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L J Cookson Consulting, Report No.XXX DRAFT

Technical review on the boron treatment of LVL to meet H1.2 conditions in New Zealand

L.J. COOKSON
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Laurie J Cookson

Date: 29 June 2016

Client: Ministry of Business, Innovation and Employment, Wellington, New Zealand.

Important Disclaimer

LJ COOKSON Independent Consulting

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OBJECTIVE

The objective of this review was to examine the decision that J-Frame (H1.2 boron treated LVL) as produced by Juken New Zealand Ltd (JNL) complies with the B2 durability provisions of the New Zealand Building Code. CodeMark compliance was provided for the product by AssureQuality in 2015 in their Product Certificate Aq-180615-CMNZ.

INFORMATION SOURCES

The main documents used for this review included:

1. CodeMark Certificate Number Aq-180615-CMNZ, issued 18 June 2015.
2. Simpson and Singh (2016) The decay resistance of boron treated LVL framing. The condition of samples after twelve months exposure. Scion report.
3. Tim Rigter (11 May 2015) letter to MBIE.
4. NZS 3640:2003, Chemical preservation of round and sawn timber.
5. NZS 3640:2003 Amendment 5 2012.
6. AS/NZS 1604.4:2012, Specification for preservative treatment. Part 4: Laminated veneer lumber (LVL).
7. AS/NZS 1605.2:2006, Methods for sampling and analysing timber preservatives and preservative-treated timber. Part 2: Determination of preservative penetration by spot tests.
8. AWPC Protocols for Assessment of Wood Preservatives.
9. Jon Tanner (10 June 2016) email to MBIE.
10. B2 Durability in New Zealand Building Code.
11. AssureQuality analysis sheets for Scion trial showing heartwood/sapwood spot test, boron penetration spot test, cross section retention and inner one-ninth retention for 10 boards from the Scion treatments for samples A (untreated LVL), C (boron treated solid pine), D (boron treated LVL), and F (boron treated 145 x 45 mm LVL). Also, retention results for samples E (lower uptake LVL).
12. Veritec analysis sheets for the three replicates (samples 1-3) of each boron treatment as shown in the Scion report.
13. Veritec analysis sheets for all ten replicates (samples 1-10) of each boron treatment used in the Scion report.
14. JNL treatment summary sheet for Scion trial which includes product dimensions when treated (from which 900 mm was cut for decay trial).
15. JNL treatment charge sheets showing vacuum periods etc. for LVL used in the Scion report.
16. Drysdale, J.A., Marston, N. and M.E. Hedley (2011). A method for studying boron redistribution and leaching in timber framing. IRG Document 11-20476.
17. Subsequent email replies from JNL and Red Stag.
18. A number of additional confidential documents supplied by JNL.

HISTORICAL

Softwood house framing in New Zealand has long been treated with boron with the anticipation that it would be needed to control *Anobium* borer. However, the risk from *Anobium* was overstated, so that in 1995 untreated framing was allowed and its use widely implemented. What was not fully realised at the time is that the same boron treatments used to control insects were also controlling decay fungi, as shown in later work by Mick Hedley. While building practices should not allow the ingress of moisture to reach house framing, changed practices such as the reduction of eave widths, monolithic cladding, and a move from metal flashings to sealants were amongst some of the factors leading to the leaky building syndrome and its associated decay problems. In response, H1.2 treatments were introduced to protect against fungal decay in interior house framing.

The Wall Frame Cavity Test was incorporated into the 2007 revision of the AWPC protocols as a method for determining which wood treatments were suitable for H1.2. In the latest 2015 revision, an I-Frame Sample Test was included, and is now the preferred method used by Scion. Not surprisingly, boron treatments at the appropriate retentions were found to be effective for H1.2 'solid wood' (as distinguished from LVL and other composites).

Boron is a leachable preservative that can redistribute after treatment (Drysdale et al. 2011), so it is worth noting that while H1.2 house framing should last at least 50 years, '...the preservative treatment is not designed for extended exposure to elevated moisture content' (commentary clause C3.1, Amendment 5). Similarly, the AWPC protocols now state that H1.2 treatments are meant to provide 'temporary (up to 5 years) protection of framing timbers' against leaky building problems. If water ingress is occurring, then associated problems such as staining and mould growth should (hopefully) allow it to be detected and remedied.

RETENTION AND PENETRATION REQUIREMENTS

For the boron treatment of solid softwood (NZS 3640), the full cross-section should have a minimum retention of 0.40% m/m boric acid equivalent (BAE) oven dried wood. An inner one-ninth retention is not applicable. This same retention should be sufficient in fully penetrated LVL, and indeed the majority of LVL retentions listed in AS/NZS 1604.4 were copied directly from AS 1604.1, the standard for solid wood. Heartwood penetration for H1.2 is not specified in NZS 3640; however, I assume it would be similar to the NZ H3 requirements where no minimum retention in heartwood is specified, as long as the timber is treated in final shape and form. Note that the retention is written as 0.40% not 0.4%, which means that retentions must be given to 2 decimal places not one, which usually prevents retentions such as 0.39% being rounded up and passed.

In 2012 in both NZS 3650 amendment 5 and AS/NZS 1604.4, a glueline additive for LVL using triadimefon and cyproconazole was included as an H1.2 treatment. Being a glueline treatment, there was no requirement for evidence of penetration of the actives into the timber itself, as it could remain associated with the glueline as long as minimum retentions in the full cross section of LVL were achieved and the maximum thickness of veneers was 4.3 mm.

For H1.2 boron treated LVL, there is no specific or unambiguous penetration guidance provided to date in the standards. Since 1939 in Australia, the main treatment method used to obtain full sapwood penetration with boron for the protection of hardwood plywood against lyctine borers was by dip diffusion of the individual veneers before gluing. However, it was found that boron then caused problems when gluing the veneers together with phenol formaldehyde (PF) resin. Therefore, the preferred treatment method for hardwood veneers moved towards dipping in NaF, followed in later years to the alternative of dipping in pyrethroids. Treatment of LVL after gluing would circumvent the adhesion problem associated with boron; however, penetration can then be inhibited by glue-bonds, the random location of impervious heartwood, and sapwood grain orientation. Penetration in radiata pine sapwood can be difficult in the tangential direction, irrespective of the severity of treatment, while the radial and longitudinal directions are easily penetrated. Therefore, while the face veneers of LVL are easily treated, penetration of the interior veneers can be variable.

s 9(2)(b)(i), s 9(2)(b)(ii)

[redacted]

To provide guidance on what penetration pattern should be used for boron treated LVL for use in New Zealand, there is clause 1.9 in AS/NZS 1604.4 which states 'Preservative penetration shall be in accordance with this Standard (AS/NZS 1604.4)'. However, there is no penetration requirement in AS/NZS 1604.4 for H1.2 (clause 2.3.2) as the only treatment mentioned is the glueline treatment with triadimefon and cyproconazole. Therefore, JNL uses the penetration guidance given for H1 in clause 2.2.2 where 'All preservative-treated veneers shall show evidence of the distribution of the preservative in the sapwood.' This clause is actually meant for lyctine borer control in hardwoods under Australia's H1 exposure conditions. However, it is usually transferable to New Zealand's H1.1 where *Anobium* borer, especially in softwoods, is of greater concern. The feeding mechanisms between the two groups, borers and fungi, are quite different with one decaying on the microscopic level while the other ingests larger pieces. Therefore, a better distribution or microdistribution of preservative may be required to control fungi than is needed to control insect pests. The penetration requirement for the fungal hazard in H1.2 is likely to be better inferred from other hazard classes that include a fungal hazard, such as H3. Clause 2.2.2 in H1 may not adequately cover H1.2.

Nevertheless, the phrase 'evidence of preservative penetration' is used for the hazard classes more extreme than H1.2, for example in H3. Meeting an H3 penetration pattern should also meet H1.2. Where the phrase is being used for 'veneer penetration' (e.g. clause 4.2 (b)) that is meant for LVL where the veneers were treated prior to gluing (clause 1.4.15). As the J-Frame is treated after gluing, it is considered to be an envelope penetration (clause 4.2 (a)). There are several options for H3 envelope penetration, which can include (clause 4.2 (a) (iii)) '...and all sapwood in any veneer shall show evidence of preservative penetration.' The main difference between this and similar phrases using 'evidence of' as used in clause 2.2.2 is the emphasis placed on 'all'. In 2.2.2 the evidence should be in all veneers, while in 4.2 (a) (iii) the evidence should be in all sapwood. I cannot recall the details of this fine difference, or whether it was intended, but it may mean that 2.2.2 is passed if boron is found in just some sapwood locations within the veneers, as long as all veneers have some penetration. To pass clause 4.2 (a) (iii) it may require all sapwood to be penetrated, or does it mean that some portion of the sapwood in each veneer should contain some penetration, which would make it similar to clause 2.2.2? Clause 1.8.2 also states that LVL 'shall show evidence of the preservative in the penetration zone..'

To add to the ambiguity, AS/NZS 1605.2:2006 (Determination of preservative penetration by spot tests) states that 'the preservative shall be continuously distributed over the penetration zone...' This standard should be followed when conducting spot tests such as those for boron, and the phrase 'continuously distributed' sets a higher threshold for detection of preservative penetration than would 'evidence of distribution'.

An opinion provided by s 9(2)(a) on 5 August 2015 considers penetration statements for H1 and H1.2 and concludes that 'It is therefore a reasonable interpretation that the analysis zone for a minimum penetration pattern for H1.2 LVL should be full sapwood penetration.' This would be a stringent penetration requirement for LVL, requiring full sapwood penetration as is required for H1.2 solid wood in NZS 3640. The difficulty of penetrating all internal sapwood in LVL is allowed for to some extent in AS 1604.4 for H3 where the various options can allow for some level of unpenetrated sapwood.

There are discussions in Australia and New Zealand on how best to align these various phrases, and there are revisions to the AS/NZS 1604 series currently in the preballot draft phase. However, any changes have not been finalised so that JNL should use the wording currently available in the standards. Nevertheless, it can be concluded that AS/NZS 1604.4 does not provide a clear penetration specification for non-glueline treatments for H1.2.

AS/NZS 1604.4 also requires some level of heartwood penetration; although, it could be argued that this heartwood penetration does not apply in New Zealand, along similar lines to its non-requirement for solid wood when treated in final form as stated in NZS 3640 for H3.1 and H3.2, and by omission, presumably in H1.1 and H1.2 as well.

The CodeMark Certificate Aq-180615-CMNZ shows that JNL treats in accordance with clause 1.9 of AS/NZS 1604.4:2012. JNL seeks to meet treatment compliance by targeting a high retention combined with evidence of distribution in the sapwood in the penetration zone. However, the previous discussion shows that the Australian and New Zealand standards have yet to catch up with the H1.2 boron treatment of LVL after gluing, and provide unambiguous penetration guidelines. In future revisions of the standards, the penetration pattern required should be determined from the treatments that perform well in H1.2 durability trials. The final proof of what works will be obtained from durability trials, rather than untested penetration pattern specifications. The opinion provided by s 9(2)(a) s 9(2)(a) also states that 'While Points 1 and 2 (which deal with penetration and the chemical used) may be reasonable projections, they require underpinning by efficacy trials that demonstrate comparable decay resistance performance of H1.2 LVL.'

SCION H1.2 DECAY TRIAL

Preparation of test material

Concerns were raised by Red Stag about the independence of test specimen preparation for the Scion I-Frame Sample Test, and the veracity of the associated retention and penetration analyses. The AWPC protocols state, 'If test timbers are treated by the preservative company, then the treatment work shall be witnessed by an independent party, and/or a representative sample of test specimens shall be chemically analysed by an independent laboratory.' The former does not appear to have occurred; however, a representative sample was taken for chemical analysis so that this requirement was fulfilled. Scion tested six timber types of radiata pine:

A = J-Frame untreated control 90 x 45 mm profile.
B = Solid wood untreated control 90 x 45 mm.
C = Solid wood H1.2 boron treated 90 x 45 mm.
D = J-Frame H1.2 boron normal uptake 90 x 45 mm.
E = J-Frame H1.2 boron lower uptake 90 x 45 mm.
F = J-Frame H1.2 boron normal uptake 140 x 45 mm (wide pieces).

I have since learnt that all J-Frame treatments were conducted by JNL, while the solid wood H1.2 boron treated timber was obtained elsewhere (original treatment lengths not specified). The E samples refer to an experimental treatment schedule, so that these samples do not require detailed consideration in this review.

The Scion report provided retention and penetration results for samples 1-3 from each of the boron treated samples that they tested, which on its own is not enough for CodeMark approval, and spurred concern from Red Stag. However, I have since been provided with the full set of analyses by both AssureQuality and Veritec for all ten replicates of each treatment. The J-Frame for test was originally treated as 2360 mm (90 x 45 mm profile) or 3000 mm (140 x 45 mm profile) lengths. Specimens were cut by Juken 450 mm from the treatment ends and sent to AssureQuality, and then 900 mm long samples were cut centrally from the original lengths and sent to Scion. Scion then cut 100 mm long samples from either end, and then again cut 4 mm wafers (across the grain) from those blocks for chemical analysis. They sent the wafers directly to Veritec. Note the requirement for samples to be cut at least 150 mm from an original treatment end (Appendix B4 of AS/NZS 1604.4:2012) was met.

A brief summary of the analytical results are that:

1. Both analytical laboratories obtained exactly the same average retention (0.75% BAE) for samples C (solid pine H1.2 boron).
2. The BAE retentions obtained by Veritec were generally lower than obtained by AssureQuality for the same board numbers from samples D and F (J-Frame). Possibly, this difference may be attributed to the samples for AssureQuality being cut nearer to the original treatment ends than those cut for Veritec. I note that there were concerns by Red Stag about results obtained from AssureQuality for J-Frame during routine quality control, in part citing independent testing by WPMA. However, an email from Dr Jon Tanner, Chief Executive of WPMA has indicated that the WPMA work was wrongly cited and blind comparisons were made where results were not attributed to specific laboratories. Differences in penetration results between laboratories could also arise from the ambiguous penetration requirements being gleaned from standards.
3. AssureQuality also analysed the untreated J-Frame, and the penetration spot tests confirmed there was no boron treatment, and all retentions were below BAE detectable limits (<0.01% m/m).
4. Both sets of analyses showed that all boron treated timbers had retentions greater than 0.40% m/m BAE, except for two from Veritec where samples F3 and F10 had the slightly low retentions of 0.37% and 0.34% respectively. If these retention results had been for predominately sapwood LVL then they should be considered retention failure. However, if the LVL was predominately heartwood, which is difficult to treat so that most boron would therefore be in the sapwood, then it might indicate retention pass (as in NZ a boron heartwood retention is not required). From the Scion report, the mean sapwood content of J-Frame samples D was 89% while for J-Frame samples F it was 35%. This heartwood factor should be considered in any standardisation of boron treatment for LVL. Perhaps the minimum heartwood content in LVL should be limited to 50% (or some higher number) so that the 0.40% BAE can remain the unequivocal retention minimum for full cross section. A minimum heartwood content would also limit the amount of decay susceptible but difficult to treat timber being included. It should also be noted that both samples F3 and F10 passed the H1.2 decay test and lacked any signs of decay.
5. The AssureQuality analyses showed that boron was detectable (above 0.01% m/m BAE) in the inner one-ninth of all solid pine C samples, except for one where the central ninth was composed of heartwood. For the inner one-ninth of D samples only two had detectable boron, while for F samples three had detectable boron, four lacked detectable boron and three were composed of heartwood. These results reflect the

difficulty of deeply penetrating the inner veneers of LVL. Nevertheless, a central ninth (core) retention is not applicable to H1.2 (NZS 3460, Table 6.1).

Red Stag mentioned that the first three commercial treatment batches of a new process should be independently audited for compliance before the product is sold to the marketplace. I am not aware of whether these initial steps were taken, but JNL has a quality control programme in place. J-Frame was introduced into the market place before the Scion H1.2 decay test was undertaken. I have the analytical results from the Scion material for this review, as well as additional earlier analyses of treatment batches. The QA system that JNL uses through AssureQuality looks rigorous, although it does rely on the penetration ambiguities already discussed.

When checking the penetration of boron, it should be remembered that unlike other preservatives, the sample should be cut and then radially split (with the grain) to provide the surface that is spot tested (AS/NZS 1605.2:2006, clause 1.5). For other preservatives, the surface tested is cut across the grain. The reason boron-treated wood is prepared differently is that boron can smear across the surface with the saw blade (although I don't recall having problems with dry samples when cutting across the grain).

The AWPC protocols on page 11 state that the ends of test samples at least 600 mm long shall be end sealed before treatment. The aim here is avoid testing high uptake or over-treated ends especially when treated as smaller lengths in pilot plant facilities. The J-Frame supplied by JNL was not end sealed, however, as the 900 mm long test samples were cut from the centre of lengths at least 2360 mm long, end effects were avoided and should satisfy AWPC requirements. Indeed, using the centres from such long lengths better reflects commercial realities.

The protocols also assume that all sapwood will be treated (page 10 under 'preservative treatment' for Wall frame cavity test which also applies to the I-Frame Sample Test), although the protocols were mainly written for solid wood, with some minor references to wood composites in the preface. Penetration requirements in the standards have higher authority than those suggested in the protocols, and for LVL standards do allow some level of unpenetrated sapwood.

The spot test photographs in Appendix 1 of the Scion report (Veritec tested samples, cut across the grain) confirm that not all of the cross section of LVL was penetrated with boron. The darker red areas show boron penetration, while the paler yellow areas show a lack of penetration. Sample D1 appears to be fully penetrated, while most other LVL examples have an unpenetrated core. For some, this unpenetrated core in the internal veneers extends close to the edge of some LVL samples. It seems likely that not all sapwood was treated, although in places it may show 'evidence of penetration'.

Decay test

The accepted 'Fungal Cellar' H1.2 test procedures are described in the AWPC protocols, and include the I-Frame Sample Test used by Scion. These tests were originally designed for solid wood samples, where the wide face of framing timbers adequately represents the treatment patterns also found on the thin face. Therefore, the pre-inoculated squares of feeder strips nailed onto the wide faces of boards as required on page 12 of the protocols were representative of the thin faces. However, the penetration patterns in LVL are quite different on their wide and thin (edge) faces. The wide faces will usually have their face veneers uniformly and fully treated, while the thin face will expose the edges of many veneers (photos show that J-Frame is composed of 12 veneers), some of which may include veneers with only shallow penetration. The thin edge will be the weak point in LVL treated after gluing, so that is the area that should be specifically targeted in durability testing. In any future testing of LVL, and other composites for that matter, I would like to see both the wide and thin faces inoculated with feeder strips.

