Efficacy of RotStop

Onsite Boron Injection Treatment

In the Remediation of

Leaky Dwellinghouses

A review of available knowledge and understanding prepared for;

Department of Building and Housing

By Alan Light
NZCB, MBOINZ, MNZIBS
Alan Light Building Consultants Ltd

Contents

1. Introduction

Addressing the underlying durability concerns of timber without undertaking expensive cladding removal, reclad and upgrade work is possible with development of recent technology by cost effectively introducing chemical treatment previously absent or insufficient.

Valid concerns have been raised as to efficacy of this approach. The concerns are equally applicable to all remediation options. This study considers those concerns in the light of current knowledge and also previous published papers and studies that have been available for some time. This allows an assessment of this emerging technology with a comparison of prevailing treatments in new timber and an informed appraisal of this approach

Chemical treatment of timber is a longstanding and well established practice in NZ. Recent leaky home experience has illustrated the vulnerability of timber and the natural tendency for wood to decay. In nature there is a natural cycle of tree growth, fungal attack even during a tree's life and certainly at the end with the eventual decomposition of the tree to the forest floor. We now attempt to interrupt this cycle by treating the wood with chemicals to increase resistance to fungal attack to ensure a longer life and create a better use of the material.

This report discusses current thinking and available knowledge of pre-treatments so that a proper context in regard to post treatments can be established. It reviews a commercially available Boron based injection system 'RotStop' to evaluate its efficacy in the light of this current thinking and industry knowledge. It considers issues already raised in a recent DBH report and a DBH determination

Other reasons to remove cladding such as allowing for detailed inspection and damage replacement may still be valid and required but this is not the focus of this report.

2. The Background:

Remediation of leaky building is a challenging and demanding process in which the goal is to restore the economic value of the building and satisfy the building performance for its intended life. The remediation work undertaken will vary from a simple repair of a leak in one discrete location with perhaps no requirement to replace any damaged materials to a dwelling so badly damaged and irredeemable that the most cost effective solution is to demolish and rebuild. The DBH have produced a remediation guide[1] that is available on its web site (www.DBH.govt.nz)The majority of leaky homes fall closer to the lower end of the extremes with a few leaks but with uncertainty in condition and with a lack of confidence in construction materials and methods and timber that now may have been subject to unacceptable moisture levels for indeterminate periods of time and unknown effects from fungal influence

[1] DBH – External Moisture; A guide to weathertightness remediation-Nov 2007

A building with widespread damage and water ingress over some years will likely require a reclad to address all its issues at some stage. The challenge for a building surveyor is in attempting to establish the extent of work required when confronted with a building that has a cladding envelope (in whole or part) that is;

1. Vulnerable to water ingress but to which current damage is limited, and
2. the building is safe and healthy and has sufficient residual structural properties to be able to continue doing an adequate job or has only issues that can be adequately addressed with discrete repair……..

……..but the timber durability is unknown and the threat of early and ongoing decay to advance is not mitigated or suppressed.

UTKD timber use was referenced in the NZS 3602 1995[2]. This presumed an in-service moisture range of no more than 16% (to provide assurance of durability compliance. This moisture range has proved difficult to maintain with decay infection likely when it is exceeded for indeterminate periods. Unchecked infection once established can continue to cause decay damage in untreated timber at only moderate moisture levels.

The NZS 3602 treatment recommendations are under review at present [3]with a view to streamlining the application of the standard (with a minimum H1.2 required generally to provide an even simpler solution).

The 2003 changes reflect the more pragmatic appreciation that dwellings do leak and greater treatment protection of timber is required to more vulnerable areas to enable windows of time for repair before damage initiates. These 'windows' will depend on degree and duration of ingress and may be a relatively short timeframe. This new approach provides uncertainty for owners of dwelling houses that may have incorporated untreated, low treated or simply unknown treatment levels that the industry no longer have confidence in.

While timber decay is understood to require moisture levels close to fibre saturation (over 30% mc) for a period of time for decay to establish, it is also becoming better understood that established decay can be sustained and continue to develop in moisture conditions possibly only slightly over the 18% mc that untreated timber is deemed to be compliant at (according to the conditions of use that NZS 3602 1995 allowed). There is also concern that interstitial condensation available perhaps for short periods in a daily cycle and even free water in small pockets of framing may be sufficient to sustain decay over a long period. This is evolving scientific understanding and this knowledge is increasing incrementally as more work is done and findings understood. These effects were previously unobservable when treatment in timber prevented fungal growth in most of these circumstances.

[2] NZ Standards NZS 3602 Table 1 1995 and 2003 Table 1
[3] DBH - B2 consultation document - Sept 2010

3. Current Approach to Timber Treatment to Resist Decay

The treatment of radiata pine is well established process in NZ and the nature of radiata pine, with its open structure, has a good capacity to accept treatment.

NZS 3602 was revised in 2003 to provide greater protection for new dwellings. It provides for a risk based treatment assessment with position in the building now a determining factor rather than simply the expected environment as under the 1995 standard. The standard still allows UTKD framing in low risk areas and in particular where associated with low risk weathertightness such as brick veneer cladding and some roof framing

This risk assessment approach is relevant to remediation work where risk can be assessed based on historical performance and building design and weathertight risk factors associated with particular details and elements exposure.(refer fig 6 and 8 NZS 3602 below)

NZS 3602 allows a designer to specify appropriate timber and treatment requirements. Hazard classes are defined that allow a designer to specify treatment for a wide range of uses depending on use and exposure (from mild to extreme marine conditions).This standard in Table 1 D 13[4] now requires generally a treatment of H1.2 for framing where monolithic claddings are fixed directly to framing and comply with E2AS1 (these may or may not incorporate a drained and ventilated cavity but usually will). Table 1D12 allows for H3.1 where monolithic claddings are fixed directly to framing and **do not comply** with E2AS1[5].

It follows that providing greater treatment could satisfy many current concerns around direct fix claddings as the application would provide for an upgrade to current code compliance without the high reclad costs usually required. H3 treated timber under NZS 3502 1995 did not have a maximum moisture range for use. NZS 3602 2003 has 20% or less for H3.1 (due to potential leaching characteristics). H3.2 is suitable for external exposed use with no restriction (except not in ground contact). A high retention BAE also has the capacity to effectively sterilise timber of decay fungi as long as there is sufficient broad spectrum approach to also deal with other fungi besides common brown rots and soft rots and leaching [6]that requires free water (more than just high moisture content) is addressed.

This demonstrates the principles in current weathertightness based on 4 D's (Deflection, Drying, Drainage, and Durability) that the Durability can be utilised to offset deficiencies in other D's and help establish general compliance with the Building Code if that is the desired outcome. A 5th D 'Detection' can also be a prudent consideration and allows for verification and validation of actual performance, and allows an appropriate reactive maintenance response.

