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The development of accelerated test methods to evaluate the durability of framing timber

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ABSTRACT

Various accelerated decay resistance trials, including small simulated wall units, samples exposed in enclosed tanks and 'I' samples in stacks, have been explored and used to test the durability of treated and untreated radiata pine framing at Scion since 2001. These testing methods have been established to determine the effectiveness of commercial formulations in preventing decay in framing subjected to intermittent wetting. These are relatively short term test methods requiring a minimum of 12 months testing.

Results of these tests have been used to develop suitable preservative formulations and retentions for Hazard Class H1.2 for inclusion in New Zealand Standard for Chemical Preservation of Round and Sawn Timber (NZS, 3640). In New Zealand framing hazard Class H1.2 is for timber that is protected from the weather but with a risk of wood reaching a moisture content conductive to decay.

In this communication, we discuss the advantages and disadvantages of these test methods.

1. Introduction

Timber frame construction is the predominant form of residential construction used in New Zealand, Australia, USA and many Scandinavian countries. In New Zealand, Standard NZS 3602 (NZS 3602, 2003), specifies durability requirements of wood and wood based building components. NZS 3602 refers to timber treated to hazard classes as defined by NZS 3640, Chemical Preservation of Round and Sawn Timber. Hazard Classes are divided into H1, H1.2, H3.1, H3.2, H4, H5 and H6, based on the biological hazards expected for the end use situation of timber. Hazard Class H1.2 in NZ relates to wall framing which is defined as "Protected from the weather, above ground, but with a possibility of exposure to moisture" (NZS 3640, 2003). The hazard class was developed to overcome the leaky building syndrome that has been prevalent in NZ for last 15–20 years (Hedley et al., 2002; Groufsky, 2008; Singh et al., 2013). Hazard Class H1.2 had not been regarded as at high risk to decay until some years after the use of untreated, kiln-dried radiata pine was approved in the building code in 1993 (Hunn et al., 2002).

Problems with leaky buildings and decay of framing began to show up in the late 1990's (Hardie, 1997). These were associated with changes in building design, building materials and workmanship. Many of the leaky buildings included features such as a lack of eaves, stucco style cladding, seamless wrap around cladding systems and complex roof designs (Hazleden and Morris, 1999; Hunn et al., 2002). In response to decay developing in framing, companies involved in the wood preservation industry began looking at specialised framing treatment systems that would be suitable for kiln-dried framing which may be subjected to occasional wetting (Hedley et al., 2002; Page et al., 2003). In 2003, H1.2 was introduced, an indoor decay hazard requiring temporary protection should the wood get wet through leaks in the building envelope – protection for sufficient time for the leaks to be detected and rectified (NZS 3640, 2003).

The development of protocols to assess preservative systems for temporary (up to 5 years) protection of framing timber is an ongoing activity at Scion. There are few internationally recognised methods for testing the resistance of framing to decay. Currently, only one method is listed in the Australasian Wood Preservation Committee's (AWPC, 2007) protocols for preservative evaluation in Australian and New Zealand.

This paper summarises the various test methods evaluated and developed for Hazard Class H1.2 testing since 2001. H1.2 is comparable to UC2 in the United States and hazard class 2 in Europe and many other parts of the world.

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2. Materials and methods

2.1. The simulated wall unit method

The initial approach was to build wall sections that contained most of the features found in exterior wall construction in New Zealand where there had been decay problems. This included vertical and horizontal framing components, nailed together, fibre-cement exterior cladding attached directly to the framing, insulation in the wall cavities and a lining material on what would normally be on the interior side of the frame.

The wall units were relatively small, only 0.6 m high × 0.5 m wide with two vertical "studs", a top and bottom plate and a single horizontal dwang between the two studs at their mid-point. The timber used was kiln-dried, framing grade, 90 × 45 mm, gauged radiata pine that included some heartwood. Treated or untreated timber wall units were produced, and all timber in each unit had the same treatments.

Once the timber components were assembled the frames were immersed in water and placed in a pressure cylinder. A short low pressure schedule was used for each treatment group to raise the moisture content in the framing to above 30%. Different schedules were used for each preservative type to accommodate different water absorbency rates associated with water-based and LOSP or water repellent treated wood. The back, bottom and top of the units were then covered with polythene.

