Summer Camp 2024

Forensic Engineering Practice Lessons

Case Study of a Multi Building Cladding Failure in New Zealand

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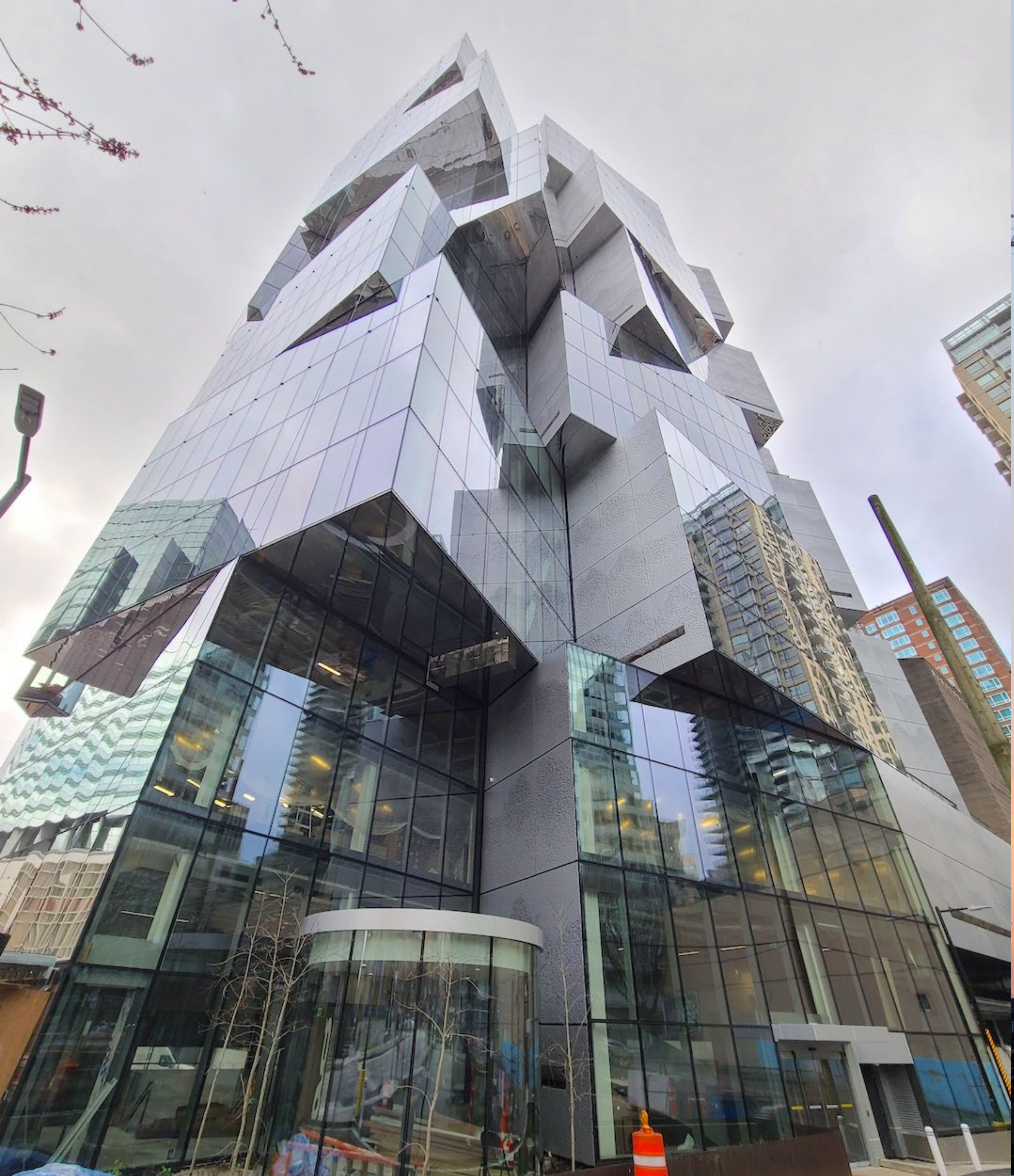


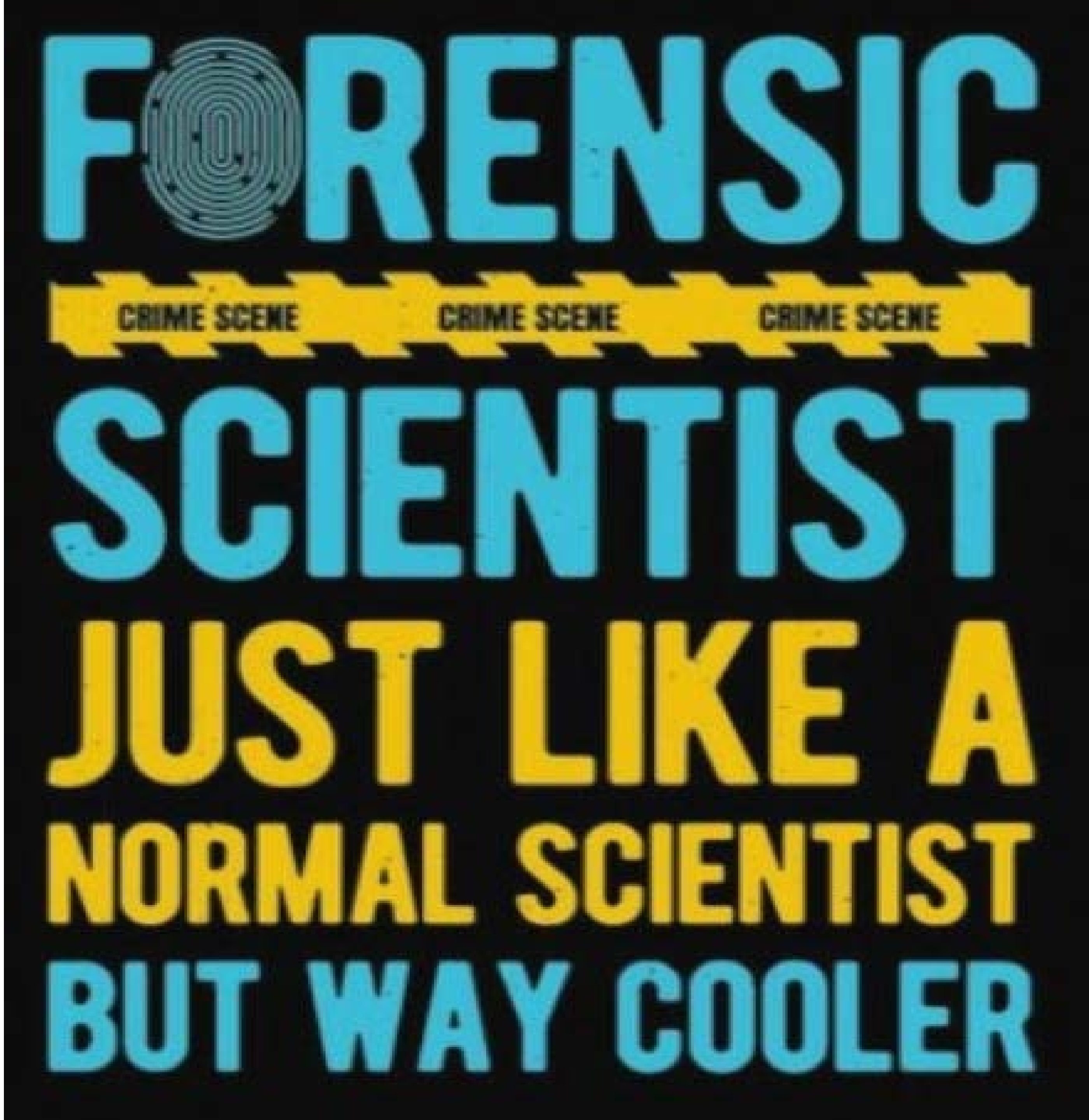

WORLD OF
FAÇADES



Forensic Engineering
is

"CSI For Buildings"



Forensic Engineering is NOT

- Cherry Picking
- Code quoting
- Red Herrings
- Guessing
- Surveying

Four engineers get into a car. The car won't start.

The Mechanical engineer says:
"It's a broken starter".

The Electrical engineer says:
"Dead battery".

The Chemical engineer says:
"Impurities in the gasoline".

The IT engineer says:
"Hey guys, I have an idea how about we all get out of the car and get back in".

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Typical Plaintiffs' Case

1. Water got in - made things bad!
2. Cladding separates the rot from rain.
3. Did some testing…. it failed.
4. Problem = defective product/installation
5. Same system on all buildings.
6. System will eventually fail everywhere.
7. Everything needs to be replaced.

QED ?

(Quod Erat Demonstrandum)

"scientific microphone drop"

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Typical Defendants' Case:

1. Cladding was not installed perfectly
2. Maintenance was not perfect
3. Some areas performing well
4. Did some testing – Passed
5. Cladding is good
6. Problem: Bad Installation & maintenance

QED ?

