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Summary of Tests on Untreated Douglas-fir, Treated and Untreated Radiata pine for Use as Framing in Domestic Construction in New Zealand

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EXECUTIVE SUMMARY

The aftermath of the “Leaky Building Crisis” of the late 1990s to early 2000s led to a raft of changes in building standards, with particular reference to preservative treatment requirements for some framing components. The intention of the treatment was to offer temporary decay resistance, should a building leak, until such time as the leak was identified and rectified. Framing durability would still be based on the concept of the timber not attaining a moisture content suitable for decay during the life of the building.

Limited scope remained for use of untreated framing in low risk locations within a building, e.g. internal walls. Although untreated Douglas-fir had been used successfully for many years, mostly for exterior framing and cladding combinations, **its use in exterior walls was now restricted to single story buildings with masonry veneer cladding.** In other respects, Douglas-fir was considered to be no different from radiata pine and was required to be preservative treated when used in situations where radiata pine was required to be treated.

This ruling caused considerable disquiet among Douglas-fir growers and manufacturers of Douglas-fir framing who were of the belief that **expected performance of untreated Douglas-fir could be considered more closely equivalent to expected performance of H1.2 treated radiata pine than to that of untreated radiata pine.**

These differences of opinion led to the development of this suite of studies to determine the relative durability position of untreated Douglas fir vis à vis untreated radiata pine and H1.2 treated radiata pine.

This report will summarise six different trials conducted at Scion between 2003 and 2009. In addition, an independent audit of the literature comparing Douglas-fir to untreated and treated radiata pine was undertaken by **Dr. Paul Morris** (Group Leader, Durability Protection) from FPInnovations, Canada. Dr. Morris has twenty-seven years’ experience in wood preservation/durability research. He has authored over 250 papers, technical reports, contract reports and other publications. His conclusions are summarised.

Trial 1: **Ten lengths of Douglas-fir and six lengths of radiata pine** were exposed to natural rainfall in Rotorua over 55 days in winter 2003. From an initial mean moisture content of 11% and 15% for radiata pine and Douglas-fir respectively, the moisture levels rose to 35% and 20%. The Douglas-fir never reached the threshold **27% moisture content (required to initiate decay)** and proved to be much more difficult to wet than the radiata pine.

Trial 2: Radiata pine and Douglas-fir sapwood and heartwood samples were dried to a common moisture content and then hung outside vertically or horizontally for 55 days. The moisture content of horizontally positioned wood increased 7.1% compared with vertically positioned wood. The Douglas-fir had a 6.6% or 0.9% lower moisture content for horizontally or vertically positioned radiata pine wood, respectively. Radiata pine and Douglas-fir heartwood samples had a 5.2% or 1.8% lower moisture content than sapwood samples.

Trial 3: The stability of Douglas-fir and radiata pine structural timber was assessed when subjected to moisture cycling. Stud length samples of Douglas-fir and radiata pine were exposed to repeated wetting and drying. The radiata pine showed the greatest permeability, but warping was not important for either species. Green Douglas-fir had the greatest timber instability during the drying phase prior to the trial starting.

Trial 4: Decay resistance testing. **Model house frame units were made that simulated walls that are exposed to moisture. All untreated radiata pine units failed after one and a half years and all untreated Douglas-fir samples failed after three years. Boron treated radiata pine samples resisted decay for more than five years.**

Trial 5: The durability of Douglas-fir was compared with approved framing species and timber treatments. Untreated sapwood samples from all species showed appreciable decay after three years. Macrocarpa and Larch heartwood samples showed slower rates of decay than samples from radiata pine, Douglas-fir and Lawson cypress. Boron treated sapwood showed no decay. Untreated sapwood of all species should not be used in areas where framing might become wet.

Trial 6: Progress of decay and stiffness loss with time in Douglas-fir and radiata pine. Samples of untreated radiata pine and Douglas-fir heartwood and sapwood as well as treated radiata pine were placed in a moisture tank and tested for water uptake, decay, mould and deflection every 4-8 weeks over one year. Untreated radiata pine sapwood decayed rapidly. The heartwood showed both greater decay resistance and less deflection than the sapwood samples. Despite the presence of observable decay, Douglas-fir heartwood, did not recorded any stiffness loss. This suggests that the presence of observable decay – the main criterion for replacement of framing when a “leaky building” is rehabilitated – may not reflect residual stiffness, which could be retained when leaks were rectified and the framing dried.

Conclusions of Dr Paul Morris of FPInnovations, Canada.

The durability of treated and untreated radiata pine and Douglas-fir in New Zealand wood frame buildings was compared. The main conclusions were:

1. The current requirements for five years protection would be provided only by boron treatment
2. If the required protection period were shortened to 2-3 years, a Douglas-fir heartwood product would provide adequate decay resistance
3. Untreated Douglas-fir sapwood would not be assured to provide two year protection
4. The minimum probable times from leak initiation to unacceptable decay (following periodic wetting) may be:
 - ≤1 year Untreated radiata pine sapwood
 - 1.5-2.7 years Untreated Douglas-fir sapwood
 - 3-6 years Untreated Douglas-fir heartwood
 - >5 years Boron treated radiata pine sapwood

While Douglas-fir heartwood could not be regarded as equivalent to H1.2 treated radiata pine, it was superior to untreated radiata pine, particularly in low/medium risk situations.

On the basis of these trials, the Department of Building and Housing has proposed to extend framing situations where Douglas-fir can be used untreated in low risk domestic constructions.

INTRODUCTION

Prior to revision of NZS 3602 “Timber and wood-based products for use in buildings” in 1995 and subsequent acceptance of its provisions as Acceptable Solutions within the NZ Building Code, Douglas-fir was accepted as an alternative to H1 treated radiata pine. At that time, the major, if not sole, durability concern was **resistance to wood borers**, such as *Anobium punctatum* and *Abeodontus tristis*. On this premise, it was widely accepted from results of laboratory and field tests **that untreated Douglas-fir (both sapwood and heartwood) was as resistant as H1 treated radiata pine treated with either water based boron, CCA formulations or the recently introduced Light Organic Solvent Preservatives (LOSP)**. The active ingredients of LOSPs are synthetic pyrethroids, such as permethrin.

There was some opposition to introduction of **LOSP treated framing on the grounds that the actives were purely insecticides**, whereas boron compounds had fungicidal properties and therefore would be useful in protecting framing from decay in the event of leaks. However, the H1 Hazard Class by definition did not recognise a decay hazard since conditions of use were inside and fully protected from the weather by roofs and walls, so these misgivings were put to one side.

During the early 1990s, changes in building practices moved in favour of use of dry (less than 20% moisture content) framing at the outset of commencement of construction, rather than the traditional practice of installing the framing “wet” and allowing it to dry naturally to 20% moisture content before enclosing. **It had also been shown in laboratory trials that kiln dried and planer gauged (now the preferable option to “rough sawn” framing) had inherent resistance to insect attack, so long as it was kept dry, which was a prerequisite when conforming to the H1 Hazard Class.**

Surveys of **older untreated radiata pine constructions** had been undertaken and it was shown that **wood borer attack in these was infrequent** (although such buildings contained a higher proportion of borer resistant heartwood than would be found today). It was argued that in terms of fit for purpose in **enclosed framing, protected from the weather**, untreated kiln dried planer gauged radiata pine was equivalent, in terms of resistance to insect borer attack – the only durability requirement for Hazard Class H1 – to H1 treated and untreated Douglas-fir.

In 1995 NZS 3602 was amended to include any of these three options, in equivalent framing situations.

Because of the relatively low cost of producing kiln dried, untreated radiata pine framing as opposed to boron treatment, followed by kiln drying and gauging, the former quickly became the preferred choice, with **H1 LOSP treated radiata pine** developing a sizeable market share, particularly in the North Island. Use of Douglas-fir framing was still widespread in the South Island where it had been used, ungraded, for many years and **tended to be sourced from fairly young forests. This resulted in a high sapwood proportion in the manufactured framing product.**

Much has been written about the “Leaky Building Crisis” which developed in the early 2000s. Generally, it was a consequence of radical changes in domestic building practices. Chiefly these were:

- Popularity of “Mediterranean Style” houses featuring monolithic claddings directly fixed to framing
- Narrow or no eaves
- Enclosed parapets and balconies
- Complex junctions
- Lack of window flashings or their incorrect installation
- Reduction in a skilled work force capable of adequately erecting these new styles

The most obvious result was rainwater penetration through defects in the cladding, flashing systems or sealants, and excessive wetting of the exterior wall framing which resulted in its swelling, hence exacerbating further defects in the cladding and decay of the untreated framing.

An early reaction was a voluntary one from manufacturers of Exterior Insulated Face Seal (EIFS) claddings, a generic term for most of the monolithic cladding systems in use world wide. Their response was to require all framing to which their products would be fixed to, be preservative treated to a level which would inhibit decay should the framing get wet. This was to be an informal requirement – the level of treatment being dubbed “H1Plus” – which would be outside any preservation standard and the Building Code. This approach was quickly recognised as being unworkable and any treatment (active ingredient and retention within the framing) would need to be standardised and incorporated into relevant standards.