[4] NZ Standards NZS 3602 page 29
[5] DBH New Zealand building Code acceptable solution E2 External moisture 2005
[6] J A Drysdale - Boron for the preservation of wood - June 1994 3. Discussions page 9

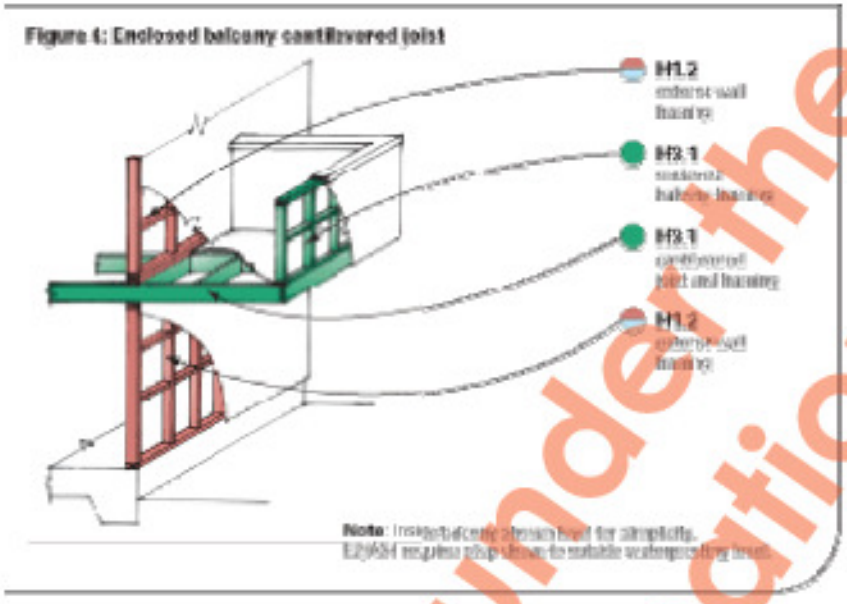
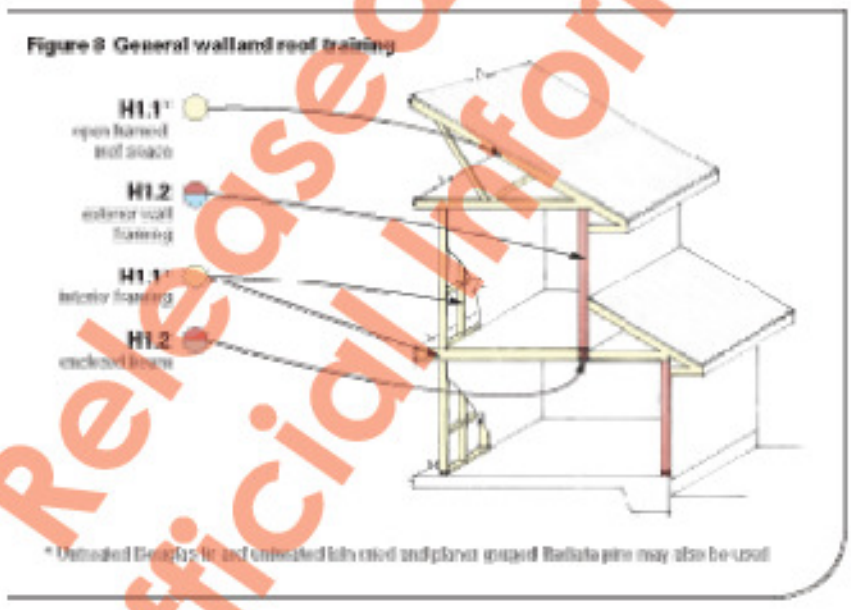


Fig 4 (and fig 5 below) [7]from NZS 3640 illustrates the current treatment approach whereby more vulnerable and critical elements receive a greater level of timber treatment

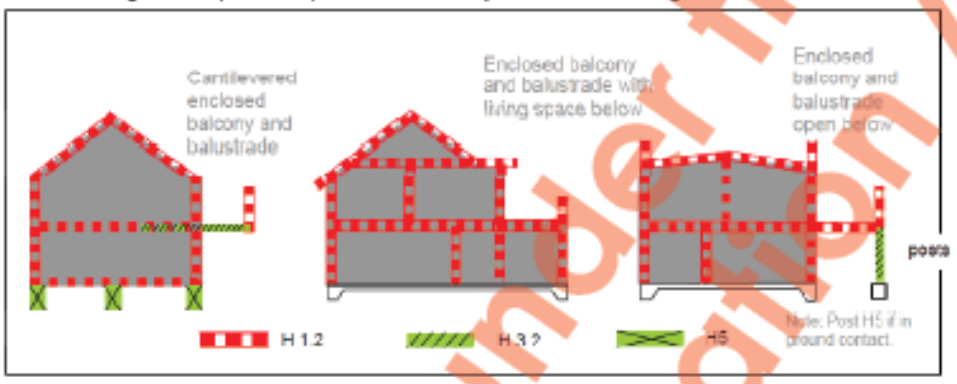


[7] NZ Standards NZS 3602 2003

H1.1 provides resistance to borer only and isn't intended as a decay treatment and it is in effect UTKD.

Recently the DBH released a B2 consultation document [8]on proposal to simplify the hazard class including a single H1.2 hazard class for all framing except for cantilevered decks (refer appendix) DBH - B2 consultation document - Sept 2010

Figure 1 Proposed simplified treatment requirements for framing timber in houses



This is a similar approach and simplifies new building work with fewer differences in treatment but still illustrates the previous risk targeted approach.

4. Current Timber Treatment

NZS 3640[9]sets out the requirements for preservation treatment of timber to provide protection from decay. It generally relates to new freshly milled timber and treatments are expected to be done at treatment plants under quality assurance procedures agreed with the NZ Timber Preservation Council (NZTPC).

Boron is referenced in this NZS 3640[10] standard as a preservative. The compound H3BO3 is utilised A hazard class rating of H1.2 requires a Boron retention level of 0.4% expressed as %m/m oven dry weight of wood. This is expressed as %BAE Boron Acid Equivalent.

To meet the 3640 standard for H1.2 full sapwood penetration is required [11]and minmum average retention level of .4% is required [12] NZTPC approves QA testing that satisfies this requirement. I have discussed this process with Kevin Hing at NZTPC. Generally this QA requires each charge of timber to be tested. Most process approved will require in the first instance testing on say first 3 charges but as charges are passed testing is reduced to every 5th charge and then if they pass to every 10th charge and then every 40 charges. Failure to pass QA requires a response with perhaps retreatment and the QA process dropping back to the next level of testing.

[8] DBH - B2 consultation document - Sept 2010
[9] NZ Standards NZS 3640 2003 revised March 2004
[10] Ibid chapter 6.1
[11] Ibid 6.1.1.1
[12] Ibid 6.1.1.3

Testing in practice requires 10 samples in each charge with 9 samples required to be passed for a charge. This establishes a 90% assurance of treatment levels. This appreciation is important (that 90% is sufficient assurance) when considering comparisons with on site treatments. It would be unreasonable to expect greater levels of assurance from onsite treatment that from highly controlled QA assured plant treatments. Penetration is expected to be over the whole cross section for a pass.

