INFORMATION SHEET

# STRUCTURAL DESIGN

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## SERVICEABILITY 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

In serviceability design the serviceability action combinations for the structure are compared against serviceability limits. Combination Actions are given in AS/NZS 1170.0, along with serviceability factors ($\psi$).

There is also a table of Suggested Serviceability Limit State Criteria in AS/NZS1170.0:2002 Table C1, however it should be emphasised that these limits are a guide and the designer should exercise engineering judgement.

All members deflect when subjected to load. In design, the aim is to keep deflections within acceptable limits, which often governs the design of timber beams. Shear deflection as well as bending deflection may need to be considered for fabricated I-beams and box beams.

Initial elastic deflections can be calculated using standard engineering analysis. NSZ 3603 specifies that allowance for long term deflection be made by multiplying the calculated elastic deflection for each part of the load by the duration of load factor for deflection $k_2$ corresponding to that part of the load, as given in Table 1.

### DURATION OF LOAD FACTOR $K_2$

Duration of load factors for sawn timber are shown in Table 1.

**Table 1: Duration of load factor $k_2$ for deflection**

| Duration of load | Moisture content at time of loading | $k_2$ | |
|---|---|---|---|
| | | For bending, compression or shear | For tension |
| 12 months or more | 25% or more | 3.0 | 1.5 |
| 12 months or more | 18% or less | 2.0* | 1.0 |
| 2 weeks or less | Any | 1.0 | 1.0 |

* For glue laminated timber use 1.5

The reason for the lower creep in glulam is that the members are generally much larger than sawn timber on which the creep factors are based. The greater size means that the member cannot respond to fluctuations in atmospheric humidity and so experience the changes in moisture content which are the principal cause of creep deformations in timber.

### TYPES OF LOAD

Loads of different duration have different effects on timber beams.

1. Instantaneous elastic deflection occurs as soon as any load is applied. Instantaneous deflections due to permanent loads from building weight or permanent fixtures occur during construction and remain throughout the life of the structure.
2. Long term deflection results from creep under permanent loads. It is usually assumed for calculation purposes that long term loads include permanent loads and some proportion, say 40%, of the imposed load. Refer to AS/NZS 1170.0 Section 4.3.
3. Intermittent deflections due to imposed loads and wind forces come and go, and vary according to the load present at any time. It is rare for full design levels of imposed actions to apply for long periods of time.

## CAMBER

Manufactured beams can be made with an initial upward curve or camber to compensate for permanent load deflections including long term creep, in order to provide almost horizontal soffits in the long term. Typical camber provided in glue laminated beams is 1/400 of the span. Structural fit should be considered in relation to the amount of camber specified.

## ACCEPTABLE DEFLECTIONS

The object of serviceability design is acceptable performance during expected service conditions for the design life. The objective may be to prevent damage to ceiling plaster or wall glazing elements, to maintain a pleasing appearance, or to prevent uncomfortable movement. Deflection is typically limited to some proportion of the span.

Table 2 shows some of the limits recommended by AS/NZS 1170.0. Application of serviceability limits involves engineering judgment. For example, it can be argued that live load deflections are irrelevant for some roof members and so purlins could be designed for creep plus permanent load deflection of L/250.

The limits in Table 2 may be too lenient for some beams, particularly if beams are directly over sliding doors or extensive glazing, in which case an absolute deflection limit might be chosen.

For example, for lintel beams, a limit of 9 mm deflection under imposed load alone is often used. Long span floor beams may prove uncomfortable under imposed load deflection unless they are kept less than an absolute limit, say 12 mm under full permanent and imposed load. The effect of vibration may also need attention.

**Table 2: Load combinations and typical criteria for the serviceability limit state**

| Element | Serviceability parameter | Applied action | Element response |
|---|---|---|---|
| Roof or floor members | Visual appearance or cracking of plaster lined walls | G & $\psi/Q$ | Span/300 |
| Normal floors | Felt mid-span deflection | G & $\psi_s Q$ | Span/400 |
| Special floors | Felt mid-span deflection | G & $\psi/Q$ | Span/600 |
| NOTES:<br>Special requirements for vibration of floors are not included.<br>See Table C1 of AS/NZS 1170.0 for more guidance. | | | |

In any event, the choice of the most suitable limit is the responsibility of the designer. The designer should ensure that limits are appropriate to each specific case.

The deflection of every member should be seen in relation to the building system as a whole. For example, the deflection at the mid-span of a beam will be increased by any movement at the supports, especially when the support is at the mid-span of another beam.

