INFORMATION SHEET

STRUCTURAL CONNECTIONS

PLY GUSSETS

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

TYPES OF PLY GUSSET JOINT

Diagram 1 shows the plywood gusset joint in four variations.

The thickness of each plywood gusset is generally about one-fifth that of the glue laminated (glulam) or laminated veneer lumber (LVL) member but may be reduced if reinforced with a sheet of high tensile steel reinforcement glued between or under the sheets of plywood. The use of three to five rows of nails at approximately 50 mm centres is typical.

a) **Internal haunch:** commonly used in industrial buildings. If columns are erected with plates attached, a convenient seating is provided for rafter members.
   If used with a masonry boundary wall, the corner can be cut out for an internal box gutter, but this requires special analysis.

b) **External haunch:** used where an eaves overhang is needed or a low internal eave height would reduce headroom.

c) **Mitred knee:** less economical of plywood and glulam use than (a) but suits smaller buildings where frames are completely assembled on the ground before erection.

d) **Apex joint:** usually completed before the rafter members are erected.

Note that, in all these joints, a timber stiffener is required to provide buckling restraint to the edge of the plywood gusset that is clear of the glulam or LVL members.

Diagram 1: Four variations of plywood gusset joints

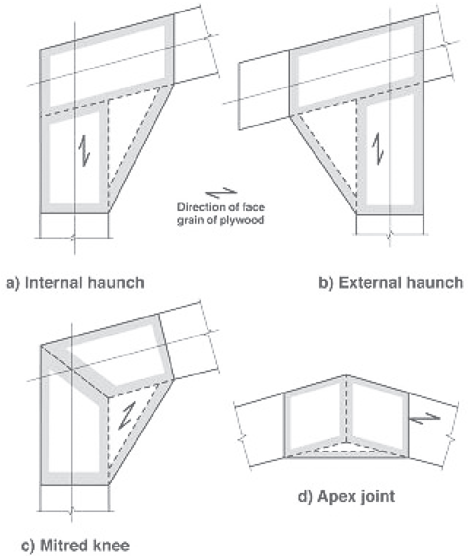

Illustration: Courtesy Timber Design Guide, 2007.

GUSSET DESIGN

Gussets can be designed assuming a bilinear stress distribution for internal or external gusset knee joints, or a linear distribution for apex or mitred knee joints as shown in diagram 2 for a rafter of slope Θ.

Diagram 2: Assumed stress distributions in plywood gusset joints

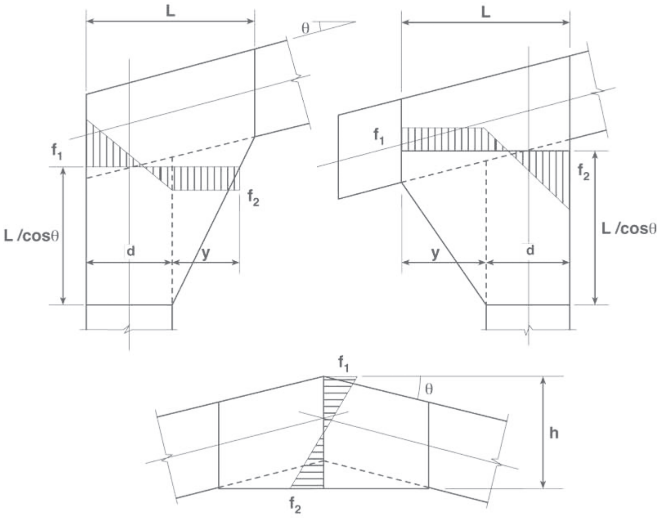

Illustration: Courtesy Timber Design Guide, 2007

Note that the horizontal dimension of the gusset is L and the vertical dimension is L/cosΘ so that the same nailing pattern can be used on both the rafter and the column.

