ALTERNATIVES TO RADIATA PINE FOR HOUSE FRAMING TO NZS 3604:1993

Michael J Collins BE (Hons)*

Abstract

There is a steady demand for information on the use of species other than radiata pine for light timber frame construction. Some of these species are listed in NZS 3602:1990 but many are not. This paper describes simple engineering methods to provide tables, compatible with NZS 3604:1990, for alternative species for timber frame construction. These methods are then used to derive tables for the more common timber frame members in a number of indigenous and exotic species.

Introduction

The Light timber framing code for New Zealand is based on the structural properties of average radiata pine. With increasing frequency, people are requesting information that would allow them to use species other than radiata pine or those listed in NZS 3602[2]. These enquiries are often forwarded to NZ Forest Research Institute for reply. We have generally responded to these enquiries on an ad hoc basis but a more comprehensive response that can be used to advise 95% of enquirers would be useful. This paper aims to go some way towards providing that information.

The end users of this paper will include sawmillers, farmers, builders and others with access to alternative timber supplies from individual trees or small wood lots. They are not generally skilled in engineering analysis but can be expected to do straightforward calculations, given the formulae and the reasons for them.

The light timber framing market

Light timber framing is the largest single end use of sawn timber in New Zealand, absorbing roughly twice as much value of framing as is exported and having a retail value of around $B1. In 1993, $B2.9 worth of buildings were constructed of which $B1.5 was residential buildings. Almost all of these buildings would have had timber frames. If even just a small proportion of these were framed in species other than the main softwoods of radiata pine and Douglas fir, a significant volume of timber would be involved and would release radiata pine for other purposes.

Code requirements

Compliance with NZS 3604, the Light timber Frame Building Code[1], is the prime requirement for the issue of a building consent on the basis of submitted plans. NZS 3604 is the principal acceptable solution (means of compliance) with the New Zealand Building Code, for light timber construction. NZS 3604 itself calls up NZS 3602[2] which is the standard for specifying timber and wood products. This code specifies the species, grade and treatment permitted for the various applications in light timber construction.

NZS 3602 lists a number of alternatives to radiata pine and often these alternatives cover the enquirer's needs. Where they don't, we offer advice on the basis of what information we have about the species in question.

Demand for alternative species

With ample radiata pine and Douglas fir on the market, why should people be looking for alternatives?

The most common reason is simply that the trees exist and are being felled. Rather than burn the timber, it seems worthwhile to use it for a higher value use and structural framing is one of the options. For instance, New Zealand grown Californian redwood (sequoia sempervirens) has been planted in isolated pockets around the Bay of Plenty and is desirable as a durable cladding material. The remainder of the log, unsuited for weatherboards, is often sawn for framing and the question arises as to whether and under what constraints can this framing, which is of significantly lower strength and stiffness than radiata pine, be used for structural components in building.

Another reason is that the price of radiata pine is often related to the export market. When this market is booming there are opportunities of getting lower cost framing by searching for logs of alternative species. The demand for information on alternatives is not large but it seems reasonable to meet it.

Basis for recommending alternative species

General properties to be taken into account

The main considerations in looking for structural framing substitutes for radiata pine are:-

- Stiffness
- Strength grade for grade
- Nail holding and fastening properties
- Durability
- Stability and shrinkage
- Drying times for closing in

Stiffness is at the head of the list as stiffness determines the spans for most members in light timber framing. The stiffness and strength of timber are compared in this case on the basis of clear wood properties. I.e. the properties of timber without defects. Defects are controlled by grading rules and the defects which are admitted for certain grades can be expected to have similar percentage strength reduction effects on different species.

Strength and stiffness for timber are related, so a species which is stiff enough will generally also be strong enough for direct substitution for radiata pine, grade for grade.

Lower strength species are generally of low density and this affects joint strength. The fastening recommendations of NZS 3604 presuppose timber of given density and nailholding. Lower density species may require additional fastening provisions in critical areas. On the other hand, very high density species may be difficult to fasten without predrilling.

The 1995 revision of NZS 3602 permits the use of planed, kiln dried, untreated radiata pine in dry interior above-ground situations. Otherwise, framing members must be heart or treated to resist insect attack. Many alternative species such as cypresses have a high percentage of heartwood so may be used untreated, but the sapwood of all species, other than radiata pine as specified above, must be treated for structural use.

