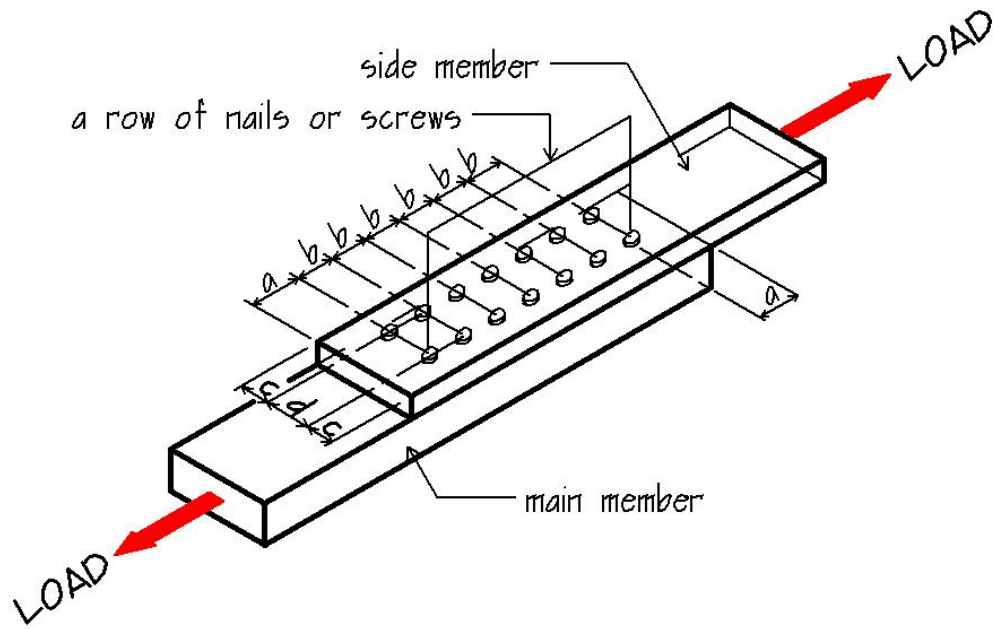


Figure 3. Nail and Screw Spacing

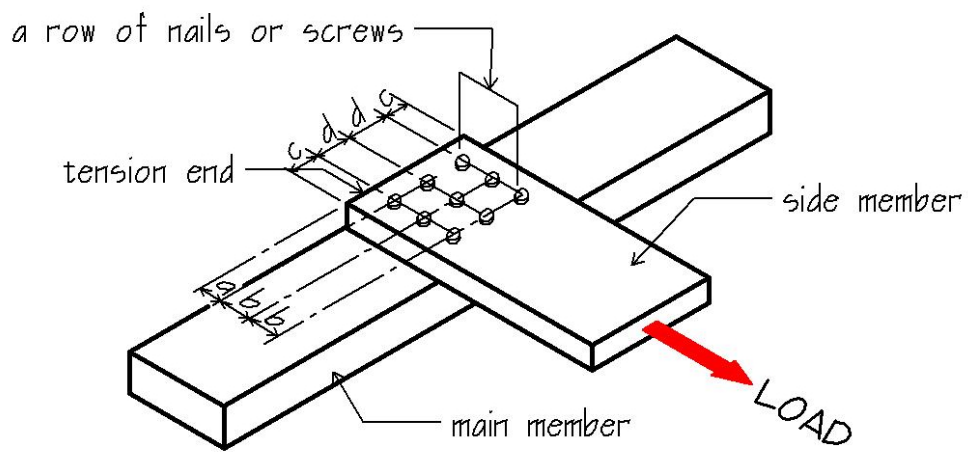


Figure 4. Nail and Screw Spacing

NAIL AND SCREW PROPERTIES RELEVANT TO WOOD DESIGN

The bending yield strength,  $F_{yb}$ , of the nail or screw is a factor in determining a laterally loaded connection capacity. Reference 1, pp. 96-101, uses the following values for both nails and screws:  $F_{yb} = 100000$  psi for  $.099'' \leq D \leq .142''$ ,  $F_{yb} = 90000$  psi for  $.142'' < D \leq .177''$ ,  $F_{yb} = 80000$  psi for  $.177'' < D \leq .236''$ ,  $F_{yb} = 70000$  psi for  $.236'' < D \leq .273''$ . Nails and screws may be made of higher strength materials such as stainless steel or lower strength materials such as aluminum. A 30% increase in  $F_{yb}$  may be assumed for hardened steel nails (Ref. 2, p. 144). While tension failure is unlikely, the stress should be compared with the allowable for withdrawal loads. It is the designer's responsibility to account for the minimum properties of the materials.

Power driven nails have achieved acceptance in the market place and in the building codes. The nail bending yield strengths are equal to those given above and the load capacities are calculated in the same way as for hand driven nails (Ref. 6, p. 2). Proper adjustment of the nail gun is very important as overdriving the nails may result in reduced load capacity. Coated nails have capacities at least equal to uncoated nails (Ref. 6, p. 2).

Wood screws may have either rolled threads or cut threads. For rolled threads, the shank diameter is equal to the thread root diameter. The threads project above the shank. For cut threads, the thread root diameter is less than the shank diameter. The threads cut into the shank. For a given screw sizes, the outside thread diameters are equal (Ref. 1, p. 167). Typically, screws are threaded for two-thirds of the screw length.