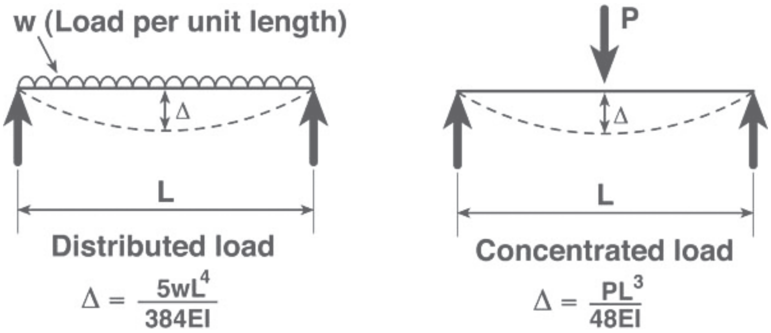
Shrinkage at supports must also be taken into account. Likewise, the movement that becomes visible in a series of floor joists is not only the L/300 relative to the span but the absolute movement relative to the wall closest to the last joist.

This is particularly important in the design of members of longer span in buildings requiring attention to architectural detail.

## EVALUATING DEFLECTIONS

Total deflection in any beam is the sum of bending deflection, shear deflection, and in a fabricated beam, deflection due to movement in the fabricated joint. The diagram below shows the equations for calculating short-term bending deflection for two common cases.

**Deflection formulae for a simply supported beam with two common loading cases**




### Bending deflection

The bending deflection is inversely proportional to the modulus of elasticity of the timber. The E-value given in the code is an average value for the species and grade under consideration.

The modulus of elasticity of radiata pine may vary from 3 to 12 GPa depending on wood quality. Pieces containing pith or corewood are usually at the low end, whereas timber from the outer wood of older trees (flat growth rings) may be nearer the high end of this range.

There is also variation between trees and between sites, with dense timber from the north of New Zealand tending to have higher stiffness than less dense timber.

Deflection is inversely proportional to the moment of inertia, I, a geometrical property of the cross-section. For rectangular beams the moment of inertia is calculated from

$$I = b\,d^3 / 12$$

where

b is the width of the beam

d is the depth of the beam

### Shear deflection

In addition to bending deflection, beams are deformed by shear stresses leading to additional deflection known as shear deflection.

Shear deflections are not normally calculated for solid rectangular beams as they are usually less than 10% of elastic bending deflections, and in any case, the E-values given for graded timber generally include some allowance for shear deflection. Shear deflections should be checked for heavily loaded plywood web beams or I-beams.

### Deflection due to joint slip

In nailed plywood web beams, slip at the flange-web joints can result in significant additional beam deflections. The amount of slip depends on the nail stiffness, the spacing of the nails and the properties of the web material.

For most beams, deflection due to joint slip is no more than 1.5 times the bending deflection, but for short squat beams it may be two times. If the flanges are mechanically spliced, some deflection may also result from movement in the splice.

There is no joint slip in glued plywood web beams. Bolted joints cannot provide fully rigid connections because of the need to drill slightly oversize holes to allow the bolts to be inserted.

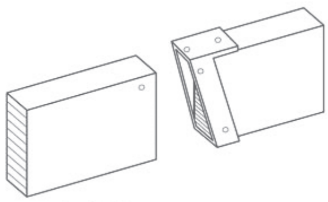
### Cantilever beam construction

(a) Long continuous beam

(b) Cantilever beam system with larger beam at centre

(c) Cantilever beam system with smaller beam at centre

(d) Columns rearranged to suit single beam depth



(e) Pinned connection detail

## Long-term deflection

Initial elastic deflections are directly proportional to the level of load and are recoverable if the load is removed. Creep is additional deflection that occurs with time under the action of permanent loads. Creep is primarily dependent on changes in moisture content and on the level of stress in the timber.

NZS 3603 and AS 1720 state that total deflection under a permanent load (due to both the initial load and the long-term creep) should be calculated by multiplying the initial elastic deflection resulting from the permanent load by the $k_2$ factor shown in Table 1. Long term deflections of green timber allowed to dry in service are extremely variable for individual members. These deflections are partly due to creep and partly due to shrinkage, and may vary from zero deflection to five times the initial elastic deflection.

Mechano-sorptive creep causes increased deflections with time due to fluctuations in moisture content. The use of kiln dried timber is the best method of controlling long term deflections, especially for important members carrying heavy loads, and is recommended for most structural applications.