Stability and shrinkage, although last in the list above, are important with respect to quality of finish and ease of assembly of the frame. In severe cases timber may be too distorted to be of any real use for building. Shrinkage can also affect joint strength and stiffness and contribute to squeaking floors. The New Zealand timber grading rules[5] place limits on the distortion of timber but if frames are assembled green, it is also important that the timber dries without distorting to the extent that it affects subsequent finishing. In general, cypress species are amongst the most stable of the generally available softwoods and some of the eucalyptus species present the greatest distortion problems. It may save a lot of subsequent disappointment if the stability of the timber is checked by sawing a small sample before embarking on a larger project.

Drying times are important where timber is used green and the frame allowed to dry naturally before closing in. Drying depends on weather conditions as well as timber properties. Some species, such as red beech are very slow to dry naturally and special techniques must be used to kiln dry them.

Species stronger and stiffer than radiata pine

Where species are stronger than radiata pine, the simplest option is to use the tables as they exist in NZS 3604. Usually the economic penalties for doing this are not large compared with the advantages of using the species available. Alternatively thicknesses can be reduced (to a minimum of 35 mm to preserve nail edge distances) or spans or spacing increased. Simple rules for doing this are given in section 3.

Species weaker and less stiff than radiata pine

Where species are significantly weaker than radiata pine, measures have to be taken to ensure that the structure will perform adequately. The easiest way is simply to reduce the allowable spans, although reduction of spacing or increase of thickness can also be used. Rules for doing this are given in section 3.

Joint loads are carried by the fastener in bearing or withdrawal and often by the members in bearing one upon the other. A reduction in span will generally reduce the loading on the joints. However there are critical joints that should be modified to ensure that the strength is not reduced unacceptably with a lower density species. These joints are identified in section 5.4.

Rules for modifying tables to allow for stronger or weaker species

In simple terms, for the purposes of this exercise, it can be assumed that the members in NZS 3604 have been sized on the basis of their stiffnesses and that they carry uniformly distributed loads. In a small number of cases, for instance short studs whose size is determined by bearing strength on the bottom plate, this assumption will be unconservative but with negligible consequences. It is also assumed that the deflection limitation is measured as a proportion of the span, i.e. relative deflection.

In some instances, absolute deflection may have determined the allowable span in NZS 3604. However when adjustments are being made for weaker species, the assumption that relative span was the determining criterion is always conservative as the deflection limit in this case reduces with reduction in allowable span.

Relative deflection of a uniformly loaded beam is proportional to the load, inversely proportional to the thickness and modulus of elasticity, inversely proportional to the cube of the beam depth and proportional to the cube of the beam span.

For uniformly loaded beams limited by relative deflection, adjustments can be made to the thickness of members in inverse proportion to their moduli of elasticity, to their spacing in proportion to their moduli of elasticity, to their depth in inverse proportion to the cube root of the moduli of elasticity or to the spans in inverse proportion to the cube root of their moduli of elasticity.

These relationships can be expressed mathematically as follows:-

for a UDL beam:-

$$\frac{y}{l} = \frac{wl^3S}{KEbd^3}$$

where	y	is	deflection
	l	is	span
	S	is	spacing of members
	w	is	uniformly distributed load
	K	is	a constant related to loading conditions
	E	is	modulus of elasticity
	b	is	thickness of member
	d	is	depth of member in the direction of the load

For constant y/l,

$$\frac{l_1^3.S_1}{E_1.b_1.d_1^3} = \frac{l_2^3.S_2}{E_2.b_2.d_2^3}$$

Where subscript **1** refers to original member in code species
subscript **2** refers to new member in alternative species

Whence,

$$l_2 \propto l_1^3.\sqrt[3]{\frac{E_2}{E_1}}$$ span is proportional to cube root of stiffness

$$S_2 \propto S_1.\frac{E_2}{E_1}$$ spacing is proportional to stiffness

$$b_2 \propto b_1.\frac{E_1}{E_2}$$ thickness is proportional to inverse of stiffness

$$d_2 \propto d_1^3.\sqrt[3]{\frac{E_1}{E_2}}$$ depth is proportional to inverse of cube root of stiffness

Alternatively, where the desired species is of a different MoE value from standard radiata pine, an alternative section size may be chosen on the basis of the product of modulus of elasticity, E, and section moment of inertia, I, being greater than the value implied by the tables in NZS 3604.