The proper installation of screws in either withdrawal or lateral loading typically requires a pilot hole. The recommended hole sizes are based on the shank diameter,  $D$ , and the specific gravity,  $G$ , of the wood. For screws loaded laterally a pilot hole for the threaded portion and a larger pilot hole for the shank are recommended. The hole sizes are given in Table 4. If pilot holes are used for nails, the diameter should not exceed 90% of  $D$  for wood of  $G > .6$ , and 75% of  $D$  for wood of  $G \leq .6$ .

Table 4. Pilot Hole Sizes for Screws (Ref 1, pp. 66 ,67)

G	Withdrawal Load	Lateral Load
$> .6$	approx. $.9D$	threaded = root $D$ shank = shank $D$
$.5 < G \leq .6$	approx. $.7D$	threaded $.88$ root $D$ shank $.88$ shank $D$
$\leq .5$	none required	threaded $.88$ root $D$ shank $.88$ shank $D$

The use of lubrication to facilitate insertion of screws does not affect the allowable load. Screws are to be screwed in, not driven in.

Nail length and diameter are related to the penny weight, and screw diameters are related to the gage number. A 10d ("10 penny") "box" nail is 3" long and has a diameter of  $.128''$ . A #12 screw has a shank diameter of  $.216''$  and a thread root diameter of  $.171''$  (Ref.1, pp. 167, 168). The spreadsheet includes tables giving dimensions of many common sizes of nails and screws.



## LOAD APPLICATION

Loads may be applied laterally (sideways) or in withdrawal (direct pull) or at an angle that cause a combination of lateral and withdrawal loading. Single shear (two member) lateral loads are illustrated in Figures 3 and 4. A double shear (three member) lateral loads is illustrated in Figures 5. These loads are resisted by shear in the nails or screws and dowel bearing on the members. Three member joints are included in this discussion for completeness, but it is often difficult to achieve adequate penetration of the nail or screw into the far side member. It is more practical to nail or screw the side pieces from both sides or to use bolts for this situation if it is possible. For lateral loads, the spreadsheet is limited to two member connections.