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Background

- →833 schools in New Zealand,
- →Water infiltration and decay,
- →NZ experts investigating failure,
- →NZ Building Code:
  - →Install wall assembly in accordance with manufacturer's instructions.
  - →NZ 4284 water test.
- →$1.4 Billion

Stuff ≡ national

New Zealand schools leak millions

Daniel Adams • 05:00, Mar 04 2013

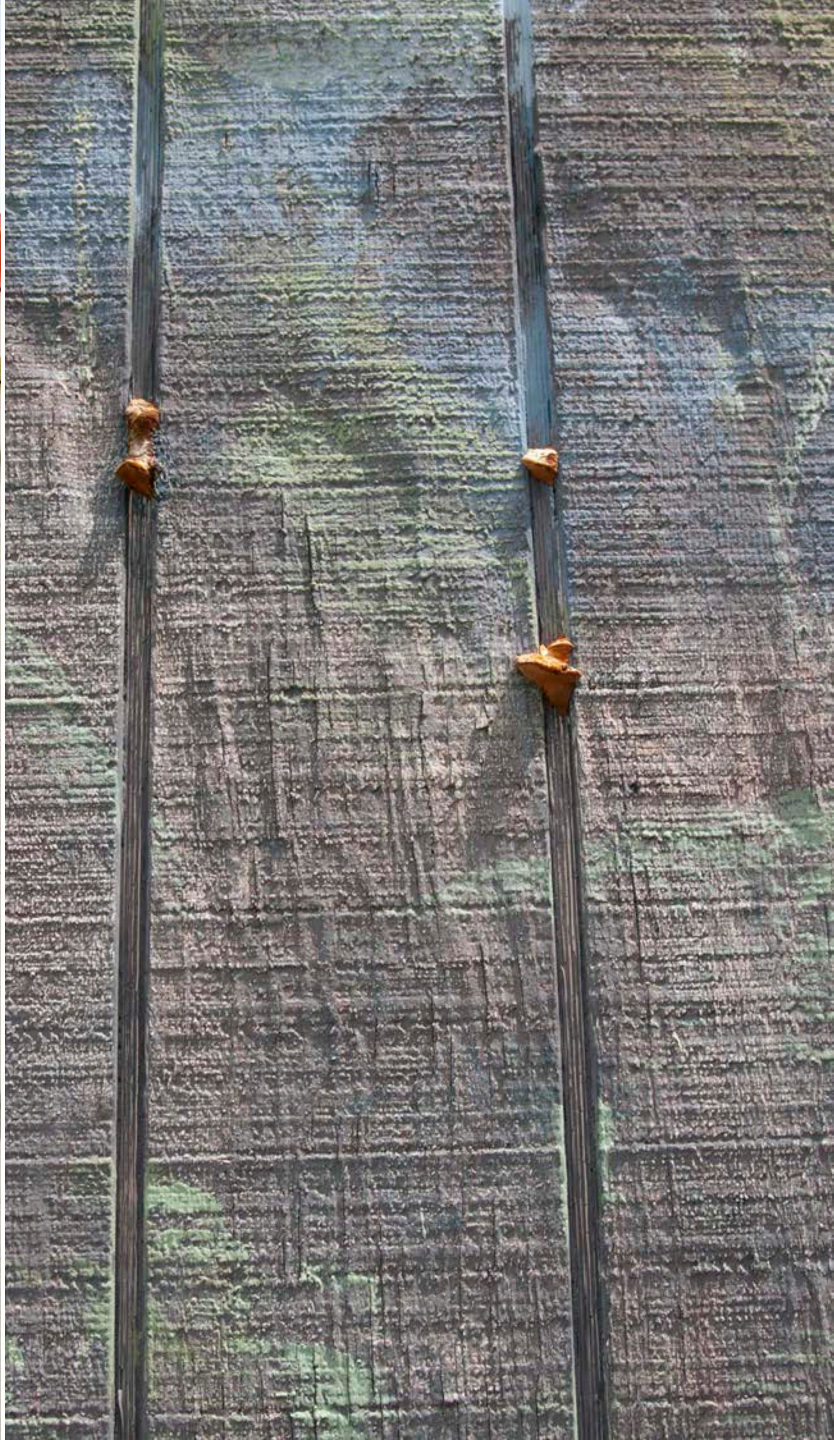
BRUCE MERCER/FAIRFAX NZ

FINALLY DRY: Te Rapa School principal Vaughan Franklin is happy his school's leaky issues have finally been resolved.

Thirty more schools have been confirmed as having leaking buildings that are expected to cost up to $1.4 billion to repair.

Official information released to the Waikato Times also shows legal action over issues caused by poor design, materials failure,

Center of Wall Issues



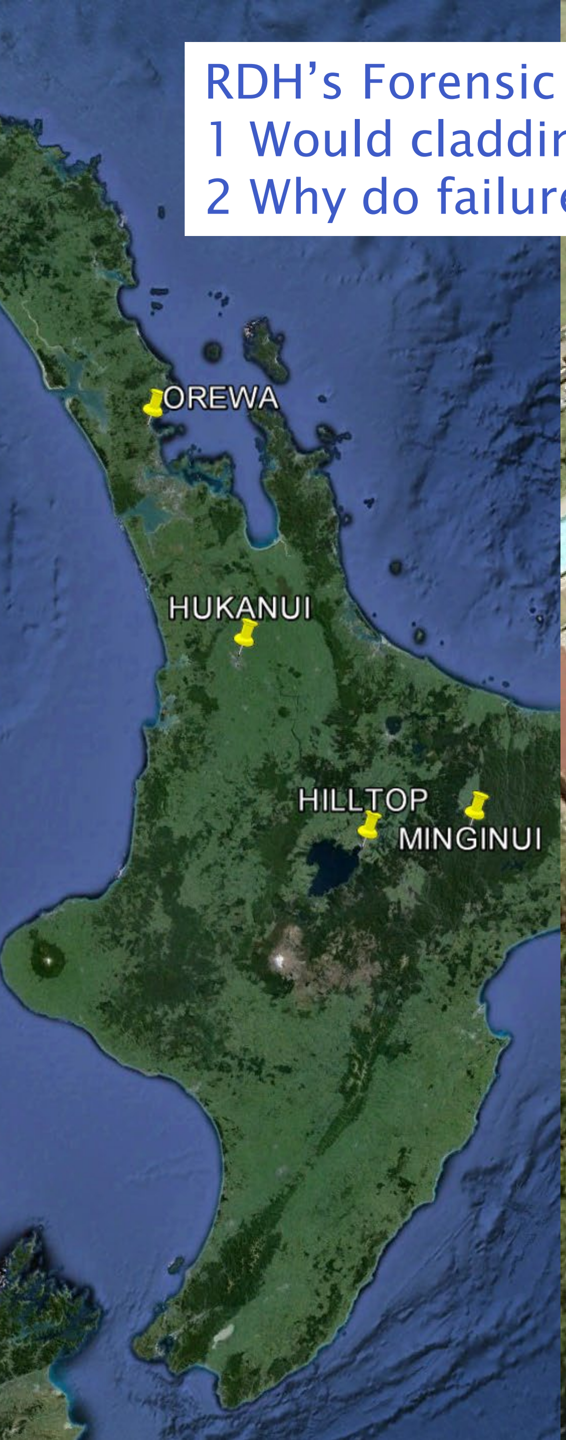
Interface Details
Included in Manufacturers Installation Instructions

Roofing and A-Typical Interface Details
Not Included in Manufacturers Installation Instructions

RDH’s Forensic Mandate

1 Would cladding system have failed if built in accordance with manufacturer's instructions

2 Why do failures occur in some areas and not others



NZ is Different !

New Zealand Exposure Risk Score Categories

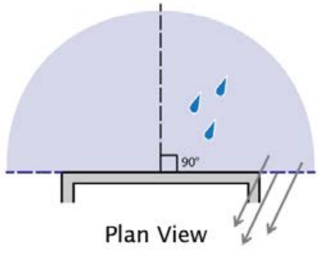
Risk Factor	Score(5)	Risk severity	Comments
A: Wind zone	0	**Low risk**	Low *wind zone* as described by NZS 3604
	0	**Medium risk**	Medium *wind zone* as described by NZS 3604
	1	**High risk**	High *wind zone* as described by NZS 3604
	2	**Very high risk**	Very High *wind zone* as described by NZS 3604
	2	**Extra high risk**	Extra High *wind zone* as described in NZS 3604 (4)
B: Number of storeys	0	**Low risk**	One *storey*
	1	**Medium risk**	Two *storeys* in part
	2	**High risk**	Two *storeys*
	4	**Very high risk**	More than two *storeys*
C: Roof/wall junctions	0	**Low risk**	Roof-to-wall intersection fully protected (e.g. hip and gable roof with *eaves*)
	1	**Medium risk**	Roof-to-wall intersection partly exposed (e.g. hip and gable roof with no *eaves*)
	3	**High risk**	Roof-to-wall intersection fully exposed (e.g. *parapets*, *enclosed balustrades* or *eaves* at greater than 90° to vertical with soffit *lining*)
	5	**Very high risk**	Roof elements finishing within the boundaries formed by the exterior walls (e.g. lower ends of aprons, *chimneys*, *dormers* etc)
D: Eaves width (1)(2)	0	**Low risk**	Greater than 600 mm for single storey
	1	**Medium risk**	451–600 mm for single storey, or over 600 mm for two storey
	2	**High risk**	101–450 mm for single storey, or 451–600 mm for two storey, or greater than 600 mm above two storey
	5	**Very high risk**	0–100 mm for single storey, or 0–450 mm for two storey, or less than 600 mm above two storey
E: Envelope complexity	0	**Low risk**	Simple rectangular, L, T or boomerang shape, with single *cladding* type
	1	**Medium risk**	Moderately complex, angular or curved shapes (e.g. Y or arrowhead) with no more than two *cladding* types
	3	**High risk**	Complex, angular or curved shapes (e.g. Y or arrowhead) with multiple *cladding* types
	6	**Very high risk**	As for High risk, but with junctions not covered in C or F of this table (e.g. box windows, pergolas, multi-storey re-entrant shapes etc)

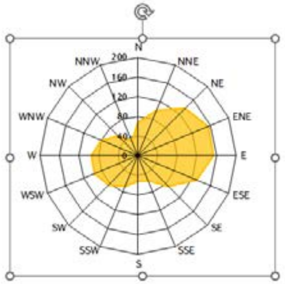
MAX Risk = 22

Additional NZ Exposure Risks: Driving Rain

→ Wind zones do not take into account prevailing wind direction for **Driving Rain**