I.e. $E_2 \times I_2 \geq E_1 \times I_1$

Where jointing is critical, the number of nails should be increased in inverse proportion to the density. Thus if the density is .75 of the standard density, the number of nails should be increased by a factor of 1/.75 = 1.3.

The numbers of fasteners should be rounded to the nearest whole fastener. Thus where 2 nails are used in the original joint, 3 nails should only be used if the number required is 25% or more greater. I.e. the number is 2.5 nails or more. This implies a reduction in density of 20% or greater. When increasing the number of nails, care should be taken to preserve realistic edge and end distances and nail spacing to avoid splitting and weakening of the joint.

List of common alternative species and their properties

Structural Properties

For convenience a list of common alternative species is given in Table 1 along with their bending strength and stiffness (modulus of elasticity) and their density in relation to radiata pine. These properties are averages based on tests of small clear (defect free) specimens and are for comparative purposes only. They are not suitable for use in design. Eucalyptus species are not mentioned in this table as they are difficult to saw and dry well, with adequate recoveries of building timber.

Properties of timber vary within tree, within stand and from one part of the country to another. Hence the figures below are broad averages. Some species are naturally more variable than others so that the range of properties about the average may be much wider for radiata pine, for instance, than for lusitanica cypress. Some of the data are based on a large number of tests from samples taken around the country. Others may be based on data from 2 or 3 trees from 1 or 2 locations only. Thus the reliability of the data varies from one species to another. In the end, commonsense must prevail. If a lot of timber is clearly below average density, the figures given below should not be relied on absolutely.

The density quoted below is a standardised air dry density based on the weight and volume at 12% moisture content. This m.c. is not often achieved for building timber by air drying. A more likely m.c. is 15% to 18% mc. depending on the season. The m.c. can be measured with a moisture meter or by weighing a sample of the timber and drying at 100°C until constant weight is achieved. The difference between the two weights expressed as a percentage of the oven dry weight is the m.c. To correct the density as measured, to density at 12 % m.c., use the formula below.

$$Dt_{12} \cong Dt_{15\text{-}18} \times .988 - 4$$

Where Dt_{12} etc. is Density at test (weight and volume measured at 12 % m.c.).

Table 1. List of alternative species and their structural properties

Species	Ref	Strength MoR MPa	Stiffness MoE GPa	Density at 12% mc kg/m³	Ratio to radiata E_1/E_2	Ratio to radiata E_2/E_1	Ratio to radiata $\sqrt[3]{(E_1/E_2)}$	Ratio to radiata $\sqrt[3]{(E_2/E_1)}$
beech hard	3	113	14.2	745	0.63	1.58	0.86	1.16
beech, mountain	3	116	12.5	645	0.72	1.39	0.90	1.12
beech, red	3	116	11.6	630	0.75	1.33	0.91	1.10
beech, silver	3	100	12.0	610	0.75	1.33	0.91	1.10
Californian redwood	3	63	6.6	380	1.36	0.73	1.11	0.90
contorta pine	3	91	9.7	495	0.93	1.08	0.98	1.03
Corsican pine	3	77	8.0	510	1.13	0.89	1.04	0.96
Douglas fir	3	78	8.8	480	1.02	0.98	1.01	0.99
European Larch	3	97	9.7	560	0.93	1.08	0.98	1.03
kahikatea	3	75	10.7	450	0.84	1.19	0.94	1.06
kauri	3	88	9.1	560	0.99	1.01	1.00	1.00
Lawson cypress	3	98	12.1	480	0.74	1.34	0.91	1.10
lusitanica	3	70	6.5	460	1.38	0.72	1.11	0.90
macrocarpa	3	74	7.9	475	1.14	0.88	1.04	0.96
maritime pine	4	97	10.5	530	0.86	1.17	0.95	1.05
matai	3	76	8.1	610	1.11	0.90	1.04	0.97
miro	3	94	10.1	625	0.89	1.12	0.96	1.04
ponderosa pine	3	71	6.9	480	1.30	0.77	1.09	0.92
poplar	3	62	6.8	465	1.32	0.76	1.10	0.91
radiata pine	3	90	9.0	500	1.00	1.00	1.00	1.00
rewarewa	3	125	18.3	740	0.49	2.03	0.79	1.27
rimu	3	88	9.6	595	0.94	1.07	0.98	1.02
tawa	3	114	13.2	720	0.68	1.47	0.88	1.14
western red cedar	3	50	4.7	370	1.91	0.52	1.24	0.81