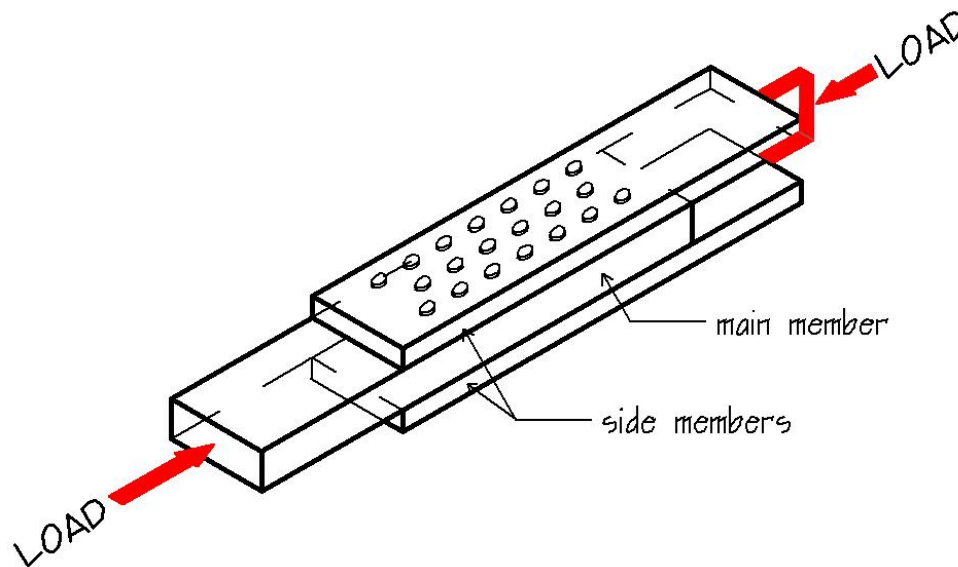


Figure 5. Double Shear Lateral Loading

Nails and screws also have the capacity to carrying load in direct withdrawal in side grain as illustrated by Load A in Figure 6. Loads may be at an angle other than  $0^{\circ}$  (withdrawal) and  $90^{\circ}$  (lateral) to the axis of the lag screw as shown in Figure 6. This is a combination of withdrawal and lateral loading. In Figure 6, the screw with Load B is inserted at an angle,  $\beta$ , and the load is parallel to the surface. The threaded penetration is measured perpendicular to the load (Ref. 1, p. 72). The screw with Load C is perpendicular to the surface but the load is at an angle,  $\alpha$ , to the surface. If the angles are equal, the calculations are identical.

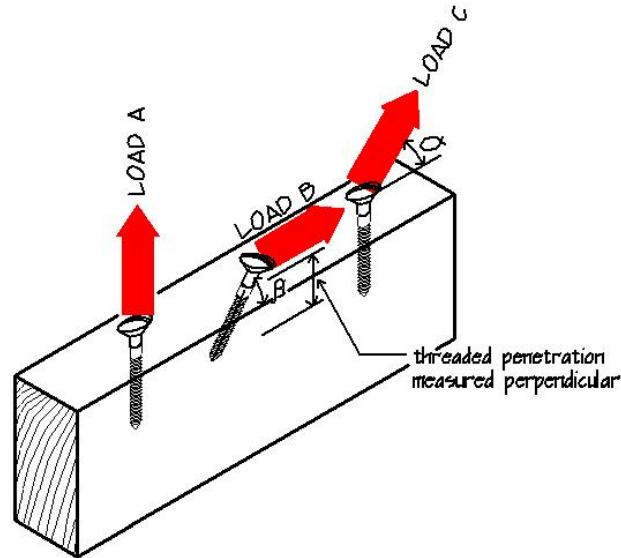


Figure 6. Withdrawal and Combined Loading

## STEEL SIDE PLATES

Steel side plates are accommodated by using the same formulas that are used for wood side plates except a higher value of dowel bearing ( $F_{es}$ ) is used. A value of 61850 psi is suggested by reference 1, p.96, for A33 steel. That is the default value for the spreadsheet, but other values can be used as is illustrated in Example 4. Manufacturers of metal hangers for wood structures publish load capacities for their proprietary devices. The spreadsheet is not intended to be used for those devices.