To achieve a H3.1 to NZS 3640[13] requires a retention of various chemical options for example Propiconazole and tebuconazole (1:1) to .06% m/m (dry weight of wood), and a pass in the particular penetration test.

This is part of the RotStop treatment currently as Propiconazole is added to ensure White rots are targeted (as they are otherwise Boron tolerant) The proportions of Boron and Propiconazole/Tubiconazole are such that if a 1% BAE is achieved then a .05 w/w Propiconazole is achieved. A 1.2% BAE would mean that the H3.1 requirement of .06 w/w is attained. This would satisfy a H3.1 rating even without the Boron and the combination is a more effective mix.

[13] Ibid 6.3 and table 6.2

5. Timber Treatment surface treatments

Recently the DBH accredited a series of alternative treatments product certified under s269 BA 2004.[14] This process Timbersaver is based on boron, surface applied spray application to 4 sides of the timber penetration specified to 3mm deep. The retention level achieved is described as 0.4% BAE. The process assumes that wetting of timber will diffuse treatment further through the timber. The process does not allow the penetration test to be complied with and is an alternative solution to NZS 3640. The appraisal describes the assumption of boron diffusing further into the timber in the presence of water from a leak. This recognises the mobility of boron that is soluble and transported into the framing by water that becomes polluted with the boron as it passes through it.

6. Timber surface applied on site as part of remediation

It is standard practice [15]for existing framing either untreated or with unknown or low treatment to have exposed surfaces coats with brush or spray applied treatment. The requirement for site treatment is stated in Auckland Council practice note BLD 126 PN (refer appendix). Soluble boron based applications (e.g. Protim Framesaver) are considered more effective as moisture transports boron into the timber whereas solvent based treatment such as Metalex only protect the timber that is directly treated .
Any opportunity to improve durability is prudent and desirable. In practical terms this means that treatment should be applied to exposed faces. In the case of a bottom plate this could mean 3 faces depending on whether interior lining was removed (but not the bottom face) and 2-3 sides of studs depending on whether they were accessible or restricted by adjacent framing as in the case of trimming studs and doubling studs around windows and under beams and the like.

Scion (New Zealand Forest Research Institute) have been undertaking verification work on Framesaver with a trial under laboratory conditions [16]whereby various samples of timber have been infected with decay and then framesaver applied on 1, 2, 3, and 4 sides and kept in a damp environment. This study has been now running for 2 years and has recently been extended. Reports have been issued at regular intervals. The initial reports were very encouraging but the recent 18 month study issued Oct 2010 has suggested that there is decay developing with *"patches of fresh mycelium had either developed or expanded in the high moisture content exposure tanks on almost of the untreated samples, the copper napthenate samples treated on one or two faces and the boron samples treated on one edge. …..decay was developing on a few of the control samples or "treated 2 edge" samples and on wetter samples in the bottom two layers of the stack. Current assessments suggest that the trial is at a critical stage and that deterioration in samples treated on only one or two sides will accelerate from now on"*[17]
It is unclear why the assumption of boron transport isn't working in all cases but the testing relies on lateral transfer of treatment across the grain and through growth rings with timber ends sealed that could be resisted by the summer rings more dense nature and therefore difficult for moisture and therefore the boron to penetrate through. The injection process sidesteps this issue as treatment is introduced more directly into the entire timber structure.

One of the common justifications for removing cladding is to allow surface treatment of framing. It is an expensive process and this Scion report casts doubt on the long term reliance on this treatment in the context of high moisture conditions. This raises issues as to the cost

[14] www.dbh.govt.nz/product-certification-register
[15] DBH – External Moisture; A guide to weathertightness remediation-Nov 2007 Page 51
[16] Scion; The Efficacy of brush on remedial treatments on radiata pine 18 month progress report Oct 2010
[17] Ibid page 1 summary

effectiveness of this approach given the timber may not receive effective added protection from ongoing decay as expected. Further investigation is required into this issue.

7. Timber treatment affect with boron

It is useful to understand the effect of water on the concentration retained boric salts. Boric Acid is commonly referred to as such in both its state as a solid and when combined with water to create its acid. When we refer to a BAE we are referring to Boron Acid Equivalent which is the amount of acid formed in the presence of water. Boric Acid concentration however will vary with the same amount of salts in different water amounts and be progressively diluted with greater moisture content levels.

Alternatively as timber dries the Boron Acid concentration will rise as the moisture level proportion drops. This explains why decay has been observed in treated wood in the past. If the wood is wet enough for long enough the decay fungi will be able to act on timber while Boron Acid concentration is relatively low. The nature of a leak is therefore critical to the performance of treatment. If a leak is intermittent the moisture content will fluctuate from wet to dry and while approaching dry state the Boron Acid concentration will increase creating a harsher environment for decay fungi which can otherwise tolerate weaker concentrations at higher moisture contents.

Boron is particularly effective against common brown rot and soft rot and works by destroying the fungus digestive tract. Some other fungi such as white rots have different digestion system that is not affected by boron and this needs consideration. There are hundreds of fungi in the environment that could establish as any time. In nature fungi are adaptive and will change the enzymes they produce if a tree has a toxin that causes resistance to the fungi.

It is believed that where brown rots and white rots are competing for food supply the brown rot usually is more prevalent. Introducing boron knocks the brown fungi but the white rot left is in fact allowed to flourish in an environment now more conducive to decay and the white rot is no longer competing with brown rot. Early damage from brown rot may also weaken timber structure and assist later white rot development. Fruiting white rot observed during early RotStop trials has demonstrated that a broad spectrum approach is needed to compliment the boron.

This dynamic performance is also active in other treatments with CCA treatment most effective when the timber (expected to be exposed to wet environment) doesn't remain wet for long but allows treatment to become more toxic during natural drying periods. Observation has shown poor performance of even CCA H3 treatments where the wood does not get an opportunity to dry (e.g. deck; low to damp ground, a shady area damp even in summer, subject to water ponding .Ground contact also emulates this harsh environment).

8. Remediation scopes and damage

Claddings (and direct fix monolithic claddings in particular) with deflection qualities previously considered adequate are now better understood and acknowledged to have little capacity for drying and drainage of water that may get past the face seal that many of these claddings rely on.

The dilemma for remediators is to mitigate the inherent risks associated with existing construction as result of its design, construction methods, and / or materials used in its construction. The dilemma is further exacerbated when the timber has become infected with incipient or early decay and issues of future likely damage need to be considered as a result. There is a lot of debate as to what constitutes damage to a building and the difference between wear and tear (even if accelerated) and structural impairment or even when thresholds unsafe or insanitary are met. Present thinking is based on premise that early decay inevitably will advance to serious damage and this is only a matter of time.