As this debate continued, the Building Industry Authority (BIA) put out for public comment a revision of B2/AS1 Durability Clause of the Building Code with various options for preservative treatment. Scion (Forest Research) responded with results from tests established specifically to evaluate preservative treatments for framing. Our submission was quite specific as to the purpose of these treatments, which were based on preservative formulations available at the time and which could be used at economical retentions.

The sole purpose of the treatment was to protect framing, should leaks develop, until the leaks were fixed. This assumes that the causes of leaks can be identified and that they are capable of being rectified. Based on that assumption, it was thought plausible that this period would be up to five years following development of the leak, ten years at most.

The development of NZS 3640 “Chemical preservation of round and sawn timber” in 2003 was a revision of MP 3640:1992, “Minimum requirements of the NZ Timber Preservation Council”.

A radical change was the splitting of Hazard Class H1 into two sub-classes to reflect the fact that some framing could be subjected to intermittent wetting and therefore at risk of decay. See below.

Hazard Class	Exposure	Service Conditions	Biological Hazard	Typical Uses
H1.1	Protected from the weather, above ground	Protected from weather, always dry	Borers	Interior finishing timber – see NZS 3602
H1.2	Protected from the weather, above ground, but with a possibility of exposure to moisture	Protected from weather, but with a risk of moisture content conducive to decay	Borers, decay	Wall framing – see NZS 3602

When revision of NZS 3640 was nearing completion, the next task was to revise NZS 3602:1996, “Timber and wood-based products for use in buildings”. A particular problem was to determine which parts of the timber frame were going to require preservative treated (decay resistant) framing and in which parts untreated kiln dried radiata pine or untreated Douglas-fir could be used.

Perhaps the most contentious issues were the relative durabilities of radiata pine and Douglas-fir.

On the one hand, it was argued, Douglas-fir had been used untreated (and ungraded for heartwood and sapwood) for over 50 years without known durability problems. It was also noted that it was mainly used in the South Island which had few instances of “Leaky Building Syndrome” when compared with, say, Auckland, where problems of decay were mainly confined to untreated radiata pine.

It was also argued that Douglas-fir was more resistant to moisture ingress, especially liquid water and was inherently more naturally durable. However there was little hard data to back up these anecdotal observations, or where performance data were available, it was insufficiently robust – being based on relatively short term trials – to allow any firm conclusions to be drawn.

The end result was that in framing situations where radiata pine was deemed to require preservative treatment, Douglas-fir should also be treated to the same level.

The following report attempts to bring together available information generated at Scion to demonstrate differences (and similarities) between Douglas-fir and radiata pine with regard to wetting and drying under various exposure conditions, and resistance to decay following exposure to those conditions.

Wetting and drying of Douglas-fir and radiata pine when exposed to natural rainfall

Previous research has shown that a minimum wood moisture content of 27% is necessary for decay to be initiated in radiata pine sapwood when it is in contact with decaying wood. For the purposes of this report and conclusions, the conservative assumption is made that the minimum moisture for decay initiation is the same for Douglas-fir sapwood and heartwood and for radiata pine heartwood. However, once initiated, the rate of decay would be less in most examples of radiata pine heartwood and even less in Douglas-fir heartwood because of their comparative and greater natural durability than sapwood.

It is well-known that Douglas-fir (sapwood and heartwood) is a refractory species and is difficult to impregnate with water, even under pressure. Radiata pine sapwood, on the other hand, is much more permeable to liquid water. Radiata pine heartwood has more variable permeability; some being as permeable as sapwood, some being almost as refractory as Douglas-fir.

Although both timbers would differ little in susceptibility to decay if they attained the same moisture content (~ 27% MC), there would be significant differences in resistance to moisture uptake if both were exposed to the same wetting regimes, such as that represented by rainfall. With radiata pine being more permeable, it would be expected to attain a moisture content suitable for decay much more readily than Douglas-fir.

Trial 1: Preliminary Trial

To test that hypothesis, ten 3.5 m lengths of Douglas-fir and six 3.5 m lengths of radiata pine were selected from stock at Scion (Forest Research at that time). Douglas-fir samples tended to be more "hearty" than radiata pine samples. A 10 mm thick section was taken approximately one metre from one end and initial moisture content determined by weighing the section, oven drying and re-weighing.

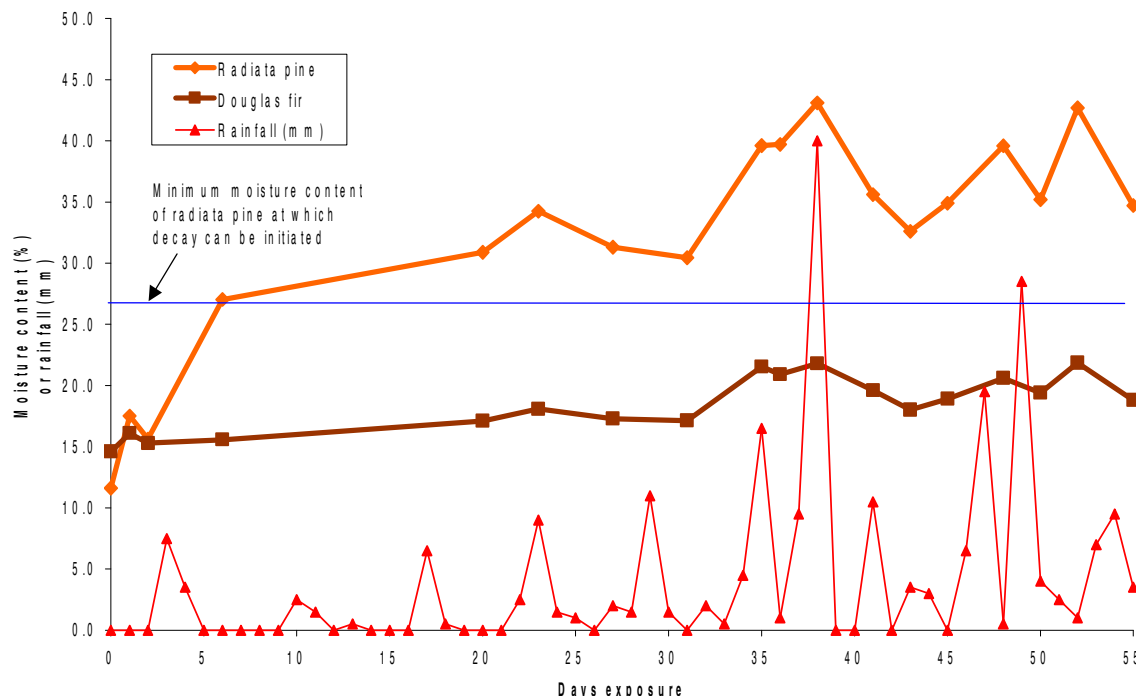
Residual 2.5 m lengths were weighed and lightly hosed with water. Samples were then laid out on bearers on an open asphalted area of the Scion campus. Samples were sufficiently high off the ground to avoid additional wetting by rain splash. Samples were weighed at irregular intervals, although the frequency of weighing increased as the trial progressed. Moisture contents were calculated at each weighing from initial moisture content, initial sample weight and increase/decrease in weight from the previous weighing. The trial started on 29 July 2003 and ended 55 days later on 22 September 2003.

Daily rainfall was recorded at a weather station located approximately 1 km NE of the trial. Although neither temperatures nor sunshine hours were recorded, the weather could be regarded as typical for late winter in Rotorua.

After the first 6 days' exposure – during which time 11 mm of rain fell – the radiata pine moisture content reached the minimum required to initiate decay in that species (blue line in Figure 1). The moisture content remained above that minimum for the next 49 days, after which the trial was terminated. In contrast, the moisture content of Douglas-fir samples never approached the required

minimum moisture content. In one 24 hour period in this test (Day 38), framing was subjected to 40 mm rainfall. During that time, the moisture content of Douglas-fir rose from 20.9% to 21.8%, well below the threshold moisture content of 27% required to initiate decay. In comparison, the moisture content of radiata pine rose from 39.7 to 43.1% on that day.

Fig 1 Moisture content of 90 x 45 x 2500 mm radiata pine and Douglas fir exposed to natural rain wetting after initial artificial wetting on Day 0



Conclusions from the trial were that Douglas-fir is more difficult to wet than radiata pine, and under the conditions of the test failed to reach a moisture content where there would be a risk of decay if it was in contact with decaying wood. Conversely, radiata pine reached this moisture content after six days' exposure to rainfall and never went below that moisture content for the remainder of the trial.

Trial 2: Moisture content changes in Douglas-fir and radiata pine exposed to the weather

Forty pieces of dried 90 x 45 mm gauged radiata pine 2.4 m in length were obtained from central North Island sources, 20 pieces consisting entirely of sapwood and 20 of heartwood.

