

# INFORMATION SHEET

## STRUCTURAL CONNECTIONS

## NAILS

### PERFORMANCE/DESIGN DATA

The information provided below has been taken from the New Zealand Timber Design Guide 2007, published by the Timber Industry Federation and edited by Professor A H Buchanan. To purchase a copy of the Timber Design Guide, visit [www.nztif.co.nz](http://www.nztif.co.nz)

#### EFFECT OF WOOD SPECIES ON JOINT

NZS 3603 gives fastener strengths for five classes of wood quality, which are specified as joint groups J1 to J5. Some species or materials may be classified in different joint groups for different modes of loading. The manufacturers of engineered wood products (such as LVL) publish the appropriate joint group for their products after experimental testing. Fastener strengths given here are only for radiata pine and Douglas fir. See NZS 3603 for other materials or species.

#### CHARACTERISTIC FASTENER STRENGTH

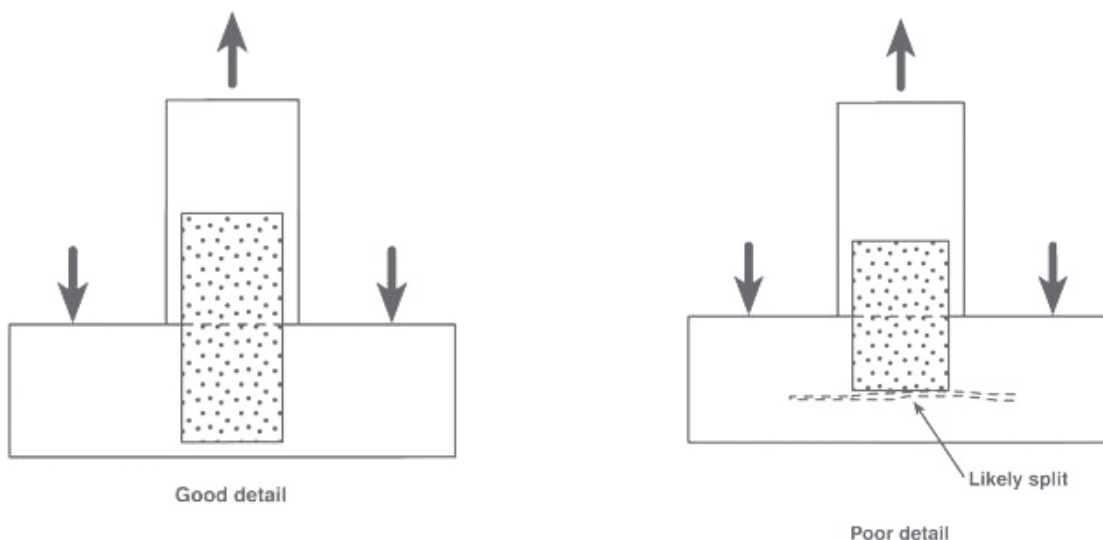
NZS 3603 specifies the characteristic strengths for nails as a function of fastener diameter, see table 1 for shear strengths fixing into radiata pine and Douglas fir. The characteristic strengths have been derived by applying a soft conversion multiplier of 2.95 to the basic working strengths used in the previous version of NZS 3603. The original basic working loads were determined from tests of solid timber joints incorporating various fastener diameters, using the lesser of:

- the lower 5 percentile ultimate strength, divided by a load duration and safety factor of 4.15, and
- the lower 5 percentile strength at 0.4 mm slip divided by a safety factor of 1.25.

For nails, the characteristic strength  $Q_k$  (N) diameter  $d$  (mm) is given by  $Q_k = 71d^{1.9}$ .

To determine the design strength, these characteristic strengths are modified to take account of such factors as timber moisture content, timber thickness, fastener length, end grain, double shear, multiple fastener joints and duration of load.

**Diagram 1: Steel nail-on plate inducing stresses in tension perpendicular to the grain**



## DESIGN STRENGTH

The design strengths for laterally loaded fasteners should be determined by multiplying the appropriate characteristic strengths (see table 1) by one or more of the following factors to take account of the actual service condition of the joint. NZS 3603 limits the maximum design strength to  $1.6/\phi$  times the characteristic strength given in table 1.

**Table 1: Characteristic strengths (N) for one plain steel nail in single shear in side grain in dry timber**

Nail diameter (mm)	2.0	2.24	2.5	2.8	2.87	3.15	3.33
Strength (N)	268	331	407	504	526	631	695
Nail diameter (mm)	3.55	3.75	4	4.5	5	5.3	6
Strength (N)	790	868	990	1,240	1,510	1,690	2,130

## LOAD DURATION

The modification factor  $k_1$  from NZS 3603 should be applied to the characteristic fastener strengths to take account of load duration.

## MOISTURE CONDITION

A reduction factor of 0.85 should be applied to the characteristic strengths of nails when the joints are:

- fabricated dry but become wet in service, or
- fabricated green and remain green in service, or
- fabricated green and allowed to dry in service.

The reduction factors for conditions 1 and 2 above can be explained by noting that the crushing resistance of the timber under the fastener shank reduces with increasing moisture content.

The reduction for condition 3 is due to the timber shrinking with drying, resulting in a gap of as much as 1.0 mm at the interface of the two timber members. This gap causes a reduction in the initial stiffness of the joint and design strength.

