COLUMN 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

COMPRESSION MEMBERS

Slenderness

In design of compression members, a distinction needs to be made between “short columns” and “long columns”. The design of short columns depends on the crushing strength of the wood, because premature failure by buckling does not occur.

For the design of long columns, the possibility of an instability failure resulting from buckling must be considered. The more slender the member, the greater the possibility of buckling, and the lower the design strength. Buckling must be considered about both the X and Y axes, where X is the major axis and Y is the minor axis as shown in diagram 1.

Diagram 1: Major and minor axes for a rectangular cross section
Diagram 2

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Design Equations

To provide sufficient compressive strength, a section size must be chosen which satisfies the design equations for columns, given by:

\[ N_c^* < \phi N_{ncx} \quad \text{and} \quad N_c^* < \phi N_{ncy} \]

where

- \( N_c^* \) is the design level of axial load, resulting from the factored applied loads
- \( \phi \) is the strength reduction factor (from Table 1)

\( N_{ncx} \) and \( N_{ncy} \) are the nominal compressive strengths considering buckling about the X and Y axes, respectively, given by:

\[ N_{ncx} = k_i k_{sx} f_c A \quad \text{and} \quad N_{ncy} = k_i k_{sy} f_c A \]

where

- \( k_i \) is the load duration factor (see Table 1)
- \( k_{sx} \) and \( k_{sy} \) are stability factors, in the X and Y directions
- \( f_c \) is the characteristic stress in compression parallel to the grain (see Table 2)
- \( A \) is the cross sectional area (\( A = bd \) for rectangular cross sections)

Buckling needs to be considered separately about the X and Y axes. For full length columns with no intermittent points of restraint, \( k_{sx} \) and \( k_{sy} \) are obtained from diagram 2 using the slenderness coefficients \( S_x \) and \( S_y \) given by

\[ S_x = k_{i0} L / d \quad \text{or} \quad S_y = k_{i0} L / b \]

where

- \( k_{i0} \) is the effective length factor from diagram 3
- \( L \) is the length of the column
For columns with intermittent points of restraint, \( k_8 \) is obtained from diagram 2 using the slenderness coefficient \( S \), given by

\[
S_x = \frac{L_{ay}}{d} \quad \text{or} \quad S_y = \frac{L_{ax}}{b}
\]

where

- \( L_{ay} \) is the length between points of restraint preventing column buckling in the weak direction
- \( L_{ax} \) is the length between points of restraint preventing column buckling in the strong direction

Values of \( L_{ax} \) and \( L_{ay} \) are shown in diagram 4 for a typical column with different restraints in the X and Y directions.

**Table 1: Duration of load factor \( k_1 \) for strength**

<table>
<thead>
<tr>
<th>Duration of load</th>
<th>Type of load</th>
<th>( k_1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permanent</td>
<td>Dead loads and live loads that are essentially permanent such as stores (including water tanks and the like), library stacks, files, fixed plant, soil.</td>
<td>0.6</td>
</tr>
<tr>
<td>Medium</td>
<td>Snow loads, live loads, crowd loads, concrete formwork, vehicle, pedestrian, and livestock loads. Erection loads and maintenance loads.</td>
<td>0.8</td>
</tr>
<tr>
<td>Brief</td>
<td>Wind, earthquake, impact and pile driving loads.</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Modulus of Elasticity (GPa) for dry machine stress graded timber**

<table>
<thead>
<tr>
<th>Species</th>
<th>Grade</th>
<th>Modulus of elasticity E</th>
<th>Lower bound modulus of elasticity Elb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiata pine and</td>
<td>MSG15</td>
<td>15.2</td>
<td>11.5</td>
</tr>
<tr>
<td>Douglas fir</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MSG12</td>
<td>12.0</td>
<td></td>
<td>9.0</td>
</tr>
<tr>
<td>MSG10</td>
<td>10.0</td>
<td></td>
<td>7.5</td>
</tr>
<tr>
<td>MSG8</td>
<td>8.0</td>
<td></td>
<td>5.4</td>
</tr>
<tr>
<td>MSG6</td>
<td>6.0</td>
<td></td>
<td>4.0</td>
</tr>
</tbody>
</table>

Modulus of rigidity shall be taken as \( G = E/15 \).

Table 1: Characteristic stiffness values for machine stress graded timber from NZS3603 Amendment 4. Reproduced from NZS 3603 with the permission of Standards New Zealand under Licence 000702 - to purchase NZS13603 go to www.standards.co.nz
Diagram 3: Effective length factor $k_{10}$ for column end conditions

<table>
<thead>
<tr>
<th>Condition of end restraint</th>
<th>Deflected shape of member</th>
<th>$k_{10}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restrained at both ends in position and direction</td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>Each end held in position and substantially restrained against</td>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td>rotation (by two bolts)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>One end fixed in position and direction and the other</td>
<td></td>
<td>0.85</td>
</tr>
<tr>
<td>restrained in position only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restrained at both ends in position only</td>
<td></td>
<td>1.0</td>
</tr>
<tr>
<td>Restrained at one end in position and direction, and at the</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>other partially restrained in direction but not in position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restrained at one end in position and direction but not</td>
<td></td>
<td>2.0</td>
</tr>
<tr>
<td>restrained in either position or direction at the other end</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Effective length factor $k_{10}$

The stability of axially loaded compression members depends on the degree of end restraint. For members pinned at both ends, the effective length is the full length of the member, $L$. For members which are not pinned at both ends, the effective length is given by $k_{10} L$ where $k_{10}$ is the effective length factor given in diagram 3. A $k_{10}$ factor of 1.0 is normally used unless end rotational restraint can be confidently relied on. The adequacy of lateral restraints can be checked against the requirements of NZS 3603 Appendix B if necessary.