Thirty pieces of 90 x 45 mm Douglas-fir 2.4 m in length were sourced from each of four locations: Rotorua, Canterbury, Tapanui and Naseby. Shipments contained samples which were 100% heartwood and up to 90% sapwood. Samples were received either green or dried. Green samples were forced-air dried in the laboratory so the moisture content of all samples at the commencement of the trial would be as similar as possible (Table 1). It was felt inappropriate to kiln dry Douglas-fir to a constant moisture content, since kiln drying this material is not a common industrial practice.

Table 1 Initial mean moisture contents

Shipment/location	Initial mean moisture content (%)
Douglas-fir Rotorua	13.4
Douglas-fir Tapanui	14.8
Douglas-fir Naseby	14.9
Douglas-fir Canterbury	13.4
Radiata pine sapwood CNI	12.1

The sapwood percentage of each piece of Douglas-fir timber was estimated and the pieces from each separate source were divided into pairs with similar sapwood content. A nail was fixed at one end of one of each pair of samples so that it could be hung vertically from wire mesh which formed the East wall of a building located on the Scion campus. The roof of this building was sufficiently high so that it did not impede exposure to rainfall, although exposure was essentially limited to three surfaces of each sample.

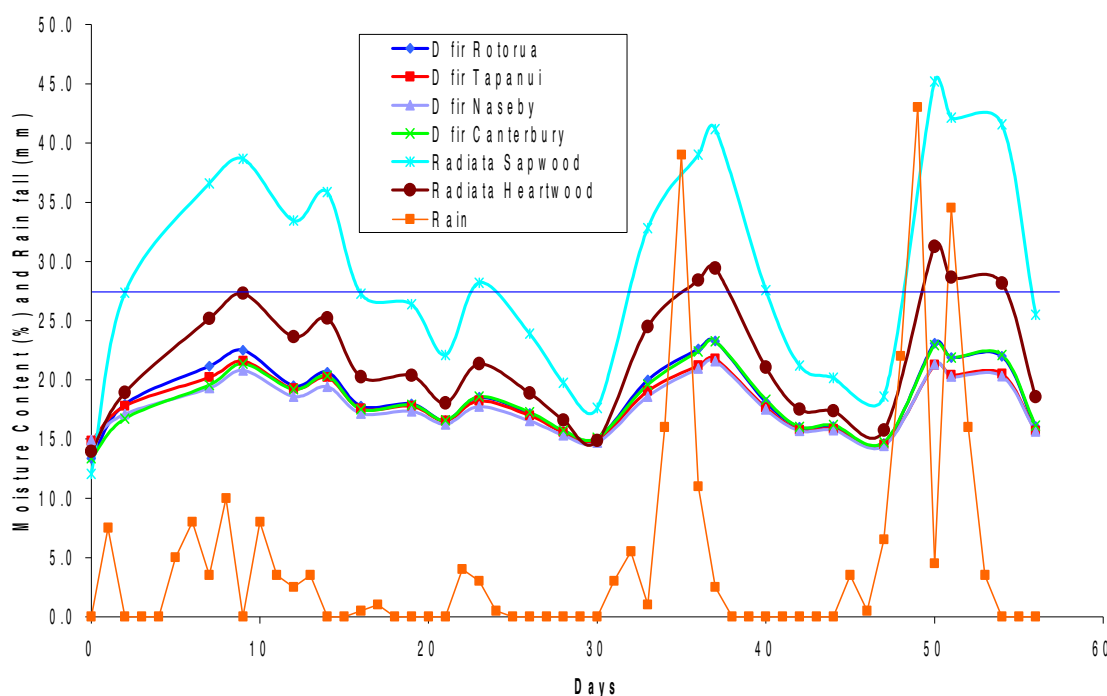
The other pair of each sample was exposed horizontally in the same manner as the preliminary trial.

All wood samples of Douglas-fir and radiata pine were weighed immediately before exposing the test material to the weather over a 56-day period from 22 October 2003. All samples were weighed at intervals. Weight gains and losses were then converted into changes in moisture content of individual samples.

Results

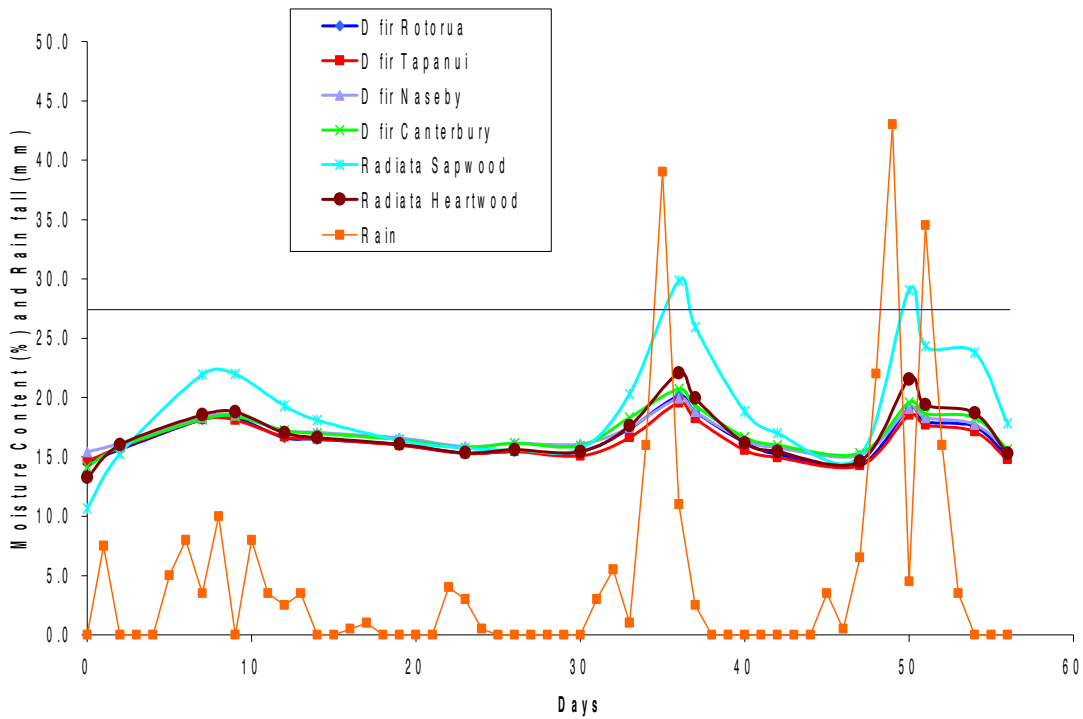
Changes in moisture content over the 55-day exposure period are shown in Figure 2 (horizontal exposure) and Figure 3 (vertical exposure). Included in each figure is a line drawn at 27% moisture content, which is the limiting moisture content of radiata pine for decay to be initiated if susceptible wood is in contact with decaying wood.

Fig 2 Main trial horizontal samples



Overall, how the wood was positioned was very important, with an average increase in moisture content of 7.1 percent for horizontally positioned wood as compared to vertically positioned wood. The wood from Douglas-fir and radiata pine behaved quite differently. Positioned horizontally, the wood from Douglas-fir had on average a moisture content of 6.6 percent less than radiata pine.

Fig 3 Main trial vertical samples



The moisture content of vertically positioned wood was much less dependent on species, both being low, with an average difference of 0.90 percent.

The amount of sapwood also affects the moisture uptake and again there are substantial differences between the two species. In absolute terms, the difference in moisture content between pieces consisting of total sapwood and total heartwood was 5.2 percent for radiata pine and only 1.8 percent for Douglas-fir. Furthermore, pieces of Douglas-fir sapwood on average contained substantially less moisture than pieces of radiata pine heartwood or sapwood. There were no obvious moisture absorbency differences in Douglas-fir from the various sources.

Douglas-fir timber shows major differences from radiata pine in terms of susceptibility to moisture uptake. Both trials confirmed the 'refractory' reputation of Douglas-fir and the 'absorbent' reputation of radiata pine. At a practical level, Douglas-fir heartwood and sapwood can be regarded as equally impermeable.

While the above clearly demonstrates that Douglas-fir is inherently more difficult to wet than radiata pine, the trial set up did not simulate wetting and drying regimes which may be encountered in wall cavities, where wetting, and particularly drying, may be restricted.

Thus a Building Research Association of New Zealand (BRANZ) study showed that Douglas-fir absorbs water in a radial and tangential direction at about half the rate of radiata pine when exposed in a controlled leaking cavity situation, but if both attain the same moisture content, drying rates are the same. Drying of both may take ten times longer in winter than in summer. Similarly, the aspect in relation to compass direction will also influence drying rates – framing in North-facing walls will dry more rapidly than that in South-facing walls.

As well as raising moisture contents to levels which may promote decay, intermittent wetting may also lead to distortion of the framing, and if rigid claddings such as "Hardibacker"/stucco, are directly fixed to such framing, they will be placed under stress, which could exacerbate movement of the cladding resulting in further leaks. In theory, if Douglas-fir is less prone to wetting (i.e. is less absorbent) than radiata pine, such risks would be less with Douglas-fir.