Recent decisions have provided some clarification to the understanding of damage. Arrow/QBE decision(Arrow International Ltd v QBE Insurance CIV 2007-485-74 (23 June 2009)) was an insurance dispute where serious decay had occurred but the case turned on when the damage was caused in relation to a policy exclusion date . MacKenzie J stated

> [85] I find on the evidence, that the fungal or microbial damage such as to cause an alteration of the physical state of the timber to an extent which impaired its value and usefulness had occurred before 30 May 2002.

This suggests that early decay is not trigger for damage but it has to reach a point where performance is impaired and unstoppable. It follows that halting further decay is appropriate mitigation and may even avoid the actual damage as it mitigates the economic loss.

Developing understanding in this area suggests that rather than assuming all decay as damage an assessment process is required. The Scion report [18](refer appendix) uses a recognised decay rating based on ASTMD 1758 (6) Standard Test method [19]

This provides an objective assessment of the timbers fitness for purpose.

Decay Ratings

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

(note; ASTM does not provide for 'T' but this is a useful addition to this standard by Scion)
Work undertaken by Scion and Auckland University suggests that decay rating 6 and above could be 'fit for purpose timber' and lower ratings subject to evaluation and structural assessment in the context of the whole building.

[18] The Efficacy of brush on remedial treatments on radiata pine 18 month progress report Oct 2010 appendixIn
[19] International standards –ASTM D1758 10.3 page 4

After the final editing of this report the writer was given a copy of a May 2008 Scion report. This report[19] was by Mick Hedley(and others) and dealt with the rates of decay and the loss of stiffness experienced as a result of that progressive decay. The report utilised the ASTM decay rating above and stated (page 4) *"it wasn't until the mean Index of Condition fell below 6 that deflection under load exceeded that at the start"* . In terms of the QBE decision the threshold of *change to the physical state of the timber to an extent that impaired its values and usefulness*, the threshold can now be understood to be quantified by the ASTM threshold of less than 6.

It is understood that a rating of 6 or more could be retained if issues of future decay were addressed and its structural importance appreciated (For example; some further decay in a cantilevered beam at a critical position would be perhaps unacceptable but the same level of decay in a perimeter joist over a wall plate acceptable). This is an important consideration as currently any decay is considered damage due to the future likely progression of that decay and when efforts to mitigate this are limited.

Assessment of decay therefore needs to be in the context of its structural significance, its purpose in the structure and likely future performance conditions of in-service use.

Reliably introducing measures to interrupt decay cycle addresses the fundamental concern in relation to early and incipient decay. The issue of any decay being damage is not valid and as stated in the conclusion to the scion report[20] "*remedial treatments of the Borocol type could be applied as a cost effective alternative to replacing the partly decayed framing*". This is a statement of efficacy in regard to post treatment that *DBH had in their possession.*

Auckland Council are now accepting ' rot maps' of the external walls based on all the information available on the dwelling to show the areas that are in question and to better understand the extent of any damage in relation to current leaks and timber condition. This applies to both recladding and targeted repair consents.

A more mature understanding of likely structural impact of some decay (knowing decay progress has been addressed) allows for a more considered appreciation of what constitutes damage in a building.

The RotStop injection process that has the capacity to provide a high retention (with full cross-section penetration protection) has a higher degree of reliance than surface only painted on treatment applications.

Auckland University undertook a study published in 2009 (refer appendix) that simulated rot by removal of timber and testing strength. This study found that smooth shaping that emulated gradual decay was not associated with the same strength loss as if a cut was made to notch the wood. It also considered a method of firing metal rods (nails) from a nail gun at a set pressure to evaluate stiffness in comparison to penetration and there was a correlation established that could allow such a penetration test to be used to establish strength on site. More work is required to develop this approach.

[19] Scion-Comparison of rates of decay and loss of stiffness of Radiata Pine and Douglas Fir framing timber May 2008
[20] Ibid page 5

9. The Boron Injection System –Rot Stop

The liquid preservative in RotStop is based on existing technology and is essentially boric acid in glycol with some oils and other additives. A broad spectrum of chemicals including Propiconazole (for white rots) are added. The injection process is the delivery system[21] utilised to get the treatment into the timber.

The RotStop process needs to be considered as a part of the overall remediation process This supplements previous investigations and the moisture detection probes inserted as part of initial moisture survey and any other information. The information gathered from all processes means that there is an ability to map the timber condition over the whole dwelling. This allows understanding of likely moisture ingress and an assessment of extent of damage. Critical structural components can be further inspected.

Two holes are drilled, one at 200 down from the ceiling and 1.0 m below this. The studs are located by stud finder and visual assessment. The drilling of holes as well as providing injection points allows an assessment at the time of timber condition and moisture levels and strength tests are also possible. A decision can even be made to defer injection to selected walls with extensive decay if work is imminent and replacement of timber likely. Injection anyway can help feed treatment to wood below in an area subject to ingress with unknown extent of decay and there is benefit is knowing decay is potentially stopped and the area sterilised of fungi and moulds.

The injection process involves bottles of RotStop inserted with a pressure seal into the stud hole and connected to CO2 cylinder or small compressor to provide positive pressure to liquid of about 15psi. This is sufficient to pressure system. The rate of intake is recorded. If intake is too fast this could indicate a hole in stud (or decayed framing) as conversely a slow uptake could indicate a knot and be a cause of poor absorption.
Some product will ooze down the outside of the stud to be absorbed back into timber and is also caught by interior lining, cladding, nogs and plates

If required, holes are repositioned to avoid knots and holes, and bottles reapplied. The solution is clear but care is taken to protect carpet with some leakage to the interior expected but wetting of the mid floor area is beneficial as an area of greater timber mass. Gravity ensures that areas are well treated below injection points.

In this way the injection material is understood to follow leakage paths in the structure. This mimicking of water ingress paths is important as the preservative (because it is water soluble and mobile) has the ability to be transported by future water leaks further into any timber that may not be so well treated. Because the process is injection based it does not have the same

[21] RotStop manual –Stop up Group

limitations of a solely surface applied treatment as in scion trials where lack of cross grain movement may be an issue?
Experience shows most decay occurs below known ingress points and typically a wall is vulnerable below window heads and around windows and doors. The RotStop treatment injection is most effective in these areas

As well as studs lintels and beams can be injected with a foaming RotStop utilised that fills lintel voids and allow slow absorption into the timber. This recognises that in some areas such as lintels and beams the vertical gravity capacity is not present and horizontal transfer is not so efficient. By trapping the boron in a 'foaming' solution that RotStop is held in the wall space longer and this increases absorption into the timber as the RotStop is available to the timber for longer. This also allows treatment to external corner studs where one of the three studs usually provided in not directly accessible from the interior wall. Foaming into the stud space allows greater absorption into the stud.