The AWPC protocols require that 'Samples should be placed on edge in a stack with 15-20 mm thick untreated wood or plastic fillets between each layer.' There was some possibility that the edges would be exposed indirectly to decay fungi if the stickers had been untreated pine. Fungi could have travelled from the untreated controls onto the stickers and then throughout the rest of the stack. However, plastic stickers were used.

The Scion report shows that there was only one length of boron treated J-Frame (a wide board, 145 x 45 mm) out of 30 lengths (if samples E are included) that had any fungal decay. The single board (sample F5) with decay was rated 9, indicating that decay was not more than one mm deep. I consider this level of decay to be superficial. Additionally, the decay appears to have arisen because the board was located within a non-representative location at the very bottom of the stack where the edge sat in pooled or free water longer than intended. Finally, the decay was soft rot, rather than brown rot arising from the intended fungal inoculum. The fungal isolation work of Stahlhut into the leaky building problem showed that decay was predominantly caused by brown rot fungi not soft rot fungi. I do not consider the superficial decay of one board by soft rot to indicate treatment failure.

In future revisions of the AWPC protocols, I would suggest that some minor level of decay (such as not more than 1 mm deep) be allowed in H1.2 testing before a treatment is considered unsuitable. It is common practice in other AWPC laboratory trials to allow a mean of 3% mass loss or decay and still consider that the treatment was successful. Similarly, for H2 and H3 termite field testing a mean mass loss of up to 5% is allowed.

The AWPC protocols state on Page 10 (under 'preservative treatment' for Wall Frame Cavity Test which also applies to the I-Frame Sample Test) that a minimum of 3 retentions of each preservative shall be tested. There could be some discussion about whether these variations are really needed for an H1.2 test where existing wood preservatives with well established toxic thresholds are already known. However, there are some variations in J-Frame that would be worthy of further testing so that we better understand any limitations of the treatment. Variations in heartwood content would appear to be a variation worthy of examination. JNL also targets a higher uptake rate to meet the minimum BAE retention of 0.40% m/m required in cross section for H1.2. Indeed, all samples D in the Scion trial had retentions ranging from 0.54-0.89% m/m (Veritec analyses). It may be useful to test whether LVL with retentions closer to the minimum (e.g. 0.40-0.50% m/m) would also pass durability testing, which might arrest future pressures to reduce cost by reducing retention to this level. It is possible that a somewhat higher BAE may be needed to be counteract any penetration issues in LVL compared to solid wood. In summary, the parameters tested in an H1.2 durability trial should become the parameters specified.

The minor decay of untreated J-Frame is noteworthy. I have seen a number of papers where untreated LVL hot pressed to temperatures of 140-150°C will readily decay. However, the J-Frame process includes a preceding step where veneers are high temperature dried at 200°C. This temperature falls within the range used to produce some thermo-modified woods. Thermo-modification significantly improves resistance to brown rot. The Scion trial has shown that even untreated J-Frame has improved durability, with results ranging from no decay (the majority of samples) to superficial decay (not more than 1 mm), although 3 samples did have the establishment of light decay (1-5 mm deep). It would be interesting to check the moisture content of various samples during the test, to ensure that J-Frame has wetted sufficiently for decay to occur. If not, then perhaps improved hydrophobic properties are part of the reason for its improved durability (compared to wetted solid pine). The risk of rapid failure of J-Frame is certainly much less than for untreated solid pine. If the parameters found effective by JNL should eventually become included within standards, the boron retentions and penetrations would need to be coupled with this level of thermo-modification. That is, any other LVL heated to a maximum of 150°C and then boron treated would need its own new set of H1.2 durability tests.

CONCLUSIONS

1. The granting of CodeMark for J-Frame was premature (it was granted prior to durability testing).
2. The penetration guidelines across the three standards (NZS 3640, AS/NZS 1604.4:2012, and AS/NZS 1605.2:2006) do not provide sufficient guidance for the H1.2 treatment of LVL with boron after gluing.
3. The durability of J-Frame has not been tested fully in the Scion trial, as J-Frame edges were not directly exposed to fungal inoculation.
4. The risk of rapid J-Frame failure appears to be low, as even untreated J-Frame had improved durability against brown rot. The resistance of untreated J-Frame is likely due to a level of wood modification through coincidental 'thermo-treatment' of veneers when heated to 200°C for drying. Risk is certainly much less than for untreated pine framing where widespread decay or failure was the norm in the Scion trial.
5. Additional testing is required. The fungal inoculum in the I-Frame Sample Test should have the feeder strips nailed on both the wide and thin edges of each sample (LVL, and solid wood for proper comparison). This additional inoculation could be nailed to the existing J-Frame under test, if the test is still running.
6. If a new durability test is installed, then another full set of analyses should be conducted as before. Again, Scion should cut the samples for analysis and send them directly to their chosen analytical laboratory.
7. The testing of variations would be useful to better define any limitations in the treatment. The main variations to test include the effect of heartwood content, so that sapwood content might be low, mid or high (perhaps 35%, 50-60%, 80+%). Also for a given sapwood content, another variation might be to test a BAE retention that is close to the minimum of 0.40% m/m and another as would be obtained by JNL's 'normal uptake' schedule.

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Date: 21 July 2016

Client: Ministry of Business, Innovation and Employment, Wellington, New Zealand.

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OBJECTIVE

The objective of this review was to examine the decision that J-Frame (H1.2 boron treated laminated veneer lumber or LVL) as produced by Juken New Zealand Ltd (JNL) meets the performance requirements of B2 Durability provisions of the New Zealand Building Code. CodeMark compliance was provided for the product by AsureQuality in 2015 in their Product Certificate Aq-180615-CMNZ, where B2 compliance was accepted through the Alternative Solutions process.

INTRODUCTION

Since the 1950s, softwood house framing in New Zealand was treated with boron in the anticipation that it would be needed to control *Anobium* borer. However, the risk from *Anobium* was overstated, so that in 1995 untreated framing was allowed and its use widely implemented (Hedley, 2003). What was not fully realised at the time is that the same boron treatments used to control insects were also controlling decay fungi. While building practices should not allow the ingress of moisture to reach house framing, changed practices such as the reduction of eave widths, monolithic cladding, and a move from metal flashings to sealants were amongst the factors leading to the leaky building syndrome and its associated decay problems. In response, H1.2 treatments were introduced to protect against fungal decay in interior house framing.

The Wall Frame Cavity Test was incorporated into the 2007 revision of the Australasian Wood Preservation Committee's (AWPC) protocols as a method for determining which wood treatments were suitable for H1.2. These protocols are widely used and accepted in New Zealand and Australia for determining the durability of various preservative treatments for various hazard classes. In the latest 2015 revision, an I-Frame Sample Test was included, and is now the preferred method used by Scion. Boron treatments at the appropriate retentions were found to be effective in controlling the wood decay fungal hazard in H1.2 for 'solid wood' (as distinguished from LVL and other composites). This good performance agreed with the pre-1995 experience where decay generally was not a problem in houses built with boron treated framing.

Boron is a leachable preservative that can be lost from wood or redistributed within wood after treatment (Drysdale *et al.* 2011), so it is worth noting that while H1.2 house framing should last at least 50 years, '...the preservative treatment is not designed for extended exposure to elevated moisture content' (commentary clause C3.1, Amendment 5). Similarly, the AWPC protocols now state that H1.2 treatments are meant to provide 'temporary (up to 5 years) protection of framing timbers' against leaky building problems that might elevate wood moisture content above the fibre saturation point (around 25% mc), allowing fungal decay. If water ingress is occurring, then associated problems such as staining and mould growth should allow it to be detected and remedied.

B2 Durability CodeMark compliance through Alternative Solution was accepted by AsureQuality by referencing NZS 3640:2003, NZS 3602:2003, NZS 3604: 2011, and AS/NZS 1604.4: 2012. Wood treatment is specified according to two factors, retention, which is the amount of preservative in wood, and penetration, which is the depth to which the preservative has spread within the wood. For LVL, the relevant clause guiding treatment is 1.9 'Use in New Zealand' in AS/NZS 1604.4: 2012. This clause states that LVL 'shall be treated to the preservative retention requirements for H1.2 as set out in NZS 3640', which is a standard for solid wood. Similarly, Section 2.3.9 of NZS 3604 deals with Engineered

Wood Products (EWP, including LVL), and clause 2.3.9.4 indicates that EWP may be used if preservative treatment complies with NZS 3602 though if not already specified in NZS 3602 then it must have the level of treatment required for kiln-dried radiata pine structural grades.

Further, for the Alternative Solution for J-Frame penetration requirements, clause 1.9 in AS/NZS 1604.4: 2012 states that 'Preservative penetration shall be in accordance with AS/NZS 1604.4.' However, there is no penetration requirement for H1.2 in AS/NZS 1604.4: 2012 so penetration is analysed to H1. Penetration tests to H1 should show 'Evidence of Penetration' (AsureQuality, 2015 CodeMark Evaluation).

Since the granting of CodeMark approval for J-Frame, a series of complaints were made (Rigter, 2015), that the approval process was flawed, that the J-Frame being produced does not comply with B2 Durability, that the supply of samples for the Scion decay test was not independent or representative of commercial production, and that a level of decay occurred in J-Frame in the Scion test.

ALTERNATIVE SOLUTION: TREATMENT REQUIREMENTS

Retention

For the boron treatment of solid softwood, the full cross-section should have a minimum retention of 0.40% m/m boric acid equivalent (BAE) oven-dried wood (NZS 3640: 2003). An inner one-ninth retention is not applicable. According to clause 1.9 of AS/NZS 1604.4, this same minimum retention is required in LVL. There is no reason to doubt that the same preservative retention should be needed to protect timber, whether as solid wood or LVL, if the penetration patterns are similar. Indeed, the majority of LVL retentions listed in AS/NZS 1604.4 were originally copied directly from AS 1604.1, the standard for solid wood. Note that the retention is written as 0.40% not 0.4%, which means that retentions must be given to 2 decimal places not one, which prevents retentions such as 0.39% being rounded up and passed.

Heartwood penetration for H1.2 is not specified in NZS 3640; however, it follows from New Zealand's H3 requirements (clause 6.3.1.1.2) that 'For timber treated in final shape and form, no minimum heartwood penetration is specified.' As confirmation that heartwood penetration should not be required for H1.2 when treated in final shape and form, Clause 3.2 in NZS 3640: 2003 states 'Treatment for service at a higher hazard class number satisfies all requirements for service at a lower hazard class number,...' In solid wood, the location of growth rings assists when determining heartwood regions based on small colour differences between sapwood and heartwood, and/or spot tests. The location of heartwood in LVL is more difficult to locate as growth ring structure is obliterated so that heartwood may be in different locations between each veneer. AS/NZS 1605.1: 2006 provides a spot test for heartwood/sapwood determination.

A number of quality control analyses for J-Frame were provided by JNL and AsureQuality, including analyses for the samples sent to Scion as part of the durability decay test. An AsureQuality analysis on 15/12/2014 of ten samples (not part of the Scion test) showed that all had BAE cross-section retentions of 1.04 to 1.96% m/m. An AsureQuality analysis on 28/5/2015 of another ten samples showed that all had BAE cross-section retentions of 1.09 to 2.23% m/m.

Of the Scion samples, samples D were 90 x 45 mm profiled J-Frame treated by normal schedule, and the Scion report showed that they had a mean sapwood content of 89%. For the ten boards analysed, AsureQuality obtained retentions of 0.62-1.70% m/m. Veritec analysed samples from the same test boards and obtained retentions of 0.54-0.89% m/m. All of these analyses show that J-Frame is treated to above 0.40% m/m BAE and therefore meets standard retention requirements for LVL.

An exception obtained from the Scion samples were for samples F which were 140 x 45 mm profiled J-Frame treated by normal schedule. For the ten boards analysed, AsureQuality retentions were 0.60-1.10% m/m (all passing standard requirements) while from Veritec the retentions were 0.34-0.68% m/m. Two samples analysed by Veritec were below requirements at 0.37% for sample F3 and 0.34% for sample F10. Both values cannot be rounded up so indicate retention failure according to the more conservative results obtained by Veritec.

However, the Scion report shows that samples F contained only 35% sapwood, meaning that 65% was heartwood. There is no guidance on whether percentage heartwood content should have a bearing on cross-sectional retention in LVL. Heartwood does not require treatment when treated in final form. It would be difficult to separate heartwood and sapwood samples in LVL for separate analyses. As heartwood is difficult to treat, most boron would be located in the sapwood, so that it seems reasonable to assume that the sapwood components of samples F3 and F10 would have greater than 0.40% m/m BAE.

Nevertheless, without further guidance on what influence heartwood content should have on cross-sectional retention in LVL, the analyses showed that there were two failures for cross-sectional retention using the conservative numbers from Veritec. JNL should adjust treatments until new analyses show that minimal cross-sectional retention is always achieved. Such treatment variation might be accomplished by using a harsher treatment cycle, or by limiting heartwood content. It should be noted that both samples F3 and F10 passed the H1.2 Scion decay test and lacked any signs of decay.

Independence of sampling, analytical laboratories

Concerns were raised by Red Stag about the independence of test specimen preparation for the Scion J-Frame Sample Test, and the veracity of the associated retention and penetration analyses. The AWPC protocols state, 'If test timbers are treated by the preservative company, then the treatment work shall be witnessed by an independent party, and/or a representative sample of test specimens shall be chemically analysed by an independent laboratory.' The former does not appear to have occurred; however, as a representative sample was taken independently by Scion for chemical analysis this AWPC requirement was fulfilled. Scion tested six timber types of radiata pine:

A = J-Frame untreated control 90 x 45 mm profile.
B = Solid wood untreated control 90 x 45 mm.
C = Solid wood H1.2 boron treated 90 x 45 mm.
D = J-Frame H1.2 boron normal uptake 90 x 45 mm.
E = J-Frame H1.2 boron lower uptake 90 x 45 mm.
F = J-Frame H1.2 boron normal uptake 140 x 45 mm (wide pieces).

All J-Frame treatments for the Scion trial were conducted by JNL, while the solid wood H1.2 boron treated timber was obtained elsewhere (original treatment lengths not specified) (Paul Jordan, pers. comm.; JNL 2014 sample preparation). The E samples refer to an experimental treatment schedule, so that these samples do not require detailed consideration in this review as they do not fall under the CodeMark evaluation.

The Scion report provided retention and penetration results for samples 1-3 (C1-C3, D1-D3, E1-E3, F1-F3) from each of the boron treated samples that they tested, which on its own is not enough for CodeMark approval. For this review, the full set of analyses by both AsureQuality (13 documents) and Veritec (two documents) for all ten replicates of each treatment was provided by JNL. The J-Frame for test was originally treated as 2360 mm (90 x 45 mm profile) or 3000 mm (140 x 45 mm profile) lengths. Specimens were cut by Juken 450 mm from the treatment ends and sent to AsureQuality, and then 900 mm long samples were cut centrally from the original lengths and sent to Scion. Independently, Scion then cut 100 mm long samples from either end, and then again cut 4 mm wafers (across the grain) from those blocks for chemical analysis. They sent the wafers directly to Veritec. Note the requirement for samples to be cut at least 150 mm from an original treatment end (Appendix B4 of AS/NZS 1604.4:2012) was met in both instances.

The AWPC protocols (page 11) state that the ends of test samples must be at least 600 mm long and shall be end sealed before treatment. The aim is to avoid testing high uptake or over-treated ends especially when treated as smaller lengths in pilot plant facilities. The J-Frame supplied by JNL was not end sealed; however, as the 900 mm long test samples were cut from the centre of lengths at least 2360 mm long, end effects were avoided. This should satisfy AWPC requirements. Indeed, using the centres from such long lengths better reflects commercial realities.

In conclusion, the independence of test specimen sampling was met. JNL also uses AsureQuality as an independent auditor of their J-Frame production.

Red Stag was concerned about the analytical results being obtained from AsureQuality, questioning why J-Frame was consistently passing retention and penetration requirements (Rigter, 2015). As part of this concern, Rigter (2015) cited independent testing of several analytical laboratories by the Wood Processors & Manufacturers Association of New Zealand (WPMA). However, an email from Dr Jon Tanner, Chief Executive of WPMA has indicated that the WPMA work was wrongly cited and blind comparisons were made where results were not attributed to specific laboratories (Tanner, 2016).

This review has little to draw upon for providing comment on the accuracy of AsureQuality results. However, some comparison can be made between the retention results obtained by Veritec and AsureQuality for the Scion samples, as both laboratories analysed samples from the same boards.

1. Both analytical laboratories obtained exactly the same average retention (0.75% boric acid equivalent or BAE) for samples C (solid pine H1.2 boron).
2. The BAE retentions obtained by Veritec were generally lower than obtained by AsureQuality for the same board numbers from samples D and F (J-Frame). While all samples were cut more than 150 mm from original treatment ends, it remains possible that the difference in retention can be attributed to the samples for AsureQuality being cut nearer to the original treatment ends than those cut for Veritec. A proper comparison should have test samples cut adjacent to each other.

AsureQuality should determine whether its procedure for determining boron retentions in LVL is giving an overestimation of retentions.

Penetration

The most contentious issue for the boron treatment of LVL will concern penetration. Treating veneers with boron before gluing can allow full penetration of all sapwood, and for example, is a process that was used in the 1940-50s in Australia for the protection of hardwood veneers from lyctine borers. However, the boron in treated veneers can cause adhesion problems when gluing with phenol formaldehyde (PF) resin. Treatment of LVL after gluing circumvents the adhesion problem associated with boron; however, penetration can then be inhibited by glue-bonds, the random location of impervious heartwood, and sapwood grain orientation. Penetration in radiata pine sapwood can be difficult in the tangential direction, irrespective of the severity of treatment, while the radial and longitudinal directions are easily penetrated. Therefore, while the face veneers of LVL are easily treated, penetration of the interior veneers can be variable and limited, making them more susceptible to decay.

s 9(2)(b)(i), s 9(2)(b)(ii)

[redacted]

For preservative penetration in LVL, the relevant guidance is in clause 1.9 in AS/NZS 1604.4: 2012, where 'Preservative penetration shall be in accordance with AS/NZS 1604.4.' However, there is no penetration requirement in AS/NZS 1604.4: 2012 for H1.2 (clause 2.3.2) as the only treatment mentioned is a glueline treatment with triadimefon and cyproconazole. This glueline treatment was added in 2012 to both NZS 3640 amendment 5 and AS/NZS 1604.4. Being a glueline treatment, there was no requirement for evidence of penetration of the actives into the timber itself, as it could remain associated with the glueline as long as minimum retentions in the full cross section of LVL were achieved and the maximum thickness of veneers was 4.3 mm.