Although the above tests clearly show large differences in relative wettability and thus potential differences in resistance to decay based on this, they do not quantify effects on relative distortion.

Trial 3: Comparative study of stability between New Zealand Grown Douglas-fir and radiata pine structural timber when subjected to moisture cycling

A trial was undertaken to compare the relative stability of stud-length samples of 100 x 50 mm radiata pine and Douglas-fir when subjected to a number of wetting and drying cycles. Samples of Douglas-fir, both green and dry, and kiln-dried radiata pine, were obtained from one central North Island and two South Island sources representing a typical mix of frame 1 grade for each resource.

Each stud sample was weighed and scanned for any initial distortion using the 'Warpmaster'. Samples were then positioned individually in a rack so they were free to move while equilibrating and in the case of the green studs while air drying. When the green Douglas-fir samples reached approximately 15% moisture content, all samples were re-measured for weight and distortion. Samples were then given a 1 hour soak in water to simulate rain wetting and re-measured for weight and distortion. This sequence was repeated a second time after re-drying the samples to approximately 15%. Distortion levels between samples for each measurement period were compared.

The trial confirmed the 'refractory' reputation of Douglas-fir, and the 'absorbent' reputation of radiata pine. During the wetting/drying cycles, the radiata pine absorbed three to four times more water than the Douglas-fir. The soaking period confirmed previous findings that, at a practical level, Douglas-fir heartwood and sapwood can be regarded as equally impermeable, independent of where it is grown in New Zealand ^[1]

Increases in timber warp during the course of the trial were greater in green Douglas-fir than in either dried Douglas-fir or kiln-dried radiata pine. The increased warp for green Douglas-fir occurred during the initial two-month period of drying rather than in the subsequent wetting/drying cycles.

Although the greater permeability of radiata pine led to greater timber movement and consequent change in warp during the repeated wetting/drying cycles compared with Douglas-fir, the level of warp induced by these cycles was of no practical significance for either species.

The perception that Douglas-fir framing remains more stable while drying down when erected green, or erected dry, than kiln-dried radiata pine, is not supported by this research. In fact, the greatest timber instability noted in the trial was in the green Douglas-fir during the initial 2-month period of drying. Although radiata pine exhibited more movement than Douglas-fir during wetting/drying cycles simulating exposure to rain, the levels of timber movement induced by these cycles was of little practical significance for either species.

The next section considers relative decay profiles of Douglas-fir and radiata pine when the moisture content of the timber reaches the point where decay fungi will cause damage. Of special relevance is how these decay/moisture content profiles relate to those of preservative treated framing.

Decay Resistance Testing

Two basic test formats have been used to determine decay resistance of untreated and treated framing timber. In both tests an inherent feature is that the moisture content of the wood is artificially raised by momentarily soaking in water. In the case of species resistant to water uptake, such as Douglas-fir, or timber treatments which impart water repellancy, such as LOSP, water is impregnated under low pressure. Thus, the tests are designed to determine relative decay resistance when the wood moisture content is consistently at a level which is conducive to decay, irrespective of whether such moisture contents could be consistently attained in an actual framing situation.

In the first type of test, which was originally developed to determine required preservative retentions for framing timber subjected to intermittent wetting, model house frame units (two studs, top and bottom plates and a central “dwang”) are constructed using short (500 mm) lengths of either preservative treated or untreated framing timber. Constructed frames are impregnated with water to raise the initial moisture content to 35-40 % moisture content. The back face of each unit is then covered with black polythylene to maintain a high moisture contents within the wall cavities. Two locations on each stud, at the stud/dwang and stud/bottom plate interfaces are swabbed with alcohol and a 35 x 70 x 7 mm “feeder strip”, pre-decayed in the laboratory by brown rot fungi, are tacked in place on the swabbed area.

Blocks of pre-wetted fibreglass insulation were then placed in the wall cavity and the remaining face covered with a layer of building paper and fibre cement board. Units are stored in a controlled environment room maintained at 27°C and 95% relative humidity. Units are lightly sprayed with water once a week in order to maintain wood moisture content at levels suitable for decay.



Figure 4: Inoculated unit prior to fixing building paper and fibre cement cover



Figure 5: Frame units in controlled environment room (cover removed from one)

A second test procedure utilises 750 x 90 x 45 mm samples. These are either untreated or preservative treated. Samples are wetted up to a moisture content of 35-40% as with the frame units. Immediately prior to inoculation with decay feeder strips, approximately 100 mm is cut from each end of the samples and then stapled back in place. The inoculation feeder strip is placed over the join. The end pieces are easily detached at assessments and can provide additional information on progress of decay within tests samples.

Trial 4: Comparative decay resistance of Douglas-fir and untreated and boron treated radiata pine model frame units

This trial compared the decay resistance of untreated Douglas-fir (a mixture of sapwood and heartwood), with that of untreated radiata pine sapwood and radiata pine sapwood treated to retentions of boron, 0.40% Boric Acid Equivalent (BAE), the H1.2 retention and 0.30% BAE. These are standard terms for expressing boron retentions in framing timber.

Decay assessment results are summarised in Table 2. The Index of Condition is the average decay rating for all of the components in a set of units. Units were considered to have failed after all of the horizontal components failed.

All of the untreated radiata pine units were in poor condition after 52 weeks, five bottom plates and two dwangs having failed. All remaining components contained severe decay. These failed and the units were withdrawn from test at the 78-week assessment.

The untreated Douglas-fir units all contained moderate-severe decay in all components at the 52-week assessment. After 78 weeks exposure one unit failed along with all bottom plates and three dwangs in the remaining four units. Two more units failed after 104 weeks, one after 130 weeks and the final failure was at the 156-week assessment.

Table 2: Progressive Deterioration of Units (Index of Condition*/number of units failed)

Timber type	Number of Weeks in Test				
	52	104	156	209	260
Untreated radiata	2.5	All Failed after 78 weeks			
Untreated D.fir	4.8	1.2 (3)	All Failed after 156 weeks		
Low uptake boron (0.30 % BAE)	10.0	9.7	9.2	8.8	8.3
High uptake boron (0.40 % BAE)	10.0	9.9	9.7	9.3	9.3

Index of Condition is a standardised notation for representing the extent of decay, in which:

10 = No decay or insect damage.

9 = First stages of decay or damage up to 3% of cross-section.

8 = lightly established decay, 3-10% of cross-section.

7 = Well established decay, 10-30% of cross section.

6 = Deep established decay, 30-50% of cross section.

4 = Severe decay, nearing failure, more than 50% of the cross section.

0 = failed through decay.

In the boron treated units, soft rot decay, initially in the very wet sections of bottom plates and dwangs, was recorded in the low uptake units after 78 weeks. This progressed very slowly throughout the trial period and gradually spread to studs and top plates where the moisture content was above 40%. After five years, soft rot was 5-10 mm deep across the upper face of most of the bottom plates and dwangs plus the bottom ends of the studs in the low retention (0.30 % BAE m/m) treated group. In the high retention (0.40 % BAE m/m) treated group, soft rot was present but relatively shallow and only on the wetter sections of components.



Figure 6: Douglas-fir unit after three years' exposure showing almost complete decay

Conclusions

At similar moisture contents, the durability of Douglas-fir is about twice that of untreated radiata pine.

After five years exposure, the boron preservative (boric acid) prevented brown rot decay development at both 0.30 % and 0.40 % BAE m/m retentions. Soft rot has developed in wetter sections of the frames (dwangs and bottom plates), but development has been very slow, particularly in units treated to 0.40 % BAE m/m.

Thus under these extreme conditions, Douglas-fir could not be considered to be the equivalent of H1.2 treated radiata pine.

Trial 5: Durability of Douglas-fir in comparison to other approved framing species and preservative treatments

The following species and treatments were used in this trial. These were based on those species and treatments approved for framing in NZS 3602:2003, "Timber and wood-based products for use in buildings".

1. Radiata pine, kiln dried untreated.
2. Douglas-fir sapwood, untreated.
3. Douglas-fir heartwood, untreated.
4. Douglas-fir sapwood, H1.2 treated with boron.
5. Lawson cypress sapwood, untreated.
6. Lawson cypress heartwood, untreated.
7. Lawson cypress sapwood, H1.2 treated with boron.
8. Lawson cypress sapwood, H1.2 treated with LOSP.
9. Macrocarpa sapwood, untreated.
10. Macrocarpa heartwood, untreated.
11. Macrocarpa sapwood, H1.2 treated with boron.
12. Macrocarpa sapwood, H1.2 treated with LOSP.

As with the previous trial, all samples were tested at a consistent moisture content (35-40% MC), although moisture contents tended to increase during the course of the trial.

Samples were 750 x 90 x 45 mm prepared and inoculated as described previously. Samples were placed in between fillets in lidded plastic tanks which could accommodate about 75 samples per tank. Assessments for decay were made at intervals over a three-year period.