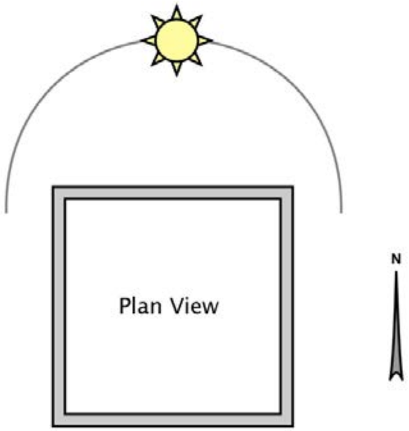
→ Wind within 90° of the facing direction contributes to driving rain



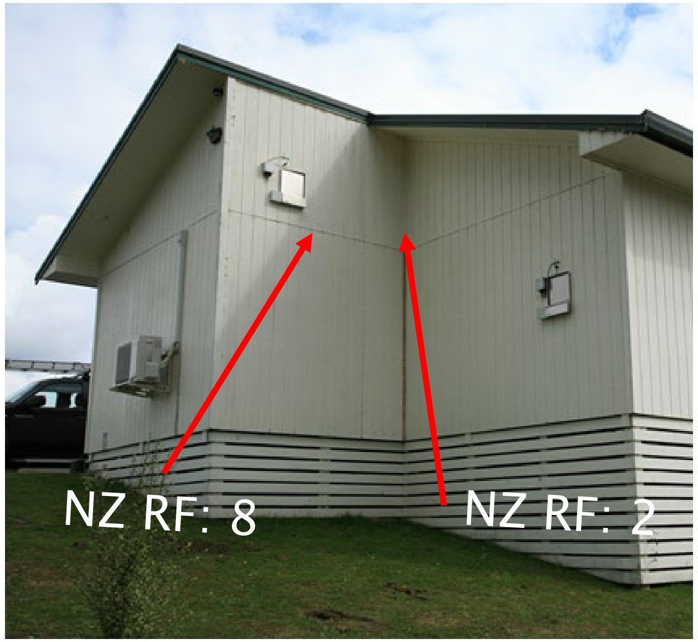


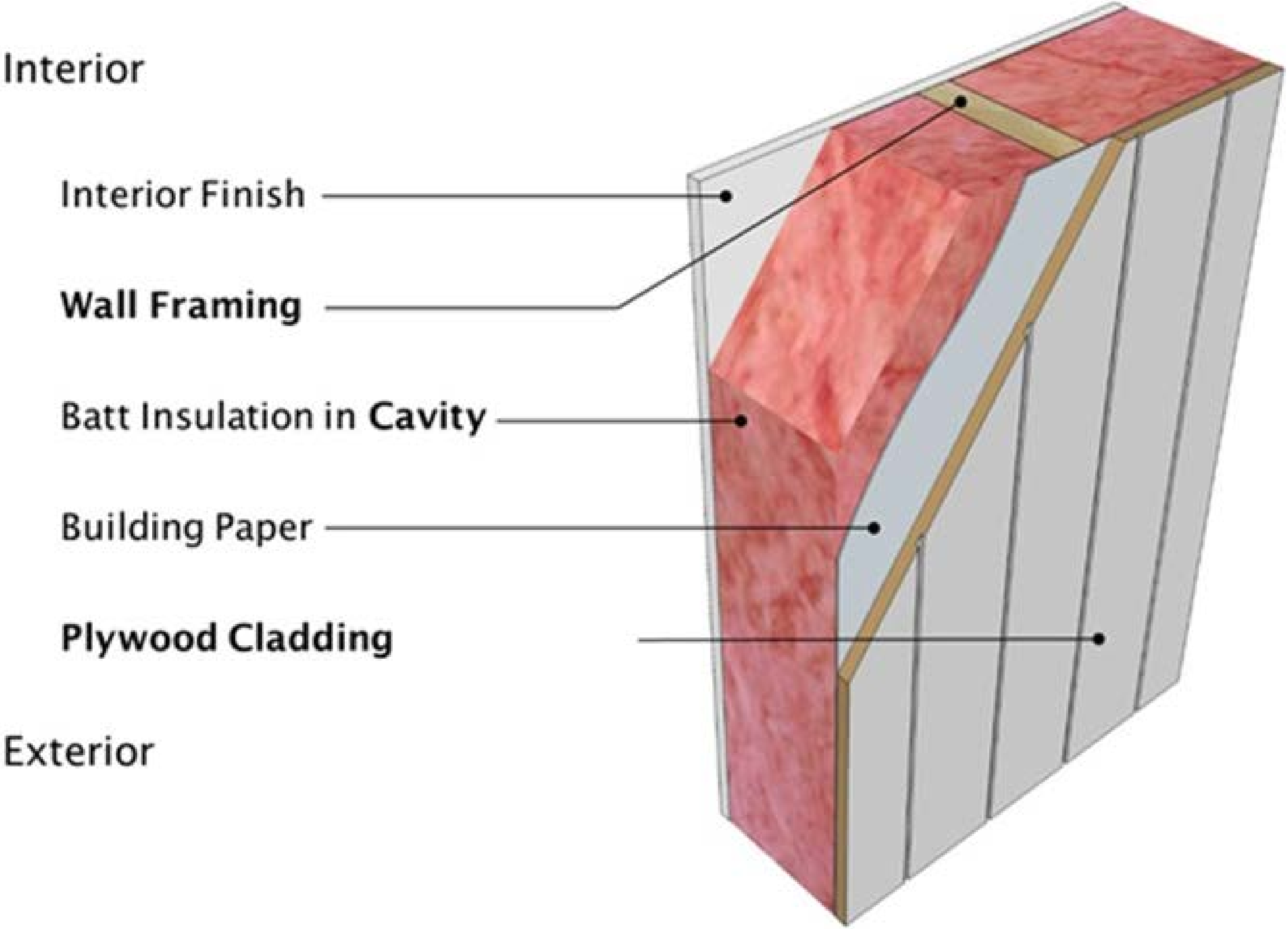
Additional NZ Exposure Risks: Solar Radiation

→ North-facing elevations shown to be at lower risk of moisture accumulation due to solar drying potential