Some of these numbers are rounded for convenience of tabulation.
Many other species are grown in New Zealand. For data on other species contact NZFRI, PB 3020, Rotorua. Ph 07 347 5899, Fx 07 347 9380

Durability

The resistance of timber to insect attack & fungal decay, its durability, is important as a 50 year life is required for structural purposes by the New Zealand Building Code. No sapwood of New Zealand grown species may be regarded as durable so, other than kiln dried planed radiata pine, sapwood must be preservative treated for structural use. It is beyond the scope of this article to discuss suitable do-it-yourself preservation processes. However diffusion processes with boron preservatives are more suitable for diy treatment of timber protected from direct wetting than pressure processes.

Principal alternative species tables

Applying the formulae given in section 3 to some of the main tables in NZS 3604 for a range of E values, gives the following tables. Allowable spans are adjusted for bearers, joists and rafters. Toothed metal plate trusses are the product of engineering design and one species should not be replaced with another unless the original design is checked by a qualified person.
Alternative section sizes for the same loading conditions are given for studs and lintels. This is done on the basis of maintaining the same bending stiffness for different values of E. That is, at least the same value of the product (moment of inertia) × (modulus of elasticity), I × E, is maintained for the alternative species, as is implied by the tables in NZS 3604. Top and bottom plates should be increased in size as for the studs.
Generally, basing section size on maintaining comparable member bending stiffness, should ensure that both short and longer term deflections (creep) are controlled.
It is assumed for the purpose of these tables that NZS 3604 was based on radiata pine with an E value of 9.0 GPa. Hence values of E less than 9 require reduced spans or increased sizes and values of E greater than 9 may allow increased spans or reduced sizes.

Bearers and joists

Table 2 Bearers

MoE value E, GPa	Span factor	Allowable span, m for Bearer Spacing, m		
		1.3	**1.65**	**2.0**
5	.822	1.07	1.36	1.62
6	.874	1.14	1.44	1.75
7	.920	1.20	1.52	1.84
8	.961	1.25	1.59	1.92
10	1.036	1.35	1.71	2.07
12	1.101	1.43	1.82	2.20

Table 3 Joists

Size mm	MoE E MPa	Max span m at spacing mm 400	450	600	MoE E MPa	Max span m at spacing mm 400	450	600	MoE E MPa	Max span m at spacing mm 400	450	600
100 x 40	**5**	1.36	1.32	0.99	**6**	1.44	1.40	1.05	**7**	1.52	1.47	1.10
100 x 50		1.48	1.44	1.03		1.57	1.53	1.09		1.66	1.61	1.15
125 x 40		1.73	1.71	1.19		1.83	1.82	1.27		1.93	1.91	1.33
125 x 50		1.89	1.81	1.32		2.01	1.92	1.40		2.12	2.02	1.47
150 x 40		2.14	2.06	1.48		2.27	2.18	1.57		2.39	2.30	1.66
150 x 50		2.30	2.22	1.64		2.45	2.36	1.75		2.57	2.48	1.84
200 x 50		3.12	2.96	2.67		3.32	3.14	2.84		3.49	3.31	2.99
225 x 50		3.53	3.37	3.04		3.76	3.58	3.23		3.95	3.77	3.40
250 x 50		3.95	3.78	3.41		4.19	4.02	3.63		4.41	4.23	3.82
300 x 50		4.73	4.52	4.11		5.02	4.80	4.37		5.29	5.06	4.60
	MoE				**MoE**				**MoE**			
100 x 40	**8**	1.59	1.54	1.15	**10**	1.71	1.66	1.24	**12**	1.82	1.76	1.32
100 x 50		1.73	1.68	1.20		1.86	1.81	1.29		1.98	1.93	1.38
125 x 40		2.02	2.00	1.39		2.18	2.15	1.50		2.31	2.29	1.60
125 x 50		2.21	2.12	1.54		2.38	2.28	1.66		2.53	2.42	1.76
150 x 40		2.50	2.40	1.73		2.69	2.59	1.86		2.86	2.75	1.98
150 x 50		2.69	2.60	1.92		2.90	2.80	2.07		3.08	2.97	2.20
200 x 50		3.65	3.46	3.12		3.94	3.73	3.37		4.18	3.96	3.58
225 x 50		4.13	3.94	3.56		4.45	4.25	3.83		4.73	4.51	4.07
250 x 50		4.62	4.42	3.99		4.97	4.76	4.30		5.28	5.06	4.57
300 x 50		5.53	5.29	4.81		5.96	5.70	5.18		6.33	6.05	5.50