The following figures illustrate progression of decay during the first 9 months' exposure.



Figure 7: Larch sapwood sample before exposure. Decay inoculum attached at joint



Figure 8: After four weeks' exposure. Sapstain and mould developing on Lawson cypress sapwood samples (arrowed).



Figure 9: After twenty-four weeks' exposure. Decay developing on Douglas-fir (arrows) and Lawson cypress sapwood (stars)



D fir

larch

Lawson's

Figure10: After thirty-eight weeks' exposure. Moderate to severe decay in all samples which have extensive mycelial growth, larch, Douglas-fir and Lawson cypress sapwood

The estimated moisture content, mycelium spread, surface and joint decay ratings after 52 weeks, 103 weeks and 157 weeks are summarised in Table 3. The rating system used is shown in Appendix I.

Table 3: Average Moisture Content, Mycelium Spread, Surface and Joint Decay Ratings

	Moisture Content %			Mycelium Spread			Surface Decay			Joint Decay		
Weeks	52	103	157	52	103	157	52	103	157	52	103	157
Radiata Pine KD	23	na	na	3.5	5.0	5.1	4.9	4.4	2.1	5.0	4.5	2.0
Macrocarpa												
Sapwood	33	30	28	3.2	3.6	3.6	7.9	6.9	6.8	7.7	6.9	6.6
Heartwood	39	37	37	1.6	1.8	2.2	9.8	9.4	9.4	9.9	9.4	9.4
Sapwood/Boron	50	53	56	1.3	1.2	1.4	10	10	10	10	10	10
Larch												
Sapwood	21	na	na	4.8	4.7	5.0	5.2	4.6	4.6	5.6	3.6	4.0
Heartwood	31	25	19	3.1	3.4	3.4	8.4	7.7	6.8	7.2	5.8	5.6
Douglas-fir												
Sapwood	22	na	na	3.1	3.6	4.0	6.6	6.3	5.5	6.1	5.5	5.2
Heartwood	25	15	na	2.8	3.6	4.0	8.3	6.4	4.8	8.2	5.3	4.4
Sapwood/Boron	50	52	55	1.5	1.3	1.4	10	10	10	10	10	10
Lawson Cypress												
Sapwood	40	30	30	3.5	4.3	3.7	8.4	6.5	6.4	7.8	6.4	6.2
Heartwood	39	38	40	2.1	2.0	2.4	10	9.8	9.8	9.9	9.7	9.3
Sapwood/Boron	58	63	66	1.8	1.4	1.4	10	10	10	10	10	10

The average moisture content of samples increased steadily over the first 9-12 months of the test and then remained relatively constant or increased slightly over the next two years. As decay advanced in the sapwood samples, and in the heartwood of Douglas-fir and larch, individual sample weights decreased. After the first nine months' exposure, decay reduced the calculated moisture content in these groups. While most of the samples were above 25% moisture content throughout the exposure period, some of the Douglas-fir and larch heartwood samples remained below the average moisture content in the tank. Boron treated samples were consistently wetter than the average moisture content. The moisture content of LOSP treated macrocarpa and Lawson cypress samples remained similar to that of the heartwood in those species, throughout the exposure period.

Decay mycelium spread from feeder blocks over the sapwood and heartwood of untreated samples. On untreated sapwood, mycelium spread was generally accompanied by decay. On the Douglas-fir and larch heartwood decay developed very slowly, but on macrocarpa and Lawson cypress heartwood there was virtually no decay until more than a year's exposure. There was very little mycelium development onto treated samples from feeder blocks. For the first year or so of the trial, *Oligoporus placenta* mycelium formed thick white fluffy patches in places, often spreading to adjacent samples in several layers. *Antrodia xantha* mycelium was quite extensive on many samples and developed just as quickly as *O. placenta* on radiata pine. However, it was much less visible and did not spread from the sample on which it had originally developed.

By the 52-week assessment, decay had become well established in the sapwood of all species, and some of the radiata pine control samples were close to failure. In the Douglas-fir and larch, decay was spreading from the sapwood into the heartwood section of the same samples but in Lawson cypress and macrocarpa the decay generally stopped abruptly at the heart-sapwood boundary. In heartwood samples, there was lightly established decay in the Douglas-fir, larch, and one macrocarpa sample but no significant decay on the Lawson cypress. Overall the ratings were similar for surface and joint decay. None of the boron treated samples contained decay, but there was internal decay in the sapwood of one LOSP treated Lawson cypress sample.

Over the second year of exposure, decay continued to extend in the better radiata pine samples but ratings decreased only slightly. They all contained severe decay but had not disintegrated. Most of the larch sapwood samples also contained severe decay after a year, and this continued to extend slowly into the heartwood of those samples. The Douglas-fir sapwood samples contained considerably less decay than the larch after a year, but decay rates over the second year were similar to those of the larch. Decay continued to develop steadily in the sapwood of macrocarpa and Lawson cypress but generally stopped at the heart-sapwood boundary. It was also beginning to develop in the heartwood under thick *O. placenta* mycelium, particularly on the Lawson cypress, both in sapwood and heartwood samples. One macrocarpa heartwood sample contained severe decay. There was moderate-severe internal decay in one Lawson cypress and one macrocarpa sample that had been LOSP treated. There was no decay in boron treated samples.

After 157 weeks' exposure most of the radiata pine samples were beginning to disintegrate and five were removed from the exposure tanks. Over the third year's exposure, decay in Douglas-fir sapwood samples continued to increase at a steady rate whereas decay ratings for larch sapwood changed very little. Sapwood in the larch group amounted to approximately 40% of the samples, and this was similar in the Douglas-fir sapwood group (38%). There is no obvious explanation as to why Douglas-fir samples containing sapwood decayed at a slower rate than larch for the first two years or so. The larch heartwood samples had decayed at a slightly slower rate than the Douglas-fir heartwood samples, throughout the trial. However, larch heartwood in the "sapwood" samples decayed more quickly than the heartwood in the equivalent Douglas-fir samples.

All of the sapwood on the untreated macrocarpa and Lawson cypress had decayed by the 157-week assessment and one macrocarpa heartwood sample also contained severe decay. Five Lawson cypress heartwood samples contained light-moderate decay in areas where there had previously been extensive mycelium but few signs of decay. One sample in each of the LOSP

treated macrocarpa and Lawson cypress groups contained moderate internal decay pockets; otherwise there was no decay in either the boron or LOSP treated samples.

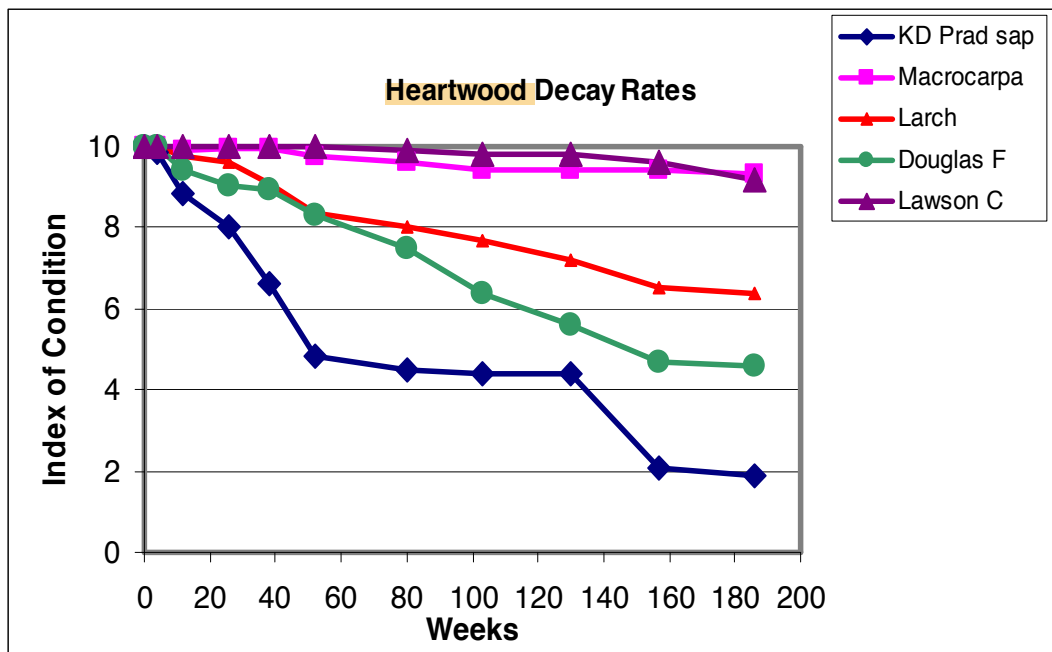


Figure 11: Summary of decay rates of heartwood samples during the test period. The test confirms that when at similar moisture contents, Douglas-fir heartwood is more durable than radiata pine heartwood, although less durable than larch and the Lawson cypresses.