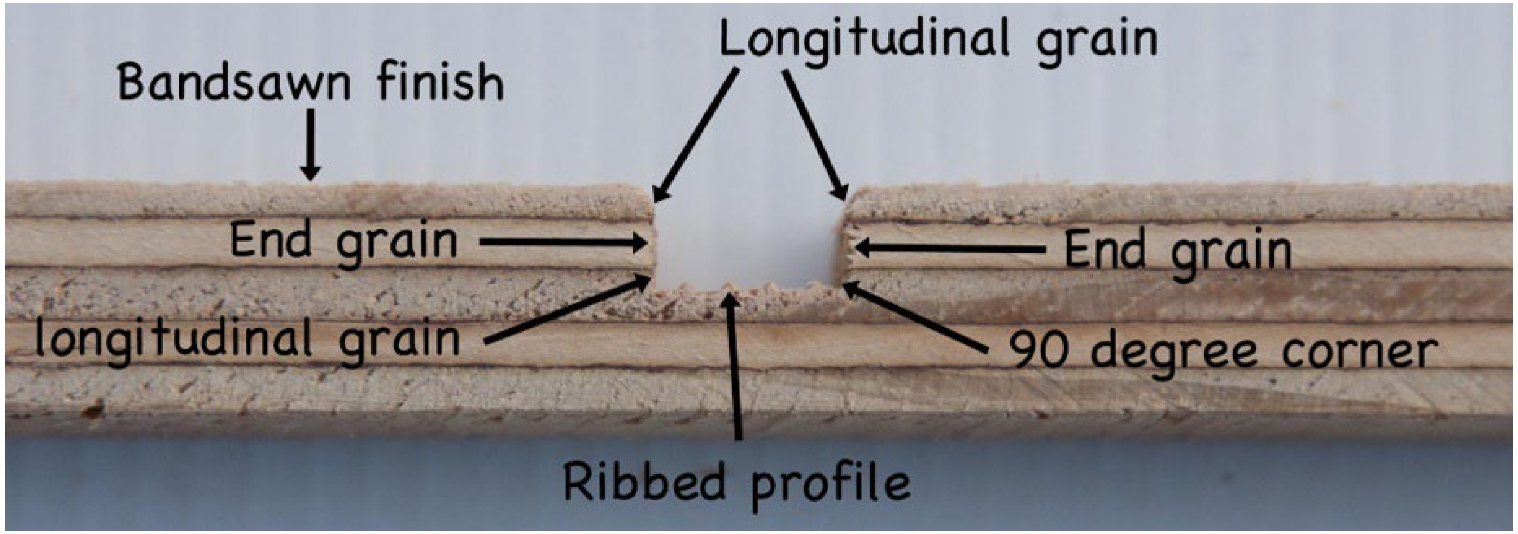
The Problematic Wall Assembly

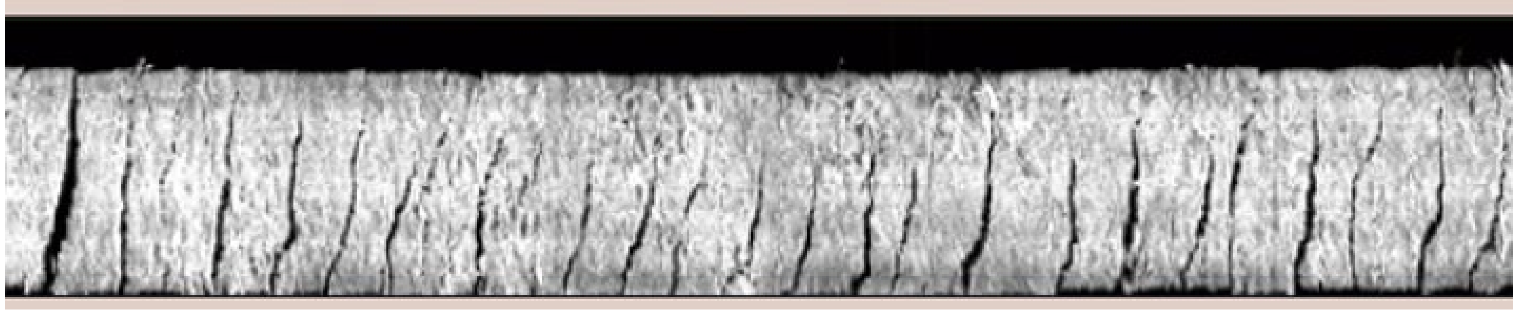


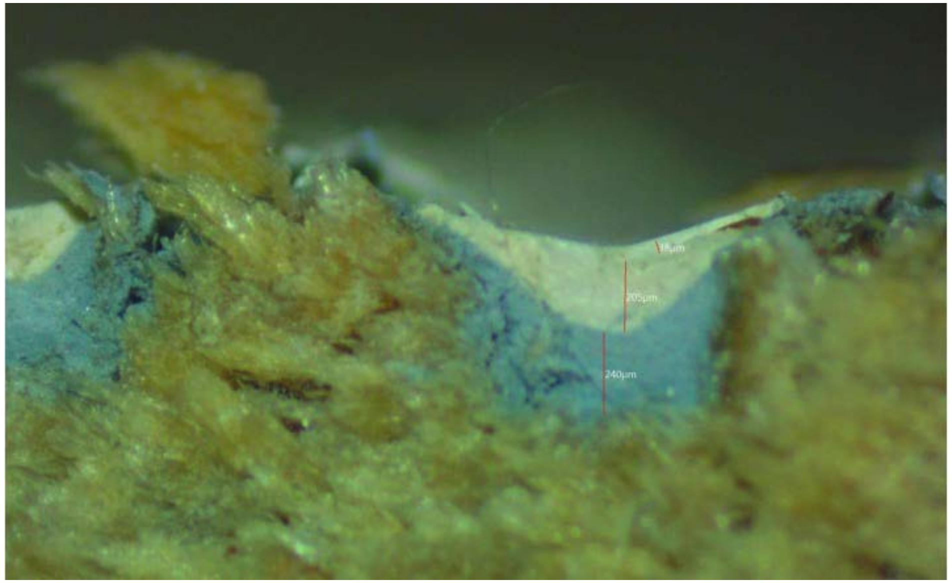


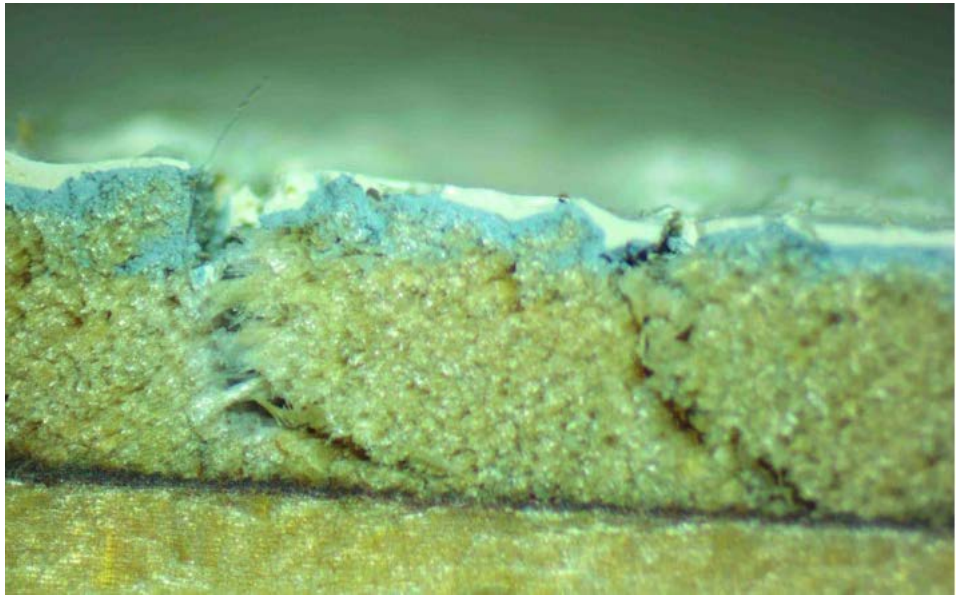
higher score = higher risk

Painted Treated Radiata Pine Plywood Cladding









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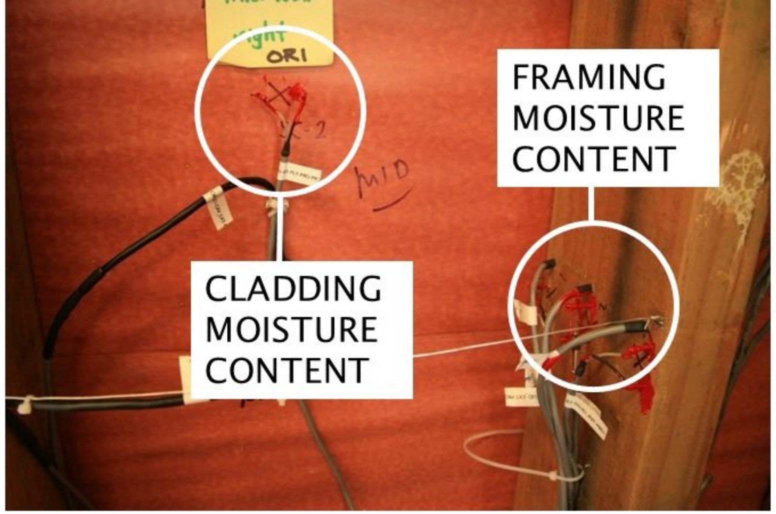
CAUTION
This product is to be kept dry
Cladding should be fixed the same day
North
Exterior


FRAMING MOISTURE CONTENT
CLADDING MOISTURE CONTENT


RELATIVE HUMIDITY


DRIVING RAIN & CLADDING WETTING SENSORS


WEATHER STATION


SILL MOISTURE CONTENT

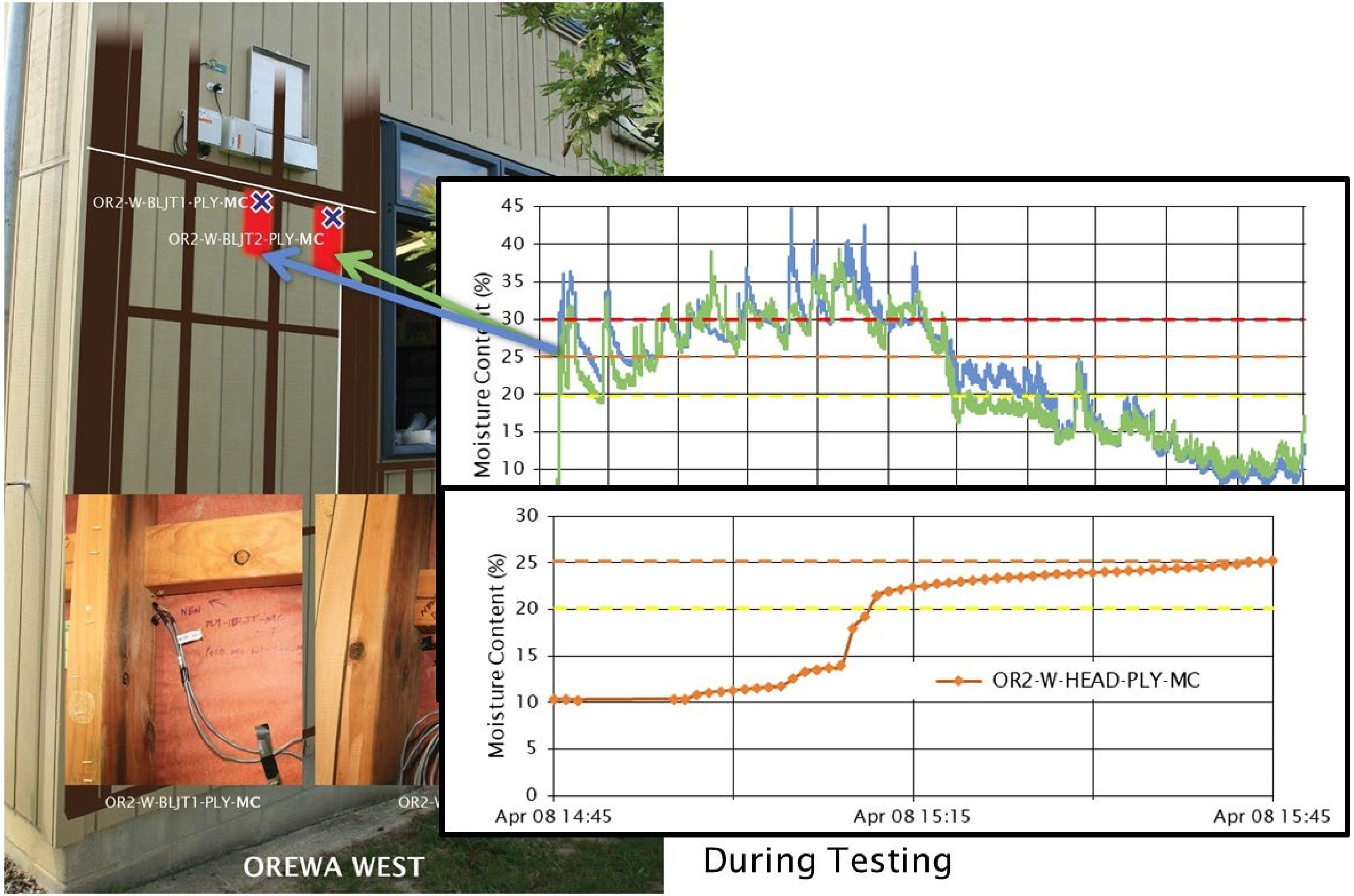

INDOOR TEMPERATURE & RELATIVE HUMIDITY

Field Testing While Monitoring (NZ 4284)