Pinus radiata sapwood feeder blocks, approximately 7 × 43 × 70 mm with variable grain orientation, were sterilized by exposure to ethylene oxide gas and placed in prepared containers with 2% malt-agar nutrient medium inoculated with a pure culture of common leaky building associated fungi (Eaton and Hale, 1993); either *Coniophora puteana* or a *Oligoporus placenta*. They were then incubated for nearly four weeks at 25 °C and 85% RH (Singh et al., 2013).

The partly decayed feeder blocks were fixed to the upper surface of the bottom plate and the dwang, adjacent to the studs. On one side the two feeder blocks contained *O. placenta*, on the other side the decay fungus was *C. puteana*. Before the decay feeder blocks were installed in the units, the surfaces adjacent to the feeder block positions were swabbed with alcohol. The insulation was immersed in water and allowed to drain before it was installed in the cavities, then the building paper and fibre cement exterior cladding were attached.

Half of the assembled units were placed in a controlled conditions facility at Scion, where the temperature was constant at 25 °C and the relative humidity was approximately 95%. Frame units were stacked in racks and sprayed with water for a short period each week to simulate occasional rain wetting. The remaining units were placed on bearers in a shaded outdoor area where they were fully exposed to wetting by rain.

Units were usually assessed after 12 weeks and 26 weeks exposure and at six-monthly intervals thereafter using a standard (AWPA Standard E7-93). The fibre-cement panel, building paper and fibreglass insulation were removed. The moisture content of each framing component was measured using a resistance type moisture meter with 30 mm long probes. Each component was assessed for mould, decay mycelium spread and decay as shown in Appendix 1. Mould rating and decay mycelium spread rating were only used to check activity on the surface (data is not presented). They were ignored when samples were assessed for decay. The exposed surfaces of the framing were probed with a blunt, 3 mm diameter, steel probe to determine decay. Each component was given numerical decay ratings as shown in Appendix I. The insulation, building paper and sheathing panel were refitted and the unit returned to the exposure racks.

2.2. The enclosed tank method

The enclosed tank method was established to compare a large number of treatment variables for resistance to decay in framing. The tanks were plastic, approximately 1 m long, 750 mm wide and up to 800 mm deep. They had a drain hole about 20 mm above the bottom and a tight fitting lid. Samples were placed on 40 mm thick bearers in the bottom of the tank with subsequent layers separated by 20 mm thick fillets (Fig. 1). A rigid panel was placed on fillets on top of the stack and a 40 mm thick foam plastic blanket fitted between that and the lid. The bottom of the tank was filled with water to a depth of about 20 mm and the foam blanket was saturated with water to maintain a humid atmosphere in the tanks. The tanks were kept in the controlled conditions facility (25 °C and 95% RH), or outside and regularly opened (usually weekly) so that the samples could be sprayed with water.

In the initial test the objective was to determine the approximate moisture content in framing required to initiate decay. Framing samples approximately 700 mm long were pre-wet to give five moisture content ranges i.e., <20%, 20–25%, 25–30%, and 30–40%. Samples from each moisture content group were placed in separate tanks. They were stacked on the flat, with pre-decayed feeder blocks infected with a brown rot fungus attached on one face at each end. At one end of the samples the feeder block was colonised by *Antrodia xantha*, while the feeder block at the other end was colonised by *Oligoporus placenta*. These two fungi were included because they are often isolated from leaky building timbers (Schmidt and Moreth, 2003; Schmidt, 2007; Stahlhut, 2008).

In subsequent tests where resistance to decay was the only variable to be measured, framing samples 500–700 mm long were rewetted to above 25% moisture content and stacked in layers in the tanks. Assessments of samples were at similar intervals to those for wall units using the same mould, mycelium development and decay rating systems. Data is only presented for decay rating. The samples were weighed before each assessment and the approximate moisture content of each sample was determined.

In tests where rates of strength loss and decay were to be compared, samples were 950 mm long and a single decay feeder block, containing *O. placenta*, was attached mid-length on one edge of the samples. Samples without feeder blocks were also included. Assessments were more frequent at 2–8 week intervals and included weight, deflection as a plank under constant load (Singh et al., 2013) as well as decay development ratings.

Fig. 1. Samples in an enclosed tank test. The decay feeder block at the far end was *Antrodia xantha*, while at the near end it was infected with *O. placenta*.