Therefore, JNL uses the penetration guidance given for H1 in clause 2.2.2 where 'All preservative-treated veneers shall show evidence of the distribution of the preservative in the sapwood.' This clause is actually meant for lyctine borer control in hardwoods under Australia's H1 exposure conditions. However, it is transferable to New Zealand's H1.1 where *Anobium* borer, especially in softwoods, is of greater concern. The feeding mechanisms between the two groups, borers and fungi, are quite different with one decaying on the microscopic level while the other ingests larger pieces. Therefore, a better distribution or microdistribution of preservative may be required to control fungi than is needed to control insect pests.

Earlier versions of AS/NZS 1604.4 were clearer. Clause 1.9 in both the 2004 and 2010 editions again stated that penetration of LVL should be in accordance with the same standard. In those editions, the only option in the relevant section was H1. H1.2 was not mentioned. Therefore, 'All preservative-treated veneers shall show evidence of the distribution of the preservative in the sapwood.' clearly applied to the boron treatment of LVL for H1.2.

To add to the ambiguity, AS/NZS 1605.2:2006 (Determination of preservative penetration by spot tests) states that 'the preservative shall be continuously distributed over the penetration zone...' This standard should be followed when conducting spot tests such as those for boron. The exact meanings of 'continuously distributed' and 'evidence of distribution' have not been provided in the standards. My interpretation of these terms as they apply to a sapwood veneer can be illustrated in Figures 1-4. Continuously distributed means there are no gaps in penetration. 'Evidence of distribution' can be met by a much wider range of penetration patterns, ranging from the same one shown for continuous distribution (Figure 1) through to a minimum where even minor penetration is still 'evidence of distribution' (Figures 2-3). The phrase 'continuously distributed' sets a higher threshold for detection of preservative penetration than 'evidence of distribution'.

Figure 1. 'Continuously distributed' penetration in a sapwood veneer.

Figure 2. An example of the minimum penetration needed for 'evidence of distribution'.

Figure 3. Another example of the minimum penetration needed for 'evidence of distribution'.

Figure 4. Veneer not penetrated.

There are discussions in Australia and New Zealand on how best to align these various phrases, and there are revisions to the AS/NZS 1604 series currently in the preballot draft phase that may or may not improve clarity. However, any changes have not been finalised so that JNL should use the wording currently available in the standards. Nevertheless, it can be concluded that AS/NZS 1604.4: 2012 does not provide a clear penetration specification for non-glueline treatments for H1.2.

JNL and AsureQuality have used Alternative Solution to obtain guidance, and use H1's 'evidence of distribution' as its test for penetration. This approach is reasonable given the clear guidance for such an approach in the 2004 and 2010 editions of AS/NZS 1604.4, and the absence of countering guidance in AS/NZS 1604.4: 2012. Not surprisingly due to the relative ease of meeting this penetration requirement, all J-Frame samples analysed and examined for this review have 'evidence of penetration' so pass penetration requirements.

An example of the penetration obtained in the Scion samples was provided in its appendix, and those for samples D1-D3 are replicated in Figure 5. D1 appears to be fully penetrated. However, some of the interior veneers in D2 and D3 have limited penetration.

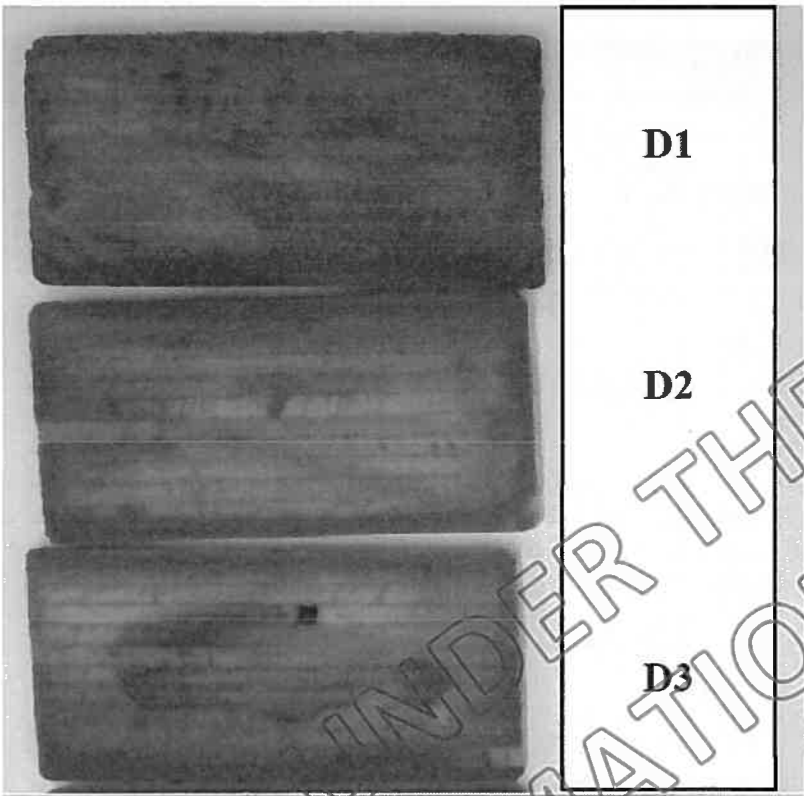

Figure 5. Boron penetration in 90 x 45 mm J-Frame. The darker red areas show boron penetration, while the paler yellow areas show a lack of penetration. From Simpson and Singh (2016).

While JNL is justified in using 'evidence of distribution' to determine penetration in J-Frame and obtain CodeMark approval, the phrase is too weak to ensure durability. Decay may begin on the edge of a veneer that has limited penetration. Also, if J-Frame is cut or machined after treatment, then unpenetrated sapwood could be exposed and will be susceptible to decay. A similar problem was demonstrated in glulam treated after gluing with light organic solvent preservatives (Cookson, 2013). Therefore, a Verification Method should also be used to test the durability of J-Frame under H1.2 conditions to prove its B2 durability. A similar opinion was provided by s 9(2)(a) on 5 August 2015 where penetration and retention 'require underpinning by efficacy trials that demonstrate comparable decay resistance performance of H1.2 LVL.' The final proof of what works will be obtained from durability trials, rather than untested penetration pattern specifications.

VERIFICATION: SCION H1.2 DECAY TRIAL

The accepted 'Fungal Cellar' H1.2 test procedures are described in the AWPC protocols, and include the I-Frame Sample Test used by Scion. As part of this trial, the test samples are inoculated with two species of brown rotting fungi using pre-infected feeder strips about 7 x 35 x 35 mm (AWPC 2015, page 12). Pre-infected feeder strips are then tacked onto the wide face of the test samples. This procedure was followed for the J-Frame test.

These H1.2 tests were originally designed for solid wood samples, where the wide face of framing timbers adequately represents the treatment patterns also found on the thin face. Therefore, the results obtained by tacking pre-inoculated feeder strips onto the wide faces of samples were representative of what would also occur on the thin faces. However, the penetration patterns in LVL are quite different on their wide and thin (edge) faces. The wide faces will usually have their face veneers uniformly and fully treated, while the thin face will expose the edges of many veneers, 12 veneers in the case of J-Frame (Figure 5). These veneer edges may include some with only shallow penetration (Figure 5). From a durability perspective, the thin edge will therefore be the weak point in LVL treated after gluing, and should be specifically targeted in durability testing. This was not done in the Scion trial.

The AWPC protocols require that 'samples should be placed on edge in a stack with 15-20 mm thick untreated wood or plastic fillets between each layer.' There was the possibility that the LVL edges would be exposed indirectly to decay fungi if the stickers had been untreated pine. Fungi could have travelled from the untreated controls onto the stickers and then throughout the rest of the stack. However, plastic stickers were used.

While the I-Frame Sample Test was correctly followed as outlined in the AWPC protocols, in any future testing of LVL, and other composites for that matter, both the wide and thin faces should be inoculated with infected feeder strips.

The Scion report shows that there was one length of boron treated J-Frame (a wide board, 145 x 45 mm) out of 30 lengths (if samples E are included) that had fungal decay. The single board (sample F5) with decay was rated 9, indicating that decay was not more than one mm deep. I consider this level of decay to be superficial. Additionally, the decay appears to have arisen because the board was located within a non-representative location at the very bottom of the stack where the edge sat in pooled or free water longer than intended. Finally, the decay was soft rot, rather than brown rot arising from the intended fungal inoculum. The fungal isolation work of Stahlhut *et al.* (2007; 2008) into the leaky building problem showed that decay was predominantly caused by brown rot fungi, although soft rot fungi can also occur. I do not consider the superficial decay of one board by soft rot to indicate durability failure.

The AWPC protocols state on Page 10 (under 'preservative treatment' for Wall Frame Cavity Test which also applies to the I-Frame Sample Test) that a minimum of three retentions of each preservative shall be tested. Three non-overlapping groups of retentions were not tested. However, there seems little value in testing such a range of retention variations where existing wood preservatives with well established toxic thresholds are already known. A more worthy variation to test for J-Frame is heartwood content. Also, JNL targets a higher uptake rate to meet the minimum BAE retention of 0.40% m/m required in cross section for H1.2. Indeed, all samples D in the Scion trial had retentions ranging from 0.54-0.89% m/m (Veritec analyses). JNL should consider testing J-Frame with retentions closer to the minimum as well (e.g. 0.40-0.44% m/m), so they can understand whether to arrest any future pressures to reduce cost by reducing retention to this level. It is possible that a somewhat higher BAE may be needed to counteract penetration issues in LVL compared to solid wood. If a lower retention is not tested, then the minimum retention specified for J-Frame should be 0.54% m/m BAE. In summary, the parameters tested in an H1.2 durability trial should become the parameters specified.

The minor decay of untreated J-Frame in the Scion test is noteworthy. AsureQuality analysed the untreated J-Frame, and the penetration spot tests confirmed that there was no boron treatment, and all retentions were below BAE detectable limits (<0.01% m/m). Untreated LVL and plywood hot pressed to temperatures of 140-150°C will readily decay (e.g. Da Costa *et al.*, 1972). However, the J-Frame process includes a preceding step where veneers are high temperature dried at 200°C. This temperature falls within the range used to produce some thermo-modified woods (Militz, 2008). Thermo-modification significantly improves resistance to brown rot. The Scion trial has shown that even untreated J-Frame has improved durability, with results ranging from no decay (6 samples) to superficial decay (not more than 1 mm, 1 sample), to light decay (1-5 mm deep, 3 samples). The risk of rapid failure of J-Frame is certainly much less than for untreated solid pine which in the Scion trial had severe decay.

CONCLUSIONS

1. The granting of CodeMark for J-Frame as being compliant with B2 Durability was through Alternative Solution, and was justified because it followed (for retention) or did not contravene (for penetration) the existing standards NZS 3640 and AS/NZS 1604.4:2012.
2. However, the penetration guidelines across the three standards (NZS 3640, AS/NZS 1604.4:2012, and AS/NZS 1605.2:2006) are conflicting and ambiguous for the H1.2 treatment of LVL with boron after gluing.
3. The phrase 'evidence of distribution' as a specification for penetration is too weak to be relied upon on its own as demonstration of durability. A Verification Method is required.
4. The verification of the durability of J-Frame has not been tested fully in the Scion trial, as J-Frame edges were not directly exposed to fungal inoculation.
5. The risk of rapid J-Frame failure appears to be low, as even untreated J-Frame had improved durability against brown rot. The resistance of untreated J-Frame is likely due to a level of wood modification through coincidental 'thermo-treatment' of veneers when heated to 200°C for drying. Risk is certainly much less than for untreated pine framing where widespread decay or failure was the norm in the Scion trial.
6. Additional H1.2 durability testing is required. The fungal inoculum in the I-Frame Sample Test should have the feeder strips nailed on both the wide and thin edges of each sample (LVL, and solid wood for proper comparison). This additional inoculation could be nailed to the existing J-Frame under test, if the test is still running.
7. If a new durability test is installed, then another full set of analyses should be conducted as before. Again, Scion should independently cut the samples for analysis and send them directly to their chosen analytical laboratory.
8. The testing of variations would be useful to better define any limitations in the J-Frame treatment. The main variations to test include the effect of heartwood content, so that sapwood content might be low, mid or high (perhaps 35%, 50-60%, 80+%). Also for a given sapwood content, another variation is to test a BAE retention that is close to the minimum of 0.40% m/m and another as would be obtained by JNL's 'normal uptake' schedule.
9. Without additional durability testing, I was not able to determine that the 50 year performance requirement of B2 Durability in the New Zealand Building Code was met.

CONSIDERATIONS FOR STANDARDS, AWPC PROTOCOLS.

1. Remove the ambiguity in AS/NZS 1604.4 and clearly state which penetration pattern should be followed for non-glueline H1.2 treatments for LVL.
2. Provide a diagram in AS/NZS 1604.4 of preservative penetration patterns in veneers, such as shown in Figures 1-4, so that the meaning of terms such as 'continuously distributed' or 'evidence of distribution' becomes clear. Eventually, as guided by durability testing, a term such as 'evidence of distribution over at least X% of the veneer,' may be applicable for H1.2 LVL treated after gluing.
3. In future revisions of the AWPC protocols, some minor level of decay (such as not more than 1 mm deep) should be allowed in H1.2 testing before a treatment is considered unsuitable. It is common practice in other AWPC laboratory trials to allow a mean of 3%

mean mass loss or decay and still consider that the treatment was successful. Similarly, for H2 and H3 termite field testing a mean mass loss of up to 5% is allowed.

4. Any testing of LVL durability presented for changes to standards should indicate the temperatures used for LVL production, so that it is clear whether durability is due solely to preservative treatment, or preservative treatment plus a level of thermo-modification.
5. The AWPC protocols should also require the inoculation of engineered wood products with pre-infected feeder strips to occur on both the wide and thin faces of samples in H1.2 testing.

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GLOSSARY AND ABREVIATIONS

AWPC = Australasian Wood Preservation Committee.
BAE = Boric acid equivalent.
Continually distributed = Penetration pattern where spot test for a preservative indicates its presence throughout the entire penetration zone.
Engineered wood = Wood products that have been made by gluing smaller pieces together, such as reconstituted wood, plywood, LVL, and glulam.
Efficacy = Whether a timber treatment can withstand a prescribed biodeteriogen.
Evidence of distribution = Penetration pattern where spot test for a preservative indicates its presence throughout the entire penetration zone, or within limited locations within the penetration zone.
JNL = Juken New Zealand Ltd.
LVL = Laminated veneer lumber.
Penetration = The depth to which a prescribed preservative is present in timber.
Penetration pattern = The depth and level of continuity to which a prescribed preservative is present within a region of timber.
Penetration zone = The region of timber that should contain preservative.
Retention = Amount of preservative within a section of timber. Where expressed as a percentage, retention is on the basis of mass per unit mass.
Solid wood = Wood without divisible parts glued together.
WPMA = Wood Processors & Manufacturers Association of New Zealand.

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Commercial in Confidence

L J Cookson Consulting, Report No.153

Technical review on the boron treatment of LVL to meet H1.2 conditions
in New Zealand

L.J. COOKSON
Independent Consulting

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Laurie J Cookson

Date: 9 September 2016

Client: Ministry of Business, Innovation and Employment, Wellington, New Zealand.

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OBJECTIVE

The objective of this review is to determine if J-Frame (H1.2 boron treated laminated veneer lumber or LVL) as produced by Juken New Zealand Ltd (JNL) meets the performance requirements of B2 Durability provisions of the New Zealand Building Code, and if CodeMark certification was justifiable. CodeMark compliance was provided for the product by AsureQuality in 2015 in their Product Certificate Aq-180615-CMNZ, where B2 compliance was accepted through the Alternative Solutions process.

INTRODUCTION

Since the 1950s, softwood house framing in New Zealand was treated with boron in the anticipation that it would be needed to control *Anobium* borer. However, the risk from *Anobium* was overstated, so that in 1995 untreated framing was allowed and its use widely implemented (Hedley, 2003). What was not fully realised at the time is that the same boron treatments used to control insects were also controlling decay fungi. While building practices should not allow the ingress of moisture to reach house framing, changed practices such as the reduction of eave widths, monolithic cladding, and a move from metal flashings to sealants were amongst the factors leading to the leaky building syndrome and its associated decay problems. In response, H1.2 treatments were introduced to protect against fungal decay in interior house framing.

The Wall Frame Cavity Test was incorporated into the 2007 revision of the Australasian Wood Preservation Committee's (AWPC) protocols as a method for determining which wood treatments were suitable for H1.2. These protocols are widely used and accepted in New Zealand and Australia for determining the durability of various preservative treatments under various hazard classes. In the latest 2015 revision, an I-Frame Sample Test was included, and is now the preferred method used by Scion. Boron treatments at the appropriate retentions were found to be effective in controlling the wood decay fungal hazard in H1.2 for 'solid wood' (as distinguished from LVL and other composites). This good performance agreed with the pre-1995 experience where decay generally was not a problem in houses built with boron treated framing.

Boron is a leachable preservative that can be lost from wood or redistributed within wood after treatment (Drysdale *et al.* 2011), so it is worth noting that while H1.2 house framing should last at least 50 years, '...the preservative treatment is not designed for extended exposure to elevated moisture content' (commentary clause C3.1, Amendment 5). Similarly, the AWPC protocols now state that H1.2 treatments are meant to provide 'temporary (up to 5 years) protection of framing timbers' against leaky building problems that might elevate wood moisture content above the fibre saturation point (around 25% mc), allowing fungal decay. If water ingress is occurring, then associated problems such as staining and mould growth should allow it to be detected and remedied.

B2 Durability CodeMark compliance through Alternative Solution was accepted by AsureQuality by referencing NZS 3640:2003, NZS 3602:2003, NZS 3604: 2011, and AS/NZS 1604.4: 2012 (Figures 1-2). Wood treatment is specified according to two factors, retention, which is the amount of preservative in wood, and penetration, which is the depth to which the preservative has spread within the wood.