OR2-W-STUD-BLIT-MC
OR2-W-PLY-HEAD-MC
OR2-W-CAV_INT/EXT-MID-RH
OR2-W-STUD_INT/MID/EXT-MID-MC
OR2-W-PLY-BWIN-MC
OR2-W-STUD_EXT-BWIN-MC
OR2-W-PLY-MID-MC
OR2-W-CAV_INT/EXT-BWIN-RH
OR2-W-PLY-LOW-MC
OR2-W-SILL_EXT-BWIN-MC
OR2-W-SILL_INT/MID/EXT-COR-MC


Spray area shaded

Water Testing and Leak Tracing - While Monitoring



During Testing

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Laboratory Testing – “Perfectly” Built Test Hut

Stuff ☰ business

The hut that was built to leak

Rob Stock • 11:39, Jul 04 2018

SUPPLIED

A small building, called a test hut, has been built specifically by the Ministry of Education to see whether it would leak in a bid to gather evidence for its leaky schools claim

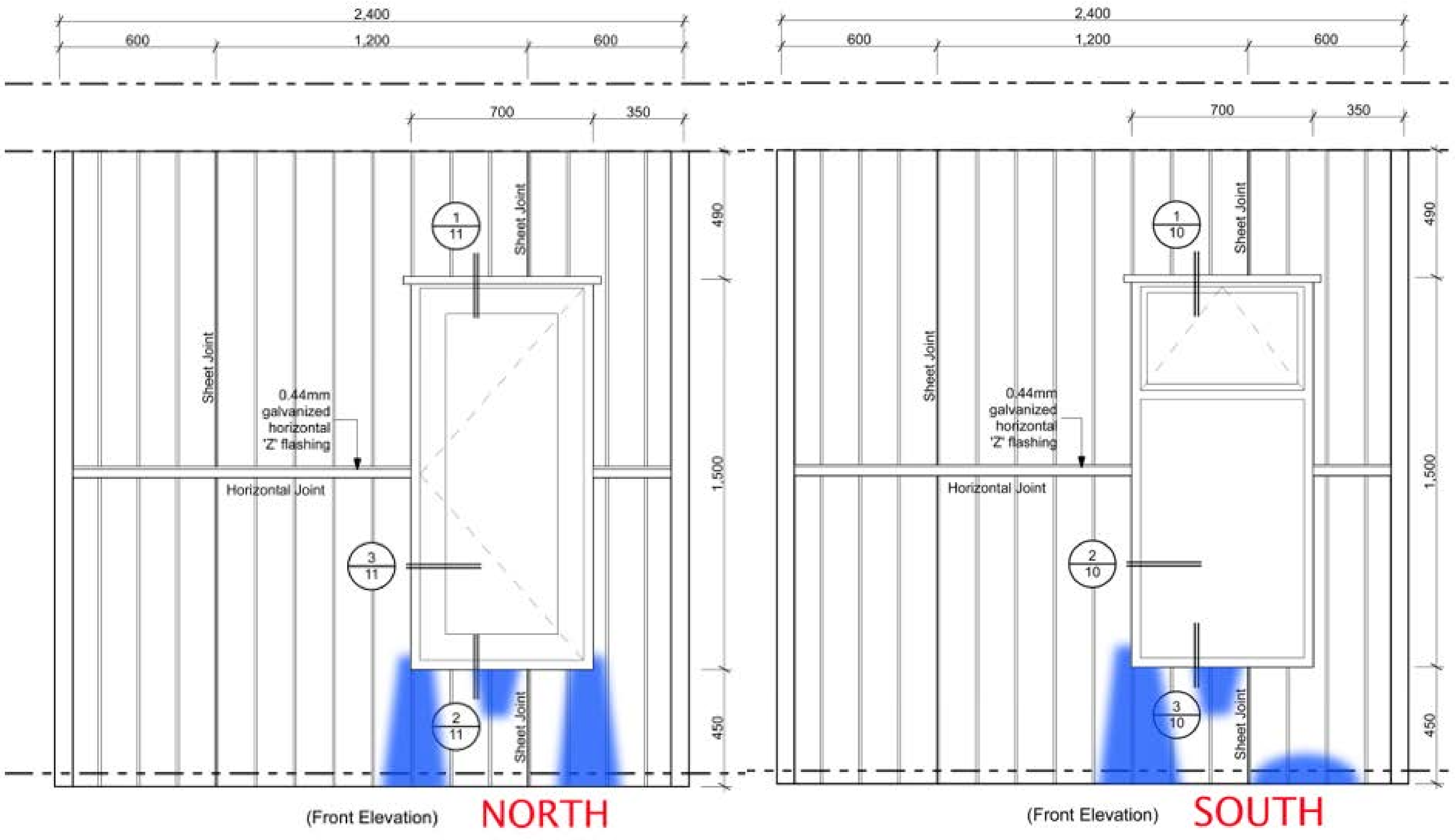

Figure 17.11 Test hut North and South walls, exterior view, leaking from façade testing

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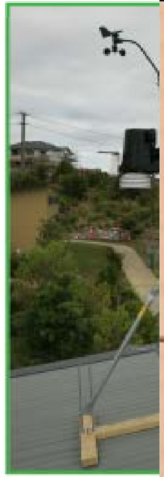
Key Findings from Field Monitoring & Testing

→Primary Failure Causal Factors in order of impact:

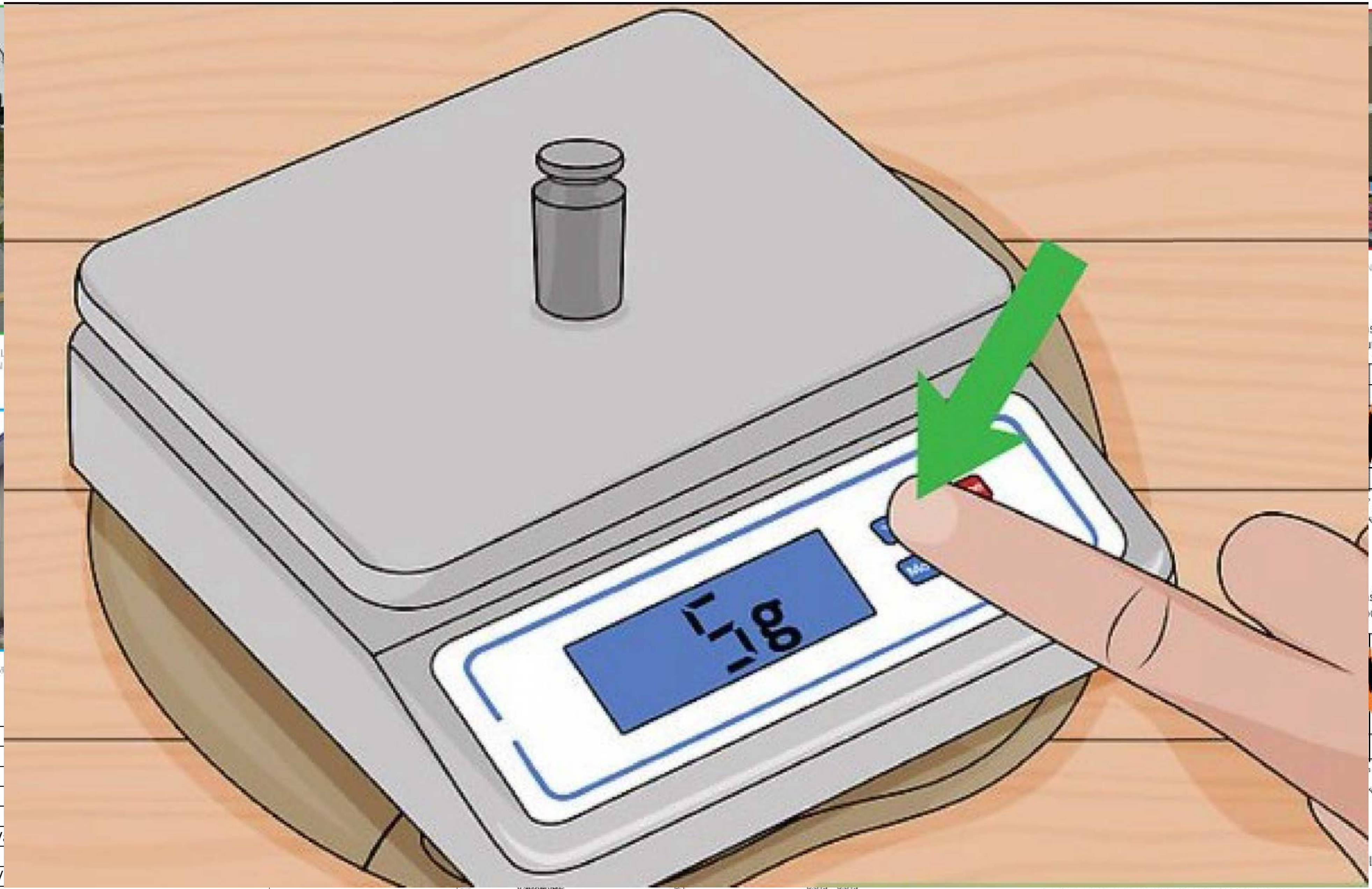
1. Water leakage through “compliant” interface details
2. Exposure to driving rain (overhangs, site, Location)
3. Base-of-panel absorption
4. Centre-of-wall wetting (in exposed areas only)