With some framing treatments it was likely that preservative penetration was limited to the outer few millimetres and that the untreated core would be vulnerable to decay when the timber was cut after treatment. This included engineered wood products such as laminated veneer lumber (LVL) and plywood. For these tests the samples were end-sealed with epoxy paint before an 85 mm long block was cut off each end and then reattached using stainless steel staples. Decay feeder blocks were placed on the surface of the main samples, at each end, adjacent to the stapled joints (Fig. 1). These samples were assessed as previously except that staples were removed from the joints and the joint surfaces were rated separately for decay development. Samples were stapled back together after assessment.

2.3. "I" sample tests

The enclosed tank method did not contain the most common joint found in traditional wall framing, i.e., where a treated longitudinal grain surface is in close contact with a freshly cut end. To simulate this joint a 90 mm long block was cut from each end of 900 mm long framing samples. The ends of the blocks were sealed with epoxy paint. These blocks were then placed across the end of the sample that they were cut from and stapled in place so that the treated surface was in contact with the freshly cut end-grain of the main sample. This formed an "I" shaped assembly.

Samples were pre-wetted and decay feeder blocks were attached to the main sample on the faces, immediately adjacent to the end block. The *O. placenta* feeder block at one end was on one face and the *A. xantha* feeder block at the other end was on the opposite face. Samples were placed on edge in a filleted stack, with the epoxy painted ends of the end blocks in contact (Fig. 2). Along the top of the stack, two rows of soaker hose were attached with the perforations in the hose facing down. Fibre cement sheets were placed on fillets over the top of the stack and a 30 mm thick foam plastic blanket was placed on top of those sheets. The stack was completely enveloped in polythene film in a controlled condition room where the temperature was 27 °C and the relative humidity about 85%. The spray system was turned on for 10 min every 7–10 days and surplus water from the spray was able to drain slowly from the bottom of the stacks.

The assessment of samples from these stacks was similar to that for the enclosed tank method. End blocks were removed and the exposed main sample ends were assessed for decay. The samples were stapled back together and returned to their original position in the stack.

3. Results and discussion

3.1. The simulated wall unit method

The original test was intended to show whether the small wall units would produce similar decay to that seen in leaky buildings, whether the method would be suitable for testing preservatives for framing and whether meaningful results could be obtained within a relatively short time (Hedley et al., 2002).

The wall units were small enough to move around while incorporating many of the elements that were present in "leaky buildings". They allowed easy removal of the cladding for assessment of the framing in the enclosed section of the unit. Polythene was used on the "back" of the units instead of plaster board because it was likely to be longer lasting and would be lighter. The main requirement was that it would help to maintain a moist atmosphere in the unit while allowing any surplus water to slowly drain out.

Decay spread rapidly from the feeder blocks in the untreated control units. The framing in these started to decay within 12 weeks of installation (Fig. 3).

Within six months severe decay had developed in the untreated, kiln-dried framing units and after twelve months components in these units were beginning to fail (Fig. 4).

Units exposed in the controlled conditions facility contained more decay than those exposed outside. Similar to previous research, where the use of decay feeder blocks was shown to increase the rate of decay (Morris et al., 2009), our test clearly indicated that feeder blocks from known sources caused rapid deterioration of framing timber.

The moisture content in the frame units varied with top plates and the upper section of the studs remaining relatively dry whereas the bottom plates became very wet. This influenced decay development on the various components but was regarded as being similar to the type of conditions that would prevail in "leaky buildings" (Hedley et al., 2009).

In an early test the decay feeder blocks were fixed directly to the framing. It was noted that feeder blocks in one group of treated

Fig. 2. "I" samples in an exposure stack. The decay feeder blocks visible on the right were *O. placenta*. The feeder blocks at the left end were on the reverse face and were infected with *A. xantha*.

Fig. 3. An untreated wall unit after twelve weeks exposure. The fibreglass insulation has been removed from the lower half to allow assessment of decay. Mycelium from the *O. placenta* feeder blocks (on the left) was spreading through the fibreglass insulation and on the surfaces of the framing. *C. puteana* mycelium (on the right) had spread up the right stud across the dwang into the fibreglass and across the building paper.