Some product is released as a gaseous form during evaporation to further transfer the boron around the wall including insulation nogs and linings. This has a sterilising affect on moulds and oils added to the solution help bind spores that reduces their ability to spread.

Permanent probes are used to verify injection with rises in moisture level below boron injection points giving confirmation of boron injection arrival with corresponding increase in moisture level readings.
During the Chatfield determination this process was demonstrated to the DBH and the ability to deliver RotStop to the timber stud was evident. I was present at this demonstration and have observed this and seen its simplicity demonstrated. It is also a process that allows careful recording of data and rates and this is capable of being well organised on site with good methodical recording undertaken

Care must be taken to identify areas that may not receive treatment due to unusual site issues. Retreatment to poorly served areas is considered and injection from external face is also possible.

Once completed then all the rates are analysed. A simple data record with assumptions for runoff and other factors allows for an estimation of the available treatment in any wall and an estimation of likely %BAE retention. Application rates can be factored into future remediation decisions.

10. Determination 2010-80

In Sept 2010 a determination under s178 of the BA 2004 was released. This determination 2010-80[22] was principally considering whether a building consent could be issued for targeted repairs to an existing building. The determination found that the BCA was correct to not issue the consent but not because of doubt over the scope of work but because the level of information provided during the course of the determination was not available to the BCA as part of the original consent application.

Coincidental to the actual determination was the fact that the dwelling had been subject to the RotStop boron injection process. The determination decision found that this was work that was outside the building work being considered and while it generally affirmed the process it did make some comments.

The WSG release periodic update reports to assessors; The WSG have now asked for reconsideration in WSG reports where this process has been recommended;

The November 2010 Assessor report stated;
"Boron Injection System
Attached is a recently issued determination by the Chief Executive of the Department that included the use of Boron Injection System. The comments in the determination are general observations with respect to the use of the boron injection system.
As evidence has not been verified from an independent third party in the terms of the analysis of levels of boron treatment achieved by the boron injection system, WSG does not expect to see the system appearing as a recommended remedial option in assessment reports.
Until such time as a third party provides evidence of analysis of acceptable levels of boron treatment, the boron Injection system must not be a recommended remedial solution in assessment reports. It is also noted that the boron injection system does not address the failure of weathertightness of the external envelope or does it provide a solution of such failures.
Below is an extract of determination 2010/80. (The complete determination is attached)."

It is important to consider that the determination wasn't formally considering the boron injection process but was rather commenting on this aspect as a side issue to the determination. Which was considering; "Refusal to issue a building consent for remedial work to an existing house with a code compliance certificate"

[22] www.DBH.govt.nz-building-past determinations\2010-80

Determination 2010-80 (6.6 -6.9) stated;

The boron injection system

6.6. On the view I have taken of the matter to be determined, the use of the boron injection system is not relevant to the matter of the decision of the authority to refuse to issue the building consent. This is because the boron injection system was applied to the framing as part of earlier building work and is not a part of the building consent application that is in dispute. However, I have made some general observations with respect to the boron injection system in order to assist the parties. I note these comments (paragraphs 6.7 to 6.9) are not in respect of this house, but in respect of the use of the boron injection system generally.

6.7 At the technical meeting, evidence was presented which supports the following points:

- the boron injection system uses boron, which is a well established and commonly used timber treatment
- the use of the boron injection system means the product injected into the treated or untreated pinus radiata framing assists in ensuring that the injected timber retains a level of boron that should provide protection against decay
- the natural flow pattern of the product through the timber ensures the widespread dispersal of the product through the framing in which the boron is injected
- some liquid injected will drop naturally by gravity to the bottom of the framing, and the remainder will dry by diffusion
- the product provides some protection from existing and future decay.

6.8. The evidence has not been verified by an independent third party in terms of the analysis of levels of boron treatment achieved by the boron injection system generally. I note this in respect of the system as a whole, not in respect to this house. It is my view that because of the nature of this product and method of application, the remediation company should seek analysis and testing from a truly independent third party.

6.9. I also note the effect of the product with respect to the following items does not seem to be fully known and should also be verified by an independent third party in addition to the above:

- other existing building elements, for example, the swelling of the timber which could affect wall linings and bracing, and the wall insulation
- existing toxic mould spores that could be in the wall cavity.

11. In discussion with WSG it was stated that:

"Up until now the Department has not had a published opinion about the efficacy of boron injection post treatments. That was the situation at the time of writing your report. Now that the determination has been issued we have circulated the information to the assessor and QA groups for information. I have also asked if we have any reports that have recommended this as part of the recommended remediation. We will be following up on all such reports and asking the assessor to re-consider their recommendations in light of the determination."

This report seeks to consider the issues raised and whether the assertions have substance. The question of what is 'efficacy' (webster;" *the power to produce an effect*") has to be addressed and the difference between specifying work (to be done) and the requirement of subsequent work processes to achieve the requirements to satisfy that specification needs to be considered. I take the view that I need to consider both the efficacy (the expected benefit of the process) and the likely effectiveness of that process if the work is undertaken and properly completed in general accordance with the specification as included provided for under the boron injection system in this case the RotStop injection process. There is an implied expectation in any remediation recommendation that the work will be properly specified and then carried out in a diligent and professional manner and certified as such.

When considering the degree of assurance with any remediation process it is useful to consider the level of assurance that is provided by new building work. It is after all reasonable to only expect a level as if it was new work and certainly expecting a greater level of compliance than the minimum code requirement would be unreasonable. An owners right to establish a greater level of compliance must be recognised as also is the restriction on a Building Consent Authority to insist on building work achieving performance criteria that are additional to or more restrictive than the building code in relation to that building work (s14 BA 2004).

When considering compliance with the building code determinations have consistently stated that the acceptable solution is the worst case scenario and that deficiencies can be mitigated. This allows a designer to reduce weathertight risks by mitigating the 4 D's of Drying, Drainage Deflection and Durability.

12. The concerns raised by WSG

1. WSG has no published opinion on the efficacy of boron injection post treatment?

This question raises two issues;

1. the efficacy of an injection process and

2. the efficacy of Boron treatment.

1. the efficacy of an injection process

The DBH commissioned a report by Russell Cooney [23] that was issued as a draft in 24 March 2009 and has been widely circulated after being released under Official Information Act. It raised many of the concerns now being considered. It is unclear whether further work has been commissioned by the DBH. The application of boron treatment as a site application was clearly stated;

This Cooney report stated:

3.5 IN-SITU PRESERVATION OF TIMBERS

Earlier in Section 3.3 of this report there is discussion about the risks associated with houses built with untreated or inadequately treated timbers should other timbers become wet.

The preservation of timbers used in existing structures such as buildings, bridges and boats has been the subject of on-going research and applications for many decades throughout the world and a wide range of processes have been developed for particular applications. Usually these involve exposed timbers. It is not known if any of these processes could be applied or adapted for use in treating the timbers in New Zealand houses while leaving the claddings and linings in place and this would be worth researching.