Studs and Lintels

Because of the way these tables are arranged, it is easier to simply substitute larger sizes for a given loading situation than vary spans or spacings. This is done using table 4 below which gives sizes of equivalent bending stiffness for a range of MoE values.

Table 4. Substitute sizes for timber of MoE values different from 9.0 GPa assumed for radiata pine

Nom Size d x b mm	Actual Dry Sizes d mm	b mm	E × I for E = 9 GPa	Sizes for substitute material with MoE values, GPa, of :- 5	6	7	8	10	12
75 x 50	65	45	9.3	100 x 40	100 x 40	100 x 40	100 x 40	75 x 50	75 x 50
100 x 40	90	35	19.1	100 x 75	100 x 75	100 x 40	100 x 50	100 x 40	100 x 40
100 x 50	90	45	24.6	100 x 100	125 x 40	100 x 75	100 x 75	100 x 50	100 x 40
100 x 75	90	65	35.5	150 x 40	125 x 50	100 x 100	125 x 40	100 x 75	100 x 75
125 x 40	115	35	39.9	150 x 40	150 x 40	125 x 50	100 x 100	100 x 75	100 x 75
100 x 100	90	90	49.2	150 x 50	150 x 40	150 x 40	150 x 40	100 x 100	100 x 75
125 x 50	115	45	51.3	150 x 50	125 x 75	150 x 40	150 x 40	100 x 100	125 x 40
150 x 40	140	35	72.0	150 x 75	150 x 75	150 x 50	150 x 50	150 x 40	150 x 40
125 x 75	115	65	74.1	150 x 75	150 x 75	125 x 100	150 x 50	150 x 40	150 x 40
150 x 50	140	45	92.6	150 x 100	150 x 100	150 x 75	125 x 100	150 x 50	150 x 40
125 x 100	115	90	102.7	150 x 100	150 x 100	150 x 75	150 x 75	150 x 50	150 x 50
150 x 75	140	65	133.8	200 x 75	200 x 50	150 x 100	150 x 100	150 x 75	125 x 100
150 x 100	140	90	185.2	200 x 100	200 x 75	200 x 75	200 x 50	150 x 100	150 x 75
200 x 50	180	45	196.8	200 x 100	225 x 50	200 x 75	200 x 75	150 x 100	150 x 100
200 x 75	180	65	284.3	225 x 100	225 x 75	200 x 100	200 x 100	200 x 75	200 x 75
225 x 50	205	45	290.8	225 x 100	225 x 100	200 x 100	200 x 100	200 x 75	200 x 75
200 x 100	180	90	393.7	300 x 50	250 x 75	225 x 100	225 x 75	200 x 100	200 x 75
250 x 50	230	45	410.6	300 x 50	300 x 50	225 x 100	225 x 100	200 x 100	200 x 100
225 x 75	205	65	420.0	250 x 100	300 x 50	225 x 100	225 x 100	200 x 100	200 x 100
225 x 100	205	90	581.5	300 x 75	300 x 75	300 x 50	300 x 50	225 x 100	225 x 100
250 x 75	230	65	593.1	300 x 75	300 x 75	250 x 100	300 x 50	225 x 100	225 x 100
300 x 50	280	45	740.9	300 x 100	300 x 100	300 x 75	250 x 100	300 x 50	225 x 100
250 x 100	230	90	821.3	-	300 x 100	300 x 75	300 x 75	300 x 50	300 x 50
300 x 75	280	65	1070.2	-	-	300 x 100	300 x 75	300 x 75	250 x 100
300 x 100	280	90	1481.8	-	-	-	-	300 x 100	300 x 100

A size further down the list in the first column may always be substituted for a size in the body of the table. Eg. 100 × 100 may always be substituted for a 125 × 40. Table based on dry dressed sizes.