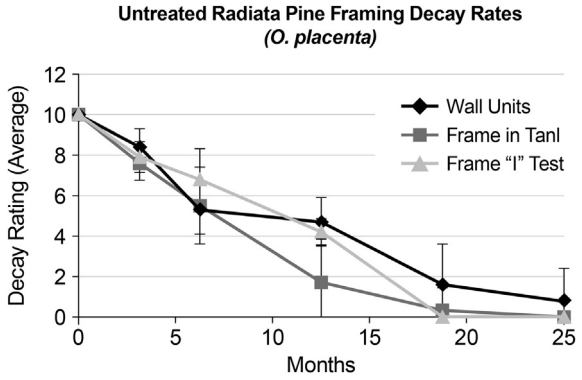

Fig. 4. A comparison of rate of decay on untreated pine using various test methods.

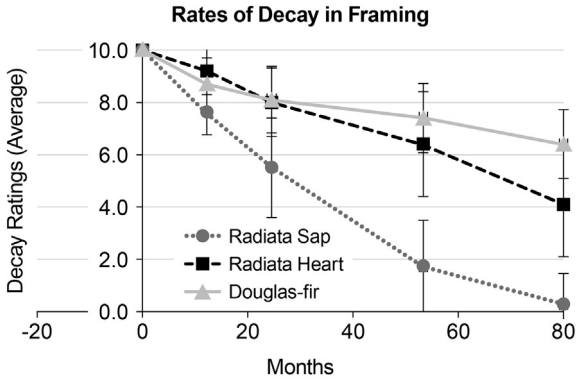

Fig. 5. Decay rates in framing from enclosed tank exposure of samples for testing of strength loss associated with decay. After 12 months radiata pine sapwood samples had largely failed and radiata pine heartwood samples all contained moderate-severe decay.

units had deteriorated and ceased activity within days of installation. This may have been caused by the preservative diffusing out of the treated samples into the feeder blocks. Subsequently a 1.5 mm thick plastic washer was placed between the feeder blocks and the framing. This appeared to have little effect on decay development from the feeder blocks.

While the original frame unit tests appeared to meet all of the objectives for testing the decay resistance of framing they were relatively expensive to assemble and required a lot of space for exposure in controlled conditions.

3.2. The enclosed tank method

The decay results were very similar to those from the wall unit tests following the patterns with untreated pine with severe decay in 6–12 months (Fig. 4) suggested that enclosing framing samples in tanks could be a suitable alternative to the wall unit method (Hedley et al., 2008).

As enclosed tank tests progressed, condensation at the top and on the side of the tanks tended to increase the moisture content of outer samples and the moisture content of samples in the centre of the tanks gradually decreased. While this obviously influenced decay development, variable moisture content was seen as likely to be a feature in normal "leaky building" situations (Stahlhut, 2008).

In the initial enclosed tank trial untreated radiata pine fillets were used between sample layers. Decay mycelium spread rapidly along fillets from control and other decaying samples. Samples immediately adjacent to the control samples were thus exposed to more contact with decaying wood than those which were some distance from control samples. In all subsequent tests, plastic fillets were placed between layers. These did not prevent mycelium spreading between samples and between layers but did reduce the amount of decaying wood that samples were in direct contact with.

Framing used in the tests was initially either kiln-dried untreated or air-dry preservative treated. It was pre-wetted before the decay feeder blocks were attached, usually to a moisture content above 25%. This was initially achieved by immersing the frames or samples in water in a tank and putting them through a low pressure treatment schedule. This re-wetting schedule varied slightly depending on the type of samples, with the intention of having all samples at similar moisture content when they were initially installed. It was argued that this introduced some bias into the tests because in "leaky buildings" framing treated with solvent-based preservatives or water repellents would absorb less water than water-based preservative treated and untreated framing (Banks, 1973; Hedley et al., 2008). In later tests all sample groups were immersed in water for a set period, equivalent to that required for re-wetting kiln-dried, untreated radiata pine above 25% moisture content.

In tests where decay rates and strength loss were compared, decay developed rapidly from feeder blocks on the wetter samples but deflection did not consistently increase until moderate-severe decay was established (Figs. 5 and 6). On untreated radiata pine sapwood samples this took 6–8 weeks with the first failures occurring after 12 weeks. Samples without feeder blocks did not develop decay until trials had been running for more than a year and were often infected by species of decay fungi different from those used in feeder blocks.

In test where end blocks were cut off and stapled back, decay developed rapidly in untreated pine framing and framing treated with products that did not contain a fungicide. It also developed in the centre of the end block joints on samples with incomplete preservative penetration and in tests of species other than radiata pine where preservative penetration was incomplete in sapwood (Fig. 7).