If M is the total moment on the joint, then the stresses in the plywood are given by:

Bilinear distribution (for internal or external gusset knee joints). Stresses are considered at the horizontal cross section shown (passing through the intersection of the column centreline and the rafter soffit):

$$f_1 = \frac{24Mk(1-k)}{td^2(4k-1)}$$

$$f_2 = f_1 \frac{(1-k)}{k}$$

$$\text{where} \quad k = \frac{(y + d/2)}{(y + d)}$$

d is the depth of the portal column

t is the effective thickness of the plywood (sum of the thickness of veneers with grain parallel to the stress for both plates)

y is shown in diagram 3 – it is easiest to obtain y from a scale drawing, but it can be calculated for an internal gusset, using:

$$y = \frac{L-d}{1+\left(1-\frac{d}{2L}\right)\sin\theta}$$

and for an external gusset: y = L-d.

Linear distribution (for apex or mitred knee joints).

The effective depth of the plate at the critical section is h cosθ where h is the total depth, so:

$$f_1 = f_2 = \frac{M}{Z}$$

$$\text{where} \quad Z = \frac{th^2 \cos^2\theta}{6}$$

It is often necessary to use a double thickness of plywood in these joints, in which case the two sheets should be glued together under conditions that will ensure a reliable glue bond.

Note that different manufacturers have different lay ups for different thicknesses of plywood. Check the manufacturers' literature to find plywood with a large percentage of parallel plies (that is, plies with grain parallel to that of the face veneers).

For F11 radiata pine plywood, the design stress in bending is:

$fb = \phi\, k_1 \times 28.8$ MPa

where k_1 is the load duration factor from the New Zealand Timber Structures Standard NZ 3603 and $\phi = 0.9$.

A limitation for large joints is imposed by the standard plywood sheet sizes of 1.2 x 2.4 or 2.7 m.

Larger and stronger plywood sheets are manufactured by several Australian manufacturers but are not available in New Zealand unless ordered in significant quantities.

For the internal haunch, the plywood thickness will be governed by the high tension stresses developed at the outer edge of the knee under closing moments.

Savings can be made by gluing a sheet of high tensile steel, 1 to 2 mm thick, between two sheets of plywood or to the plywood between it and the glulam.

Stresses in both the steel and the plywood should be checked. High strength steel (yield stress at least 350 MPa) must be used if the strength of the plywood is to be developed before the steel yields.

Pneumatic nail guns are used to shoot nails through the plywood and steel sheet. It is essential to glue the steel to the plywood (epoxy adhesive is generally used). This produces a plate that has the strength and ductility of steel but avoids the need to pre-drill for nails.

The plywood bonded to the steel stabilises it against buckling in compression and reduces the danger of nail buckling or ricochet when driving.

NAIL DESIGN

Nail loads for plywood gusset joints are calculated from the joint moment, shear loads and nail pattern dimensions, based on the rivet group analogy but with several simplifying assumptions:

- nail loads from shears and axial forces are small compared with those induced by moments
- the nail pattern is of uniform width, s, around all sides as shown in diagram 4 are considered to be concentrated along the centreline of the rows of nails along each side of the group.

Hand-driven flat head bright or galvanised nails are available in diameters of 2.8, 3.15, 3.55 and 4.00 mm.

In the larger diameters, standard nails tend to be too long but shorter nails, for example, 45 to 60 mm in length, are available on special order in minimum quantities of about 500 kg.

Pneumatically driven gun nails are available in diameters of 3.15 and 3.33 mm in various lengths from 50 to 90 mm.

Hand-driven nails are generally used with steel nailplates because each nail needs to be placed in a pre-drilled hole before driving. Gun nails are used with plywood plates.

To calculate the number of nails required for a gusset joint, first calculate the design bending moment M* at the centroid of the nail group.

Find the characteristic strength of one nail in single shear in radiata pine, Q_k from table 4.3 of the New Zealand Timber Structures Standard NZS 3603. Calculate the design strength per nail, F, using the relevant k factors.