Rafters

The tables below give rafter spans for light and heavy roofs.

Table 4a. Rafters for light roofs

Size mm x mm	E = 5 GPa 400	600	900	1200	E = 6 GPa 400	600	900	1200	E = 7 GPa 400	600	900	1200
	Span, m, for spacing, mm											
75 x 40	1.48	1.32	1.15	1.07	1.57	1.40	1.22	1.14	1.66	1.47	1.29	1.20
100 x 40	2.06	1.81	1.56	1.40	2.18	1.92	1.66	1.49	2.30	2.02	1.75	1.56
125 x 40	2.55	2.22	1.97	1.81	2.71	2.36	2.10	1.92	2.85	2.48	2.21	2.02
150 x 40	3.04	2.71	2.38	2.14	3.23	2.88	2.53	2.27	3.40	3.03	2.67	2.39
75 x 50	1.64	1.40	1.23	1.15	1.75	1.49	1.31	1.22	1.84	1.56	1.38	1.29
100 x 50	2.22	1.97	1.73	1.56	2.36	2.10	1.83	1.66	2.48	2.21	1.93	1.75
125 x 50	2.80	2.47	1.89	1.97	2.97	2.62	2.01	2.10	3.13	2.76	2.12	2.21
150 x 50	3.29	2.88	2.55	2.30	3.49	3.06	2.71	2.45	3.68	3.22	2.85	2.57
200 x 50	4.36	3.86	3.37	3.12	4.63	4.11	3.58	3.32	4.87	4.32	3.77	3.49
225 x 50	4.85	4.27	3.53	3.45	5.15	4.54	3.76	3.67	5.43	4.78	3.95	3.86
250 x 50	5.34	4.77	4.19	3.86	5.68	5.07	4.46	4.11	5.98	5.33	4.69	4.32
300 x 50	6.33	5.59	5.01	4.60	6.73	5.94	5.33	4.89	7.08	6.25	5.61	5.15
100 x 75	2.47	2.22	1.89	1.73	2.62	2.36	2.01	1.83	2.76	2.48	2.12	1.93
125 x 75	3.12	2.71	2.38	2.22	3.32	2.88	2.53	2.36	3.49	3.03	2.67	2.48
150 x 75	3.70	3.29	2.88	2.63	3.93	3.49	3.06	2.80	4.14	3.68	3.22	2.94
200 x 75	4.93	4.36	3.86	3.53	5.24	4.63	4.11	3.76	5.52	4.87	4.32	3.95
225 x 75	5.51	4.85	4.27	3.95	5.85	5.15	4.54	4.19	6.16	5.43	4.78	4.41
250 x 75	6.00	5.34	4.77	4.36	6.38	5.68	5.07	4.63	6.71	5.98	5.33	4.87
300 x 75	7.07	6.33	5.59	5.10	7.51	6.73	5.94	5.42	7.91	7.08	6.25	5.70