Evaluation Methodology:

B2 Durability	B2.3.1 Building elements must, with only normal maintenance, continue to satisfy the performance requirements of this code for the lesser of the specified intended life of the building if stated or: (a) The life of the building, being not less than 50 years, if: (i) Those building elements (including floors walls and fixings) provide structural stability to the building, or (ii) Those building elements are difficult to access or replace, or (iii) Failures of those building elements to comply with the building code would go undetected during both normal use and maintenance of the building. ~~(b) 15 years if:~~ ~~(i) Those building elements (including the building envelope, exposed plumbing in the subfloor space and in-built chimmeys and flues) are moderately difficult to access or replace, or (ii) Failure of those building elements to comply with the building code would go undetected during normal use of the building, but would be~~	Alternative	NZS3640:2003 NZS3602:2003 NZS3604.2011 AS/NZS1604.4:2012	AsureQuality - ATTP certificate AsureQuality – certificate of analysis AsureQuality – Open letter	B2 references NZS3604, 3602 and 3640. Already determined that it complies with AS/NZS4357. This Standard requires preservative treatment to AS/NZS1604.4, which in turn clause 1.9 'Use in NZ' states it must be treated to retention req.'s of NZS3640 which this product meets. There is no penetration req. for H1.2 in 1604 so penetration is analysed to H1 Section 2.3.9 of 3604 deals with Engineered Wood Products. 2.3.9.4 states EWP may be used if preservative treatment complies with 3602 though if not already specified in 3602 must have the level of treatment required for kiln dried Radiata pine structural grades. Lab analysis shows retention of Boron exceeds requirements. Penetration tests to H1 show 'Evidence of Penetration'

Figure 1. Relevant B2 Durability section from AsureQuality, 2015 CodeMark Evaluation (last column expanded in Figure 2).

B2 references NZS3604, 3602 and 3640. Already determined that it complies with AS/NZS4357. This Standard requires preservative treatment to AS/NZS1604.4, which in turn clause 1.9 'Use in NZ' states it must be treated to retention req.'s of NZS3640 which this product meets. There is no penetration req. for H1.2 in 1604 so penetration is analysed to H1 Section 2.3.9 of 3604 deals with Engineered Wood Products. 2.3.9.4 states EWP may be used if preservative treatment complies with 3602 though if not already specified in 3602 must have the level of treatment required for kiln dried Radiata pine structural grades. Lab analysis shows retention of Boron exceeds requirements. Penetration tests to H1 show 'Evidence of Penetration'.

Figure 2. Detail of last column in B2 Durability section from AsureQuality, 2015 CodeMark Evaluation.

For LVL, the relevant clause guiding treatment is 1.9 'Use in New Zealand' in AS/NZS 1604.4: 2012. This clause states that LVL 'shall be treated to the preservative retention requirements for H1.2 as set out in NZS 3640', which is a standard for solid wood. Similarly, Section 2.3.9 of NZS 3604 deals with Engineered Wood Products (EWP, including LVL), and clause 2.3.9.4 indicates that EWP may be used if preservative treatment complies with NZS 3602 though if not already specified in NZS 3602 then it must have the level of treatment required for kiln-dried radiata pine structural grades.

Further, for the Alternative Solution for J-Frame penetration requirements, clause 1.9 in AS/NZS 1604.4: 2012 states that 'Preservative penetration shall be in accordance with AS/NZS 1604.4.' However, there is no penetration requirement for H1.2 in AS/NZS 1604.4: 2012 so penetration is analysed to H1, where there should be 'Evidence of Distribution,' or as worded in the CodeMark evaluation, 'Evidence of Penetration' (AsureQuality, 2015 CodeMark Evaluation).

Since the granting of CodeMark approval for J-Frame, a series of complaints were made by Red Stag (Rigter, 2015), that the approval process was flawed and that the J-Frame being produced does not comply with B2 Durability. There were also criticisms that in a Scion decay test (Simpson and Singh, 2016) commissioned separately to the CodeMark approval process, the supply of samples was not independent or representative of commercial production, and that a level of decay occurred in J-Frame. It should be noted that these concerns did not arise as a consequence of customer complaint or in-service failure. J-Frame has been on the market since 2007.

WAS THE DECISION TO ISSUE CODEMARK APPROPRIATE?

As noted above, AsureQuality accepted B2 Durability CodeMark compliance through Alternative Solution by referencing NZS 3640:2003; NZS 3602:2003, NZS 3603:2011 and AS/NZS 1604.4:2012.

Retention

For the boron treatment of solid softwood, the full cross-section should have a minimum retention of 0.40% m/m boric acid equivalent (BAE) oven dried wood (NZS 3640: 2003). An inner one-ninth retention is not applicable. According to clause 1.9 of AS/NZS 1604.4, this same minimum retention is required in LVL. There is no reason to doubt that the same preservative retention should be needed to protect timber, whether as solid wood or LVL, if the penetration patterns are similar. Indeed, the majority of LVL retentions listed in AS/NZS 1604.4 were originally copied directly from AS 1604.1, the standard for solid wood. Note that the retention is written as 0.40% not 0.4%, which means that retentions must be given to 2 decimal places not one, which prevents retentions such as 0.39% being rounded up and passed.

A specific heartwood retention and penetration for H1.2 is not given in NZS 3640; however, it follows from New Zealand's H3 requirements (clause 6.3.1.1.2) that 'For timber treated in final shape and form, no minimum heartwood penetration is specified.' As confirmation that heartwood penetration should not be required for H1.2 when treated in final shape and form, Clause 3.2 in NZS 3640: 2003 states 'Treatment for service at a higher hazard class number satisfies all requirements for service at a lower hazard class number,...' In solid wood, the location of growth rings assists when determining heartwood regions based on small colour differences between sapwood and heartwood, and/or spot tests. The location of heartwood in LVL is more difficult to locate as growth ring structure is obliterated so that heartwood may be in different locations between each veneer. Therefore, a spot test (AS/NZS 1605.1: 2006) is required for heartwood/sapwood determination in LVL.

A number of quality control analyses for J-Frame were provided by JNL and AsureQuality. An AsureQuality analysis on 15/12/2014 of ten samples showed that all had BAE cross-section retentions of 1.04 to 1.96% m/m. An AsureQuality analysis on 28/5/2015 of another ten samples showed that all had BAE cross-section retentions of 1.09 to 2.23% m/m.

Penetration

The most contentious issue for the boron treatment of LVL concerns penetration. Treating veneers with boron before gluing can allow full penetration of all sapwood, and is a process that was used in the 1940-50s in Australia for the protection of hardwood veneers from lyctine borers. However, the boron in treated veneers can cause adhesion problems when gluing with phenol formaldehyde (PF) resin. Treatment of LVL after gluing circumvents the adhesion problem associated with boron; however, penetration can then be inhibited by glue-bonds, the random location of impervious heartwood, and sapwood grain orientation. Penetration in radiata pine sapwood can be difficult in the tangential direction, irrespective of the severity of treatment, while the radial and longitudinal directions are easily penetrated. Therefore, while the face veneers of LVL are easily treated, penetration of the interior veneers can be variable and limited, making them more susceptible to decay.

I have reviewed the proprietary process JNL uses to produce J-Frame (Paul Jordan, pers. comm.), which includes drying veneers at high temperature, hot pressing with PF resin to make the LVL, followed by treatment in final form with a boron solution using a double vacuum treatment cycle. Charges are then held post treatment for a minimum period to promote absorption/diffusion, before being kiln dried to a moisture content which complies with clause 103.9.3 of NZS 3602: 2003.

For preservative penetration in LVL, the relevant guidance is in clause 1.9 in AS/NZS 1604.4: 2012, where 'Preservative penetration shall be in accordance with AS/NZS 1604.4.' However, there is no penetration requirement in AS/NZS 1604.4: 2012 for H1.2 (clause 2.3.2) as the only treatment mentioned is a glueline treatment with triadimefon and cyproconazole. This glueline treatment was added in 2012 to both NZS 3640 amendment 5 and AS/NZS 1604.4. Being a glueline treatment, there is no requirement for evidence of penetration of the actives into the timber itself, as it could remain associated with the glueline as long as minimum retentions in the full cross section of LVL were achieved and the maximum thickness of veneers was 4.3 mm.

Therefore, JNL uses the penetration guidance given for H1 in clause 2.2.2 where 'All preservative-treated veneers shall show evidence of the distribution of the preservative in the sapwood.' This clause is actually meant for lyctine borer control in hardwoods under Australia's H1 exposure conditions. However, it is transferable to New Zealand's H1.1 where *Anobium* borer, especially in softwoods, is of greater concern. The feeding mechanisms between the two groups, borers and fungi, are quite different with one decaying on the microscopic level while the other ingests wood pieces. Therefore, the distribution or microdistribution of preservative needed to control fungi and insects is not necessarily the same. Nevertheless in AS/NZS 1604.4: 2012, the phrasing for preservative penetration in H3 includes the option for sapwood veneers of 'evidence of preservative penetration'. H3 includes a fungal decay hazard. Currently therefore, the best match for H1.2 penetration requirements would be 'evidence of distribution' or 'evidence of penetration.'

Conflicting guidance can be drawn from AS/NZS 1605.2:2006 (Determination of preservative penetration by spot tests), which states that 'the preservative shall be continuously distributed over the penetration zone...' This standard should be followed when conducting spot tests such as those for boron. The exact meanings of 'continuously distributed' and 'evidence of distribution' have not been provided in the standards. My interpretation of these terms as they apply to a sapwood veneer can be illustrated in Figures 3-6. The dark shading represents areas that are penetrated. Continuously distributed means there are no gaps in penetration. 'Evidence of distribution' can be met by a much wider range of penetration patterns, ranging from the same one shown for continuous distribution (Figure 3) through to a minimum where even minor penetration is

still ‘evidence of distribution’ (Figures 4-5). The phrase ‘continuously distributed’ sets a higher threshold for detection of preservative penetration than ‘evidence of distribution’.

Figure 3. ‘Continuously distributed’ penetration in a sapwood veneer.

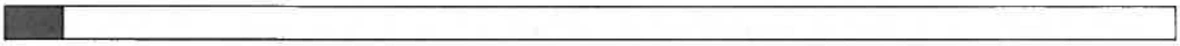

Figure 4. An example of the minimum penetration needed for ‘evidence of distribution’.

Figure 5. Another example of the minimum penetration needed for ‘evidence of distribution’.

Figure 6. Veneer not penetrated.

JNL and AsureQuality have used Alternative Solution to obtain guidance, and use H1’s ‘evidence of distribution’ as its test for penetration. This approach is feasible given the lack of countering guidance in AS/NZS 1604.4: 2012. Due to the relative ease of meeting this penetration requirement, all J-Frame samples analysed and examined for this review have ‘evidence of penetration’ so pass penetration requirements.

An example of the penetration obtained in the Scion samples was provided in its appendix, and those for samples D1-D3 are replicated in Figure 7. D1 appears to be fully penetrated. However, some of the interior veneers in D2 and D3 have limited penetration (yellowish colouration), although it is not clear whether the cause is unpenetrated heartwood or sapwood.

Conclusions

1. Section 2.3.9 of NZS 3604 dealing with Engineered Wood Products indicates that EWP such as LVL may be used if preservative treatment has the same level of treatment as in NZS 3602 for kiln-dried radiata pine structural grades.
2. The granting of CodeMark for J-Frame as being compliant with B2 Durability was through Alternative Solution, and was justified because it followed (for retention) or gave best match to (for penetration) the existing standards NZS 3640 and AS/NZS 1604.4:2012. I have highlighted some issues with the standards, and the AWPC protocols, in later sections.

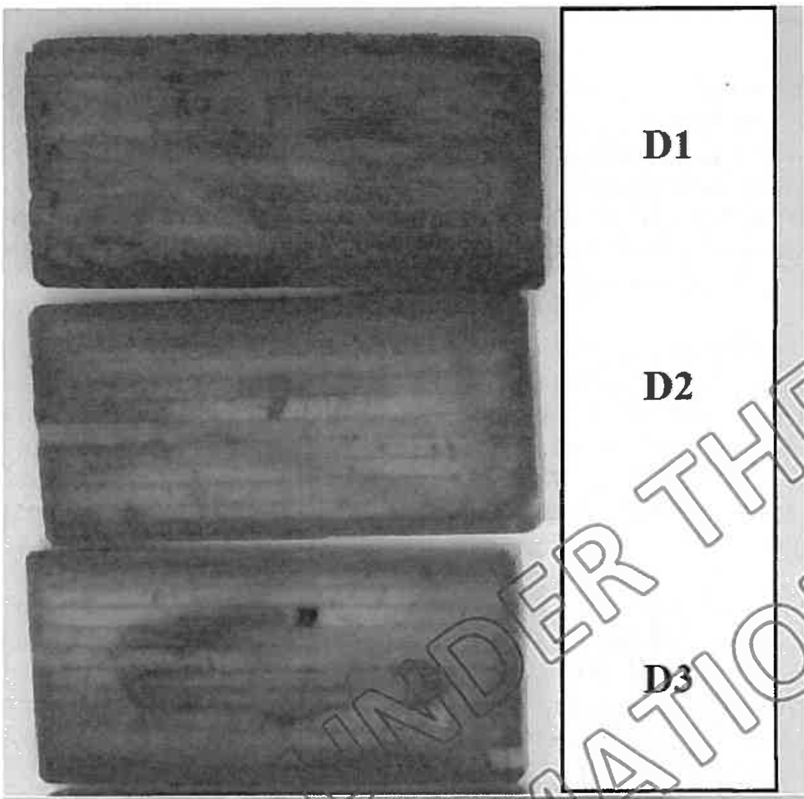

Figure 7. Boron penetration in 90 x 45 mm J-Frame. The darker red areas show boron penetration, while the paler yellow areas show a lack of penetration. From Simpson and Singh (2016).

SCION H1.2 DECAY TRIAL: POTENTIAL VERIFICATION

CodeMark for J-Frame was provided in 2015 through Alternative Solution and did not require supporting evidence from durability testing. However, an I-Frame Sample Test was subsequently conducted by Scion (Simpson and Singh, 2016), using the accepted 'Fungal Cellar' H1.2 test procedures described in the AWPC protocols.

Scion tested six types of radiata pine:

A = J-Frame untreated control 90 x 45 mm profile.
B = Solid wood untreated control 90 x 45 mm.
C = Solid wood H1.2 boron treated 90 x 45 mm.
D = J-Frame H1.2 boron normal uptake 90 x 45 mm.
E = An experimental treatment.
F = J-Frame H1.2 boron normal uptake 140 x 45 mm (wide pieces).

All J-Frame treatments for the Scion trial were conducted by JNL, while the solid wood H1.2 boron treated timber was purchased from a local building supply outlet (original treatment lengths not specified) (Paul Jordan, pers. comm.; JNL 2014 sample preparation). The E samples refer to an experimental treatment schedule, so that these samples do not require detailed consideration in this review as they do not fall under the CodeMark evaluation.

Retentions tested

The samples sent to Scion as part of the durability decay test were analysed by AsureQuality. Samples D were 90 x 45 mm profiled J-Frame treated by normal schedule, and the Scion report showed that they had a mean sapwood content of 89%. For the ten boards analysed, AsureQuality obtained retentions of 0.62-1.70% m/m. Veritec analysed samples from the same test boards and obtained retentions of 0.54-0.89% m/m. All of these analyses show that J-Frame is treated to above 0.40% m/m BAE and therefore meets standard retention requirements for LVL.

An exception obtained from the Scion samples were for samples F which were 140 x 45 mm profiled J-Frame treated by normal schedule. For the ten boards analysed, AsureQuality retentions were 0.60-1.10% m/m (all passing standard requirements) while from Veritec the retentions were 0.34-0.68% m/m. Two samples analysed by Veritec were below requirements at 0.37% for sample F3 and 0.34% for sample F10. Both values cannot be rounded up so indicate retention failure according to the more conservative results obtained by Veritec.

However, the Scion report also shows that samples F contained only 35% sapwood, meaning that 65% was heartwood. There is no guidance on what maximum percentage of heartwood is acceptable, and whether percentage heartwood content should have a bearing on cross-sectional retention in LVL. Heartwood does not require treatment when treated in final form. It would be difficult to separate heartwood and sapwood samples in LVL for separate analyses. As heartwood is difficult to treat, most boron would be located in the sapwood, so that it seems reasonable to assume that the sapwood components of samples F3 and F10 would have greater than 0.40% m/m BAE.

Nevertheless, without further guidance on what influence heartwood content should have on cross-sectional retention in LVL, the analyses showed that there were two failures for cross-sectional retention using the conservative numbers from Veritec. JNL should adjust treatments for 140 x 45 mm J-Frame until new analyses show that minimal cross-sectional retention is always achieved. Such treatment variation might be accomplished by using a harsher treatment cycle, or by limiting heartwood content. It should be noted that both samples F3 and F10 passed the H1.2 Scion decay test and lacked any signs of decay.

Decay

The Scion report shows that there was one length of boron treated J-Frame (a wide board, 145 x 45 mm) out of 30 lengths (if samples E are included) that had fungal decay. The single board (sample F5) with decay was rated 9, indicating that decay was not more than one mm deep. I consider this level of decay to be superficial. Additionally, the decay appears to have arisen because the board was located within a non-representative location of the stack at the very bottom where the edge sat in pooled or free water longer than intended. Finally, the decay was soft rot, rather than brown rot arising from the intended fungal inoculum. The fungal isolation work of Stahlhut *et al.* (2007; 2008) into the leaky building problem showed that decay was predominantly caused by brown rot fungi, although soft rot fungi do also occur. I do not consider the superficial decay of one board by soft rot to indicate durability failure.

The minor decay of untreated J-Frame in the Scion test is noteworthy. AsureQuality analysed the untreated J-Frame, and the penetration spot tests confirmed that there was no boron treatment, and all retentions were below BAE detectable limits (<0.01% m/m). Untreated LVL and plywood hot pressed to temperatures of 140-150°C will readily decay (e.g. Da Costa *et al.*, 1972). However, the J-Frame process includes a preceding step where veneers are dried at high temperature within the range used to produce some

thermo-modified woods (Militz, 2008). Thermo-modification significantly improves resistance to brown rot. The Scion trial has shown that even untreated J-Frame has improved durability, with results ranging from no decay (6 samples) to superficial decay (not more than 1 mm, 1 sample), to light decay (1-5 mm deep, 3 samples). The risk of rapid failure of J-Frame is certainly much less than for untreated solid pine which in the Scion trial had severe decay.

Conclusions

1. The I-Frame Sample Test was correctly followed as outlined in the AWPC protocols. The test results suggest that J-Frame is a durable product. However, I have concerns about the fullness of testing due to the inoculation procedure (discussed below). These concerns will be new to the AWPC Committee and may not necessarily be shared or implemented in future revisions.
2. The risk of rapid J-Frame failure appears to be low, as even untreated J-Frame had improved durability against brown rot. The resistance of untreated J-Frame is likely due to a level of wood modification through coincidental 'thermo-treatment' of veneers when heated for drying. Risk is certainly much less than for untreated pine framing where widespread decay or failure was the norm in the Scion trial. The view that risk of J-Frame failure is low is also supported by the apparent lack of in-service failure since 2007 when the product was introduced onto the market.