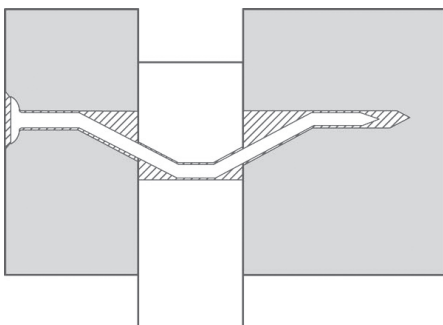
## PLYWOOD SHEATHING FASTENED TO TIMBER

For plywood sheathing fastened to solid timber, the fastener strengths are higher than those in table 1 (timber to timber joints) by a factor of 1.4. Fastening of wood-based panel products such as particle board, fibre board and hardboard to timber can be designed using the same strengths as plywood, but they may not provide the same level of ductility.

## MULTIPLE SHEAR FACES

For a joint with several shear faces, as shown in diagram 2, the design strength is directly proportional to the number of shear faces.

**Diagram 2: Three-member joint loaded in shear**



## FASTENER LENGTH AND TIMBER

The penetration into the timber holding the point of the fastener should be at least 10 diameters for nails. Fastener penetration and timber thickness affect the way the fastener bends in the timber and this, in turn, influences the design strengths

Joint strength is greatest when the fastener is long enough to develop two plastic hinges, lowest when the fastener does not bend at all. NZS 3603 gives reduced strengths when the recommended penetration requirements are not met.

**Table 2: Maximum fastener diameters for fixing sheathing to timber in shearwalls and diaphragms**

	Sheathing thickness (mm)				
	4.5*	7.5*	9	12.5	15+
Plywood	2.8*	2.8*	3.3	3.3	4.0
MDF or particleboard	Not suitable			3.3	4.0
* Not suitable for fully ductile design.					

## LARGE NUMBER OF FASTENERS

When the number of fasteners in a connection exceeds 50, the design strength on each can be increased by a factor of 1.30. For fewer nails, the factor shall be obtained by linear interpolation to a value of 1.0 for four fasteners. This accounts for variability in strengths by moving from the 5th percentile value for one fastener towards a mean value for multiple fasteners. This factor should be used for large gusset connections and plywood shearwalls.

## WIND OR SEISMIC LOADING

For wind or seismic loading of a plywood shearwall or diaphragm with radiata pine or Douglas fir framing, the strengths in table 3 should be used. These figures are approximately 1.82 times those in table 1. The figures in table 3 can be obtained from those in table 1 by taking the product of the following factors:

- brief duration of load 1.00
- large number of fasteners 1.30
- plywood with flat-head fasteners 1.40

**Table 3: Design strength (N) for one plain steel nail in a shearwall or diaphragm under wind or seismic loading**

Nail diameter (mm)	2.0	2.24	2.5	2.8	2.87	3.15	3.33
Strength (N)	488	602	741	917	957	1,148	1,265
Nail diameter (mm)	3.55	3.75	4	4.5	5	5.3	6
Strength (N)	1,438	1,580	1,800	2,260	2,750	3,080	3,880

In order to obtain ductile behaviour, large diameter fasteners should be avoided. Table 2 gives the recommended maximum diameters of fasteners.

## STEEL SIDE PLATE

Where nails are driven through tight-fitting thick steel plate, the plate effectively clamps the nail shank forcing the plastic hinge to form at the interface of the two joint members. This increases the joint stiffness significantly, and also the design strength.

A significant, although smaller, increase in stiffness also occurs when the nails are driven through loose fitting or thin steel plate. A modification factor of 1.50 should be applied to the characteristic fastener strengths in table 1 when steel plate of 3.0 mm thick or greater is nailed to solid timber. Where the steel plate is less than 3.0 mm thick, the modification factor becomes 1.25.

Manufacturers of metal connection products publish their own characteristic nail strengths, based on independent test results (see the manufacturers' literature).

## ULTIMATE STRENGTH

The ultimate strength of a joint depends on the fastener penetration, coating and diameter, but this level of strength is generally not required by designers because it occurs at large deformations well outside a working design range. However, the ultimate strength of joints may be required during capacity design procedures when they are the ductile elements, for example, within earthquake resistant bracing elements.

Table 4 tabulates an estimate of the average ultimate strength of common nails and staples used in earthquake applications. These strengths are about twice the characteristic strengths in table 1 or 50 percent larger than the wind/seismic strengths in table 3.

**Table 4: Average ultimate strength of sheathing nails loaded in shear with 12 mm thick plywood**

Nail type	Nail length (mm)	Nail diameter (mm)					
		1.85 (staple)	2.24	2.5	2.8	3.15	3.55
Bright	40	1,020		750			
	50	1,280	800	910	1,030		
	60	1,550	950	1,070	1,220	1,390	
	70			1,230	1,400	1,590	1,820
	80					1,790	2,050
	90						2,270
Galvanised	50		1,180	1,310	1,480		
	60		1,500	1,660	1,850	2,090	
	70			1,990	2,220	2,500	2,830
	80					2,900	3,340
	90						

## JOINTS LOADED IN WITHDRAWAL

NZS 3603 specifies the characteristic withdrawal strengths in terms of the nail diameter and its penetration into the timber as given in table 5. Note that galvanised nails are stronger than bright or zinc coated nails when loaded in withdrawal, although this is not recognised in NZS 3603.

**Table 5: Characteristic withdrawal strength per millimetre of fastener penetration (N/mm)**

Nail dia. (mm)	2.0	2.24	2.50	2.8	3.15	3.55	4.00	4.50	5.00	5.30	6.00	6.30
Radiata pine	5.5	6.2	6.8	7.7	8.6	9.7	11.0	12.4	13.8	14.6	16.6	17.4
Douglas fir	4.2	4.7	5.2	5.8	6.5	7.3	8.3	9.3	10.3	10.9	12.3	12.9