## FAILURE MODES AND EQUATIONS (Ref. 1, pp. 71, 72, 159)

Lateral Loads – For nails, there are four possible failure modes for the typical single shear (two member) wood to wood connection. For screws, there are three possible failure modes for the typical single shear (two member) wood to wood connection. In both cases, for steel to wood connections, the failure in bearing on the steel side member (Mode 1<sub>s</sub>) is neglected (Ref. 2, pp. 135, 137, 143, 146). The designer should make sure that the steel side member is adequate using appropriate steel design methods. Failure modes are shown in Figure 7. Formulas have been developed for the basic allowable load for each failure mode. Design involves calculating the value of each failure mode and selecting the lowest value. The formulas do not apply if there is no side member. For screws, the diameter,  $D$ , used is the root diameter.

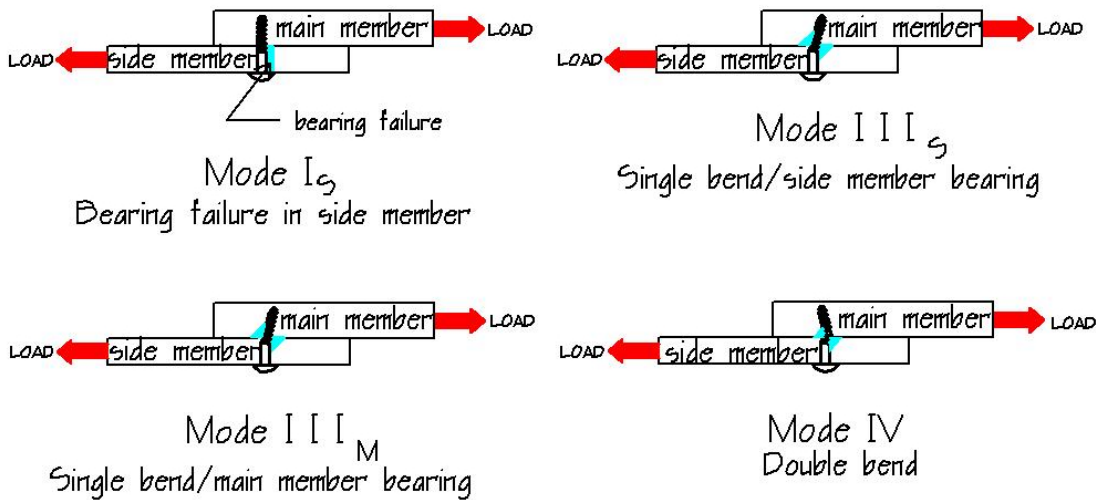


Figure 7. (Single Shear) Joint Failure Modes

Nomenclature: D = diameter (root diameter for screws)

$F_{yb}$  = dowel bending yield strength (psi)

$R_e = F_{em} / F_{es}$

$K_d = 2.2$  for  $D \leq .17$  and  $= 10D + .5$  for  $.17 < D < .25$

$L_s$  = dowel bearing length (penetration) in the side member (inches)

$L_m$  = dowel bearing length in the main member (inches)

$F_{em}$  = dowel bearing strength of main member (psi)

$F_{es}$  = dowel bearing strength of side member (psi)

Z = the allowable for a given failure mode

$$k_2 = -1 + [2(1 + R_e) + \{2F_{yb}(1 + 2R_e)D^2\} / (3F_{em}L_m^2)]^{.5}$$

$$k_3 = -1 + [2(1 + R_e) / R_e + \{2F_{yb}(2 + R_e)D^2\} / (3F_{em}L_s^2)]^{.5}$$

Single shear Mode  $I_s$  :  $Z = DL_s F_{es} / K_d$  (nails and screws – wood sides only)

Single shear Mode  $III_m$  :  $Z = k_2 DL_m F_{em} / \{(1 + 2R_e)K_d\}$  (nails only)

Single shear Mode  $III_s$  :  $Z = k_3 DL_s F_{em} / \{(2 + R_e)K_d\}$  (nails and screws)

Single shear Mode IV:  $Z = (D^2 / K_d) \{2F_{em}F_{yb} / 3(1 + R_e)\}^{.5}$  (nails and screws)

Withdrawal Loads (Ref.1, p.69) – The formula for withdrawal loads, W, for nails, per inch of penetration perpendicular to side grain is:

$$W = 1380G^{2.5}D$$

G is the specific gravity of the wood and D is the nail diameter.