SUGGESTED IMPROVEMENTS FOR AWPC PROTOCOLS H1.2 TESTING

As part of the Scion decay trial, the test samples were inoculated with two species of brown rotting fungi using pre-infected feeder strips about 7 x 35 x 35 mm (AWPC 2015, page 12). Pre-infected feeder strips were then tacked onto the wide face of the test samples.

The H1.2 tests were originally designed for solid wood samples, where the wide face of framing timbers adequately represents the treatment patterns also found on the thin face. Therefore, the results obtained by tacking pre-inoculated feeder strips onto the wide faces of samples were representative of what would also occur on the thin faces. However, the penetration patterns in LVL are quite different on their wide and thin (edge) faces. The wide faces will usually have their face veneers uniformly and fully treated, while the thin face will expose the edges of many veneers, 12 veneers in the case of J-Frame (Figure 5). These veneer edges may include some with only shallow penetration (Figure 5). From a durability perspective, the thin edge will therefore be the weak point in LVL treated after gluing, and should be specifically targeted in durability testing. This was not done in the Scion trial, as the step is not currently included in the AWPC protocols.

The AWPC protocols require that 'samples should be placed on edge in a stack with 15-20 mm thick untreated wood or plastic fillets between each layer.' There was the possibility that the LVL edges would be exposed indirectly to decay fungi if the stickers had been untreated pine. Fungi could have travelled from the untreated controls onto the stickers and then throughout the rest of the stack. However, plastic stickers were used.

There was also the possibility that decay fungi would establish in the I-joins at either end of the test pieces, especially as the ends of the longer piece were cut after treatment. These ends were not specifically inoculated, and rely on fungal growth from the inoculation on the face veneer to reach the joins. However, Figure 6 in the Simpson and Singh (2016) report appears to show that the fungal inoculation on boron-treated face veneer has withered at the inoculation site due to preservative effects, and therefore could not reach the end joins. Docked ends could be resealed with a boron-glycol preservative (Singh *et al.*, 2014).

Conclusions

1. The AWPC protocols for H1.2 were correctly followed. However, I consider that the verification of the durability of J-Frame has not been tested fully, as J-Frame edges were not directly exposed to fungal inoculum.
2. In any future testing of LVL, and other composites for that matter, both the wide and thin faces should be inoculated with infected feeder strips. For the Scion trial discussed, this additional inoculation could be nailed to the existing J-Frame under test, if the test is still running.
3. In future revisions of the AWPC protocols, some minor level of decay (such as not more than one mm deep) should be allowed in H1.2 testing before a treatment is considered unsuitable. It is common practice in other AWPC laboratory trials to allow a mean of 3% mean mass loss or decay and still consider that the treatment was successful. Similarly, for H2 and H3 termite field testing a mean mass loss of up to 5% is allowed.

ADDITIONAL ISSUES RAISED BY RED STAG

Independence of sampling

Concerns were raised by Red Stag about the independence of test specimen preparation for the Scion I-Frame Sample Test, and the veracity of the associated retention and penetration analyses. The AWPC protocols state, 'If test timbers are treated by the preservative company, then the treatment work shall be witnessed by an independent party, and/or a representative sample of test specimens shall be chemically analysed by an independent laboratory.' The former does not appear to have occurred; however, as a representative sample was taken independently by Scion for chemical analysis this AWPC requirement was fulfilled.

The Scion report provided retention and penetration results for samples 1-3 (C1-C3, D1-D3, E1-E3, F1-F3) from each of the boron treated samples that they tested, which on its own is not enough for CodeMark approval. However as mentioned earlier, the Scion samples were not needed for CodeMark evaluation by AsureQuality. Nevertheless, the treatment results for Scion samples will be discussed further in this section. For this review, the full set of analyses by both AsureQuality (13 documents) and Veritec (two documents) for all ten replicates of each treatment was provided by JNL. The J-Frame for test was originally treated as 2360 mm (90 x 45 mm profile) or 3000 mm (140 x 45 mm profile) lengths. Specimens were cut by Juken 450 mm from the treatment ends and sent to AsureQuality, and then 900 mm long samples were cut centrally from the original lengths and sent to Scion. Independently, Scion then cut 100 mm long samples from either end, and then again cut 4 mm wafers (across the grain) from those blocks for chemical analysis. They sent the wafers directly to Veritec. Note the requirement for samples to be cut at least 150 mm from an original treatment end (Appendix B4 of AS/NZS 1604.4:2012) was met in both instances.

The AWPC protocols (page 11) state that the ends of test samples must be at least 600 mm long and shall be end sealed before treatment. The aim is to avoid testing high uptake or over-treated ends especially when treated as smaller lengths in pilot plant facilities. The J-Frame supplied by JNL was not end sealed; however, as the 900 mm long test samples were cut from the centre of lengths at least 2360 mm long, end effects were avoided. This should satisfy AWPC requirements. Indeed, using the centres from such long lengths better reflects commercial realities.

Conclusion

1. The independence of test specimen sampling was met, as outlined in the AWPC protocols.

Reliability of analytical laboratories

JNL uses AsureQuality as an independent auditor of their J-Frame production. Red Stag was concerned about the analytical results being obtained from AsureQuality, questioning why J-Frame was consistently passing retention and penetration requirements (Rigter, 2015). As part of this concern, Rigter (2015) cited independent testing of several analytical laboratories by the Wood Processors & Manufacturers Association of New Zealand (WPMA). However, an email from Dr Jon Tanner, Chief Executive of WPMA has indicated that the WPMA work was wrongly cited and blind comparisons were made where results were not attributable to specific laboratories (Tanner, 2016).

This review has little to draw upon for providing comment on the accuracy of AsureQuality results. However, some comparison can be made between the retention results obtained by Veritec and AsureQuality for the Scion samples, as both laboratories analysed samples from the same boards. Note that the two laboratories use different methods of analysis for boron-treated LVL (JNL, pers. comm.).

1. Both analytical laboratories obtained exactly the same average retention (0.75% boric acid equivalent or BAE) for H1.2 boron treated solid pine (samples C).
2. The BAE retentions obtained by Veritec were generally lower than obtained by AsureQuality for the same board numbers from samples D and F (J-Frame). While all samples were cut more than 150 mm from original treatment ends, it remains possible that the difference in retention can be attributed to the samples for AsureQuality being cut nearer to the original treatment ends than those cut for Veritec. It is also possible that the differing methods of analysis between the two laboratories produce differing retention results. If so, then a calibration between the two methods would be useful.

Conclusion

1. AsureQuality should re-check whether its procedure for determining boron retentions in LVL is giving an overestimation of retentions.

SUGGESTED IMPROVEMENTS TO STANDARDS

The guidance for penetration requirements in standards for the boron treatment of LVL is ambiguous. In particular, there is a clash between AS/NZS 1604.4: 2012 (evidence of distribution) and AS/NZS 1605.2:2006 where 'the preservative shall be continuously distributed over the penetration zone...' It would be helpful if the exact meanings of 'continuously distributed' and 'evidence of distribution' were provided in the standards, such as by using diagrams similar to those provided in Figures 3-6.

While JNL is justified in using 'evidence of distribution' to determine penetration in J-Frame and obtain CodeMark approval, the phrase is too weak to ensure durability. Decay may begin on the edge of a veneer that has limited penetration. Therefore, a Verification Method should also be used to test the durability of J-Frame under H1.2 conditions to prove its B2 durability. The final proof of what works will be obtained from durability trials, such as the I-Frame Sample Test, rather than untested penetration pattern specifications.

Conclusions

1. The penetration guidelines across the three standards (NZS 3640, AS/NZS 1604.4:2012, and AS/NZS 1605.2:2006) are conflicting and ambiguous for the H1.2 treatment of LVL with boron after gluing. This reduces confidence in a CodeMark assessment based on the standards. Remove the ambiguity in AS/NZS 1604.4 and clearly state which penetration pattern should be followed for non-glueline H1.2 treatments for LVL.
2. I consider that the phrase 'evidence of distribution' as a specification for penetration is too weak to be relied upon on its own as demonstration of durability. A Verification Method is required.
3. Provide a diagram in AS/NZS 1604.4 of preservative penetration patterns in veneers, such as shown in Figures 3-6, so that the meaning of terms such as 'continuously distributed' and 'evidence of distribution' becomes clear.
4. Any testing of LVL durability presented to standards should indicate the temperatures used for LVL production, so that it is clear whether durability is due solely to preservative treatment, or preservative treatment plus a level of thermo-modification.
5. JNL has followed the correct procedures for CodeMark approval and durability testing. The 50 year performance requirement of B2 Durability in the New Zealand Building Code for timber framing requires an H1.2 treatment that will provide durability over a five year period within that 50 year life, giving time for leaky building moisture problems to be rectified. I am unable to confirm that the B2 Durability requirement has been met, for the single reason that I consider that the thin edge of J-Frame should also be tested directly against decay fungi for verification, even though this step is currently not required in the AWPC protocols.

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GLOSSARY

AWPC = Australasian Wood Preservation Committee.
BAE = Boric acid equivalent.
Continually distributed = Penetration pattern where spot test for a preservative indicates its presence throughout the entire penetration zone.
Engineered wood = Wood products that have been made by gluing smaller pieces together, such as reconstituted wood, plywood, LVL, and glulam.
Efficacy = Whether a timber treatment can withstand a prescribed biodeteriogen.
Evidence of distribution = Penetration pattern where spot test for a preservative indicates its presence throughout the entire penetration zone, or within limited locations within the penetration zone.
JNL = Juken New Zealand Ltd.
LVL = Laminated veneer lumber.
Penetration = The depth to which a prescribed preservative is present in timber.
Penetration pattern = The depth and level of continuity to which a prescribed preservative is present within a region of timber.
Penetration zone = The region of timber that should contain preservative.
Retention = Amount of preservative within a section of timber. Where expressed as a percentage, retention is on the basis of mass per unit mass.
Solid wood = Wood without divisible parts glued together.
WPMA = Wood Processors & Manufacturers Association of New Zealand.

4

Commercial in Confidence

L J Cookson Consulting, Report No.153

Technical review on the boron treatment of LVL to meet H1.2 conditions in New Zealand

L.J. COOKSON
Independent Consulting

Commercial in Confidence

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Technical review on the boron treatment of LVL to meet H1.2 conditions in New Zealand

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Date: 9 September 2016

Client: Ministry of Business, Innovation and Employment, Wellington, New Zealand.

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OBJECTIVE

The objective of this review is to determine if J-Frame (H1.2 boron treated laminated veneer lumber or LVL) as produced by Juken New Zealand Ltd (JNL) meets the performance requirements of B2 Durability provisions of the New Zealand Building Code, and if CodeMark certification was justifiable. CodeMark compliance was provided for the product by AsureQuality in 2015 in their Product Certificate Aq-180615-CMNZ, where B2 compliance was accepted through the Alternative Solutions process.

INTRODUCTION

Since the 1950s, softwood house framing in New Zealand was treated with boron in the anticipation that it would be needed to control *Anobium* borer. However, the risk from *Anobium* was overstated, so that in 1995 untreated framing was allowed and its use widely implemented (Hedley, 2003). What was not fully realised at the time is that the same boron treatments used to control insects were also controlling decay fungi. While building practices should not allow the ingress of moisture to reach house framing, changed practices such as the reduction of eave widths, monolithic cladding, and a move from metal flashings to sealants were amongst the factors leading to the leaky building syndrome and its associated decay problems. In response, H1.2 treatments were introduced to protect against fungal decay in interior house framing.

The Wall Frame Cavity Test was incorporated into the 2007 revision of the Australasian Wood Preservation Committee's (AWPC) protocols as a method for determining which wood treatments were suitable for H1.2. These protocols are widely used and accepted in New Zealand and Australia for determining the durability of various preservative treatments under various hazard classes. In the latest 2015 revision, an I-Frame Sample Test was included, and is now the preferred method used by Scion. Boron treatments at the appropriate retentions were found to be effective in controlling the wood decay fungal hazard in H1.2 for 'solid wood' (as distinguished from LVL and other composites). This good performance agreed with the pre-1995 experience where decay generally was not a problem in houses built with boron treated framing.

Boron is a leachable preservative that can be lost from wood or redistributed within wood after treatment (Drysdale *et al.* 2011), so it is worth noting that while H1.2 house framing should last at least 50 years, '...the preservative treatment is not designed for extended exposure to elevated moisture content' (commentary clause C3.1, Amendment 5). Similarly, the AWPC protocols now state that H1.2 treatments are meant to provide 'temporary (up to 5 years) protection of framing timbers' against leaky building problems that might elevate wood moisture content above the fibre saturation point (around 25% mc), allowing fungal decay. If water ingress is occurring, then associated problems such as staining and mould growth should allow it to be detected and remedied.

B2 Durability CodeMark compliance through Alternative Solution was accepted by AsureQuality by referencing NZS 3640:2003, NZS 3602:2003, NZS 3604: 2011, and AS/NZS 1604.4: 2012 (Figures 1-2). Wood treatment is specified according to two factors, retention, which is the amount of preservative in wood, and penetration, which is the depth to which the preservative has spread within the wood.

Evaluation Methodology:

B2 Durability	B2.3.1 Building elements must, with only normal maintenance, continue to satisfy the performance requirements of this code for the lesser of the specified intended life of the building if stated or: (a) The life of the building, being not less than 50 years, if: (i) Those building elements (including floors walls and fixings) provide structural stability to the building, or (ii) Those building elements are difficult to access or replace, or (iii) Failures of those building elements to comply with the building code would go undetected during both normal use and maintenance of the building. (b) ~~15 years if:~~ ~~(i) Those building elements (including the building envelope, exposed plumbing in the subfloor space and in-built chimneys and flues) are moderately difficult to access or replace, or (ii) Failure of those building elements to comply with the building code would go undetected during normal use of the building, but would be~~	Alternative	NZS3640:2003 NZS3602:2003 NZS3604:2011 AS/NZS1604.4:2012	AsureQuality - ATTP certificate AsureQuality – certificate of analysis AsureQuality – Open letter	B2 references NZS3604, 3602 and 3640. Already determined that it complies with AS/NZS4357. This Standard requires preservative treatment to AS/NZS1604.4, which in turn clause 1.9 'Use in NZ' states it must be treated to retention req.'s of NZS3640 which this product meets. There is no penetration req. for H1.2 in 1604 so penetration is analysed to H1 Section 2.3.9 of 3604 deals with Engineered Wood Products. 2.3.9.4 states EWP may be used if preservative treatment complies with 3602 though if not already specified in 3602 must have the level of treatment required for kiln dried Radiata pine structural grades. Lab analysis shows retention of Boron exceeds requirements. Penetration tests to H1 show 'Evidence of Penetration'.

Figure 1. Relevant B2 Durability section from AsureQuality, 2015 CodeMark Evaluation (last column expanded in Figure 2).

B2 references NZS3604, 3602 and 3640.
Already determined that it complies with AS/NZS4357. This Standard requires preservative treatment to AS/NZS1604.4, which in turn clause 1.9 'Use in NZ' states it must be treated to retention req.'s of NZS3640 which this product meets. There is no penetration req. for H1.2 in 1604 so penetration is analysed to H1
Section 2.3.9 of 3604 deals with Engineered Wood Products. 2.3.9.4 states EWP may be used if preservative treatment complies with 3602 though if not already specified in 3602 must have the level of treatment required for kiln dried Radiata pine structural grades. Lab analysis shows retention of Boron exceeds requirements. Penetration tests to H1 show 'Evidence of Penetration'.

Figure 2. Detail of last column in B2 Durability section from AsureQuality, 2015 CodeMark Evaluation.

For LVL, the relevant clause guiding treatment is 1.9 'Use in New Zealand' in AS/NZS 1604.4: 2012. This clause states that LVL 'shall be treated to the preservative retention requirements for H1.2 as set out in NZS 3640', which is a standard for solid wood. Similarly, Section 2.3.9 of NZS 3604 deals with Engineered Wood Products (EWP, including LVL), and clause 2.3.9.4 indicates that EWP may be used if preservative treatment complies with NZS 3602 though if not already specified in NZS 3602 then it must have the level of treatment required for kiln-dried radiata pine structural grades.

Further, for the Alternative Solution for J-Frame penetration requirements, clause 1.9 in AS/NZS 1604.4: 2012 states that 'Preservative penetration shall be in accordance with AS/NZS 1604.4.' However, there is no penetration requirement for H1.2 in AS/NZS 1604.4: 2012 so penetration is analysed to H1, where there should be 'Evidence of Distribution,' or as worded in the CodeMark evaluation, 'Evidence of Penetration' (AsureQuality, 2015 CodeMark Evaluation).

Since the granting of CodeMark approval for J-Frame, a series of complaints were made by Red Stag (Rigter, 2015), that the approval process was flawed and that the J-Frame being produced does not comply with B2 Durability. There were also criticisms that in a Scion decay test (Simpson and Singh, 2016) commissioned separately to the CodeMark approval process, the supply of samples was not independent or representative of commercial production, and that a level of decay occurred in J-Frame. It should be noted that these concerns did not arise as a consequence of customer complaint or in-service failure. J-Frame has been on the market since 2007.

WAS THE DECISION TO ISSUE CODEMARK APPROPRIATE?

As noted above, AsureQuality accepted B2 Durability CodeMark compliance through Alternative Solution by referencing NZS 3640:2003; NZS 3602:2003, NZS 3603:2011 and AS/NZS 1604.4:2012.

Retention

For the boron treatment of solid softwood, the full cross-section should have a minimum retention of 0.40% m/m boric acid equivalent (BAE) oven dried wood (NZS 3640: 2003). An inner one-ninth retention is not applicable. According to clause 1.9 of AS/NZS 1604.4, this same minimum retention is required in LVL. There is no reason to doubt that the same preservative retention should be needed to protect timber, whether as solid wood or LVL, if the penetration patterns are similar. Indeed, the majority of LVL retentions listed in AS/NZS 1604.4 were originally copied directly from AS 1604.1, the standard for solid wood. Note that the retention is written as 0.40% not 0.4%, which means that retentions must be given to 2 decimal places not one, which prevents retentions such as 0.39% being rounded up and passed.