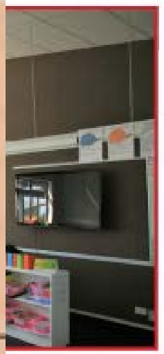
WUFI Model Development and Calibration



AIR TEMPERATURE, REL
SPEED AND DIRECTION
ROOF

RADIATION AND RAIN M
ORIENTATION





NSIDE SCHOOL

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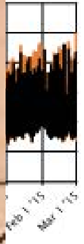

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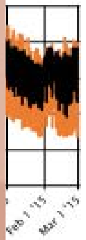

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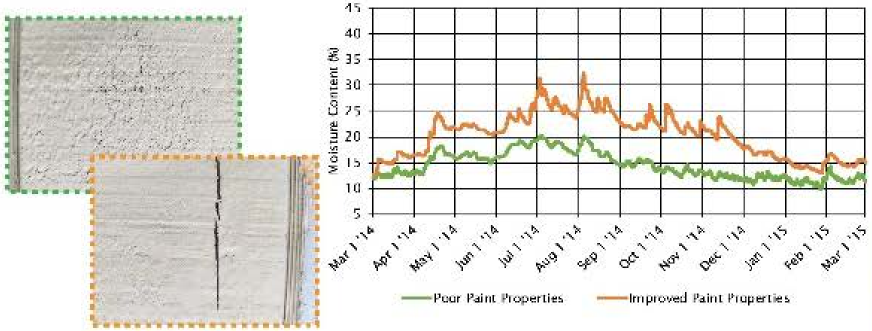
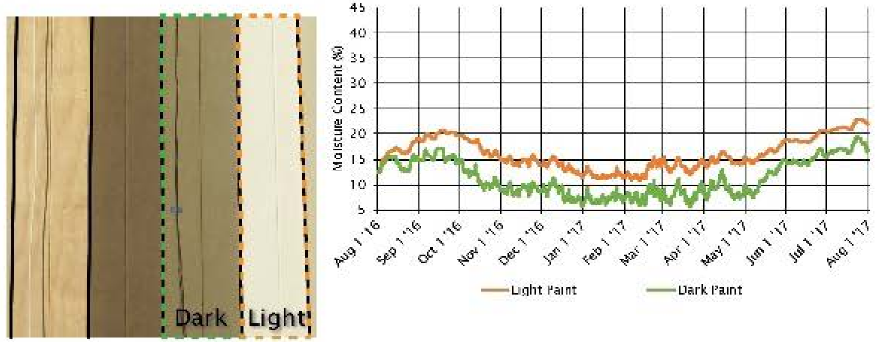
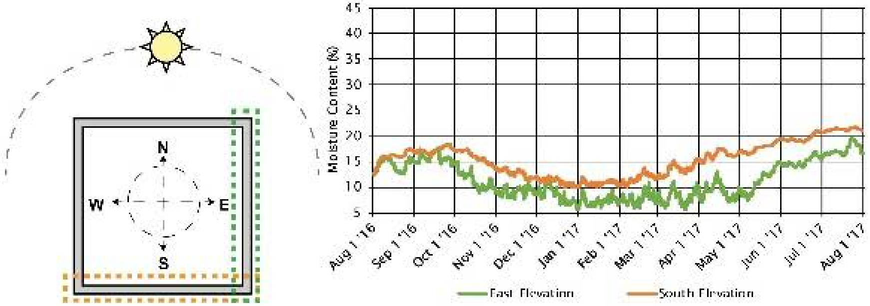
V	
A/	
Solar Absorptivity	ASTM E1918



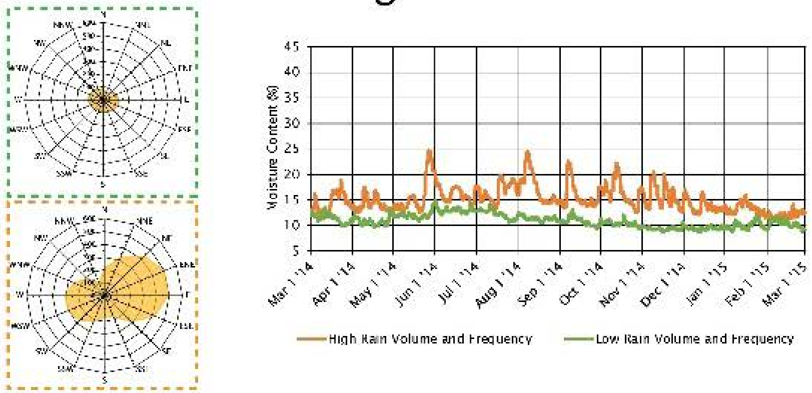
Exterior Paint and Cladding Condition



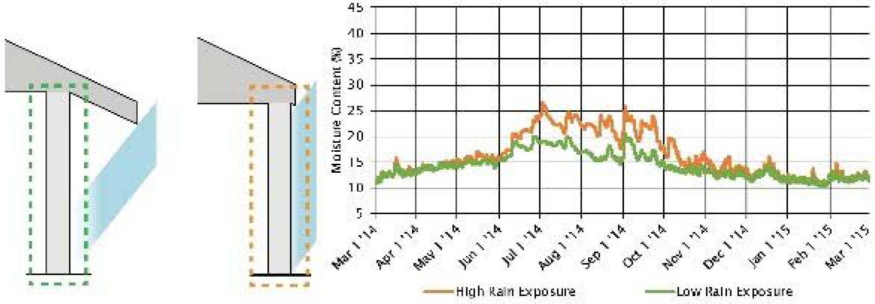
Cladding Colour



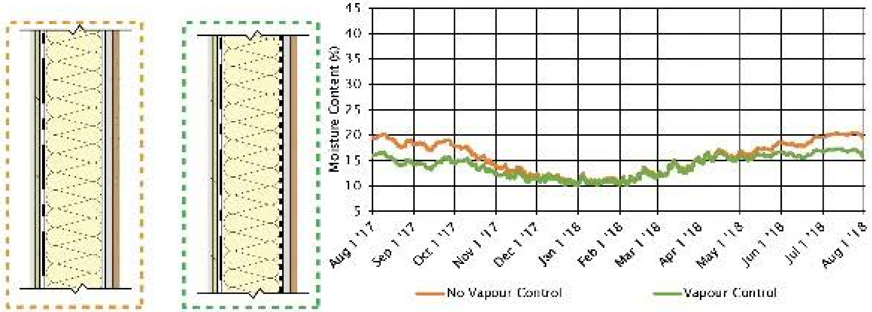
Orientation of Walls



Driving Rain Volume and Frequency



Rain Exposure



Interior Vapour Levels/Control

Relatable Risks – Visible Mould

Table 3.4 VTT mould index sensitivity classes – Example Generic Materials (Ojanen, et al., 2010)

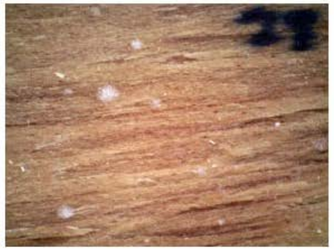
Sensitivity Class	Example Materials
Very Sensitive	Untreated wood
Sensitive	Planed wood, paper-coated products, wood-based boards
Medium Resistant	Cement- or plastic-based materials, mineral fibres
Resistant	Glass and metal products, materials with protective treatments

Mould Index	Description
0	No mould growth
1	Initial stages of growth (microscopic)
2	<10% microscopic. Several local mould growth colonies (microscopic)
3	<10% **visible** mould growth on surface; New spores produced
4	10 – 50% coverage of visible mould growth on surface, >50% microscopic
5	>50% visible mould growth on surface
6	Heavy and tight mould growth, up to 100% coverage