Solvent-borne preservatives for in-situ treatment are probably too high in risk and heat treatments probably are impractical to consider for application.

Surface-applied (by brush, roller or spray) preservatives have been used in New Zealand for some years to provide a degree of protection to sound timbers when they have been exposed during the reclad and/or reroof of moisture damaged houses. But there are many situations in a typical timber framed house where timbers abut each other (eg trimming studs, corner studs, laminated lintels and beams) and hence all surfaces are not able to be so treated. Sometimes only one face of a framing timber is exposed and can be treated and sometimes holes are drilled to try to get some preservative at the interfaces between these timbers.

[23] Russell Cooney-Timber preservation and remediation of leaky houses –March 2009

The effectiveness of these surface-applied preservatives, especially for some types of fungi, is currently being further researched. There are also some current proposals prepared for the department to research the effectiveness of such treatments when not all faces/edges of framing timbers are able to be treated.

But not all houses are having linings and/or claddings removed and, especially for those houses not known or believed to be leaking, owners will not wish to have linings/claddings removed so that the framing timbers can have some preservative treatment applied. There are also many situations with multi-storey houses and houses on steeply sloping sites where the costs associated with access make the recladding of walls much more expensive and where less expensive options may be worth considering.

There is therefore a potential market for in-situ treating the framing timbers with the linings and claddings remaining in place. One company, Hitex Building Systems Ltd, is developing their RotStop system in response to this potential market.

The RotStop system essentially involves injecting a proprietary water-based preservative under pressure into the framing timbers as a liquid via holes drilled through the linings into

the timbers. That company is also developing a foaming process designed for accessing spaces between framing timbers to in effect apply the preservative to the surfaces of timbers.

Section 4 of Appendix 1 to this report contains the relevant comments made by those spoken with about the RotStop and related in-situ treatment processes.

It is apparent from the discussions and comments that an effective and efficient in-situ treatment process would be highly desirable, especially for those houses which are currently undamaged or have little damage from leaks and whose cladding systems are or can be made sound.

However, as has been identified there are many unknowns about a water-borne in-situ preservative process in general, and the RotStop process in particular, and which would first require a considerable amount of research. Quite apart from the effectiveness and cost-effectiveness of any such system in getting preservatives into all of the at risk framing timbers, the main questions relate to the effects of the comparatively large amounts of introduced water and the preservative chemicals on the health of the house occupants and on the integrity of other elements of the house.

2. Efficacy of Boron Treatment

The use of Boron per se as a timber treatment is well established with a proven reliability over many years. The New Zealand standard for timber treatments is NZS The New Zealand Standard has published a standard.

Jenanette Drysdales paper presented to the International research group on wood preservation in June 1994 [24]described studies and boron applications and veracity of retention levels.

The DBH has not published specific information on boron injection. The DBH guide to weathertightness remediation discuss the issue briefly on Page 63

"In-situ treatment In-situ treatment Some concentrated preservatives (applied by brush or airless spray) are commonly used in New Zealand.Boron-based in-situ preservative requires predampening of the timber.

LOSP (Light Organic Solvent Preservative)-type preservatives can be suitable in some situations, provided the wood is essentially dry.

In some instances, it may be appropriate to undertake targeted repairs, that is, leaving the timber in-situ and applying suitable preservatives. In such cases, it is important to follow the advice of a laboratory specialist who is experienced in the use and effectiveness of in-situ timber treatment"

[24] Jeanette Drysdale- Boron treatments for the preservation of wood- A review of efficacy data for Fungi and termites June 1994

13. The concerns raised by Determination 2010-80

The determination has accepted the points made in 6.7

> 6.7 At the technical meeting, evidence was presented which supports the following points:
>
> - the boron injection system uses boron, which is a well established and commonly used timber treatment
> - the use of the boron injection system means the product injected into the treated or untreated pinus radiata framing assists in ensuring that the injected timber retains a level of boron that should provide protection against decay
> - the natural flow pattern of the product through the timber ensures the widespread dispersal of the product through the framing in which the boron is injected
> - some liquid injected will drop naturally by gravity to the bottom of the framing, and the remainder will dry by diffusion
> - the product provides some protection from existing and future decay.

This affirmative statement amounts to a statement on efficacy on its own.

It then states;

> 6.8 The evidence has not been verified by an independent third party in terms of the analysis of levels of boron treatment achieved by the boron injection system generally. I note this in respect of the system as a whole, not in respect to this house. It is my view that because of the nature of this product and method of application, the remediation company should seek analysis and testing from a truly independent third party.

As with other timber treatments the assurance of level of treatment is an assumption the designer is entitled to make. When a level of treatment is specified that conforms to a particular standard or specification then it is for others to verify that the appropriate standard or specification has been followed. There is a process now of branding and colour coding different treatments to comply with NZS 3640 with quality assurance measures also stated or at least provision made for approval from the NZ Timber Preservation Council for particular treatment plants to comply with treatment requirements. (refer 3.0 above). There is no certainty in this approval but a method only that provides a level of assurance. One of the problems faced by remediators now is created by the uncertainty of previous treatments and the realisation that many treatments are difficult to identify and verify; this is particularly true for LOSP treatments which don't use Boron.

It is unclear what the basis of this DBH Determination statement is. I have been given a report from Primaxa (PN195 dated 2 June 2008) that supports the view that in this case boron levels have been sufficient to kill brown rot fungi and preclude decay[25]. This was the conclusion after culturing and testing 13 samples. Primaxa are at the forefront of research and analysis of decay and treatments. Dr Adrian Spiers was spoken to in preparation of this report and was very positive in his support and impressed with results he was seeing in regard to timber treated with boron injection methods. He is now including retreatment as a remediation option to address decay issues.

[25] Primaxa PN195 Naul page 3

For example, the total shrinkage that occurs at a given moisture content for Radiata pine used in a domestic building which is not air conditioned compared with the size at FSP is:

At a moisture content of	The fraction of total shrinkage that has occurred is
24%	1/3
20%	2/3
16% (EMC)	3/3

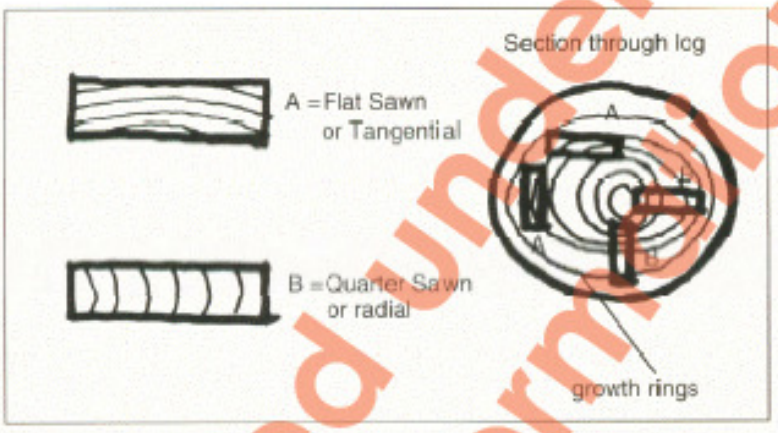


Figure 1. Growth ring orientation

Table 4. Shrinkage rates for commonly used timbers

Species	Percent shrinkage from green to 12%		
	Radial	Tangential	Longitudinal
Radiata pine	2.1	3.9	0.06
Douglas fir	2.8	4.9	0.08
Rimu	3.0	4.2	0.07
Corsican pine	2.8	5.4	0.08
European larch	2.0	4.9	0.07
Tawa	3.4	6.7	0.10
Western red cedar (imported)	1.5	2.5	0.04