Factors for nail design from NZS 3603

Section 4.2.2.2 of NZS 3603 has several k factors affecting the strength of nails loaded in shear:

Steel side plate < 3.0 mm in thickness	$k_p = 1.25$
Steel side plate ≥ 3.0 mm in thickness	$k_p = 1.5$
Plywood or particleboard with flat head nails	$k_p = 1.4$
More than 50 nails in a connection	$k_{50} = 1.3$

(use linear interpolation for four to 50 nails).

The design strength per nail is given by:

$$F = \phi\, k\, k_1\, Q_k$$

where: $\phi = 0.8$ for nails

k_1 is the duration of load factor

k is the product of k_p and k_{50} given above.

Assume a certain number of rows of nails (usually two or three) and estimate the centreline dimensions of the nail group as shown in diagram 3 where:

$s = c(n-1)$

c is the spacing between rows of nails, and

n is the number of rows of nails.

Calculate the average nail pitch, p, around the equivalent rectangle of nails.

For $\Theta \leq 15°$ $\quad p = 3.6nFrq / M^*$

where:

F is the design strength for each nail

r and q are as shown in diagram 3

M* is the design bending moment.

An alternative to this method is to set up a spreadsheet using the rivet group analogy (equation 4.3 in NZS 3603).

NZS 3603 gives a minimum spacing for nails along the grain of 10 diameters in radiata pine or 20 diameters in other species.

Across the grain, a spacing of 5 diameters in radiata pine and 10 in other species may be used.

The ability of radiata pine to accept high nailing densities is a particular advantage in this type of construction.

Diagram 3: Dimensions of nail group used in design

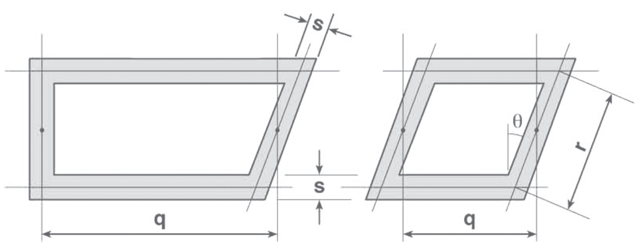

Illustration: Courtesy Timber Design Guide, 2007

Diagram 4: Typical nail layout in a gusset joint

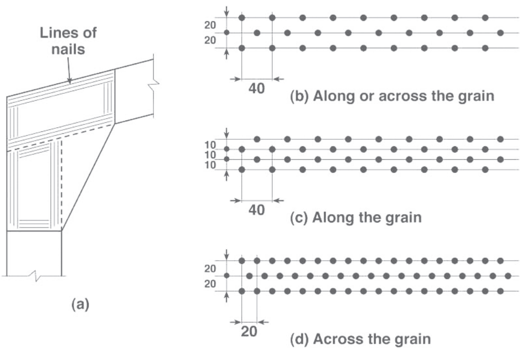

Illustration: Courtesy Timber Design Guide 2007

Diagram 4 shows recommended nail layout patterns for use in gusset joints.

Illustration (a) in the diagram shows a typical gusset with three rows of nails. A few nails have been left out of the extreme corners to reduce stress concentrations in the glulam members.

The nail spacings shown meet the code requirements for 4.0 mm diameter nails. The same spacings are often used for 3.5 mm diameter nails. For smaller diameter nails, the spacing can be reduced slightly, if necessary.

The nail pattern shown in illustration (b) in diagram 4 is the most useful because it can be used both along and across the grain. With this pattern, one long template can be used for an entire joint with no danger of confusing the spacing in different grain directions.

For joints where a denser nailing pattern is needed (small steel plates or glulam beams more than 90 mm thick), it is recommended that the nail patterns of illustrations (c) and (d) be used along and across the grain respectively. (It is convenient to use a cardboard template and spray paint to mark out the nail pattern on plywood gussets.)

SCREW DESIGN

Some designers prefer to use screws rather than nails for gusset joints. The equations given above generally apply to screwed as well as nailed joints. See section 4.3 of the New Zealand Timber Structures Standard NZS 3603 for calculating the capacity of individual screws.