The formula for withdrawal loads,  $W$ , for screws, per inch of threaded penetration perpendicular to side grain is:

$$W = 2850G^2D$$

$G$  is the specific gravity of the wood and  $D$  is the screw diameter.

Tensile stress at the screw root diameter should be checked.

Combined Lateral and Withdrawal Loads (Ref. 1, p. 76) – The formula for determining allowable load,  $Z'_\alpha$ , at an angle,  $\alpha$ , between the wood surface and the nail or screw is:

$$Z'_\alpha = W'pZ'/(W'p\cos^2\alpha + Z'\sin^2\alpha)$$

$W'$  is the factored (adjusted by load factors) withdrawal load

$Z'$  is the factored (adjusted by load factors) lateral load

$p$  is the length of penetration (threaded penetration for screws) measured perpendicular to the member

$\alpha$  is the angle between the load and the wood surface

## MEMBER FAILURE

The capacity of a joint may be controlled by the allowable load on the main member or the side member. Members could be in bending, tension, or compression. For example, in Figure 4 the side member is in tension and the main member is in bending. In Figure 3, both members are in tension. In Figure 5, members are in compression. Regardless of calculated nail or screw capacity, the load should not exceed the strength of the wood. The spreadsheet does not check member load capacities.

## USING THE SPREADSHEET

The Excel© 2003 spreadsheet, NAILSCREW©, has the appropriate formulas embedded and provides some useful technical data. These are in protected cells so that they will not be inadvertently changed. Data for other species and grades can be obtained from references 3 and 4 or similar sources. Information provided by the user is entered into yellow or turquoise colored unprotected cells. An unprotected light yellow “Job Notes” pad is also provided. Results of the calculations are provided in red colored cells. Insofar as possible, the nomenclature used in the foregoing explanation is used in the spreadsheet. Many of the cells have explanatory notes attached. The spreadsheet works well to try alternate design solutions. Lateral loading is limited to two member (single shear) connections. The main member is always wood; the side member may be wood or steel.

Example problems follow with explanations. Example Problem 1 is entered into the spreadsheet.

Example Problem 1: Use a connection like that shown in Figure 3.

Side member is S4S 1x8 No.1 Doug Fir-Larch`

Main member is S4S 3x8 No.1 Doug Fir-Larch

#14 x 3” steel screws

Load is snow load; other factors are normal.

The values entered into the various spreadsheet cells are shown in Table 5.

Table 5. Spreadsheet Entries for Example Problem 1.

Cell	E22	E23	E24	E25	E26	E27	E28	E29	E30
entry	L	s	g	w	s	.216	3.0	*	*
Cell	E31	E32	E33	E34	E35	E36	E37	E38	F27
entry	80000	.75	2.5	.5	.5	0	90	*	.171
Cell	M36	M37	E51	E52	E53	E54	E55	E56	
entry	*	*	14	1.15	1.0	1.0	1.0	1.0	

\*inactive, could be blank or any value

The unfactored answer provided is 126 pounds per screw based on Yield Mode III<sub>s</sub> and the total is 2036 pounds.

Example Problem 2: Use a connection like that shown in Figure 3.

Side member is S4S 1x8 No.1 Doug Fir-Larch`

Main member is S4S 3x8 No.1 Doug Fir-Larch

12d common nails

Load is snow load; other factors are normal.

The values entered into the various spreadsheet cells are shown in Table 6.

Table 6. Spreadsheet Entries for Example Problem 2.