2019/01/14

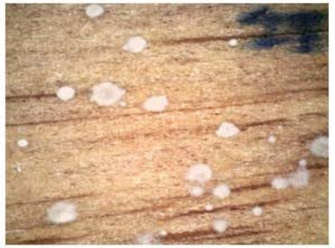
2019/01/20

2019/01/28



2019/02/05

2019/02/15



2019/02/28

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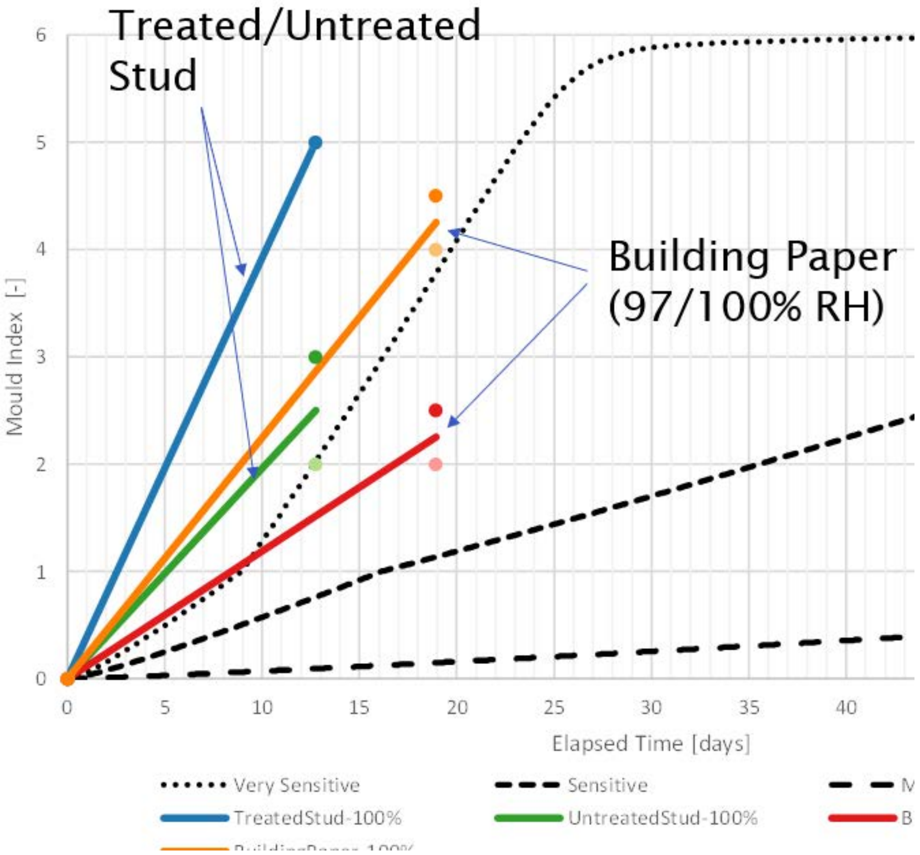
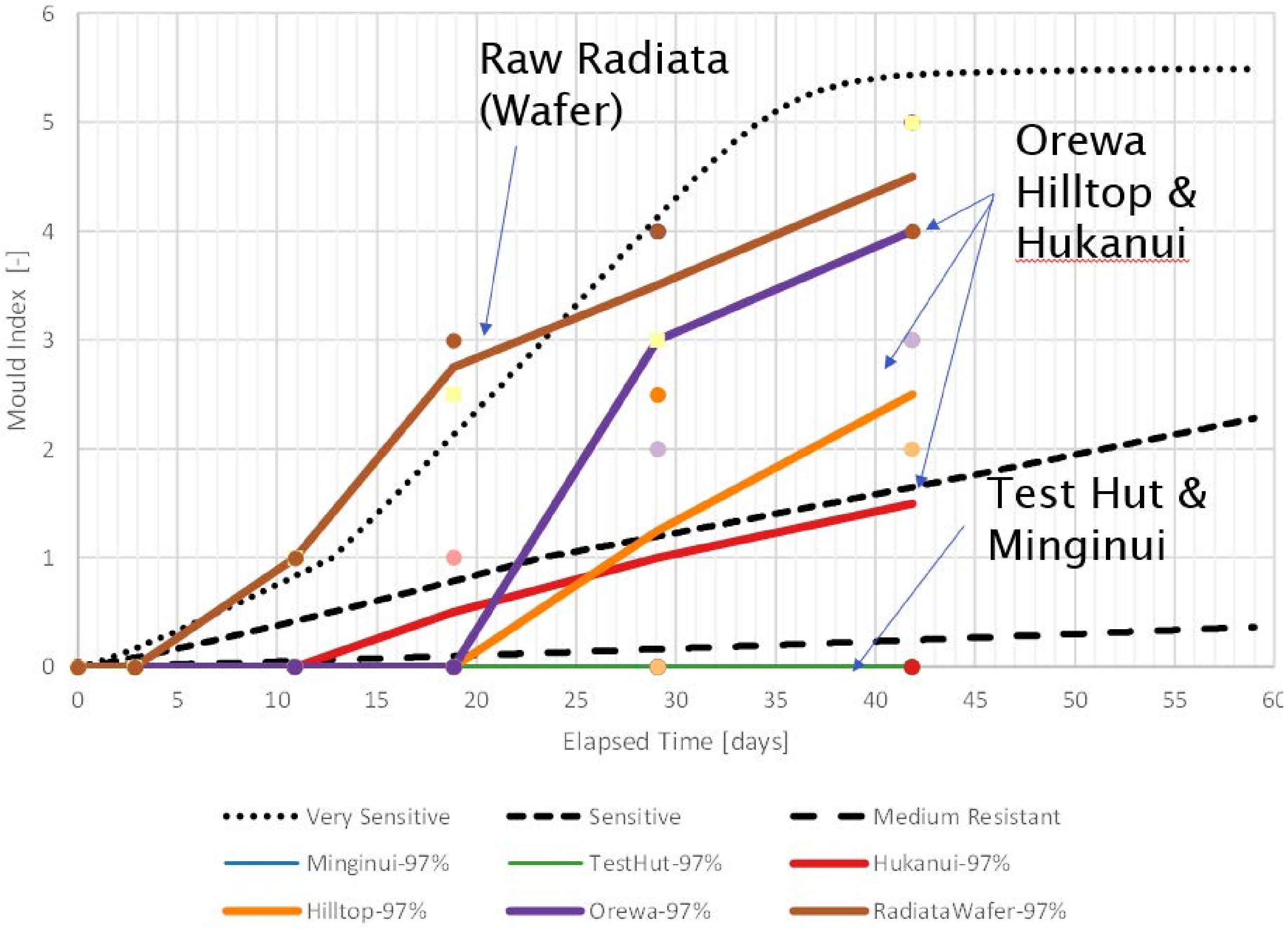
Stud and Building Paper Samples



Cladding Samples
Mould Growth within 97% RH Chamber



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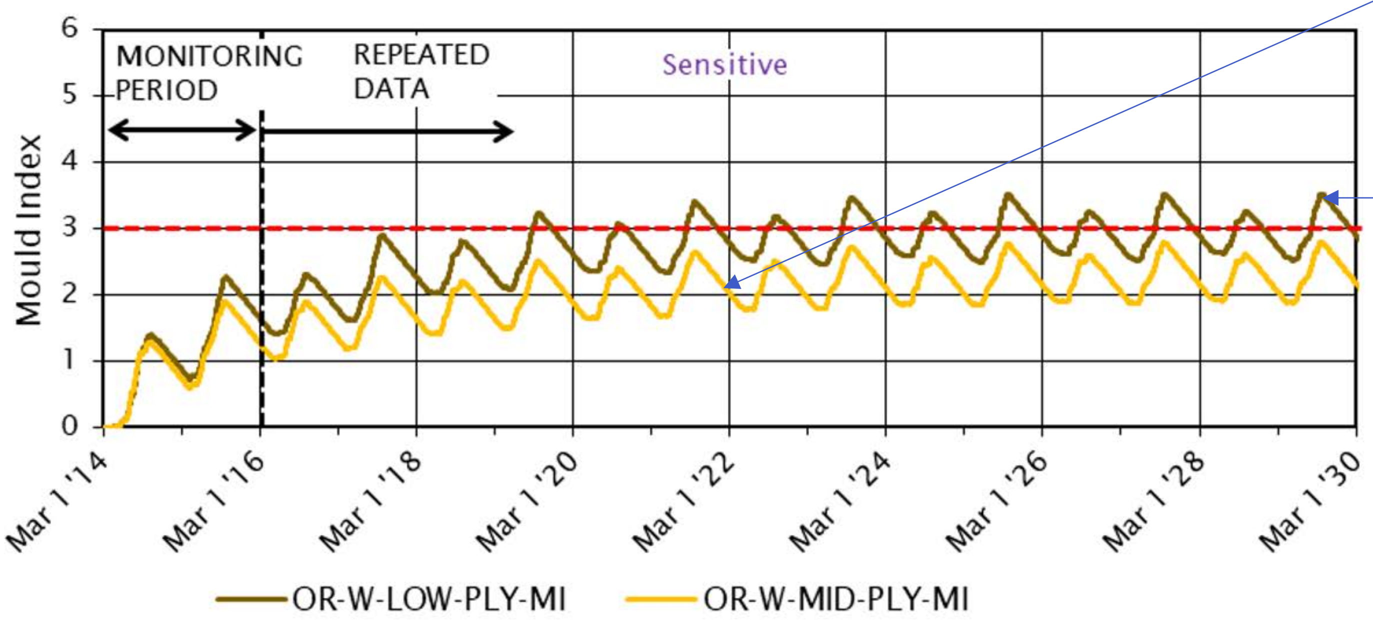
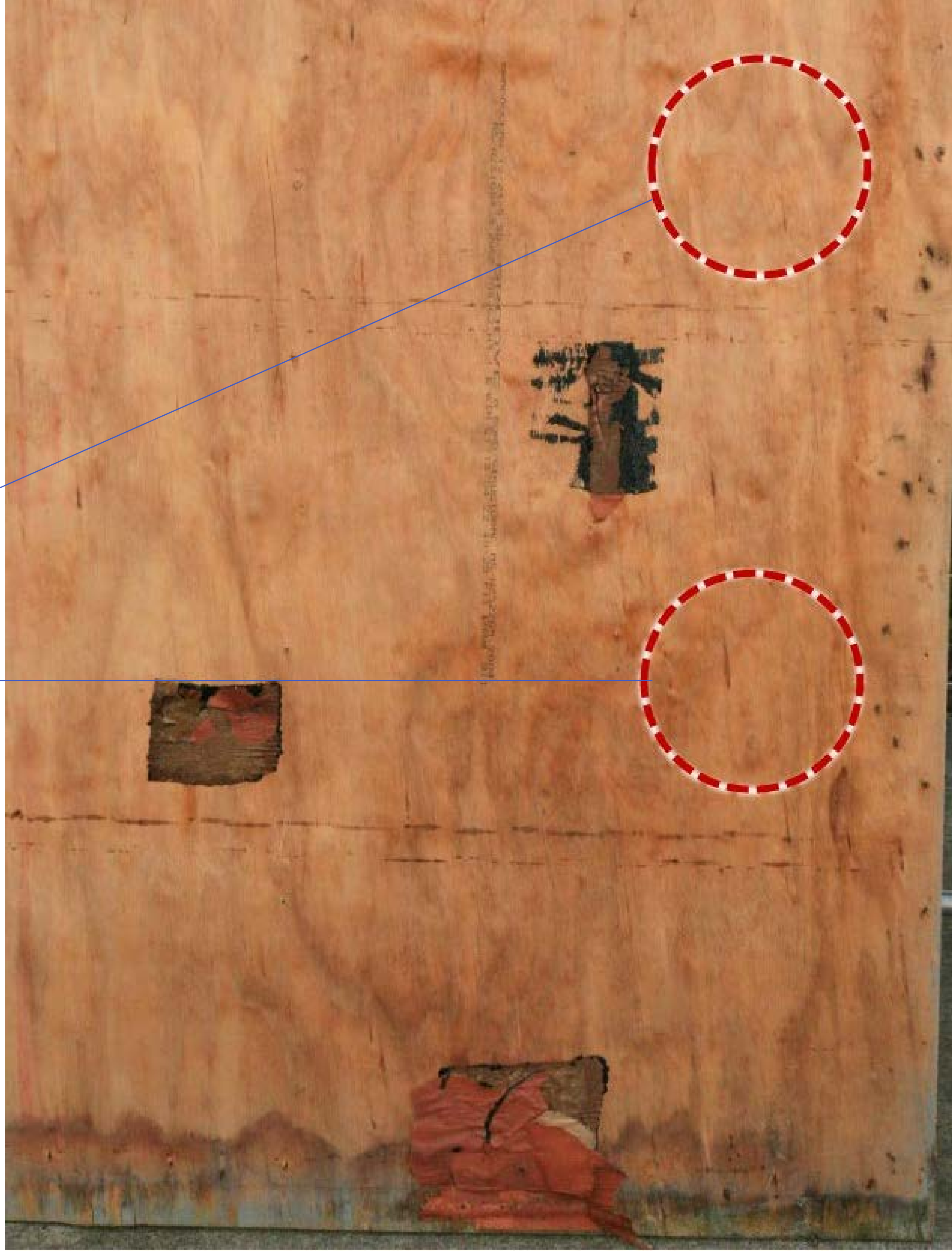
Relatable Risk - Center of Wall in Plywood Cladding