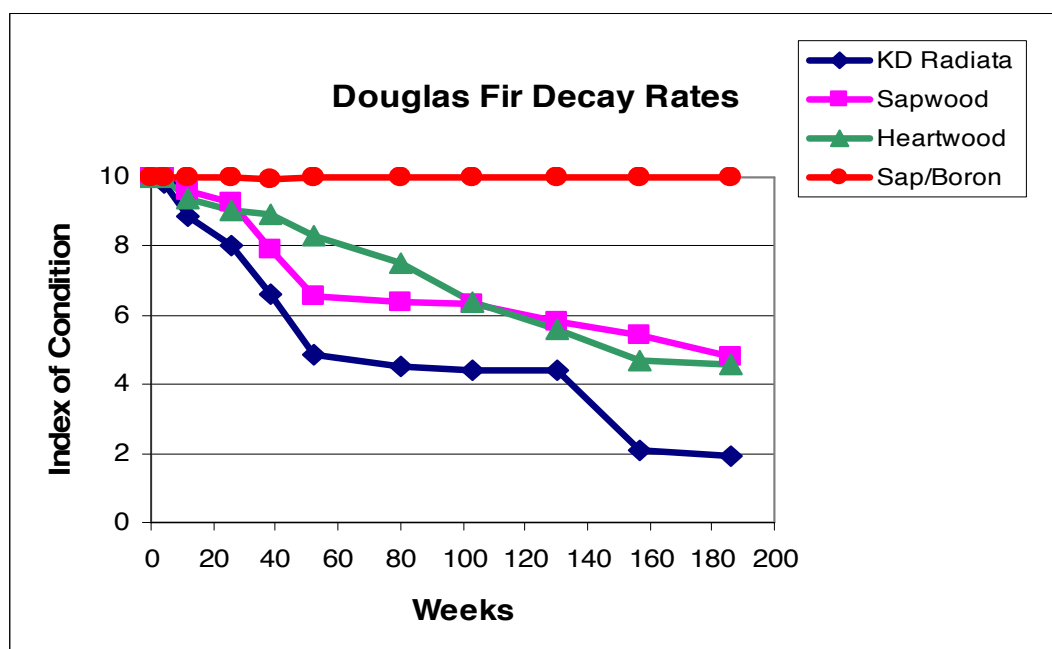


Figure 12: A comparison of the durability of Douglas-fir sapwood and heartwood with untreated radiata pine sapwood and H1.2 treated Douglas-fir. In this test, there was little difference in the durability of Douglas-fir sapwood and heartwood, although both were more durable than untreated radiata pine sapwood. No decay occurred in the H1.2 treated Douglas-fir.

Conclusions

Untreated sapwood of all species should be excluded from all areas where framing could become wet.

Untreated Douglas-fir and larch heartwoods are more resistant to decay than sapwood, but will decay in continually damp conditions.

H1.2 boron treated macrocarpa, Douglas-fir and Lawson cypress samples have shown good resistance to decay over a three-year period.

Variable LOSP penetration into the sapwood of macrocarpa and Lawson cypress has resulted in internal decay pockets and indicates that this type of treatment may be unreliable in sapwood of these species.

So far, we have shown quite clearly that:

- Douglas-fir does not wet as rapidly, or to the same extent, as radiata pine when exposed to rain wetting and unrestricted drying.
- Under these circumstances it is unlikely to consistently meet moisture contents conducive to decay, i.e. in excess of 27% mc.
- But in the event that it did reach such moisture contents, the decay resistance of both sapwood and heartwood is greater than that of untreated radiata pine, but substantially less than H1.2 treated radiata pine.

Trial 6: Progress of decay and stiffness loss with time in Douglas-fir and radiata pine

Another important consideration is the effect that decay has on residual strength of the timber. Douglas-fir producers contended that Douglas-fir was more resistant to moisture uptake (as demonstrated above), it was more durable than radiata pine (but marginally so) and was stronger and stiffer. This latter distinction implied that in the event that Douglas-fir framing became decayed, it would still retain greater stiffness than undecayed radiata pine. Although it has been shown that it is more resistant to rain-wetting, there was no comparative information on rates of decay of radiata pine and Douglas-fir and the effect on loss of stiffness. An important aspect of this trial was to try to factor in the distinction between wetting characteristics of Douglas-fir and radiata pine, but to ensure that Douglas-fir could, at some time, attain a moisture content suitable for decay.

Thus, prior to inoculation with decay fungi, all samples were subjected to the same wetting cycle, but no attempt was made to ensure they all reached similar moisture contents.

Five different treatment groups of 20 boards each were included in the trial:

- Radiata pine, untreated, kiln dried sapwood.
- Radiata pine, untreated, kiln dried heartwood.
- Radiata pine, kiln dried H1.2 LOSP (IPBC + permethrin) treated.
- Douglas-fir, kiln dried untreated "sapwood".
- Douglas-fir, kiln dried untreated heartwood.

The timber was all planer gauged 1000 x 90 x 45 mm. Douglas-fir "sapwood" samples were cut from timber containing a high proportion of sapwood, but heartwood could not be entirely eliminated and ranged from 0 to 75% within samples with an average of 35%. Samples had a partially decayed feeder block, 70 x 35 x 7 mm, infected with *Oligoporus placenta* brown rot attached at the centre of one 45 mm edge.

Prior to installation, samples were immersed in water for two hours. They were then randomly placed on edge, with the feeder blocks facing upward, in 1.0 m (long) x 0.8 m (wide) x 0.6 m (deep) plastic tanks (Figure 13). Layers of samples were separated by 10 x 10 mm plastic stickers. There was water in the tanks about 20 mm deep. The tanks were placed on a level site at the Scion campus, in an area partly shaded by large trees.



Figure 13: Arrangement of samples in the exposure tank

Assessment Methods

Stiffness measurement

At intervals of between four and eight weeks, samples were removed from the tank, weighed, assessed for decay and mould and tested for deflection as a plank in a static bending test. Deflection caused by a central 80 kg load was measured with a dial gauge set against the bottom face of the sample immediately below the load. Samples were then returned to their original position in the exposure tanks. Because the moisture content of all samples rose to above fibre saturation point (26% MC) after 12 weeks, no corrections for differences in moisture content were required to allow for the effect of moisture content on measured residual stiffness.



Figure 14: Stiffness testing assembly

Decay Ratings

The surface of the samples under the decay mycelium was tested with a blunt probe to determine whether the decay fungi were damaging the framing. The decay rating system used was similar to AWP Standard E7-93, although it specifically applied to the area on each board with greatest decay.

- 10 = No decay or insect damage.
- 9 = First stages of decay or damage, up to 3% of cross-section.
- 8 = Lightly established decay, 3-10% of cross-section.
- 7 = Well established decay, 10-30% of cross section.
- 6 = Deep established decay, 30-50% of cross section.
- 4 = Severe decay, nearing failure, more than 50% of the cross section.
- 0 = Failed

Results and Discussion

Moisture content calculations were based on sample weight (Figure 15). The initial soaking period immediately raised the moisture content of radiata pine sapwood to a level suitable for decay

(>27% MC). The other samples gradually absorbed moisture from the atmosphere to reach this moisture content, although it took 24 weeks for Douglas-fir to reach this level.

Because the weight of boards was reduced by significant decay, measurement of moisture content was discontinued after 36 weeks when the effect of decay was obviously affecting the weight of the untreated boards.

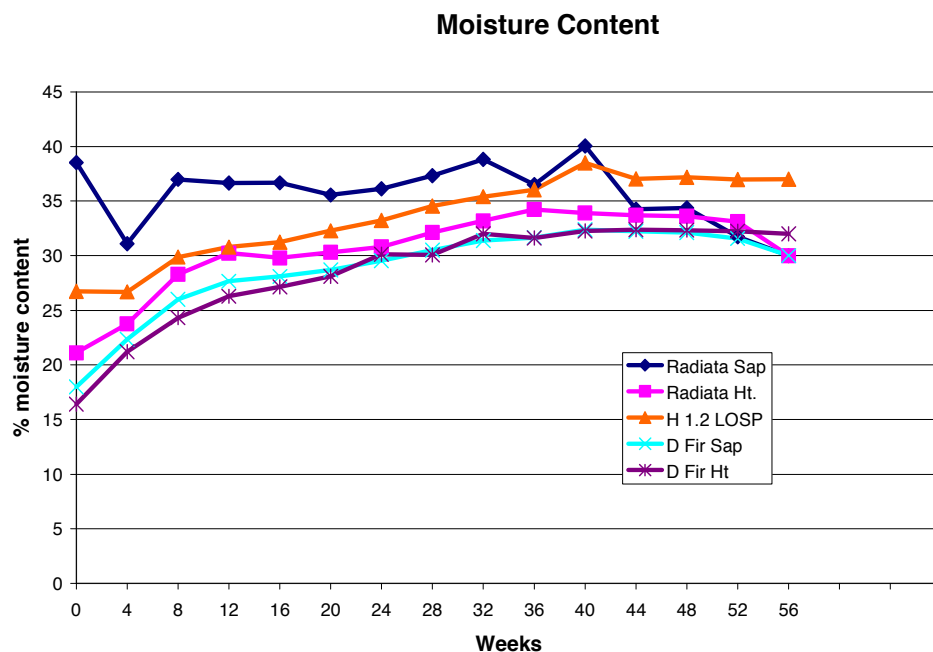


Figure 15: Mean moisture content of test samples.