A 47mm thick stud will therefore be expected to swell between 1.0 to 1.80 mm. This is most noticible when 2 or 3 studs are side by side and increases of 3 to 5.4 mm are possible. This has been observed to separate plaster lining joints and corners. The damage if apparent is treated as part of remediation work. As timber is often already wet the effect of movement is often insignificant and advantages outweigh disadvantages to dwelling.

By addressing the fundamental deficiency in the poor durability of the timber the first step is taken. The next step is to allow the diffusion of boron through the structure, allowing a period for the structure to dry before addressing any leaks. The whole process is monitored with readings of moisture probes at regular intervals to assess the process. The sharp rise in readings at injection is one confirmation of effective injection and remaining high readings indicate leaks that while a concern can now be evaluated against the treatment data delivered to this area and repairs considered in a managed process over time.

It is also understood [27]that damp timber has less stiffness and beams and lintels can sag when wet. This needs consideration in each case. As a general rule the method of injection does not saturate lintels and beams where apart from ends the treatment is delivered by foam application to lintel cavities to allow a slower absorption and a 'drier' process. Mid floor areas are areas where a large mass of timber is present and accordingly there is a desire to allow as much absorption as possible in this vulnerable mass. The nature of NZ construction is that the perimeter joist and joist ends are not subject to a sagging issue and perimeter joists are usually supported directly by top plates of the wall below.

Expert assessment is required to identify any unusual and particular construction concerns in respect to building response to injection. This assessment is required with all remediation proposals.

b. Wall linings and bracing:

The effect on wall bracing and linings is not significant and while plasterboard is observed to absorb some moisture this is transitory and absorption of boron beneficial to lining. The plasterboard manufacturer of course does not consider damp environment to be normal use but experience has shown that interior plaster board linings are tolerant of moisture unless subject to free water over a sustained period. This is most apparent in older homes from say the 1980's where linings are still in good condition even where timber framing has decayed completely after being subject to water ingress over a long period.

It is understood that the drying mechanism in face sealed direct fixed systems is slow as it relies on diffusion through the external paint system and internally through interior lining. The difference between dampness caused by leaks and 'dampness' caused by RotStop injection is that the latter means a greater absorption of treatment into all parts of the building which is a beneficial factor and the longer the treatment is available the better the treatment affect. (An incidental benefit to plasterboard is absorption of boron treatment as a mould inhibitor that was part of plasterboard process until recent times). If this was an issue the effect of leaks on the same elements would already be impacting and this remediation process must be understood as part of an overall process to rehabilitate the dwelling. Plaster boards can be re-screwed if required and any popping and cracking rectified when the dwelling is stabilized again.

[27] BRANZ Bulletin 343 moisture in timber page 5

Manuafacturers requirements clearly recommend that plasterboard never gets wet but in service experience shows plasterboards have tolerance to short term exposure. Any wetting of material during the process is short term and the ability to restore integrity evident.

Wall lining and bracing elements may already be impaired as a result of water ingress and the structural integrity should anyway be assessed for possible replacement, (if there are concerns as to fitness for purpose and structural stability) preferably by a suitably qualified expert.

c. Effect of corrosion on fastening and metal fixings;

This issue was addressed by in an Opus review study by Willie Mendeno 2010;[28]

It stated

> Borate-based wood preservatives have been proposed as environmentally friendly alternatives to copper-based preservatives. Borate-based preservatives have relatively low toxicity other than to insects and fungi, and do not contain potentially harmful heavy metals. Handling of borate-based preservatives is therefore safer than for many copper-based preservatives. In addition, the water solubility of borates offers the potential to treat water-damaged timber framing in leaky buildings, by using existing leak paths to deliver the borate to damp-affected timber prior to repair of the leak(s). It is acknowledged, however, that the solubility of borates in water that makes transport into the wood much easier, means that in wet conditions they can potentially be leached out.
>
> Copper-based compounds are known to be potentially corrosive to aluminium, galvanized and ferrous fasteners because of the possibility of copper deposition triggering galvanic corrosion of the substrate metal. It appears likely that borates would be less corrosive than copper compounds.
>
> There is a substantial body of published opinion, primarily in trade literature, that suggests that borates are not corrosive to steel, but these claims are not generally backed by any hard evidence or references.

And concluded;

> Although borates have been identified as a potential corrosion risk in wet conditions, there is no evidence that they promote corrosion under the dry conditions which would be expected to prevail after the initial application and subsequent repair of leaks. Corrosion in wet conditions and leaching would not be an issue when the product is used as intended.
>
> Based on these considerations, borate-preserved wood presents no more of a corrosion risk to steel fasteners than copper-based preservatives and there is a reasonable expectation that the longer-term corrosion rate will be lower.

As well there are oils in the formulation that could even offer protection to the metal. This needs greater study and is an issue that needs addressing in relation to use of metal

[28] Willie Mandeno corrosion review Opus Oct 2010

fastening generally, but the effect of the oils to reduce oxidation by excluding air is understood.

d. Wall insulation;

Wet insulation loses its insulation capacity. This is particularly evident in fibre based insulation materials such as fiberglass blanket. Insulation would be expected to not dry well as its insulation qualities preclude this. Batts are the most common insulation in NZ and experience has shown (and the writer has observed this) that insulation is largely unaffected. This appears to be because the injection is concentrated at studs with irrigation around the timber and gross flooding of the cavity that might saturate insulation does not occur. Any dampness at batt edge is more easily dried as absorption transfers injection material back into framing during its drying phase.

Thermal imaging is a useful tool to assess the efficiency of current insulation and also confirm the performance after injection process. Where insulation issues are perceived or discerned then provision can be made for this in either short term or immediate work. Damp materials have poor insulation properties as a rule (as insulating air is replaced by moisture) and thermal efficiency may be compromised in a leaky building anyway. There is always the option to remove internal lining at some stage to upgrade and reinstate thermal insulation.

Impact on insulation will depend on the construction design details utilized. Polystyrene may have been used either as EIFS or internal packing between studs and is generally unaffected by moisture. Blown in macerated products often poorly installed and applied to the exterior wrap of the cavity could be affected and these need assessment. The common batts can be affected by wetting that reduces thermal efficiency however this hasn't been observed as an issue in RotStop injected dwellings.