Size mm x mm	E = 8 GPa 400	600	900	1200	E = 10 GPa 400	600	900	1200	E = 12 GPa 400	600	900	1200
	Span, m, for spacing, mm											
75 x 40	1.73	1.54	1.35	1.25	1.86	1.66	1.45	1.35	1.98	1.76	1.54	1.43
100 x 40	2.40	2.12	1.83	1.63	2.59	2.28	1.97	1.76	2.75	2.42	2.09	1.87
125 x 40	2.98	2.60	2.31	2.12	3.21	2.80	2.49	2.28	3.41	2.97	2.64	2.42
150 x 40	3.56	3.17	2.79	2.50	3.83	3.42	3.00	2.69	4.07	3.63	3.19	2.86
75 x 50	1.92	1.63	1.44	1.35	2.07	1.76	1.55	1.45	2.20	1.87	1.65	1.54
100 x 50	2.60	2.31	2.02	1.83	2.80	2.49	2.18	1.97	2.97	2.64	2.31	2.09
125 x 50	3.27	2.88	2.21	2.31	3.52	3.11	2.38	2.49	3.74	3.30	2.53	2.64
150 x 50	3.85	3.37	2.98	2.69	4.14	3.63	3.21	2.90	4.40	3.85	3.41	3.08
200 x 50	5.10	4.52	3.94	3.65	5.49	4.87	4.25	3.94	5.83	5.17	4.51	4.18
225 x 50	5.67	5.00	4.13	4.04	6.11	5.39	4.45	4.35	6.49	5.72	4.73	4.62
250 x 50	6.25	5.58	4.90	4.52	6.73	6.01	5.28	4.87	7.15	6.38	5.61	5.17
300 x 50	7.40	6.54	5.87	5.38	7.98	7.04	6.32	5.80	8.47	7.48	6.71	6.16
100 x 75	2.88	2.60	2.21	2.02	3.11	2.80	2.38	2.18	3.30	2.97	2.53	2.31
125 x 75	3.65	3.17	2.79	2.60	3.94	3.42	3.00	2.80	4.18	3.63	3.19	2.97
150 x 75	4.33	3.85	3.37	3.08	4.66	4.14	3.63	3.31	4.95	4.40	3.85	3.52
200 x 75	5.77	5.10	4.52	4.13	6.21	5.49	4.87	4.45	6.60	5.83	5.17	4.73
225 x 75	6.44	5.67	5.00	4.62	6.94	6.11	5.39	4.97	7.37	6.49	5.72	5.28
250 x 75	7.02	6.25	5.58	5.10	7.56	6.73	6.01	5.49	8.03	7.15	6.38	5.83
300 x 75	8.27	7.40	6.54	5.96	8.91	7.98	7.04	6.42	9.47	8.47	7.48	6.82

Table 4b. Rafters for heavy roofs

Size	E = 5 GPa				E = 6 GPa				E = 7 GPa			
	Span, m, for spacing, mm											
mm x mm	400	480	600	900	400	480	600	900	400	480	600	900
75 x 40	1.23	1.23	1.07	0.99	1.31	1.31	1.14	1.05	1.38	1.38	1.20	1.10
100 x 40	1.73	1.64	1.48	1.32	1.83	1.75	1.57	1.40	1.93	1.84	1.66	1.47
125 x 40	2.14	1.97	1.89	1.64	2.27	2.10	2.01	1.75	2.39	2.21	2.12	1.84
150 x 40	2.55	2.38	2.22	1.97	2.71	2.53	2.36	2.10	2.85	2.67	2.48	2.21
75 x 50	1.40	1.32	1.23	1.07	1.49	1.40	1.31	1.14	1.56	1.47	1.38	1.20
100 x 50	1.81	1.73	1.64	1.40	1.92	1.83	1.75	1.49	2.02	1.93	1.84	1.56
125 x 50	2.30	2.14	2.06	1.81	2.45	2.27	2.18	1.92	2.57	2.39	2.30	2.02
150 x 50	2.71	2.55	2.38	2.14	2.88	2.71	2.53	2.27	3.03	2.85	2.67	2.39
200 x 50	3.53	3.37	3.12	2.80	3.76	3.58	3.32	2.97	3.95	3.77	3.49	3.13
225 x 50	3.95	3.78	3.53	3.12	4.19	4.02	3.76	3.32	4.41	4.23	3.95	3.49
250 x 50	4.36	4.11	3.86	3.45	4.63	4.37	4.11	3.67	4.87	4.60	4.32	3.86
300 x 50	5.10	4.85	4.52	4.03	5.42	5.15	4.80	4.28	5.70	5.43	5.06	4.51
100 x 75	2.06	1.97	1.81	1.56	2.18	2.10	1.92	1.66	2.30	2.21	2.02	1.75
125 x 75	2.55	2.47	2.30	1.97	2.71	2.62	2.45	2.10	2.85	2.76	2.57	2.21
150 x 75	3.04	2.88	2.71	2.38	3.23	3.06	2.88	2.53	3.40	3.22	3.03	2.67
200 x 75	3.95	3.78	3.53	3.12	4.19	4.02	3.76	3.32	4.41	4.23	3.95	3.49
225 x 75	4.44	4.19	3.95	3.53	4.72	4.46	4.19	3.76	4.97	4.69	4.41	3.95
250 x 75	4.85	4.60	4.36	3.86	5.15	4.89	4.63	4.11	5.43	5.15	4.87	4.32
300 x 75	5.59	5.34	5.01	4.52	5.94	5.68	5.33	4.80	6.25	5.98	5.61	5.06