In tank tests of LVL and plywood, decay mycelium spread rapidly onto untreated samples from the feeder blocks but then appeared to degenerate and become inactive. Although feeder blocks were replaced and mycelium again spread onto the surface of the samples, degeneration of feeder blocks and mycelium recurred. Untreated and treated pine framing samples in the same tests decayed in a similar manner to equivalent samples in previous tests, to the stage where mycelium from decay in untreated timber samples spread to adjacent LVL and plywood samples. The problem with degeneration of feeder blocks on the LVL and plywood samples continued and limited decay developed indicating that this method would need to be modified if it was to be used to test LVL or plywood.

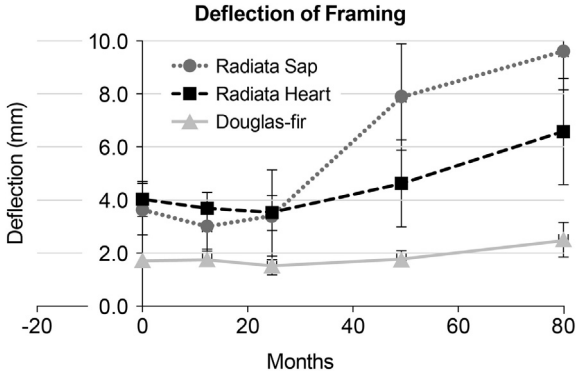

Fig. 6. Deflection of decaying framing from enclosed tank (outside) tests did not begin to increase until the rate of decay was between 7 and 6 (Fig. 5).

Fig. 7. The joint surfaces in treated macrocarpa where preservative penetration was incomplete, after 18 months exposure in an enclosed tank. There was no decay on the outside of this sample but there was severe internal decay in the sapwood.

Two features likely to have caused this problem were a high pH in the products or traces of residual formaldehyde from the phenol-formaldehyde glue. This suggests that plywood or LVL samples need to go through a leaching process prior to decay testing.

3.3. "I" sample tests

Decay development in "I" sample tests was similar to that in both the frame unit and enclosed tank tests (Fig. 4). After six months exposure there was severe decay in all of the untreated samples. As with the enclosed tank tests there was a range of moisture content in samples through the stacks although variation was more associated with the position of spray lines than with the position of samples within the stack.

Although 20 mm thick fillets were still used between layers, the main sample sections were much further apart and there was less opportunity for decay to transfer from untreated samples to adjacent treated samples. Decay from untreated control samples did infect the end blocks of a few of the adjacent treated samples but did not transfer from the end blocks into the main section of the treated samples.

The main advantage of tank and "I" sample tests over the wall unit test was that a large number of treatment variables could be tested at much lower cost. Wall units were not only expensive to construct, they required a lot of space in controlled environment facilities.

The "I" sample test's main advantage over enclosed tank tests with straight or jointed samples were that it included a common framing joint. Where a large number of samples were involved they could all be included in a single stack. In small tests involving only 20-30 samples, a tank rather than polythene film could be used to enclose the samples.

Tests exposed in ambient outdoor conditions took much longer to produce results than those exposed in controlled conditions, hence controlled conditions exposure was generally favoured for decay testing.

4. Conclusions

All the test methods showed that it was possible to get severe decay in untreated components in a 25-week exposure period.

While the wall unit test more loosely simulated the types of conditions that occurred in leaky buildings, it was relatively expensive to set up and to maintain in controlled conditions.

Tank tests using straight and jointed samples, while producing similar decay results to wall unit tests at a much lower cost, did not include joints commonly seen in building construction. Tests using "I" samples duplicated common construction joints while limiting test establishment and maintenance costs.

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Appendix I

Ratings Sytems used for Sample Assessments

Mycelium Spread Ratings

1 = No mycelium development onto the sample surface.
2 = Mycelium on the surface in the immediate vicinity of the feeder block.
3 = Active mycelium from the feeder block on the surface, spread <50 mm.
4 = Active mycelium development >50 mm from the feeder block.
5 = Extensive mycelium development over <50% of the surface area.
6 = Extensive mycelium development over >50% of the surface area.

Mould Ratings

1 = No perceivable mould.
2 = Light mould patches or a few widely scattered spots.
3 = Numerous spots or widespread light mould.
4 = Severe mould, up to 50% coverage.
5 = Severe mould, >50% coverage.

Decay Ratings

10 = No decay.
T = Trace, discolouration or softening, 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.

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