A specific heartwood retention and penetration for H1.2 is not given in NZS 3640; however, it follows from New Zealand's H3 requirements (clause 6.3.1.1.2) that 'For timber treated in final shape and form, no minimum heartwood penetration is specified.' As confirmation that heartwood penetration should not be required for H1.2 when treated in final shape and form, Clause 3.2 in NZS 3640: 2003 states 'Treatment for service at a higher hazard class number satisfies all requirements for service at a lower hazard class number,...' In solid wood, the location of growth rings assists when determining heartwood regions based on small colour differences between sapwood and heartwood, and/or spot tests. The location of heartwood in LVL is more difficult to locate as growth ring structure is obliterated so that heartwood may be in different locations between each veneer. Therefore, a spot test (AS/NZS 1605.1: 2006) is required for heartwood/sapwood determination in LVL.

A number of quality control analyses for J-Frame were provided by JNL and AsureQuality. An AsureQuality analysis on 15/12/2014 of ten samples showed that all had BAE cross-section retentions of 1.04 to 1.96% m/m. An AsureQuality analysis on 28/5/2015 of another ten samples showed that all had BAE cross-section retentions of 1.09 to 2.23% m/m.

Penetration

The most contentious issue for the boron treatment of LVL concerns penetration. Treating veneers with boron before gluing can allow full penetration of all sapwood, and is a process that was used in the 1940-50s in Australia for the protection of hardwood veneers from lyctine borers. However, the boron in treated veneers can cause adhesion problems when gluing with phenol formaldehyde (PF) resin. Treatment of LVL after gluing circumvents the adhesion problem associated with boron; however, penetration can then be inhibited by glue-bonds, the random location of impervious heartwood, and sapwood grain orientation. Penetration in radiata pine sapwood can be difficult in the tangential direction, irrespective of the severity of treatment, while the radial and longitudinal directions are easily penetrated. Therefore, while the face veneers of LVL are easily treated, penetration of the interior veneers can be variable and limited, making them more susceptible to decay.

I have reviewed the proprietary process JNL uses to produce J-Frame (Paul Jordan, pers. comm.), which includes drying veneers at high temperature, hot pressing with PF resin to make the LVL, followed by treatment in final form with a boron solution using a double vacuum treatment cycle. Charges are then held post treatment for a minimum period to promote absorption/diffusion, before being kiln dried to a moisture content which complies with clause 103.9.3 of NZS 3602: 2003.

For preservative penetration in LVL, the relevant guidance is in clause 1.9 in AS/NZS 1604.4: 2012, where 'Preservative penetration shall be in accordance with AS/NZS 1604.4.' However, there is no penetration requirement in AS/NZS 1604.4: 2012 for H1.2 (clause 2.3.2) as the only treatment mentioned is a glueline treatment with triadimefon and cyproconazole. This glueline treatment was added in 2012 to both NZS 3640 amendment 5 and AS/NZS 1604.4. Being a glueline treatment, there is no requirement for evidence of penetration of the actives into the timber itself, as it could remain associated with the glueline as long as minimum retentions in the full cross section of LVL were achieved and the maximum thickness of veneers was 4.3 mm.

Therefore, JNL uses the penetration guidance given for H1 in clause 2.2.2 where 'All preservative-treated veneers shall show evidence of the distribution of the preservative in the sapwood.' This clause is actually meant for lyctine borer control in hardwoods under Australia's H1 exposure conditions. However, it is transferable to New Zealand's H1.1 where *Anobium* borer, especially in softwoods, is of greater concern. The feeding mechanisms between the two groups, borers and fungi, are quite different with one decaying on the microscopic level while the other ingests wood pieces. Therefore, the distribution or microdistribution of preservative needed to control fungi and insects is not necessarily the same. Nevertheless in AS/NZS 1604.4: 2012, the phrasing for preservative penetration in H3 includes the option for sapwood veneers of 'evidence of preservative penetration'. H3 includes a fungal decay hazard. Currently therefore, the best match for H1.2 penetration requirements would be 'evidence of distribution' or 'evidence of penetration.'

Conflicting guidance can be drawn from AS/NZS 1605.2:2006 (Determination of preservative penetration by spot tests), which states that 'the preservative shall be continuously distributed over the penetration zone...' This standard should be followed when conducting spot tests such as those for boron. The exact meanings of 'continuously distributed' and 'evidence of distribution' have not been provided in the standards. My interpretation of these terms as they apply to a sapwood veneer can be illustrated in Figures 3-6. The dark shading represents areas that are penetrated. Continuously distributed means there are no gaps in penetration. 'Evidence of distribution' can be met by a much wider range of penetration patterns, ranging from the same one shown for continuous distribution (Figure 3) through to a minimum where even minor penetration is

still 'evidence of distribution' (Figures 4-5). The phrase 'continuously distributed' sets a higher threshold for detection of preservative penetration than 'evidence of distribution'.

Figure 3. 'Continuously distributed' penetration in a sapwood veneer.

Figure 4. An example of the minimum penetration needed for 'evidence of distribution'.

Figure 5. Another example of the minimum penetration needed for 'evidence of distribution'.

Figure 6. Veneer not penetrated.

JNL and AsureQuality have used Alternative Solution to obtain guidance, and use H1's 'evidence of distribution' as its test for penetration. This approach is feasible given the lack of countering guidance in AS/NZS 1604.4:2012. Due to the relative ease of meeting this penetration requirement, all J-Frame samples analysed and examined for this review have 'evidence of penetration' so pass penetration requirements.

An example of the penetration obtained in the Scion samples was provided in its appendix, and those for samples B1-D3 are replicated in Figure 7. D1 appears to be fully penetrated. However, some of the interior veneers in D2 and D3 have limited penetration (yellowish colouration), although it is not clear whether the cause is unpenetrated heartwood or sapwood.

Conclusions

1. Section 2.3.9 of NZS 3604 dealing with Engineered Wood Products indicates that EWP such as LVL may be used if preservative treatment has the same level of treatment as in NZS 3602 for kiln-dried radiata pine structural grades.
2. The granting of CodeMark for J-Frame as being compliant with B2 Durability was through Alternative Solution, and was justified because it followed (for retention) or gave best match to (for penetration) the existing standards NZS 3640 and AS/NZS 1604.4:2012. I have highlighted some issues with the standards, and the AWPC protocols, in later sections.

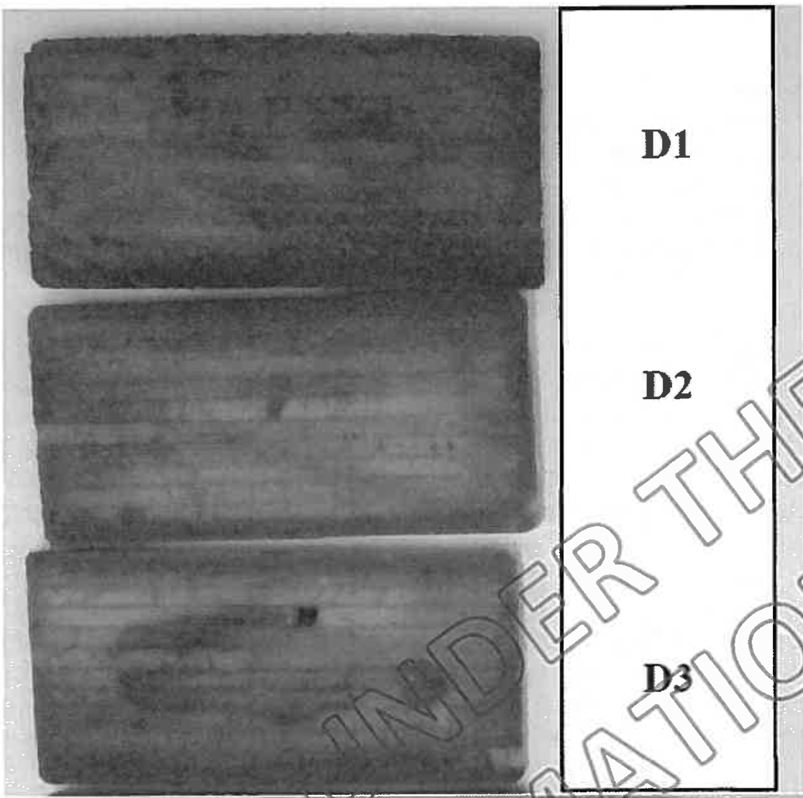

Figure 7. Boron penetration in 90 x 45 mm J-Frame. The darker red areas show boron penetration, while the paler yellow areas show a lack of penetration. From Simpson and Singh (2016).

SCION H1.2 DECAY TRIAL: POTENTIAL VERIFICATION

CodeMark for J-Frame was provided in 2015 through Alternative Solution and did not require supporting evidence from durability testing. However, an I-Frame Sample Test was subsequently conducted by Scion (Simpson and Singh, 2016), using the accepted 'Fungal Cellar' H1.2 test procedures described in the AWPC protocols.

Scion tested six types of radiata pine:

A = J-Frame untreated control 90 x 45 mm profile.
B = Solid wood untreated control 90 x 45 mm.
C = Solid wood H1.2 boron treated 90 x 45 mm.
D = J-Frame H1.2 boron normal uptake 90 x 45 mm.
E = An experimental treatment.
F = J-Frame H1.2 boron normal uptake 140 x 45 mm (wide pieces).

All J-Frame treatments for the Scion trial were conducted by JNL, while the solid wood H1.2 boron treated timber was purchased from a local building supply outlet (original treatment lengths not specified) (Paul Jordan, pers. comm.; JNL 2014 sample preparation). The E samples refer to an experimental treatment schedule, so that these samples do not require detailed consideration in this review as they do not fall under the CodeMark evaluation.

Retentions tested

The samples sent to Scion as part of the durability decay test were analysed by AsureQuality. Samples D were 90 x 45 mm profiled J-Frame treated by normal schedule, and the Scion report showed that they had a mean sapwood content of 89%. For the ten boards analysed, AsureQuality obtained retentions of 0.62-1.70% m/m. Veritec analysed samples from the same test boards and obtained retentions of 0.54-0.89% m/m. All of these analyses show that J-Frame is treated to above 0.40% m/m BAE and therefore meets standard retention requirements for LVL.

An exception obtained from the Scion samples were for samples F which were 140 x 45 mm profiled J-Frame treated by normal schedule. For the ten boards analysed, AsureQuality retentions were 0.60-1.10% m/m (all passing standard requirements) while from Veritec the retentions were 0.34-0.68% m/m. Two samples analysed by Veritec were below requirements at 0.37% for sample F3 and 0.34% for sample F10. Both values cannot be rounded up so indicate retention failure according to the more conservative results obtained by Veritec.

However, the Scion report also shows that samples F contained only 35% sapwood, meaning that 65% was heartwood. There is no guidance on what maximum percentage of heartwood is acceptable, and whether percentage heartwood content should have a bearing on cross-sectional retention in LVL. Heartwood does not require treatment when treated in final form. It would be difficult to separate heartwood and sapwood samples in LVL for separate analyses. As heartwood is difficult to treat, most boron would be located in the sapwood, so that it seems reasonable to assume that the sapwood components of samples F3 and F10 would have greater than 0.40% m/m BAE.

Nevertheless, without further guidance on what influence heartwood content should have on cross-sectional retention in LVL, the analyses showed that there were two failures for cross-sectional retention using the conservative numbers from Veritec. JNL should adjust treatments for 140 x 45 mm J-Frame until new analyses show that minimal cross-sectional retention is always achieved. Such treatment variation might be accomplished by using a harsher treatment cycle, or by limiting heartwood content. It should be noted that both samples F3 and F10 passed the H1.2 Scion decay test and lacked any signs of decay.

Decay

The Scion report shows that there was one length of boron treated J-Frame (a wide board, 145 x 45 mm) out of 30 lengths (if samples E are included) that had fungal decay. The single board (sample F5) with decay was rated 9, indicating that decay was not more than one mm deep. I consider this level of decay to be superficial. Additionally, the decay appears to have arisen because the board was located within a non-representative location of the stack at the very bottom where the edge sat in pooled or free water longer than intended. Finally, the decay was soft rot, rather than brown rot arising from the intended fungal inoculum. The fungal isolation work of Stahlhut *et al.* (2007; 2008) into the leaky building problem showed that decay was predominantly caused by brown rot fungi, although soft rot fungi do also occur. I do not consider the superficial decay of one board by soft rot to indicate durability failure.

The minor decay of untreated J-Frame in the Scion test is noteworthy. AsureQuality analysed the untreated J-Frame, and the penetration spot tests confirmed that there was no boron treatment, and all retentions were below BAE detectable limits (<0.01% m/m). Untreated LVL and plywood hot pressed to temperatures of 140-150°C will readily decay (e.g. Da Costa *et al.*, 1972). However, the J-Frame process includes a preceding step where veneers are dried at high temperature within the range used to produce some

thermo-modified woods (Militz, 2008). Thermo-modification significantly improves resistance to brown rot. The Scion trial has shown that even untreated J-Frame has improved durability, with results ranging from no decay (6 samples) to superficial decay (not more than 1 mm, 1 sample), to light decay (1-5 mm deep, 3 samples). The risk of rapid failure of J-Frame is certainly much less than for untreated solid pine which in the Scion trial had severe decay.

Conclusions

1. The I-Frame Sample Test was correctly followed as outlined in the AWPC protocols. The test results suggest that J-Frame is a durable product. However, I have concerns about the fullness of testing due to the inoculation procedure (discussed below). These concerns will be new to the AWPC Committee and may not necessarily be shared or implemented in future revisions.
2. The risk of rapid J-Frame failure appears to be low, as even untreated J-Frame had improved durability against brown rot. The resistance of untreated J-Frame is likely due to a level of wood modification through coincidental 'thermo-treatment' of veneers when heated for drying. Risk is certainly much less than for untreated pine framing where widespread decay or failure was the norm in the Scion trial. The view that risk of J-Frame failure is low is also supported by the apparent lack of in-service failure since 2007 when the product was introduced onto the market.

SUGGESTED IMPROVEMENTS FOR AWPC PROTOCOLS H1.2 TESTING

As part of the Scion decay trial, the test samples were inoculated with two species of brown rotting fungi using pre-infected feeder strips about 7 x 35 x 35 mm (AWPC 2015, page 12). Pre-infected feeder strips were then tacked onto the wide face of the test samples.

The H1.2 tests were originally designed for solid wood samples, where the wide face of framing timbers adequately represents the treatment patterns also found on the thin face. Therefore, the results obtained by tacking pre-inoculated feeder strips onto the wide faces of samples were representative of what would also occur on the thin faces. However, the penetration patterns in LVL are quite different on their wide and thin (edge) faces. The wide faces will usually have their face veneers uniformly and fully treated, while the thin face will expose the edges of many veneers, 12 veneers in the case of J-Frame (Figure 5). These veneer edges may include some with only shallow penetration (Figure 5). From a durability perspective, the thin edge will therefore be the weak point in LVL treated after gluing, and should be specifically targeted in durability testing. This was not done in the Scion trial, as the step is not currently included in the AWPC protocols.

The AWPC protocols require that 'samples should be placed on edge in a stack with 15-20 mm thick untreated wood or plastic fillets between each layer.' There was the possibility that the LVL edges would be exposed indirectly to decay fungi if the stickers had been untreated pine. Fungi could have travelled from the untreated controls onto the stickers and then throughout the rest of the stack. However, plastic stickers were used.

There was also the possibility that decay fungi would establish in the I-joins at either end of the test pieces, especially as the ends of the longer piece were cut after treatment. These ends were not specifically inoculated, and rely on fungal growth from the inoculation on the face veneer to reach the joins. However, Figure 6 in the Simpson and Singh (2016) report appears to show that the fungal inoculation on boron-treated face veneer has withered at the inoculation site due to preservative effects, and therefore could not reach the end joins. Docked ends could be resealed with a boron-glycol preservative (Singh *et al.*, 2014).

Conclusions

1. The AWPC protocols for H1.2 were correctly followed. However, I consider that the verification of the durability of J-Frame should be further tested by directly exposing its edges to fungal inoculum.
2. In any future testing of LVL, and other composites for that matter, both the wide and thin faces should be inoculated with infected feeder strips. For the Scion trial discussed, this additional inoculation could be nailed to the existing J-Frame under test, if the test is still running.
3. In future revisions of the AWPC protocols, some minor level of decay (such as not more than one mm deep) should be allowed in H1.2 testing before a treatment is considered unsuitable. It is common practice in other AWPC laboratory trials to allow a mean of 3% mean mass loss or decay and still consider that the treatment was successful. Similarly, for H2 and H3 termite field testing a mean mass loss of up to 5% is allowed.

ADDITIONAL ISSUES RAISED BY RED STAG

Independence of sampling

Concerns were raised by Red Stag about the independence of test specimen preparation for the Scion I-Frame Sample Test, and the veracity of the associated retention and penetration analyses. The AWPC protocols state, 'If test timbers are treated by the preservative company, then the treatment work shall be witnessed by an independent party, and/or a representative sample of test specimens shall be chemically analysed by an independent laboratory.' The former does not appear to have occurred; however, as a representative sample was taken independently by Scion for chemical analysis this AWPC requirement was fulfilled.

The Scion report provided retention and penetration results for samples 1-3 (C1-C3, D1-D3, E1-E3, F1-F3) from each of the boron treated samples that they tested, which on its own is not enough for CodeMark approval. However as mentioned earlier, the Scion samples were not needed for CodeMark evaluation by AsureQuality. Nevertheless, the treatment results for Scion samples will be discussed further in this section. For this review, the full set of analyses by both AsureQuality (13 documents) and Veritec (two documents) for all ten replicates of each treatment was provided by JNL. The J-Frame for test was originally treated as 2360 mm (90 x 45 mm profile) or 3000 mm (140 x 45 mm profile) lengths. Specimens were cut by Juken 450 mm from the treatment ends and sent to AsureQuality, and then 900 mm long samples were cut centrally from the original lengths and sent to Scion. Independently, Scion then cut 100 mm long samples from either end, and then again cut 4 mm wafers (across the grain) from those blocks for chemical analysis. They sent the wafers directly to Veritec. Note the requirement for samples to be cut at least 150 mm from an original treatment end (Appendix B4 of AS/NZS 1604.4:2012) was met in both instances.

The AWPC protocols (page 11) state that the ends of test samples must be at least 600 mm long and shall be end sealed before treatment. The aim is to avoid testing high uptake or over-treated ends especially when treated as smaller lengths in pilot plant facilities. The J-Frame supplied by JNL was not end sealed; however, as the 900 mm long test samples were cut from the centre of lengths at least 2360 mm long, end effects were avoided. This should satisfy AWPC requirements. Indeed, using the centres from such long lengths better reflects commercial realities.