Additional $k$ factors

Note that the parallel support factor $k_4$ should not be applied to slender compression members (members with $k_a < 1.0$) because the load carrying capacity depends on the stiffness of the wood rather than the crushing strength.

Comparison with steel design

The slenderness ratio $L/b$ used in timber design is related to the $L/r$ ratio used in steel design, where $r$ is the radius of gyration. For a rectangular member, these ratios are related as follows:

\[
r = \sqrt{\frac{I_{xy}}{A}} = \sqrt{\frac{b^3 d}{12bd}} = \frac{b}{\sqrt{12}}
\]

\[L/b = \sqrt{12}L/r = 3.46L/r\]
**T-stiffeners**

T-stiffeners are used to reduce the likelihood of buckling in slender members. The T-stiffener reduces the slenderness of a member without carrying any axial load. A typical compression member with a T-stiffener attached is shown in diagram 5. In this case, $k_6$ should be obtained from diagram 2 using the slenderness coefficient, $S$, obtained from:

$$ S = L \sqrt[4]{\frac{A_{\text{member}}}{12I_{\text{stiffener}}}} $$

(from equation D1 in NZS 3603).

**Diagram 5: Timber compression member with 'T' stiffener**

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**Composite column design**

The design of spaced timber columns was covered in the 1990 edition of NZS 3603, but is not included in later editions.

Composite columns may be designed as a single cross section if the component parts are sufficiently well joined together to prevent any inter-layer slip.

Approximate methods must be used if any slip between layers can occur. The following method is suggested as an easy way of quickly arriving at a composite column size where the members are in continuous contact but not rigidly fixed to each other.

For a two member column such as that shown in diagram 6, check the individual load capacity of each member considering stability only about the major (X) axis of the individual member. If the sum of the two individual column capacities can support the full load, they should be securely fastened together at right angles as shown in diagram 6 to form a composite column. A four member composite column can be dealt with in a similar way as shown in diagram 7. This method can also be used for T-stiffeners, considering only the main member, giving a conservative answer for short columns.

**Diagram 6: Cross section of nailed sawn timber composite column with T cross section**
Diagram 7: Cross section of a composite box column nailed from sawn timber

**COMBINED BENDING AND COMPRESSION**

For combined axial compression, and bending in the weak direction (about the Y axis), the column must satisfy:

\[ \frac{N_c^*}{\phi} \frac{N_{ncy}}{\phi} + \frac{M_y^*}{\phi} \frac{M_{nyc}}{\phi} < 1 \]

For combined axial compression, and bending in the strong direction (about the X axis), the column must satisfy:

\[ \frac{N_c^*}{\phi} \frac{N_{ncx}}{\phi} + \frac{M_x^*}{\phi} \frac{M_{nxc}}{\phi} < 1 \quad \text{and} \]

\[ \frac{N_c^*}{\phi} \frac{N_{ncy}}{\phi} + (\frac{M_x^*}{\phi} \frac{M_{nxc}}{\phi})^2 < 1 \]

where

- \( M_y^* \) and \( M_x^* \) are the applied bending moments about the Y and X axes, respectively
- \( M_{ncy} \) is the nominal bending strength about the Y axis, and
- \( M_{nxc} \) is the nominal bending strength about the X axis, including any reduction for lateral buckling (see Beam section).

For members subjected to axial compression and bending about both axes, each direction must be considered separately.

**TENSION MEMBERS**

**Design Strength**

To provide sufficient tensile strength, a section size must be chosen which satisfies the design equation given by:

\[ N_t^* \phi \leq N_{nt} \]

where

- \( N_t^* \) is the design level of axial tensile load, resulting from the factored applied loads
- \( \phi \) is the strength reduction factor (from Table 1 above)
- \( N_{nt} \) is the nominal tensile strength, given by:
  \[ N_{nt} = k_1 f_t A \]

where

- \( k_1 \) is the load duration factor (see Table 1)
- \( f_t \) is the characteristic stress in tension parallel to the grain (see Table 2)
- \( A \) is the cross sectional area (\( A = bd \) for rectangular cross sections)
Combined bending and tension
For members with both bending and axial tension loads the combined loads should be checked using the equation:

\[ \frac{N_t^*}{\phi N_{nt}} + \frac{M^*}{\phi M_n} < 1 \]

where

- \( M^* \) is the applied bending moment
- \( M_n \) is the nominal bending strength

All other terms are given earlier in this section.

Additional k factors
Where two or more members of sawn timber or glulam are connected in such a way that they resist applied loads together, then design strengths can be increased to recognise the load sharing that occurs. The design strength of multiple tensile members can be increased by the “parallel support factor” \( k_p \) from Table 2.7 of NZS 3603. The parallel support factor does not apply to multiple LVL members because of the low scatter in strength properties of engineered wood products such as LVL.

COLUMN BASE CONNECTIONS
The choice of connection used at a column base depends on the magnitude of the column forces, the likely occurrence of accidental impact forces from mobile equipment and the nature of the environment and the level of possible corrosion. No one type of connector is appropriate to all situations. Diagram 8 gives some examples of typical column base details. Column bases should be raised above slab level in exterior locations, or a waterproof membrane should be used to prevent migration of moisture from the concrete foundation into the wood.

Diagram 8: Examples of typical column base details