An unintended benefit to insulation materials is that gaseous boron emitted as part of evaporation of some of the injection product percolates through the insulation and has a sterilizing affect in material often contaminated by moulds commonly associated with leaky situations (but may not be decay fungi). (refer below mould spores)

e. Toxicity on occupants

Boron is understood to be an essential trace element but as with other beneficial elements can (in sufficient concentration) perhaps be an irritant or even toxic.

Boron treatments are well established and used over a long period of time in NZ. The issue can only be in relation to the effects immediately after injection when treatment is still absorbing into structure.

There has been much work done on toxicity of treatments[29]
The Lloyd toxicity report 1999 concluded

> "Borates are wood preservatives of low mammalian and environmental toxicity. Their action is probably via chelate complex formation with co-enzymes which results in metabolic inhibition. They have found extensive and effective use in remedial timber protection and pest control applications throughout the world. Data shows that concerns regarding the leaching of borates from treated wood has over-stated the risk of boron loss. Borates do not leach out of structural wood under typical conditions and leaching is not a concern for borate-treated structural wood as long as the wood is sheltered from rain or sealed against moisture.[30]

[29] J Lloyd MSchooman and R Stanley, CUP 452 Remedial timber treatment with Borates 1999

[30] Ibid page 7

f. Existing toxic mould spores in the cavity.

Moulds and spores are endemic in NZ environments. Timber and other materials brought to site may bring these with them and they occur naturally in the air to settle where they will and establish themselves where conditions allow.

It is the writer's observation from talking to occupants of treated dwellings that there is a general perception of a 'sweeter smell' in the property immediately after treatment. While this could be a placebo effect, it is also possible the eradication of moulds and the like creates a healthier environment which if so would negate any residual concerns in regard to possible short term toxicity and in fact provide benefits.

From a recent beagle report;

15. **Possible presence of the toxigenic mould *Stachybotrys atra* and possibly other moulds requires that caution is exercised when handling moisture compromised materials.** *S. atra* is a toxigenic mould that has been implicated in building sickness syndrome and is common in leaky wall cavities. *S. atra* is a soft rot decay fungus and degrades wood fibres and other cellulose containing materials. It is most commonly encountered on gypsum-paper board, fibre-cement board and building paper or any other wood fibre containing material.

Exposure of healthy individuals to small quantities of *S. atra* is unlikely to pose a serious health threat in most cases. However, it is wise to handle the mould (and other moulds) with caution, avoiding direct contact and inhalation of disturbed material. It is

14. Conclusion

By their very nature there is a degree of uncertainty around all remediation processes. The 4 D's need proper consideration and the reliance on RotStop assessed against a proper study of the buildings issues. In addressing the Durability D the other D's of Drying, Deflection and Drainage can and should be considered to further enhance the building performance.

The decision to make any recommendation must be made in the context of the available data and knowledge of the remediation specialist based on condition, inspections and investigations and particular circumstances on a case by case.

The veracity of boron as an effective decay treatment is established but what needs to be understood is the likely effectiveness of any treatment whether existing or post treatment injection or surface treatment.

In evaluating one process over another a proper assessment of the veracity must be undertaken so that a reasonable comparison can be made with other treatments.

The RotStop injection process while simple in approach has limitations. These limitations are governed by access to timber, ability of timber to accept and retain treatment, obstructions and openings in treatment pathways that may impede or divert treatment.

The advantage the RotStop treatment offers is to evaluate likely retention levels and assess risk in structure and either re-inject treatment or apply other remediation methods to uncertain areas that are identified. This allows for a managed remediation process that deals with the fundamental deficiency of untreated or poorly timber (being its lack of natural durability). In being able to address the concerns around the less damaged areas of a dwelling resources can be concentrated on those where damage may be unacceptable.

By having the potential to radically alter the inherent durability of untreated or poorly treated timber the fundamental risk of decay is able to be addressed. This raises the durability of the timber to meet the actual performance levels of the cladding rather than the alternative approach to raise the efficiency of the cladding (achieve a reliable in service moisture level of well under 18%) to compensate for the lack of timber durability.

By stopping the advance of decay and moulds and placing the building in a more stable condition (or at least knowing there has been mitigation of this risk) a planned repair programme can be devised that allows progressive and managed approach to the buildings problems. This allows for a whole of life approach to the dwelling rather than the attempt to rebuild at yr one with unproven technology in the hope that this will restore longevity to the building. In this way future likely damage as a result of continuing decay at only moderate moisture levels is mitigated and inevitable unstoppable damage avoided.

This allows for a more economical approach to resolving issues that can factor in such things as a claddings current economic life, the life expectancy of other elements such as roofs that may not be directly involved in current problems and the building current condition in relation to its expected maintenance cycle and lastly the owner's available resources and allows a cost effective solution to a complex and urgent situation.

The RotStop process has capacity to benefit timber to address concerns at long term durability issues in the face of recent improvements in understanding of building performance and recent understanding of leak mechanisms.

15. Appendix (and Bibliography)

DBH- External moisture- A guide to weathertightness remediation Nov 2007 (refer www.DBH.govt.nz)

NZS 3602; 1995 and 2003; Timber and wood based products for use in Building (refer New Zealand Standards

DBH - B2 consultation document – Sept 2010 (refer www.DBH.govt.nz)

DBH – E2AS1 acceptable solution for E2 External Moisture (refer www.DBH.govt.nz)

J A Drysdale – Boron for the preservation of wood June 1994 a review of efficacy data for fungi and termites (refer appendix page 1)

NZS 3640 2003; Chemical Preservation of Round and Sawn Timber. (refer New Zealand Standards

RotStop Manual –Step up group 2011 (refer appendix page 23)

DBH product certification register (refer www.DBH.govt.nz)

Scion The efficacy of brush on remedial treatments on radiata pine 18 Mths progress report Oct 2010 (refer appendix page 98)

International standards – ASTM D 1758 (refer appendix page 138)

Auckland University study evaluation timber strengths -Alan Furtado- 2009 (refer apendix)

DBH determination 2010-80 (refer www.DBH.govt.nz)

DBH-Russell Cooney Timber preservation and remediation of leaky houses March 2009 (refer appendix page 145)

Primaxa report Naul (refer appendix page 177)

Branz Bulletin 343 moisture in timber (BRANZ)

Willie Mandeno Corrosion review Opus Oct 2010 (refer appendix page 184)

J Lloyd & others CUP 452 Remedial timber treatment with borates 1999 (refer appendix page 188)

Dry Rot and its control -safeguard Chemicals ltd 1999 (refer appendix page 196)

Auckland Council practice note BLD 126PN

Scion -A comparison of rates of decay and loss of stiffness of Radiata pine and douglas Fir framing Lumber - May 2008 (refer appendix page