Conclusion

1. The independence of test specimen sampling was met, as outlined in the AWPC protocols.

Reliability of analytical laboratories

JNL uses AsureQuality as an independent auditor of their J-Frame production. Red Stag was concerned about the analytical results being obtained from AsureQuality, questioning why J-Frame was consistently passing retention and penetration requirements (Rigter, 2015). As part of this concern, Rigter (2015) cited independent testing of several analytical laboratories by the Wood Processors & Manufacturers Association of New Zealand (WPMA). However, an email from Dr Jon Tanner, Chief Executive of WPMA has indicated that the WPMA work was wrongly cited and blind comparisons were made where results were not attributable to specific laboratories (Tanner, 2016).

This review has little to draw upon for providing comment on the accuracy of AsureQuality results. However, some comparison can be made between the retention results obtained by Veritec and AsureQuality for the Scion samples, as both laboratories analysed samples from the same boards. Note that the two laboratories use different methods of analysis for boron-treated LVL (JNL, pers. comm.).

1. Both analytical laboratories obtained exactly the same average retention (0.75% boric acid equivalent or BAE) for H1.2 boron treated solid pine (samples C).
2. The BAE retentions obtained by Veritec were generally lower than obtained by AsureQuality for the same board numbers from samples D and F (J-Frame). While all samples were cut more than 150 mm from original treatment ends, it remains possible that the difference in retention can be attributed to the samples for AsureQuality being cut nearer to the original treatment ends than those cut for Veritec. It is also possible that the differing methods of analysis between the two laboratories produce differing retention results. If so, then a calibration between the two methods would be useful.

Conclusion

1. AsureQuality should re-check whether its procedure for determining boron retentions in LVL is giving an overestimation of retentions.

SUGGESTED IMPROVEMENTS TO STANDARDS

The guidance for penetration requirements in standards for the boron treatment of LVL is ambiguous. In particular, there is a clash between AS/NZS 1604.4: 2012 (evidence of distribution) and AS/NZS 1605.2:2006 where 'the preservative shall be continuously distributed over the penetration zone...' It would be helpful if the exact meanings of 'continuously distributed' and 'evidence of distribution' were provided in the standards, such as by using diagrams similar to those provided in Figures 3-6.

While JNL is justified in using 'evidence of distribution' to determine penetration in J-Frame and obtain CodeMark approval, the phrase is too weak to ensure durability. Decay may begin on the edge of a veneer that has limited penetration. Therefore, a Verification Method should also be used to test the durability of J-Frame under H1.2 conditions to prove its B2 durability. The final proof of what works will be obtained from durability trials, such as the I-Frame Sample Test, rather than untested penetration pattern specifications.

Conclusions

1. The penetration guidelines across the three standards (NZS 3640, AS/NZS 1604.4:2012, and AS/NZS 1605.2:2006) are conflicting and ambiguous for the H1.2 treatment of LVL with boron after gluing. This reduces confidence in a CodeMark assessment based on the standards. Remove the ambiguity in AS/NZS 1604.4 and clearly state which penetration pattern should be followed for non-glueline H1.2 treatments for LVL.
2. I consider that the phrase 'evidence of distribution' as a specification for penetration is too weak to be relied upon on its own as demonstration of durability. A Verification Method is required.
3. Provide a diagram in AS/NZS 1604.4 of preservative penetration patterns in veneers, such as shown in Figures 3-6, so that the meaning of terms such as 'continuously distributed' and 'evidence of distribution' becomes clear.
4. Any testing of LVL durability presented to standards should indicate the temperatures used for LVL production, so that it is clear whether durability is due solely to preservative treatment, or preservative treatment plus a level of thermo-modification.
5. JNL has followed the correct procedures for CodeMark approval and durability testing. The 50 year performance requirement of B2 Durability in the New Zealand Building Code for timber framing requires an H1.2 treatment that will provide durability over a five year period within that 50 year life, giving time for leaky building moisture problems to be rectified. While the procedures followed provide a high degree of confidence about the B2 Durability of J-Frame, additional confidence would be obtained from a trial where the thin edge of J-Frame was tested directly against decay fungi for verification, a step that should become incorporated into the AWPC protocols.

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GLOSSARY

AWPC = Australasian Wood Preservation Committee.
BAE = Boric acid equivalent.
Continually distributed = Penetration pattern where spot test for a preservative indicates its presence throughout the entire penetration zone.
Engineered wood = Wood products that have been made by gluing smaller pieces together, such as reconstituted wood, plywood, LVL, and glulam.
Efficacy = Whether a timber treatment can withstand a prescribed biodeteriogen.
Evidence of distribution = Penetration pattern where spot test for a preservative indicates its presence throughout the entire penetration zone, or within limited locations within the penetration zone.
JNL = Juken New Zealand Ltd.
LVL = Laminated veneer lumber.
Penetration = The depth to which a prescribed preservative is present in timber.
Penetration pattern = The depth and level of continuity to which a prescribed preservative is present within a region of timber.
Penetration zone = The region of timber that should contain preservative.
Retention = Amount of preservative within a section of timber. Where expressed as a percentage, retention is on the basis of mass per unit mass.
Solid wood = Wood without divisible parts glued together.
WPMA = Wood Processors & Manufacturers Association of New Zealand.

5

Commercial in Confidence

L J Cookson Consulting, Report No.153

Technical review on the boron treatment of LVL to meet H1.2 conditions in New Zealand

LJ COOKSON
Independent Consulting

Commercial in Confidence

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Technical review on the boron treatment of LVL to meet H1.2 conditions in New Zealand

Laurie J Cookson

Date: 27 September 2016

Client: Ministry of Business, Innovation and Employment, Wellington, New Zealand.

Important Disclaimer

LJ COOKSON Independent Consulting

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OBJECTIVE

The objective of this review is to determine if J-Frame (H1.2 boron treated laminated veneer lumber or LVL) as produced by Juken New Zealand Ltd (JNL) meets the performance requirements of B2 Durability provisions of the New Zealand Building Code, and if CodeMark certification was justifiable. CodeMark compliance was provided for the product by AsureQuality in 2015 in their Product Certificate Aq-180615-CMNZ, where B2 compliance was accepted through the Alternative Solutions process.

INTRODUCTION

Since the 1950s, softwood house framing in New Zealand was treated with boron in the anticipation that it would be needed to control *Anobium* borer. However, the risk from *Anobium* was overstated, so that in 1995 untreated framing was allowed and its use widely implemented (Hedley, 2003). What was not fully realised at the time is that the same boron treatments used to control insects were also controlling decay fungi. While building practices should not allow the ingress of moisture to reach house framing, changed practices such as the reduction of eave widths, monolithic cladding, and a move from metal flashings to sealants were amongst the factors leading to the leaky building syndrome and its associated decay problems. In response, H1.2 treatments were introduced to protect against fungal decay in interior house framing.

The Wall Frame Cavity Test was incorporated into the 2007 revision of the Australasian Wood Preservation Committee's (AWPC) protocols as a method for determining which wood treatments were suitable for H1.2. These protocols are widely used and accepted in New Zealand and Australia for determining the durability of various preservative treatments under various hazard classes. In the latest 2015 revision, an I-Frame Sample Test was included, and is now the preferred method used by Scion. Boron treatments at the appropriate retentions were found to be effective in controlling the wood decay fungal hazard in H1.2 for 'solid wood' (as distinguished from LVL and other composites). This good performance agreed with the pre-1995 experience where decay generally was not a problem in houses built with boron treated framing.

Boron is a leachable preservative that can be lost from wood or redistributed within wood after treatment (Drysdale *et al.* 2011), so it is worth noting that while H1.2 house framing should last at least 50 years, '...the preservative treatment is not designed for extended exposure to elevated moisture content' (commentary clause C3.1, Amendment 5). Similarly, the AWPC protocols now state that H1.2 treatments are meant to provide 'temporary (up to 5 years) protection of framing timbers' against leaky building problems that might elevate wood moisture content above the fibre saturation point (around 25% mc), allowing fungal decay. If water ingress is occurring, then associated problems such as staining and mould growth should allow it to be detected and remedied.

B2 Durability CodeMark compliance through Alternative Solution was accepted by AsureQuality by referencing NZS 3640:2003, NZS 3602:2003, NZS 3604: 2011, and AS/NZS 1604.4: 2012 (Figures 1-2). Wood treatment is specified according to two factors, retention, which is the amount of preservative in wood, and penetration, which is the depth to which the preservative has spread within the wood.

Evaluation Methodology:

B2 Durability	B2.3.1 Building elements must, with only normal maintenance, continue to satisfy the performance requirements of this code for the lesser of the specified intended life of the building if stated or: (a) The life of the building, being not less than 50 years, if: (i) Those building elements (including floors walls and fixings) provide structural stability to the building, or (ii) Those building elements are difficult to access or replace, or (iii) Failures of those building elements to comply with the building code would go undetected during both normal use and maintenance of the building. ~~(b) 15 years if:~~ ~~(i) Those building elements (including the building envelope, exposed plumbing in the subfloor space and in-built chimneys and flues) are moderately difficult to access or replace, or (ii) Failure of those building elements to comply with the building code would go undetected during normal use of the building, but would be~~	Alternative	NZS3640:2003 NZS3602:2003 NZS3604.2011 AS/NZS1604.4:2012	AsureQuality - ATTP certificate AsureQuality – certificate of analysis AsureQuality – Open letter	B2 references NZS3604, 3602 and 3640. Already determined that it complies with AS/NZS4357. This Standard requires preservative treatment to AS/NZS1604.4, which in turn clause 1.9 'Use in NZ' states it must be treated to retention req.'s of NZS3640 which this product meets. There is no penetration req. for H1.2 in 1604 so penetration is analysed to H1 Section 2.3.9 of 3604 deals with Engineered Wood Products. 2.3.9.4 states EWP may be used if preservative treatment complies with 3602 though if not already specified in 3602 must have the level of treatment required for kiln dried Radiata pine structural grades. Lab analysis shows retention of Boron exceeds requirements. Penetration tests to H1 show 'Evidence of Penetration'.

Figure 1. Relevant B2 Durability section from AsureQuality, 2015 CodeMark Evaluation (last column expanded in Figure 2).

B2 references NZS3604, 3602 and 3640.
Already determined that it complies with AS/NZS4357. This Standard requires preservative treatment to AS/NZS1604.4, which in turn clause 1.9 'Use in NZ' states it must be treated to retention req.'s of NZS3640 which this product meets. There is no penetration req. for H1.2 in 1604 so penetration is analysed to H1
Section 2.3.9 of 3604 deals with Engineered Wood Products. 2.3.9.4 states EWP may be used if preservative treatment complies with 3602 though if not already specified in 3602 must have the level of treatment required for kiln dried Radiata pine structural grades. Lab analysis shows retention of Boron exceeds requirements. Penetration tests to H1 show 'Evidence of Penetration'.

Figure 2. Detail of last column in B2 Durability section from AsureQuality, 2015 CodeMark Evaluation.

For LVL, the relevant clause guiding treatment is 1.9 'Use in New Zealand' in AS/NZS 1604.4: 2012. This clause states that LVL 'shall be treated to the preservative retention requirements for H1.2 as set out in NZS 3640', which is a standard for solid wood. Similarly, Section 2.3.9 of NZS 3604 deals with Engineered Wood Products (EWP, including LVL), and clause 2.3.9.4 indicates that EWP may be used if preservative treatment complies with NZS 3602 though if not already specified in NZS 3602 then it must have the level of treatment required for kiln-dried radiata pine structural grades.

Further, for the Alternative Solution for J-Frame penetration requirements, clause 1.9 in AS/NZS 1604.4: 2012 states that 'Preservative penetration shall be in accordance with AS/NZS 1604.4.' However, there is no penetration requirement for H1.2 in AS/NZS 1604.4: 2012 so penetration is analysed to H1, where there should be 'Evidence of Distribution,' or as worded in the CodeMark evaluation, 'Evidence of Penetration' (AsureQuality, 2015 CodeMark Evaluation).

Since the granting of CodeMark approval for J-Frame, a series of complaints were made by Red Stag (Rigter, 2015), that the approval process was flawed and that the J-Frame being produced does not comply with B2 Durability. There were also criticisms that in a Scion decay test (Simpson and Singh, 2016) commissioned separately to the CodeMark approval process, the supply of samples was not independent or representative of commercial production, and that a level of decay occurred in J-Frame. It should be noted that these concerns did not arise as a consequence of customer complaint or in-service failure. J-Frame has been on the market since 2007.

WAS THE DECISION TO ISSUE CODEMARK APPROPRIATE?

As noted above, AsureQuality accepted B2 Durability CodeMark compliance through Alternative Solution by referencing NZS 3640:2003; NZS 3602:2003, NZS 3603:2011 and AS/NZS 1604.4:2012.

Retention

For the boron treatment of solid softwood, the full cross-section should have a minimum retention of 0.40% m/m boric acid equivalent (BAE) oven dried wood (NZS 3640: 2003). An inner one-ninth retention is not applicable. According to clause 1.9 of AS/NZS 1604.4, this same minimum retention is required in LVL. There is no reason to doubt that the same preservative retention should be needed to protect timber, whether as solid wood or LVL, if the penetration patterns are similar. Indeed, the majority of LVL retentions listed in AS/NZS 1604.4 were originally copied directly from AS 1604.1, the standard for solid wood. Note that the retention is written as 0.40% not 0.4%, which means that retentions must be given to 2 decimal places not one, which prevents retentions such as 0.39% being rounded up and passed.

A specific heartwood retention and penetration for H1.2 is not given in NZS 3640; however, it follows from New Zealand's H3 requirements (clause 6.3.1.1.2) that 'For timber treated in final shape and form, no minimum heartwood penetration is specified.' As confirmation that heartwood penetration should not be required for H1.2 when treated in final shape and form, Clause 3.2 in NZS 3640: 2003 states 'Treatment for service at a higher hazard class number satisfies all requirements for service at a lower hazard class number,...' In solid wood, the location of growth rings assists when determining heartwood regions based on small colour differences between sapwood and heartwood, and/or spot tests. The location of heartwood in LVL is more difficult to locate as growth ring structure is obliterated so that heartwood may be in different locations between each veneer. Therefore, a spot test (AS/NZS 1605.1: 2006) is required for heartwood/sapwood determination in LVL.

A number of quality control analyses for J-Frame were provided by JNL and AsureQuality. An AsureQuality analysis on 15/12/2014 of ten samples showed that all had BAE cross-section retentions of 1.04 to 1.96% m/m. An AsureQuality analysis on 28/5/2015 of another ten samples showed that all had BAE cross-section retentions of 1.09 to 2.23% m/m.

Penetration

The most contentious issue for the boron treatment of LVL concerns penetration. Treating veneers with boron before gluing can allow full penetration of all sapwood, and is a process that was used in the 1940-50s in Australia for the protection of hardwood veneers from lyctine borers. However, the boron in treated veneers can cause adhesion problems when gluing with phenol formaldehyde (PF) resin. Treatment of LVL after gluing circumvents the adhesion problem associated with boron; however, penetration can then be inhibited by glue-bonds, the random location of impervious heartwood, and sapwood grain orientation. Penetration in radiata pine sapwood can be difficult in the tangential direction, irrespective of the severity of treatment, while the radial and longitudinal directions are easily penetrated. Therefore, while the face veneers of LVL are easily treated, penetration of the interior veneers can be variable and limited, making them more susceptible to decay.

I have reviewed the proprietary process JNL uses to produce J-Frame (Paul Jordan, pers. comm.), which includes drying veneers at high temperature, hot pressing with PF resin to make the LVL, followed by treatment in final form with a boron solution using a double vacuum treatment cycle. Charges are then held post treatment for a minimum period to promote absorption/diffusion, before being kiln dried to a moisture content which complies with clause 103.9.3 of NZS 3602: 2003.

For preservative penetration in LVL, the relevant guidance is in clause 1.9 in AS/NZS 1604.4: 2012, where 'Preservative penetration shall be in accordance with AS/NZS 1604.4.' However, there is no penetration requirement in AS/NZS 1604.4: 2012 for H1.2 (clause 2.3.2) as the only treatment mentioned is a glueline treatment with triadimefon and cyproconazole. This glueline treatment was added in 2012 to both NZS 3640 amendment 5 and AS/NZS 1604.4. Being a glueline treatment, there is no requirement for evidence of penetration of the actives into the timber itself, as it could remain associated with the glueline as long as minimum retentions in the full cross section of LVL were achieved and the maximum thickness of veneers was 4.3 mm.

Therefore, JNL uses the penetration guidance given for H1 in clause 2.2.2 where 'All preservative-treated veneers shall show evidence of the distribution of the preservative in the sapwood.' This clause is actually meant for lyctine borer control in hardwoods under Australia's H1 exposure conditions. However, it is transferable to New Zealand's H1.1 where *Anobium* borer, especially in softwoods, is of greater concern. The feeding mechanisms between the two groups, borers and fungi, are quite different with one decaying on the microscopic level while the other ingests wood pieces. Therefore, the distribution or microdistribution of preservative needed to control fungi and insects is not necessarily the same. Nevertheless in AS/NZS 1604.4: 2012, the phrasing for preservative penetration in H3 includes the option for sapwood veneers of 'evidence of preservative penetration'. H3 includes a fungal decay hazard. Currently therefore, the best match for H1.2 penetration requirements would be 'evidence of distribution' or 'evidence of penetration.'

Conflicting guidance can be drawn from AS/NZS 1605.2:2006 (Determination of preservative penetration by spot tests), which states that 'the preservative shall be continuously distributed over the penetration zone...' This standard should be followed when conducting spot tests such as those for boron. The exact meanings of 'continuously distributed' and 'evidence of distribution' have not been provided in the standards. My interpretation of these terms as they apply to a sapwood veneer can be illustrated in Figures 3-6. The dark shading represents areas that are penetrated. Continuously distributed means there are no gaps in penetration. 'Evidence of distribution' can be met by a much wider range of penetration patterns, ranging from the same one shown for continuous distribution (Figure 3) through to a minimum where even minor penetration is

still 'evidence of distribution' (Figures 4-5). The phrase 'continuously distributed' sets a higher threshold for detection of preservative penetration than 'evidence of distribution'.

Figure 3. 'Continuously distributed' penetration in a sapwood veneer.

Figure 4. An example of the minimum penetration needed for 'evidence of distribution'.

Figure 5. Another example of the minimum penetration needed for 'evidence of distribution'.

Figure 6. Veneer not penetrated.

JNL and AsureQuality have used Alternative Solution to obtain guidance, and use H1's 'evidence of distribution' as its test for penetration. This approach is feasible given the lack of countering guidance in AS/NZS 1604.4::2012. Due to the relative ease of meeting this penetration requirement, all J-Frame samples analysed and examined for this review have 'evidence of penetration' so pass penetration requirements.