Cell	E22	E23	E24	E25	E26	E27	E28	E29	E30
entry	L	s	g	w	n	.148	3.25	*	*
Cell	E31	E32	E33	E34	E35	E36	E37	E38	F27
entry	90000	.75	2.5	.5	.5	0	90	n	*
Cell	M36	M37	E51	E52	E53	E54	E55	E56	
entry	*	*	14	1.15	1.0	1.0	1.0	1.0	

\*inactive, could be blank or any value

The unfactored answer provided is 105 pounds per nail based on Yield Mode III<sub>s</sub> and the total is 1696 pounds.

Example Problem 3: Use a connection like that shown in Figure 8 following.  
 Side members are 10 gage A33 steel.  
 Main member is rough 3x12 No.1 Red Oak  
 Use 6 – #14 by 2 1/2” long screws each side of main member and each side of joint spaced adequately.  
 Wind loading and moist conditions.

The values entered into the various spreadsheet cells are shown in Table 7.

Table 7. Spreadsheet Entries for Example Problem 3.

Cell entry	E22 L	E23 s	E24 g	E25 s	E26 s	E27 .242	E28 2.5	E29 *	E30 *
Cell entry	E31 70000	E32 .134	E33 3.0	E34 *	E35 .67	E36 0	E37 90	E38 *	F27 .196
Cell entry	M36 *	M37 *	E51 12	E52 1.6	E53 .7	E54 1.0	E55 1.0	E56 1.0	

\*inactive, could be blank or any value

Note there are twelve screws “in the joint” used in the spreadsheet, not twenty-four. The unfactored answer provided is 226 pounds per screw based on Yield Mode III<sub>s</sub> and the total is 2963 pounds.

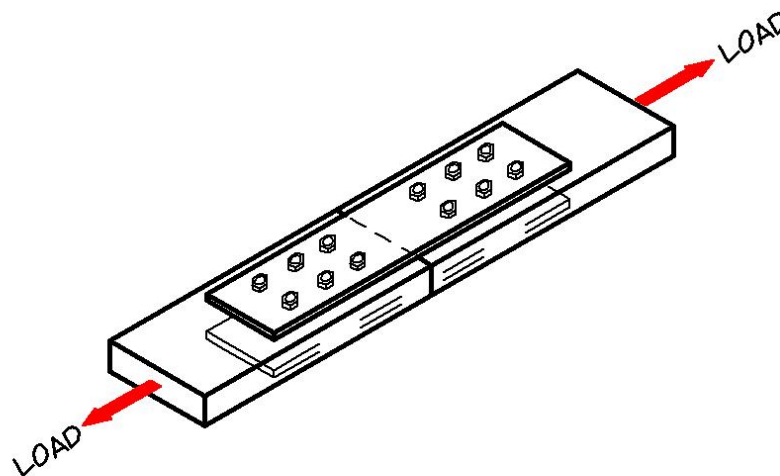


Figure 8. Steel Splice Plates on Wood

Example Problem 4. Use a connection like that shown in Figure 8.  
 Side members are 1/4" A36 steel (assume  $F_{es} = 87000$ )  
 Main member is rough 3x12 No.1 Red Oak  
 Use 6 – #14 by 2 1/2" long screws each side of main member  
 and each side of joint spaced adequately.  
 Wind loading and moist conditions.

The values entered into the various spreadsheet cells are shown in Table 8.

Table 8. Spreadsheet Entries for Example Problem 4.

Cell	E22	E23	E24	E25	E26	E27	E28	E29	E30
entry	L	s	b	s	s	.242	2.5	*	*
Cell	E31	E32	E33	E34	E35	E36	E37	E38	F27
entry	70000	.25	3.0	*	.67	0	90	*	.196
Cell	M36	M37	E51	E52	E53	E54	E55	E56	
entry	87000	7950	12	1.6	.7	1.0	1.0	1.0	

\*inactive, could be blank or any value

Note there are twelve screws “in the joint” used in the spreadsheet, not twenty-four.  
 The entry for cell M37 was determined by using the value in cell L37. The unfactored answer provided is 288 pounds per screw based on Yield Mode IV and the total is 3598 pounds.

