PLYWOOD WEB BEAM DESIGN

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

A simple method is to determine the maximum moment and divide it by the capacity of the flange in axial load to determine a starting depth. However, because strength rarely governs, this can give shallow beam depths that are found wanting when deflections are calculated.

It is better to choose an optimal span to depth ratio from experience or from other buildings, divide the span by that ratio to get a depth and then calibrate that depth to a logical multiple fraction of a cut plywood sheet. The flange strength can be checked using the axial capacity adjusted for stability in compression and the k factors appropriate to load and site conditions in both tension and compression.

Choose a plywood web thickness, check the panel shear and then calculate the deflection. If deflection is tight, a glued joint is required. If there is adequate stiffness, a nailed joint can be used. Calculate the shear flow at the flange web interface to establish the nail density, glue stress or plywood rolling stress. This method applies equally to beams, columns and diaphragms and shear walls.

DEFLECTIONS

There are three components to the elastic deflection of web beams:

- Bending deflection.
- Shear deflection.
- Nail slip.

If the splice in the chord of a web beam is made with mechanical fasteners there may also be deflection due to slip in the splice. For deflection calculations, use the EI value of the full cross-section, whether or not the web is spliced. Use an appropriate k2 for creep deflection. The simplest estimate of total deflection is found by multiplying the calculated bending deflection by a factor for shear deflection and another for nail slip.

BENDING DEFLECTION

The standard formulae for bending deflection under the applied load applies. For a uniformly distributed load w (N/mm) over a simply supported span L (mm), the bending deflection \( \delta_b \) (mm) is given by

\[
\delta_b = \frac{5}{384} \frac{wL^4}{EI}
\]

where E is the modulus of elasticity (MPa) and I is the moment of inertia of the cross section (mm\(^4\))
SHEAR DEFLECTION

An equation that may be used for calculating the shear deflection $\Delta s$ is:

$$\Delta s = \frac{M}{G A_{w}}$$

where $G$ is the shear modulus of the plywood (MPa), $M$ is the maximum bending moment in the beam (Nmm) and $A_{w}$ is the gross cross-section area of the plywood webs (mm$^2$).

DEFLECTION DUE TO NAIL SLIP

Deflection resulting from nail slip will be about 10 to 15% of the calculated bending deflection for lightly loaded beams such as roof purlins, 15 to 25% for house floor joists and 20 to 35% for office floor joists. There is no slip in a glued joint.

For single beams such as lintels carrying high loads at wider spacings, nail slip deflection may be higher and is probably about the 50% of the bending plus shear. Sandie outlined a method to calculate nail slip deflections and this was used to obtain the above values. For deep beams (where the plywood panels are shorter than they are deep) additional deflection can result from rotation of the panels.

TOTAL DEFLECTION

For an estimate of total deflection (bending plus shear) for a glued plywood web beam it is recommended that the calculated bending deflection be increased by the following factors, where $L$ is the span and $D$ the overall depth of the beam as shown in diagram 1.

<table>
<thead>
<tr>
<th>$L/D$</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>15</td>
<td>1.2</td>
</tr>
<tr>
<td>20</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Diagram 1: Basic elements of a plywood web beam

CHOICE OF GLUE OR NAILS

Glued plywood web beams may be 20% to 50% stiffer than nailed beams of the same size, but often strength or stability governs the design (particularly in roof members with load reversal) and nailed beams generally have more than enough stiffness. Gluing adds cost but a bead of adhesive is easy to apply. However, structural gluing requires factory level quality control to ensure long term performance.

For glued beams, only dried, dressed timber, LVL or glulam should be used for the chords. For nailed beams, gauged sizes could be used. but shrinkage variation between chords and stiffeners may cause some unevenness in the plywood. Using dry timber halves the potential creep deflection. Pressure can be applied to the glueline as it dries by using nails (nail-gluing).
WEB STIFFENERS
The timber structures standard NZS 3603 gives guidance on web stiffener spacings in clause 6.6.4, for webs fully stressed in shear. Proprietary beams are made without stiffeners and stiffeners are normally not required except in special situations, such as when a concentrated load from a column is applied to a flange, or at supports of the lower storey of a number of floors.

LATERAL TORSIONAL STABILITY
For all box beams, the flexural capacity will be more than for open sections because the torsional rigidity of the box section is greater. In practice there are three common restraint conditions for web beams. Firstly the compression flange is completely restrained and \( k_8 = 1.0 \) (this is the case with flooring fixed to proprietary I-beams, but temporary restraint must be provided during construction). Secondly the web beam is restrained at specified points along the span, or thirdly, the tension edge is restrained. In the following guidelines, the symbols are defined in diagram 2 apart from \( t_{eff} \) which is the effective thickness of the plywood after allowing for perpendicular plies.

Diagram 2: Basic elements of a plywood web beam

I-beams and C-beams have low torsional rigidity and the compression flange is assumed to be an unrestrained column between lateral supports a distance \( L_{ay} \) apart, so that the slenderness factor \( S \) is given by:

\[
S = \frac{L_{ay}}{B}
\]

Using this value of \( S \), \( k_8 \) is found from diagram 3 (the stability factor from NZS 3603). This is conservative and the provisions of AS1720 are helpful for critical designs.

Diagram 3: Slenderness coefficient \( k_8 \) for columns (from NZS 3603)
Box sections have substantial torsional rigidity. For an unrestrained section, $k_\theta$ will be 1.0 provided that:

$$\frac{I_x}{I_y} \geq 70 \frac{D}{L_{ay}}$$

When there is restraint of the tension edge, the required spacing between restraints must be less than:

- 5.0 Do for $I_x / I_y$ up to 20,
- 3.5 Do for $I_x / I_y$ up to 30,
- and 2.8 Do for $I_x / I_y$ up to 40,

where:

$$I_x = 0.5 B (D-T)^2 T$$

$$I_y = 0.5 D t_{eff} B^2$$

and $D_o = D-T$

If the above conditions are met, the slenderness coefficient $S$ can be calculated for box beams from the following approximate expressions. For unrestrained edges:

$$S = \sqrt{\frac{4.4 T}{C_5} \frac{L_{ay}}{t (B+t)}}$$

For tension edge restrained:

$$S = \sqrt{\frac{4.4 T (D-T)}{t (B+t)}}$$

where $C_5$ can be taken as 3.1 for equal end moments or determined from Appendix C of NZS 3603. As a quick guide COFI gives the following recommendations:

<table>
<thead>
<tr>
<th>Range of $I_x/I_y$</th>
<th>Restraint required</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>none</td>
</tr>
<tr>
<td>5-10</td>
<td>held at bottom flange at supports</td>
</tr>
<tr>
<td>10-20</td>
<td>held over full depth at ends</td>
</tr>
<tr>
<td>20-30</td>
<td>one edge held in line</td>
</tr>
<tr>
<td>30-40</td>
<td>blocking at 2.4 metres</td>
</tr>
<tr>
<td>&gt;40</td>
<td>compression flange fully restrained by decking.</td>
</tr>
</tbody>
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