An example of the penetration obtained in the Scion samples was provided in its appendix, and those for samples D1-D3 are replicated in Figure 7. D1 appears to be fully penetrated. However, some of the interior veneers in D2 and D3 have limited penetration (yellowish colouration), although it is not clear whether the cause is unpenetrated heartwood or sapwood.

Conclusions

1. Section 2.3.9 of NZS 3604 dealing with Engineered Wood Products indicates that EWP such as LVL may be used if preservative treatment has the same level of treatment as in NZS 3602 for kiln-dried radiata pine structural grades.
2. The granting of CodeMark for J-Frame as being compliant with B2 Durability was through Alternative Solution, and was justified because it followed (for retention) or gave best match to (for penetration) the existing standards NZS 3640 and AS/NZS 1604.4:2012. I have highlighted some issues with the standards, and the AWPC protocols, in later sections.

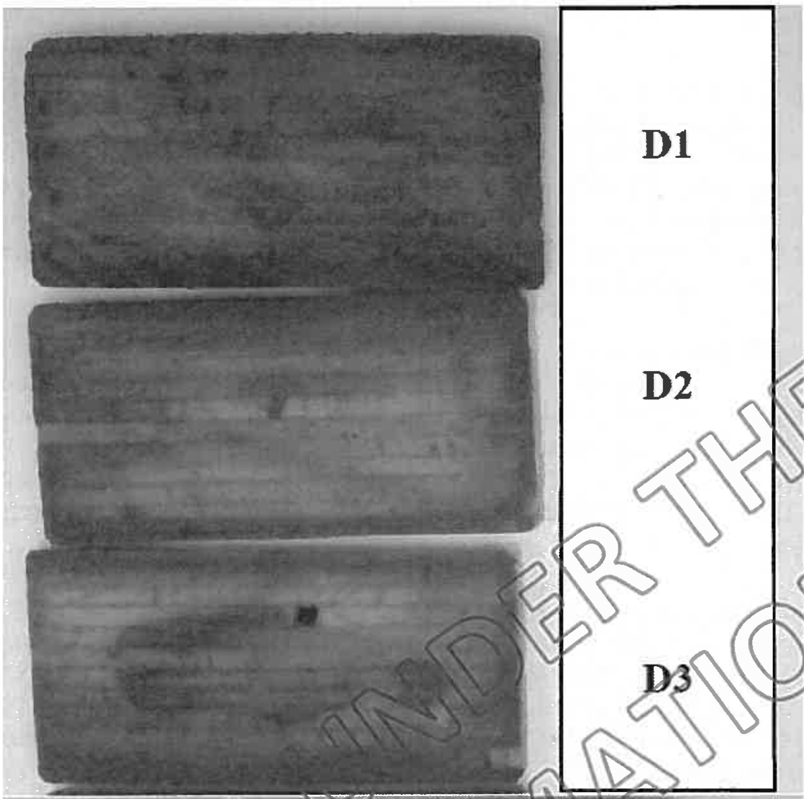

Figure 7. Boron penetration in 90 x 45 mm J-Frame. The darker red areas show boron penetration, while the paler yellow areas show a lack of penetration. From Simpson and Singh (2016).

SCION H1.2 DECAY TRIAL: POTENTIAL VERIFICATION

CodeMark for J-Frame was provided in 2015 through Alternative Solution and did not require supporting evidence from durability testing. However, an I-Frame Sample Test was subsequently conducted by Scion (Simpson and Singh, 2016), using the accepted ‘Fungal Cellar H1.2 test procedures described in the AWPC protocols.

Scion tested six types of radiata pine:

A = J-Frame untreated control 90 x 45 mm profile.
B = Solid wood untreated control 90 x 45 mm.
C = Solid wood H1.2 boron treated 90 x 45 mm.
D = J-Frame H1.2 boron normal uptake 90 x 45 mm.
E = An experimental treatment.
F = J-Frame H1.2 boron normal uptake 140 x 45 mm (wide pieces).

All J-Frame treatments for the Scion trial were conducted by JNL, while the solid wood H1.2 boron treated timber was purchased from a local building supply outlet (original treatment lengths not specified) (Paul Jordan, pers. comm.; JNL 2014 sample preparation). The E samples refer to an experimental treatment schedule, so that these samples do not require detailed consideration in this review as they do not fall under the CodeMark evaluation.

Retentions tested

The samples sent to Scion as part of the durability decay test were analysed by AsureQuality. Samples D were 90 x 45 mm profiled J-Frame treated by normal schedule, and the Scion report showed that they had a mean sapwood content of 89%. For the ten boards analysed, AsureQuality obtained retentions of 0.62-1.70% m/m. Veritec analysed samples from the same test boards and obtained retentions of 0.54-0.89% m/m. All of these analyses show that J-Frame is treated to above 0.40% m/m BAE and therefore meets standard retention requirements for LVL.

An exception obtained from the Scion samples were for samples F which were 140 x 45 mm profiled J-Frame treated by normal schedule. For the ten boards analysed, AsureQuality retentions were 0.60-1.10% m/m (all passing standard requirements) while from Veritec the retentions were 0.34-0.68% m/m. Two samples analysed by Veritec were below requirements at 0.37% for sample F3 and 0.34% for sample F10. Both values cannot be rounded up so indicate retention failure according to the more conservative results obtained by Veritec.

However, the Scion report also shows that samples F contained only 35% sapwood, meaning that 65% was heartwood. There is no guidance on what maximum percentage of heartwood is acceptable, and whether percentage heartwood content should have a bearing on cross-sectional retention in LVL. Heartwood does not require treatment when treated in final form. It would be difficult to separate heartwood and sapwood samples in LVL for separate analyses. As heartwood is difficult to treat, most boron would be located in the sapwood, so that it seems reasonable to assume that the sapwood components of samples F3 and F10 would have greater than 0.40% m/m BAE.

Nevertheless, without further guidance on what influence heartwood content should have on cross-sectional retention in LVL, the analyses showed that there were two failures for cross-sectional retention using the conservative numbers from Veritec. JNL should adjust treatments for 140 x 45 mm J-Frame until new analyses show that minimal cross-sectional retention is always achieved. Such treatment variation might be accomplished by using a harsher treatment cycle, or by limiting heartwood content. It should be noted that both samples F3 and F10 passed the H1.2 Scion decay test and lacked any signs of decay.

Decay

The Scion report shows that there was one length of boron treated J-Frame (a wide board, 145 x 45 mm) out of 30 lengths (if samples E are included) that had fungal decay. The single board (sample F5) with decay was rated 9, indicating that decay was not more than one mm deep. I consider this level of decay to be superficial. Additionally, the decay appears to have arisen because the board was located within a non-representative location of the stack at the very bottom where the edge sat in pooled or free water longer than intended. Finally, the decay was soft rot, rather than brown rot arising from the intended fungal inoculum. The fungal isolation work of Stahlhut *et al.* (2007; 2008) into the leaky building problem showed that decay was predominantly caused by brown rot fungi, although soft rot fungi do also occur. I do not consider the superficial decay of one board by soft rot to indicate durability failure.

The minor decay of untreated J-Frame in the Scion test is noteworthy. AsureQuality analysed the untreated J-Frame, and the penetration spot tests confirmed that there was no boron treatment, and all retentions were below BAE detectable limits (<0.01% m/m). Untreated LVL and plywood hot pressed to temperatures of 140-150°C will readily decay (e.g. Da Costa *et al.*, 1972). However, the J-Frame process includes a preceding step where veneers are dried at high temperature within the range used to produce some

thermo-modified woods (Militz, 2008). Thermo-modification significantly improves resistance to brown rot. The Scion trial has shown that even untreated J-Frame has improved durability, with results ranging from no decay (6 samples) to superficial decay (not more than 1 mm, 1 sample), to light decay (1-5 mm deep, 3 samples). The risk of rapid failure of J-Frame is certainly much less than for untreated solid pine which in the Scion trial had severe decay.

Conclusions

1. The I-Frame Sample Test was correctly followed as outlined in the AWPC protocols. The test results suggest that J-Frame is a durable product. However, I have concerns about the fullness of testing due to the inoculation procedure (discussed below). These concerns will be new to the AWPC Committee and may not necessarily be shared or implemented in future revisions.
2. The risk of rapid J-Frame failure appears to be low, as even untreated J-Frame had improved durability against brown rot. The resistance of untreated J-Frame is likely due to a level of wood modification through coincidental 'thermo-treatment' of veneers when heated for drying. Risk is certainly much less than for untreated pine framing where widespread decay or failure was the norm in the Scion trial. The view that risk of J-Frame failure is low is also supported by the apparent lack of in-service failure since 2007 when the product was introduced onto the market.

SUGGESTED IMPROVEMENTS FOR AWPC PROTOCOLS H1.2 TESTING

As part of the Scion decay trial, the test samples were inoculated with two species of brown rotting fungi using pre-infected feeder strips about 7 x 35 x 35 mm (AWPC 2015, page 12). Pre-infected feeder strips were then tacked onto the wide face of the test samples.

The H1.2 tests were originally designed for solid wood samples, where the wide face of framing timbers adequately represents the treatment patterns also found on the thin face. Therefore, the results obtained by tacking pre-inoculated feeder strips onto the wide faces of samples were representative of what would also occur on the thin faces. However, the penetration patterns in LVL are quite different on their wide and thin (edge) faces. The wide faces will usually have their face veneers uniformly and fully treated, while the thin face will expose the edges of many veneers, 12 veneers in the case of J-Frame (Figure 5). These veneer edges may include some with only shallow penetration (Figure 5). From a durability perspective, the thin edge will therefore be the weak point in LVL treated after gluing, and should be specifically targeted in durability testing. This was not done in the Scion trial, as the step is not currently included in the AWPC protocols.

The AWPC protocols require that 'samples should be placed on edge in a stack with 15-20 mm thick untreated wood or plastic fillets between each layer.' There was the possibility that the LVL edges would be exposed indirectly to decay fungi if the stickers had been untreated pine. Fungi could have travelled from the untreated controls onto the stickers and then throughout the rest of the stack. However, plastic stickers were used.

There was also the possibility that decay fungi would establish in the I-joins at either end of the test pieces, especially as the ends of the longer piece were cut after treatment. These ends were not specifically inoculated, and rely on fungal growth from the inoculation on the face veneer to reach the joins. However, Figure 6 in the Simpson and Singh (2016) report appears to show that the fungal inoculation on boron-treated face veneer has withered at the inoculation site due to preservative effects, and therefore could not reach the end joins. Docked ends could be resealed with a boron-glycol preservative (Singh *et al.*, 2014).

Conclusions

1. The AWPC protocols for H1.2 were correctly followed. However, I consider that the verification of the durability of J-Frame should be further tested by directly exposing its edges to fungal inoculum.
2. In any future testing of LVL, and other composites for that matter, both the wide and thin faces should be inoculated with infected feeder strips. For the Scion trial discussed, this additional inoculation could be nailed to the existing J-Frame under test, if the test is still running.
3. In future revisions of the AWPC protocols, some minor level of decay (such as not more than one mm deep) should be allowed in H1.2 testing before a treatment is considered unsuitable. It is common practice in other AWPC laboratory trials to allow a mean of 3% mean mass loss or decay and still consider that the treatment was successful. Similarly, for H2 and H3 termite field testing a mean mass loss of up to 5% is allowed.

ADDITIONAL ISSUES RAISED BY RED STAG

Independence of sampling

Concerns were raised by Red Stag about the independence of test specimen preparation for the Scion I-Frame Sample Test, and the veracity of the associated retention and penetration analyses. The AWPC protocols state, 'If test timbers are treated by the preservative company, then the treatment work shall be witnessed by an independent party, and/or a representative sample of test specimens shall be chemically analysed by an independent laboratory.' The former does not appear to have occurred; however, as a representative sample was taken independently by Scion for chemical analysis this AWPC requirement was fulfilled.

The Scion report provided retention and penetration results for samples 1-3 (C1-C3, D1-D3, E1-E3, F1-F3) from each of the boron treated samples that they tested, which on its own is not enough for CodeMark approval. However as mentioned earlier, the Scion samples were not needed for CodeMark evaluation by AsureQuality. Nevertheless, the treatment results for Scion samples will be discussed further in this section. For this review, the full set of analyses by both AsureQuality (13 documents) and Veritec (two documents) for all ten replicates of each treatment was provided by JNL. The J-Frame for test was originally treated as 2360 mm (90 x 45 mm profile) or 3000 mm (140 x 45 mm profile) lengths. Specimens were cut by Juken 450 mm from the treatment ends and sent to AsureQuality, and then 900 mm long samples were cut centrally from the original lengths and sent to Scion. Independently, Scion then cut 100 mm long samples from either end, and then again cut 4 mm wafers (across the grain) from those blocks for chemical analysis. They sent the wafers directly to Veritec. Note the requirement for samples to be cut at least 150 mm from an original treatment end (Appendix B4 of AS/NZS 1604.4:2012) was met in both instances.

The AWPC protocols (page 11) state that the ends of test samples must be at least 600 mm long and shall be end sealed before treatment. The aim is to avoid testing high uptake or over-treated ends especially when treated as smaller lengths in pilot plant facilities. The J-Frame supplied by JNL was not end sealed; however, as the 900 mm long test samples were cut from the centre of lengths at least 2360 mm long, end effects were avoided. This should satisfy AWPC requirements. Indeed, using the centres from such long lengths better reflects commercial realities.

Conclusion

1. The independence of test specimen sampling was met, as outlined in the AWPC protocols.

Reliability of analytical laboratories

JNL uses AsureQuality as an independent auditor of their J-Frame production. Red Stag was concerned about the analytical results being obtained from AsureQuality, questioning why J-Frame was consistently passing retention and penetration requirements (Rigter, 2015). As part of this concern, Rigter (2015) cited independent testing of several analytical laboratories by the Wood Processors & Manufacturers Association of New Zealand (WPMA). However, an email from Dr Jon Tanner, Chief Executive of WPMA has indicated that the WPMA work was wrongly cited and blind comparisons were made where results were not attributable to specific laboratories (Tanner, 2016).

This review has little to draw upon for providing comment on the accuracy of AsureQuality results. However, some comparison can be made between the retention results obtained by Veritec and AsureQuality for the Scion samples, as both laboratories analysed samples from the same boards. Note that the two laboratories use different methods of analysis for boron-treated LVL (JNL, pers. comm.).

1. Both analytical laboratories obtained exactly the same average retention (0.75% boric acid equivalent or BAE) for H1.2 boron treated solid pine (samples C).
2. The BAE retentions obtained by Veritec were generally lower than obtained by AsureQuality for the same board numbers from samples D and F (J-Frame). While all samples were cut more than 150 mm from original treatment ends, it remains possible that the difference in retention can be attributed to the samples for AsureQuality being cut nearer to the original treatment ends than those cut for Veritec. It is also possible that the differing methods of analysis between the two laboratories produce differing retention results. If so, then a calibration between the two methods would be useful.

Conclusion

1. AsureQuality should re-check whether its procedure for determining boron retentions in LVL is giving an overestimation of retentions.

SUGGESTED IMPROVEMENTS TO STANDARDS

The guidance for penetration requirements in standards for the boron treatment of LVL is ambiguous. In particular, there is a clash between AS/NZS 1604.4: 2012 (evidence of distribution) and AS/NZS 1605.2:2006 where 'the preservative shall be continuously distributed over the penetration zone...' It would be helpful if the exact meanings of 'continuously distributed' and 'evidence of distribution' were provided in the standards, such as by using diagrams similar to those provided in Figures 3-6.

While JNL is justified in using 'evidence of distribution' to determine penetration in J-Frame and obtain CodeMark approval, the phrase is too weak to ensure durability. Decay may begin on the edge of a veneer that has limited penetration. Therefore, a Verification Method should also be used to test the durability of J-Frame under H1.2 conditions to prove its B2 durability. The final proof of what works will be obtained from durability trials, such as the I-Frame Sample Test, rather than untested penetration pattern specifications.

Conclusions

1. The penetration guidelines across the three standards (NZS 3640, AS/NZS 1604.4:2012, and AS/NZS 1605.2:2006) are conflicting and ambiguous for the H1.2 treatment of LVL with boron after gluing. This reduces confidence in a CodeMark assessment based on the standards. Remove the ambiguity in AS/NZS 1604.4 and clearly state which penetration pattern should be followed for non-glueline H1.2 treatments for LVL.
2. I consider that the phrase 'evidence of distribution' as a specification for penetration is too weak to be relied upon on its own as demonstration of durability. A Verification Method is required.
3. Provide a diagram in AS/NZS 1604.4 of preservative penetration patterns in veneers, such as shown in Figures 3-6, so that the meaning of terms such as 'continuously distributed' and 'evidence of distribution' becomes clear.
4. Any testing of LVL durability presented to standards should indicate the temperatures used for LVL production, so that it is clear whether durability is due solely to preservative treatment, or preservative treatment plus a level of thermo-modification.
5. JNL has followed the correct procedures for CodeMark approval and durability testing. The 50 year performance requirement of B2 Durability in the New Zealand Building Code for timber framing requires an H1.2 treatment that will provide durability over a five year period within that 50 year life, giving time for leaky building moisture problems to be rectified. While the procedures followed provide a high degree of confidence about the B2 Durability of J-Frame, additional confidence would be obtained from a trial where the thin edge of J-Frame was tested directly against decay fungi for verification, a step that should become incorporated into the AWPC protocols.

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GLOSSARY

AWPC = Australasian Wood Preservation Committee.
BAE = Boric acid equivalent.
Continually distributed = Penetration pattern where spot test for a preservative indicates its presence throughout the entire penetration zone.
Engineered wood = Wood products that have been made by gluing smaller pieces together, such as reconstituted wood, plywood, LVL, and glulam.
Efficacy = Whether a timber treatment can withstand a prescribed biodeteriogen.
Evidence of distribution = Penetration pattern where spot test for a preservative indicates its presence throughout the entire penetration zone, or within limited locations within the penetration zone.
JNL = Juken New Zealand Ltd.
LVL = Laminated veneer lumber.
Penetration = The depth to which a prescribed preservative is present in timber.
Penetration pattern = The depth and level of continuity to which a prescribed preservative is present within a region of timber.
Penetration zone = The region of timber that should contain preservative.
Retention = Amount of preservative within a section of timber. Where expressed as a percentage, retention is on the basis of mass per unit mass.
Solid wood = Wood without divisible parts glued together.
WPMA = Wood Processors & Manufacturers Association of New Zealand.