Decay (Index of Condition)

The first sample failed in the untreated radiata pine sapwood group after 20 weeks, and after 105 weeks only two remained, both in poor condition. The first radiata pine heartwood sample failed after 48 weeks, 12 had failed at 105 weeks and there were two failures in the Douglas-fir heartwood group. There were no failures in the treated radiata pine group.

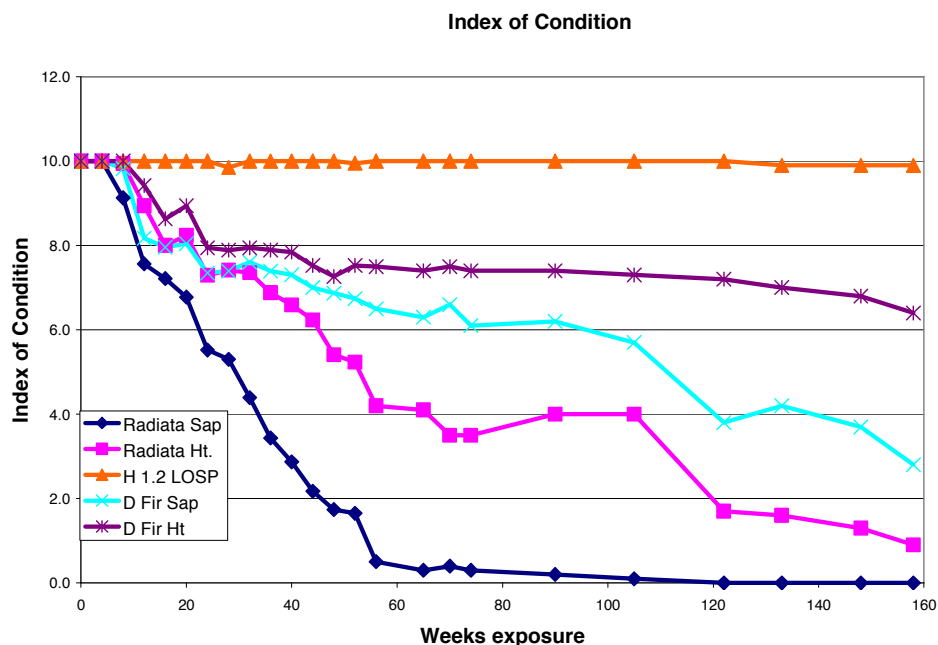


Figure 16: Index of Condition

Deflection

From Figure 17 it is seen that the initial deflections for both Douglas-fir sapwood and heartwood were approximately half that of the pine samples. The test rig was set up in such a manner that a deflection of 10 mm occurred when a sample broke.

Untreated radiata pine sapwood decayed rapidly, although it wasn't until the mean Index of Condition fell below 6 that deflection under load exceeded that at the start. Untreated radiata pine heartwood had greater decay resistance, and increases in mean deflection occurred more gradually.

Even though obvious decay was occurring in Douglas-fir, where Indices of Condition were between 6 and 8 after 64 weeks, no loss in stiffness was recorded in that time. Significant loss in stiffness in Douglas-fir sapwood commenced only at week 90 when Index of Condition was ~6. Increase in deflection of Douglas-fir heartwood commenced at week 106, and loss of stiffness progressed gradually during the remainder of the trial and tracked a similar reduction in Index of Condition. H1.2 treated radiata pine showed no loss of stiffness during the 158 weeks' exposure period, and there was only negligible loss in Index of Condition during this time.

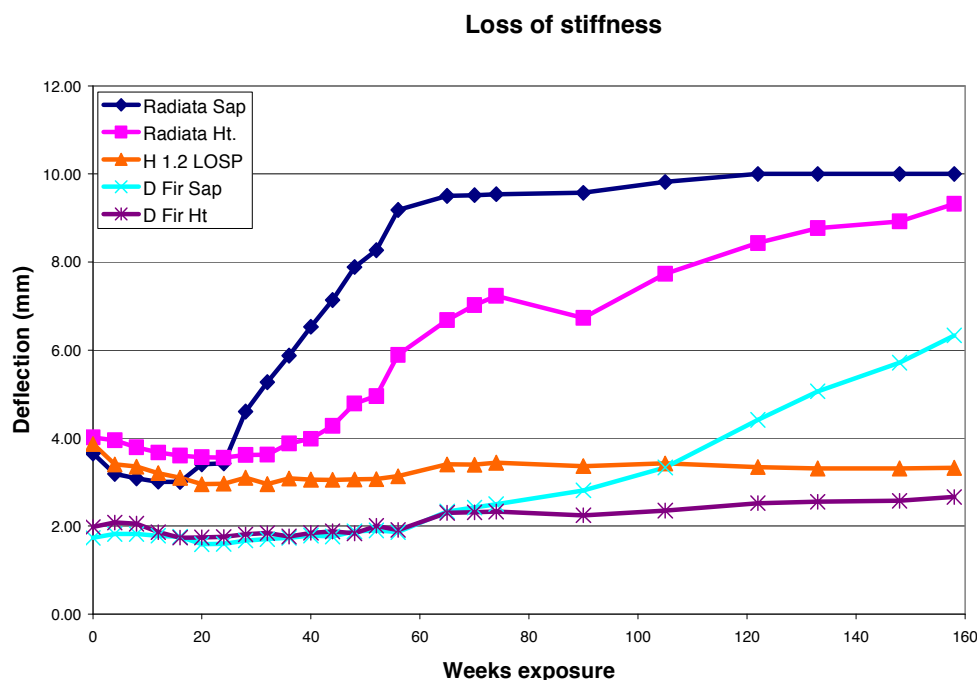


Figure 17: Deflection against time

Conclusions

Decreasing order of stiffness loss (and weeks to first measurable loss) was: untreated radiata pine sapwood (24), radiata pine heartwood (48), Douglas-fir sapwood (65), Douglas-fir heartwood (>106), treated radiata pine sapwood (>106). The results indicate that for untreated Douglas-fir in particular, the presence of observable decay – the main criterion for replacement of framing when a "leaky building" is rehabilitated – may not truly reflect residual stiffness, which would be retained when leaks were rectified and the framing dried. Remedial treatments of the Boracol® type could be applied as a very cost effective alternative to replacing the partly decayed framing.

Conclusions of Dr Paul Morris on Durability of Douglas-fir compared to untreated and treated radiata pine

This section summarises the comments and views of Dr Paul Morris, Group Leader, Durability and Protection at FPInnovations-Forintek Building Materials, Canada.

How does the relative durability of Douglas-fir lumber containing sapwood and heartwood compare to untreated and H1.2 treated radiata pine in wood frame buildings in New Zealand?

The durability required is the period between the onset of wetting due to errors in design, construction or maintenance and the time at which the problem is noted and corrected. Periods of 2 and 5 years are considered. This letter-report does not provide an extensive documentation of the background to the current situation in New Zealand, since it is assumed that the readers will be familiar with this information.

Key Assumptions:

1. The available information and data must be considered in the context of the New Zealand regulatory environment and not be influenced by Canadian codes and construction practices.
2. Under the severe wetting conditions during New Zealand's "Leaky Building Crisis", boron treated framing remained in reasonably good condition for around 5 years despite the onset of soft rot^[2].
3. The recently improved understanding of moisture issues and associated changes in design, construction and maintenance practices in New Zealand will not allow the same degree of severe wetting seen during the "Leaky Building Crisis" to occur. Buildings will be mostly in compliance the New Zealand Building Code, Clause E2/AS1 External Moisture, but errors in design, construction and maintenance will still occur.
4. The use of the 4D's as a decision aid acknowledges that Deflection, Drainage and Drying may not be 100% effective and Durability will be required for some wood components.
5. The requirement for radiata pine sapwood to be treated to H1.2 implies that there is still a probability of a decay hazard in wood frame buildings despite improvements in design. Work needs to be done by the building science community to determine if this assumption is correct by evaluating the range of moisture loads in buildings designed to meet E2/AS1. The time to unacceptable decay after the onset of wetting can be considered to have three components:
 1. Time to reach suitable moisture contents (MC) for decay.
 2. Time for colonization by wood-rotting basidiomycetes.
 3. Time for wood-rotting basidiomycetes to cause unacceptable strength loss.

