INFORMATION SHEET
STRUCTURAL CONNECTIONS

BOLTS, COACH BOLTS, COACH SCREWS AND DOWELS
PERFORMANCE AND 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

BOLTED JOINT DESIGN

The design of bolted connections outlined here is in accordance with the New Zealand Timber Structures Standard NZS 3603.

Tables give bolt capacities in radiata pine and Douglas fir (species group J5).

Refer to NZS 3603 for design of bolts in timber other than radiata pine and Douglas fir.

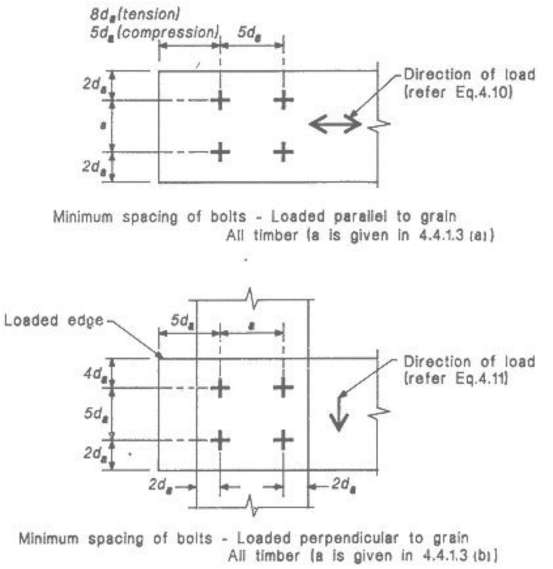
EDGE AND END DISTANCES

To avoid splitting of the timber, minimum distances between the fastener(s) and the edges and end of the member must be observed (see diagram 1).

If these distances cannot be achieved, a convenient solution is to apply a Pryda or Gang-Nail toothed plate fastener to the timber and drill through both the plate and the timber. This will help prevent splitting and increase the load transfer capacity between the bolt and the timber.

Design data on the effect of this is not available and engineering judgement must be applied.

Diagram 1: Minimum bolt spacing and edge distances from NZS 3603



Source: New Zealand Timber Structures Standard NZS 3603, Figure 4.1. Reproduced from NZS 3603 with the permission of Standards New Zealand under Licence 000702 – to purchase NZS 3603 go to www.standards.co.nz

Minimum distances are shown in diagram 1 – here the distance 'a' is given by:

For load along the grain:

$a = d_a (n – 4 + r) / (r – 1)$

but not less than $2.5d_a$

For load across the grain:

$a = 0.625b + 1.25d_a$

but not less than $2.5d_a$ or greater than $5d_a$

where:

d_a = bolt shank diameter (mm)

n = total number of bolts in joint

r = number of rows of fasteners across the grain

b = thickness of member with load across the grain (mm).

ECCENTRIC JOINTS

Eccentric joints can occur in truss chords if the axes of the web and chord members do not coincide, as shown in diagram 2 In this case, a very high shear force V* may be generated across the chord member.

The checking equation is:

$V^*_p \leq \phi\, k_1\, k_4\, k_5\, f_s\, b\, d_s$

where: ϕ = material strength reduction factor

k_1 = load duration factor

k_4 = parallel support factor

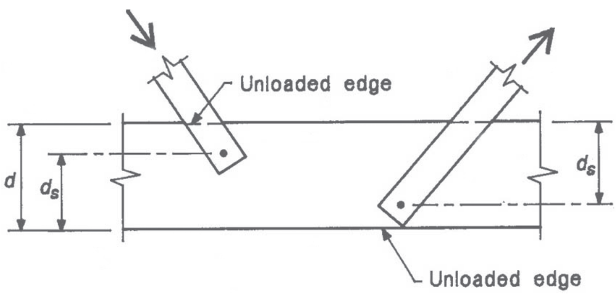
k_5 = grid system factor

f_s = characteristic shear stress

d_s = depth of member less the edge distance from unloaded edge to bolt – see diagram 2.

It will be noted that only the part of the cross section given by A = bds is considered to resist the shear force, rather than the whole cross section A = bd.