Size	E = 8 GPa				E = 10 GPa				E = 12 GPa			
	Span, m, for spacing, mm											
mm x mm	400	480	600	900	400	480	600	900	400	480	600	900
75 x 40	1.44	1.44	1.25	1.15	1.55	1.55	1.35	1.24	1.65	1.65	1.43	1.32
100 x 40	2.02	1.92	1.73	1.54	2.18	2.07	1.86	1.66	2.31	2.20	1.98	1.76
125 x 40	2.50	2.31	2.21	1.92	2.69	2.49	2.38	2.07	2.86	2.64	2.53	2.20
150 x 40	2.98	2.79	2.60	2.31	3.21	3.00	2.80	2.49	3.41	3.19	2.97	2.64
75 x 50	1.63	1.54	1.44	1.25	1.76	1.66	1.55	1.35	1.87	1.76	1.65	1.43
100 x 50	2.12	2.02	1.92	1.63	2.28	2.18	2.07	1.76	2.42	2.31	2.20	1.87
125 x 50	2.69	2.50	2.40	2.12	2.90	2.69	2.59	2.28	3.08	2.86	2.75	2.42
150 x 50	3.17	2.98	2.79	2.50	3.42	3.21	3.00	2.69	3.63	3.41	3.19	2.86
200 x 50	4.13	3.94	3.65	3.27	4.45	4.25	3.94	3.52	4.73	4.51	4.18	3.74
225 x 50	4.62	4.42	4.13	3.65	4.97	4.76	4.45	3.94	5.28	5.06	4.73	4.18
250 x 50	5.10	4.81	4.52	4.04	5.49	5.18	4.87	4.35	5.83	5.50	5.17	4.62
300 x 50	5.96	5.67	5.29	4.71	6.42	6.11	5.70	5.08	6.82	6.49	6.05	5.39
100 x 75	2.40	2.31	2.12	1.83	2.59	2.49	2.28	1.97	2.75	2.64	2.42	2.09
125 x 75	2.98	2.88	2.69	2.31	3.21	3.11	2.90	2.49	3.41	3.30	3.08	2.64
150 x 75	3.56	3.37	3.17	2.79	3.83	3.63	3.42	3.00	4.07	3.85	3.63	3.19
200 x 75	4.62	4.42	4.13	3.65	4.97	4.76	4.45	3.94	5.28	5.06	4.73	4.18
225 x 75	5.19	4.90	4.62	4.13	5.59	5.28	4.97	4.45	5.94	5.61	5.28	4.73
250 x 75	5.67	5.38	5.10	4.52	6.11	5.80	5.49	4.87	6.49	6.16	5.83	5.17
300 x 75	6.54	6.25	5.87	5.29	7.04	6.73	6.32	5.70	7.48	7.15	6.71	6.05

Critical joints

Joints which may require additional fasteners or connectors for lower density species are:-

Roofing, especially around the perimeter of the roof
Purlins to rafters especially around the perimeter of the roof
Rafters to ridge board and underpurlins
Rafters to top plate
Top plate to studs where there is no sheet material lining or cladding connecting the plate to stud
Joints in top plates
Lintels to trimming studs and other framing around openings
Diagonal wall, ceiling or roof bracing where there is no sheet material lining or cladding
Studs to bottom plate where there is no sheet material lining or cladding connecting the plate to stud
Hold-downs to studs at either end of sheet bracing elements
Connections between joist and bearers and bearers and piles
Connections for subfloor bracing

To compensate for lower density species in these joints, extra nails, wire dogs, metal plate connectors or punched steel strip may be used. Deformed shank and galvanised nails have better nail-holding in withdrawal than plain steel nails. Failures in high winds and earthquakes are often at joints. A small amount of extra expense in these areas can contribute greatly to the strength of the building under extreme loading conditions.

References

1. Standards Association of New Zealand 1990. Code of practice for light timber frame buildings not requiring specific design. NZS 3604:1990.

2. Standards Association of New Zealand 1995. Timber and wood based products for use in building. NZS 3602:1995.

3. Clifton NC, 1990: New Zealand Timbers. GP Books.

4. Forest Research Institute, 1976: Maritime Pine. What's New in Forest Research. No. 44

5. Standards Association of New Zealand 1988. New Zealand timber grading rules. NZS 3631:1988.