Component 1: Time to reach suitable moisture contents (MC) for decay

The work of Bassett and McNeil^[3] showed that radiata pine transports water tangentially 2.3 times faster than Douglas-fir and radially 3.5 times faster when exposed to liquid water in a standard water permeability test. They showed that radiata pine wetted up to around 26% MC within hours while Douglas-fir reached only about 19% MC between one and two days after wetting when dosed with 10 ml of water at a stud/dwang joint. Hedley *et al.*^[1] found that radiata pine reached 27% MC, the minimum for decay initiation (Carll and Highley^[4]; Page *et al.*^[5]; Clark *et al.*^[6]), after initial artificial wetting and 6 days of rain. Douglas-fir failed to reach 27% MC over the 49 day duration of the trial, despite 40 mm of rain on one of those days. In a follow-up study, Hedley *et al.*^[1] found that radiata pine reached 27% MC after 2 days' exposure to natural rainfall while only one of 60 Douglas-fir samples reached this critical MC at one measurement time over 55 days. However, wood components inside wall systems do not have anywhere near the drying potential of wood exposed outdoors above ground. Hedley *et al.*^[7] found that radiata pine sapwood immersed

in water for 2 hours and placed into a damp chamber reached a MC close to 40% while Douglas-fir sapwood took over 10 weeks to reach 27% MC. This was primarily as a result of absorption of water vapour since liquid water was applied only once. There was no repeat wetting as might happen in a wall system with design or construction defects.

Research in Canada (Hazleden and Morris^[8]; Finch and Straube^[9]) indicates that rainscreen cavities can improve the drying capacity of wall systems, but the stud space is still a very slow drying environment. Bassett and McNeil^[10] showed improved drying by rainscreen in hygrothermal models, though their experiments (Bassett and McNeil^[11]) apparently showed little effect. They noted that their experiment should not be thought of as simulating a water leak that recurs with every rainfall. Net drying times for water trapped in framing were found to be species independent. Drying rates were so slow in winter that very little progress occurred until the early summer months when the drying process was completed (Bassett and McNeil^[10]). Wet framing in south facing experimental walls dried so slowly in the cooler months it could be at risk of decay (Bassett and McNeil^[11]). This work focused on drying capacity and further work is required on moisture load.

Component 2: Time for colonization by wood-rotting basidiomycetes

The work of Hedley *et al.*^[7, 12] and Page *et al.*^[5, 13] used artificial inoculation with wood-rotting basidiomycetes in all cases so there are no hard data to predict the time required for colonization by spores of wood-rotting basidiomycetes on radiata pine or Douglas-fir sapwood. However there have been reports of decay of radiata pine lumber which had become wetted in the lumber yard. Douglas-fir lumber is typically not kiln dried (Hedley *et al.*^[11]) and may thus harbour incipient decay even if air dried. Consequently the time required for colonisation by wood-rotting basidiomycetes will be considered to be unimportant and equal for both lumber species.

Component 3: Time for wood-rotting basidiomycetes to cause unacceptable strength loss

Hedley *et al.*^[7] found that radiata pine sapwood soaked for two hours, placed into a damp chamber and inoculated with a wood-rotting basidiomycete took around 24 weeks to show detectable change in stiffness, whereas Douglas-fir sapwood took around 65 weeks (including 10 weeks to equilibrate to 27% MC through adsorption of water vapour). Douglas-fir heartwood took over 106 weeks (the duration of the experiment) despite having reached 27% MC after 10 weeks. Boron treated radiata pine sapwood was also sound after 106 weeks.

In a similar experiment, Page *et al.*^[13] found radiata pine sapwood dropped below a rating of 7 (commonly used as a failure threshold) after about 35 days while Douglas-fir sapwood dropped below a rating of 7 after about 50 days. Douglas-fir heartwood took about 90 days. Boron treated radiata pine sapwood was still sound after 3 years. The data from a more severe test with repeated wetting (Hedley *et al.*^[14]; Hedley *et al.*^[12]) showed both untreated radiata pine and untreated Douglas-fir sapwood dropping below a rating of 7 in considerably less than 52 weeks. Boron treated radiata pine was free from basidiomycete attack and remained above a rating of 7 but had suffered some soft rot after 6 years.

Comparative time for all three components to reach critical levels

Douglas-fir sapwood = 1.5 - 2.7 times longer than untreated radiata pine sapwood

Douglas-fir heartwood = 3 - 6 times longer than untreated radiata pine sapwood

Boron treated radiata pine sapwood = 6 - 10 times longer than untreated radiata pine sapwood (excluding soft rot)

Generally, the higher multipliers apply to low wetting high drying conditions and the lower multipliers to high wetting low drying conditions.

To support the work from New Zealand, North American studies were reviewed on the durability of Douglas-fir sapwood compared to the sapwood of other pine species. Eslyn *et al.*^[15] found that Douglas-fir sapwood had an estimated service life 2.3 times longer than lodgepole pine sapwood when small dimension cross units were exposed above ground in Mississippi. Douglas-fir heartwood gave an estimated service life at least 3 times longer than lodgepole pine sapwood.

In a later evaluation of the same study, Douglas-fir sapwood gave an estimated service life 1.8 times longer than lodgepole pine sapwood^[16]. Douglas-fir heartwood again gave an estimated service life at least 3 times longer.

Boron-treated Hem-fir L-joints exposed outdoors did not suffer from basidiomycete attack, unlike untreated controls that dropped below a rating of 7 after 4 years (Morris *et al.*^[17]). The Boron-treated joints began to suffer from soft-rot after 8 years but were still above a rating of 7 after 17 years.

While relative rates of decay in laboratory tests are reasonably easy to determine, absolute times under real-life conditions are considerably more difficult. Given all the data reviewed above, the minimum probable times from leak initiation followed by periodic wetting before the leak is fixed, to unacceptable decay may be estimated as:

- Untreated radiata pine sapwood ≤ 1 year
- Untreated Douglas-fir sapwood 1.5 – 2.7 years
- Untreated Douglas-fir heartwood 3 – 6 years
- Boron treated radiata pine sapwood > 5 years

Conclusions

- The current requirement for five years protection would be provided only by Boron treated radiata pine sapwood and Boron treated Douglas-fir.
- If the required protection period were shortened to 2 or 3 years, a sapwood-free Douglas-fir product would provide adequate decay resistance.
- Untreated Douglas-fir sapwood would not be assured to provide a 2 year protection period.

The question that I can not answer is “What is the moisture load in wall systems designed to meet E2/AS1?” because the key difference between radiata pine and Douglas-fir sapwood is the rate at which they absorb liquid water. If there is no chance of Douglas-fir reaching 26% moisture content then there is no chance of decay.

Proposals by the Department of Building and Housing allowing restricted use of untreated Douglas-fir framing in residential buildings based on the above research

Preservative free (untreated) solid Douglas-fir framing may be used for roof members protected from the weather and for internal and external wall framing protected from the weather provided that the building meets all of the following requirements:

- a. is a stand alone single family dwelling of no more than two storeys and falls within NZS 3604 limits
- b. is situated in wind zones no greater than high as defined in NZS 3604
- c. has an envelope complexity of no greater than medium risk and a deck design no greater than low risk as defined by the risk matrix in E2/AS1
- d. has drained and vented cavities complying with E2/AS1 between the framing and cladding
- e. uses roof and wall cladding systems and details conforming with Acceptable Solution E2/AS1
- f. has a risk matrix score of no more than 6 on any wall as defined in E2/AS1
- g. has a simple pitched roof incorporating hips, valleys, gables, or mono pitches, all draining directly to external gutters, but excluding internal or secret gutters, concealed gutters behind fascias; and any or any roof element finishing within the boundaries formed by exterior walls (eg, the lower ends of aprons, chimneys, dormers, clerestories, box windows, etc)
- h. has a roof slope of not less than 10°
- i. if it has a skillion roof, then the roofing material shall be corrugated iron or concrete, metal or clay tiles to ensure adequate ventilation
- j. has eaves 450 mm wide or greater for single storey houses or eaves 600 mm or greater for two storey houses.

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APPENDIX I

Rating Systems used for Sample Assessments

Mycelium Spread Rating System

- 1 = No mycelium development onto the framing surface.
- 2 = Mycelium from the feeder block on the framing surface, spread less than 5 mm.
- 3 = Active mycelium over <50% of the plate/dwang surface.
- 4 = Mycelium over >50% the plate/dwang surface.
- 5 = Extensive mycelium development over all framing components.

Decay Rating System*

- 10 = No decay or insect damage.
- T = Serious discolouration not positively identified as decay.
- 9 = First stages of decay or damage up to 3% of cross-section.
- 8 = Lightly established decay, 3-10% of cross-section.
- 7 = Well established decay, 10-30% of cross section.
- 6 = Deep established decay, 30-50% of cross section.
- 4 = Severe decay, nearing failure, more than 50% of the cross section.
- 0 = Failed, disintegrating.

*Index of condition is the average decay rating for all of the items in a group.

Mould Rating System

- 1 = No mould.
- 2 = Light mould or a few scattered spots.
- 3 = Widespread scattered mould spots.
- 4 = Patches of mould, <50% of the surfaces covered.
- 5 = Extensive or widespread mould, >50% of the surfaces covered.