Diagram 2: Example of an eccentric joint inducing shear in a timber member



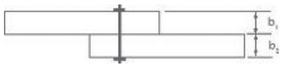
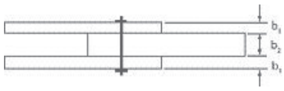
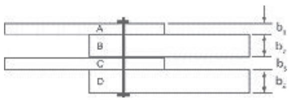
Source: Timber Design Guide, 2007.

Characteristic strengths

NZS 3603 gives characteristic strengths for single bolts in single shear that are then combined according to the number of shear planes, number of bolts and direction of load relative to the grain.

The characteristic strength is a function of the bolt diameter and the thinner of the timber members either side of the shear plane, as given below in table 1.

Table 1: Characteristic strength for a single bolt loaded parallel to grain

Type of joint	Effective timber thickness (be)	System characteristic strength
1. Two member 	Smaller of $2b_1$ and $2b_2$	Q_{kl}
2. Three member 	Smaller of $2b_1$ and $2b_2$	$2Q_{kl}$
3. Multiple member 	(i) Between A and B smaller of b_1 and b_2 (ii) Between B and C smaller of b_1 and b_2	(i) Q_{kl} (ii) Q_{kl} Total characteristic load = sum of characteristic loads
4. Alternative steel and timber members	As for types 1, 2, or 3, except that be is based on thickness of timber members only	1.25 x value calculated for joint types 1, 2 or 3

Source: Timber Design Guide, 2007

Bolted joints in single shear, parallel to grain

The characteristic strength Q_{kl} (N) for a bolt in single shear for dry radiata pine or Douglas fir loaded parallel to the grain is given by the lesser of:

$$Q_{kl} = 72.2d^2 \text{ or } Q_{kl} = 18d\, b_e$$

where:

d = bolt shank diameter (mm)

b_e = effective timber thickness (mm) given by table 1

This equation has been used to create table 2, which gives the characteristic strength Qkl for a single bolt in single shear in dry radiata pine or Douglas fir loaded parallel to the grain.

Bolted joints in single shear, across the grain

The characteristic strength Q_{kp} (N) for a bolt in single shear for dry radiata pine loaded across the grain is given by the lesser of:

$$Q_{kp} = 192d^{1.5} \text{ or } Q_{kp} = 6.45b_e d$$

where:

d = bolt shank diameter (mm)

b_e = effective timber thickness (mm) given by table 5.

In NZS 3603 there is another version of table 1 for loads perpendicular to the grain, giving the same values of b_e.

This equation has been used to create table 3, which gives the characteristic strength Qkp for a single bolt in single shear in dry radiata pine or Douglas fir loaded perpendicular to the grain.

Angle to grain

For systems loaded at an angle θ to the grain, Hankinson's formula is used:

$$Q_{(k\theta)} = \frac{(Q_{kl} Q_{kp})}{(Q_{kl} \sin^2\theta + Q_{kp} \cos^2\theta)}$$

Steel side plates

Table 1 specifies that the effective timber thickness be is based on the thickness of timber members only, and that the system characteristic strength is to be multiplied by a factor of 1.25 to account for the effect of steel members for loads parallel to the grain.

Characteristic bolt strength tables

These tables have been derived from the formulae above and appear in NZS 3603.

Table 2: Characteristic strength Q_{kl} (kN) for a single bolt loaded parallel to the grain in radiata pine

Effective timber thickness b_e (mm)	Bolt shank diameter *d* (mm)						
	8	10	12	16	20	24	30
15	2.16	2.70	3.25	4.33	5.41	6.49	
19	2.74	3.43	4.11	5.48	6.85	8.22	
35		6.31	7.57	10.1	12.6	5.1	18.9
45			9.74	13.0	16.2	19.5	24.3
65			10.4	18.5	23.4	28.1	35.2
90			10.4	18.5	28.8	38.9	48.7
130			10.4	18.5	28.8	41.5	64.9

Table 3: Characteristic strength Qkp (kN) for a single bolt loaded perpendicular to the grain in radiata pine

Effective timber thickness b_e (mm)	Bolt shank diameter *d* (mm)							
	8	10	12	16	20	24	30	36
15	0.774	0.968	1.16	1.55	1.93	2.32		
19	0.981	1.23	1.47	1.96	2.45	2.94		
35		2.26	2.71	3.61	4.52	5.42	6.78	
45			3.8	4.65	5.81	6.97	8.71	10.5
65			5.03	6.71	8.39	10.1	12.6	15.1
90			6.97	9.29	11.6	13.9	17.4	20.9
130			7.99	12.3	16.8	20.1	25.2	
180			7.99	12.3	17.2	22.6	31.6	