Example Problem 5: Use a connection like that shown in Figure 6 - Load A.  
 Use one #14 x 4" screw with 2 2/3" penetration into side grain of southern pine.  
 Long term (dead) load controls. Other conditions normal.

The values entered into the various spreadsheet cells are shown in Table 9.

Table 9. Spreadsheet Entries for Example Problem 5.

Cell	E22	E23	E24	E25	E26	E27	E28	E29	E30
entry	w	s	g	*	s	.242	*	2.67	*
Cell	E31	E32	E33	E34	E35	E36	E37	E38	F27
entry	*	*	*	*	.55	90	90	*	.196
Cell	M36	M37	E51	E52	E53	E54	E55	E56	
entry	*	*	1	.9	1.0	1.0	1.0	1.0	

\*inactive, could be blank or any value

The answer given is 501 pounds.

Example Problem 6: Use a connection like that shown in Figure 6 - Load A.

Use 40d spike with 4” penetration into side grain of southern pine.

Long term (dead) load controls. Other conditions normal.

The values entered into the various spreadsheet cells are shown in Table 10.

Table 10. Spreadsheet Entries for Example Problem 6.

Cell	E22	E23	E24	E25	E26	E27	E28	E29	E30
entry	w	s	g	*	n	.263	*	4.0	*
Cell	E31	E32	E33	E34	E35	E36	E37	E38	F27
entry	*	*	*	*	.55	90	90	n	*
Cell	M36	M37	E51	E52	E53	E54	E55	E56	
entry	*	*	1	.9	1.0	1.0	1.0	1.0	

\*inactive, could be blank or any value

The answer given is 293 pounds.

Example Problem 7: Use a connection like Load C shown in Figure 6 – Load C.

Use four #12 x 3” screws with 2 7/8” penetration into a 4” thick Douglas

Fir-Larch main member using a 3 gage steel side plate (not shown in Figure 8).

Angle of load to wood surface is 60 degrees. Damp location, wind load.

The values entered into the various spreadsheet cells are shown in Table 11.

Table 11. Spreadsheet Entries for Example Problem 7.

Cell	E22	E23	E24	E25	E26	E27	E28	E29	E30
entry	c	s	g	s	s	.216	3.0	2.0	2.88
Cell	E31	E32	E33	E34	E35	E36	E37	E38	F27
entry	70000	.239	4.0	*	.50	60	90	*	.171
Cell	M36	M37	E51	E52	E53	E54	E55	E56	
entry	*	*	4	1.6	0.7	1.0	1.0	1.0	

\*inactive, could be blank or any value



The answers provided for the lateral load based on Yield Mode IV is 842 pounds and the answer provided for the withdrawal load is 1836 pounds based on screw tensile strength. The combined (at the angle) load is 1418 pounds.

#### REFERENCES

1. American Forest and Paper Association (AF&PA), American Wood Council, 2001, *National Design Specification ANSI/AF&PA NDS-2001*, Washington D.C.
2. American Forest and Paper Association (AF&PA), American Wood Council, 1997, *Commentary on National Design Specification*, Washington, D.C.
3. American Forest and Paper Association (AF&PA), American Wood Council, 1999, *Allowable Stress Design Supplement Structural Connections*, Washington, D.C.
4. American Forest and Paper Association (AF&PA), American Wood Council, 2001, *National Design Specification Supplement*, Washington, D.C.
5. American Institute of Steel Construction, 1989, *Manual of Steel Construction, 9<sup>th</sup> Edition*, Chicago, Illinois.
6. National Evaluation Report, 1997, *National Evaluation Service, Inc.*, International Staple, Nail and Tool Association 512 West Burlington Ave., Suite 203, LaGrange, IL 60525.