DESIGN STRENGTHS

Lateral load only

Laterally loaded bolted joints, for the strength limit state, shall satisfy:

$N^* = \phi Q_n$

where:

N^* = design load on the joint (N)
ϕ = strength reduction factor 0.7 for bolts
Q_n = nominal joint strength (N)
Q_n = $n k_1 k_{12} k_{13} Q_k$

where:

n = number of bolts in joint
Q_k = characteristic strength Q_{kl}, Q_{kp} or $Q_{k\Theta}$ as appropriate (N)
k_1 = load duration factor
k_{12} = 0.7 if the joint is made in green timber, otherwise k_{12} = 1.0
k_{13} = modification factor for multiple numbers of bolts.

For joints with imposed restraint on shrinkage k13 = 0.5. For all others cases k13 is given in table 4.

Table 4: Factor k13 for design of multiple bolt joints

Total number of bolts in joint, n	4 or fewer	5	10	16 or more
k13	1.0	0.95	0.8	0.62

Note that for interpolation between n = 4 and n = 16, the expression $k_{13} = 1.114 - 0.031n$ may be used.

Combined lateral and axial load

When the load acts at an angle to the bolt axis, the component of load perpendicular to the bolt axis must satisfy the requirements listed above under Lateral load only, and the component parallel to the bolt axis must satisfy:

$N^* = \phi Q_n$

where:

N^* = design load effects on joint parallel to the axis of bolt (N)
ϕ = strength reduction factor 0.7
Q_n = nominal joint strength (N)
Q_n = 12.9 Aw for dry pine radiata or Douglas fir where:
A_w = the area of washer (mm^2).

COACH SCREWS

Lateral loads

Coach screws loaded in shear are designed in the same way as bolted joints of the same diameter, but are generally suitable for use in single shear only.

Other considerations are:

- Member thickness: If the thinner (that is, head side) member in a two-member joint has a thickness less than three times the shank diameter of the coach screw the nominal load shall be reduced in direct proportion.
- Depth of penetration: If the depth of penetration of the coach screw into the point side member is less than 10 shank diameters then the nominal strength shall be reduced in direct proportion.

Withdrawal loads

Coach screws subjected to withdrawal loads shall satisfy:

$$N^* = \phi Q_n$$

where:

N^* = design load on joint

ϕ = strength reduction factor 0.7

Q_n = nominal joint strength.

The nominal joint strength shall be taken as:

$$Q_n = n\,k\,p\,Q_k$$

where:

n = number of coach screws in the joint

p = length of thread penetration (mm)

Q_k = characteristic withdrawal strength from table 5(N/mm)

k = product of modification factors listed below

for green timber, a factor of 0.7

for duration of load, factor k_1

for coach screws in end grain a factor of 0.67.

Table 5: Withdrawal strength per mm of thread penetration in dry radiata pine or Douglas fir

Shank diameter (mm)	6	8	10	12	16
Withdrawal strength (N/mm)	83	96	107	118	136

Dowels

Dowels have a stiffness advantage over bolts because they can be made to fit into close tolerance holes, whereas bolts require a drilled hole with more clearance.

Another advantage of dowels is that they provide a pleasing visual appearance when driven below the timber surface and the holes are filled with timber plugs.

Fire protection of dowel joints can be achieved with an appropriately sized sacraficial timber plug.

Although dowels are designed in the same way as bolts, without the use of nuts and washers they lack the high post-yield strength of bolted joints.

Dowels can be used efficiently in joint design to carry the joint loads with minimal deformation, while additional small diameter bolts can be used to hold the timber members together.

Innovative connections

As an alternative to solid steel dowels, steel pipe may be used, in which case it may be assumed that the pipe acts as a solid dowel.

Split pins may be used to achieve a tight fit in the steel members of a timber to steel joint. Small diameter bolts with washers may be used in conjunction with pipes or split pins if the bolts are necessary to carry axial loads or simply to ensure that the joined members stay tightly clamped together.

Some new types of dowels have sharpened tips, which allow them to be drilled into position through wood and steel plates, without any pre-drilling of holes.