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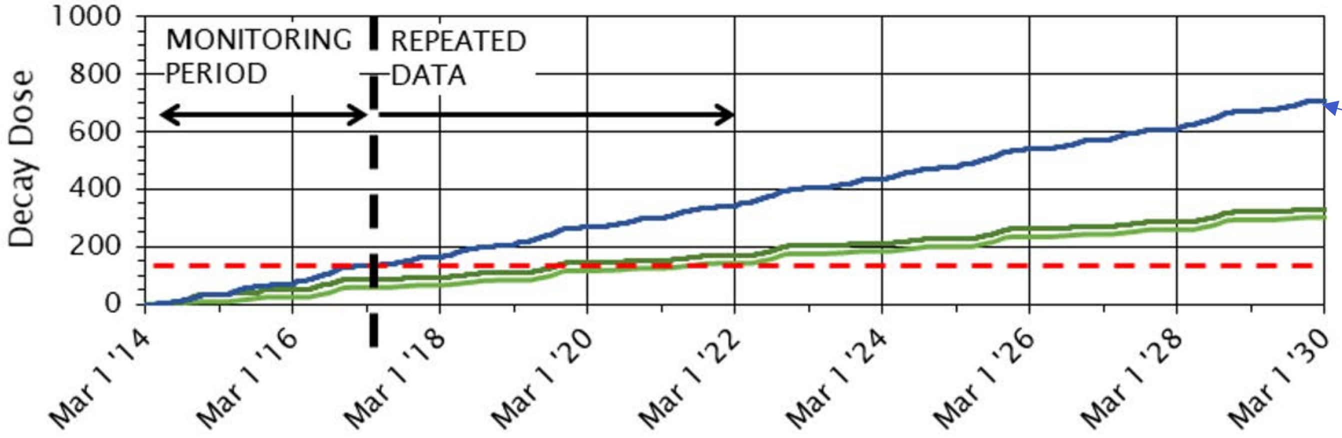
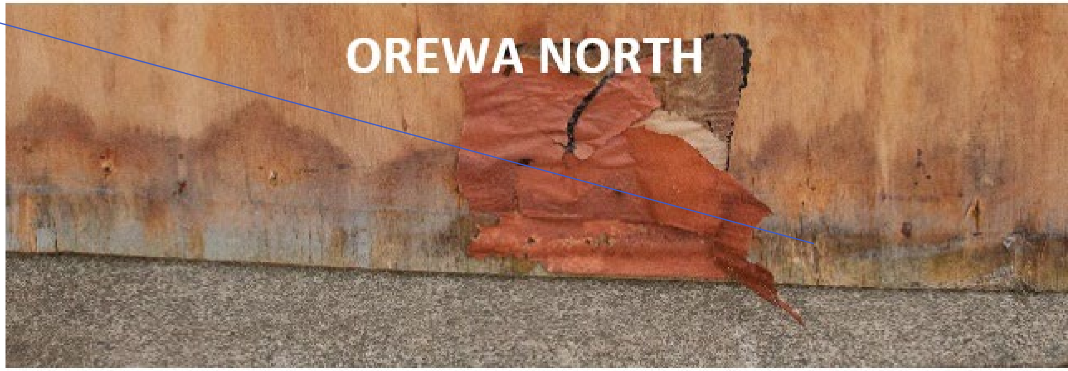
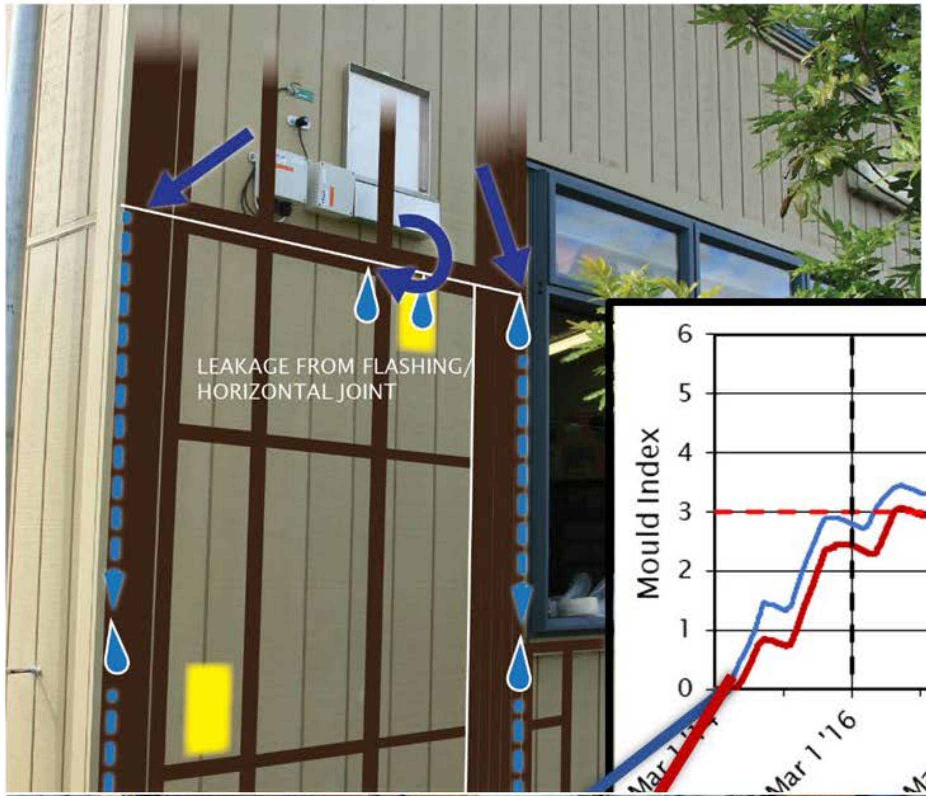
Relatable Risks – Wood Decay



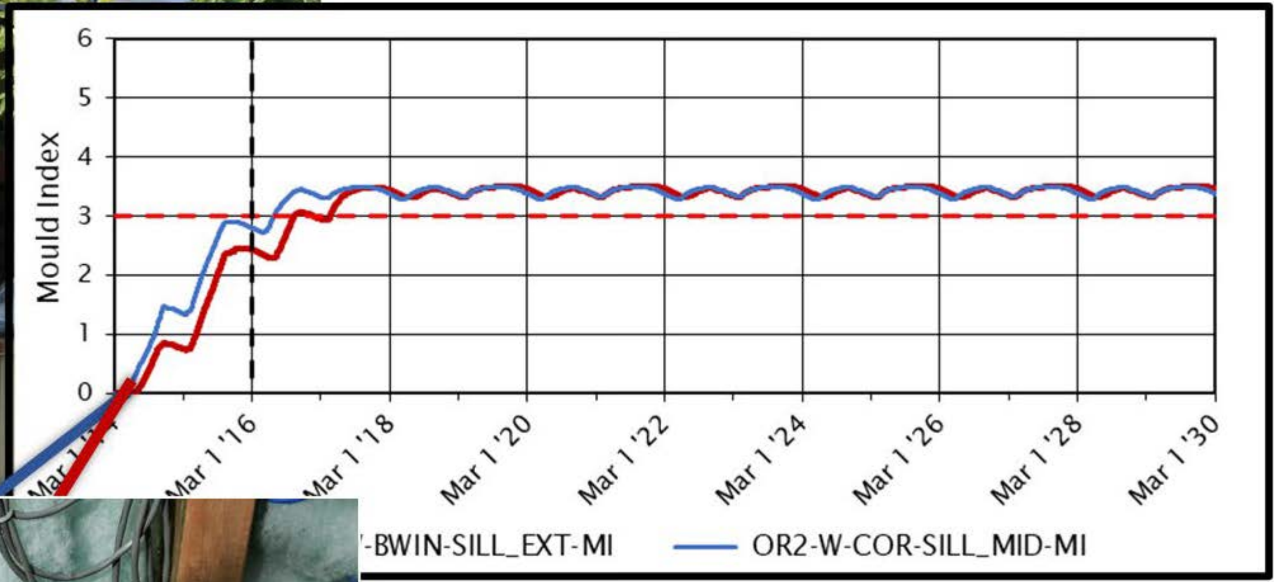
Decay Rating	Description	Dose Units
0	Sound – no decay	0-150
1	Slight Decay	150-500
2	Moderate Decay	250-600
3	Severe decay	350-800
4	Very severe decay	500+



Relatable Risk at Rainwater Leak



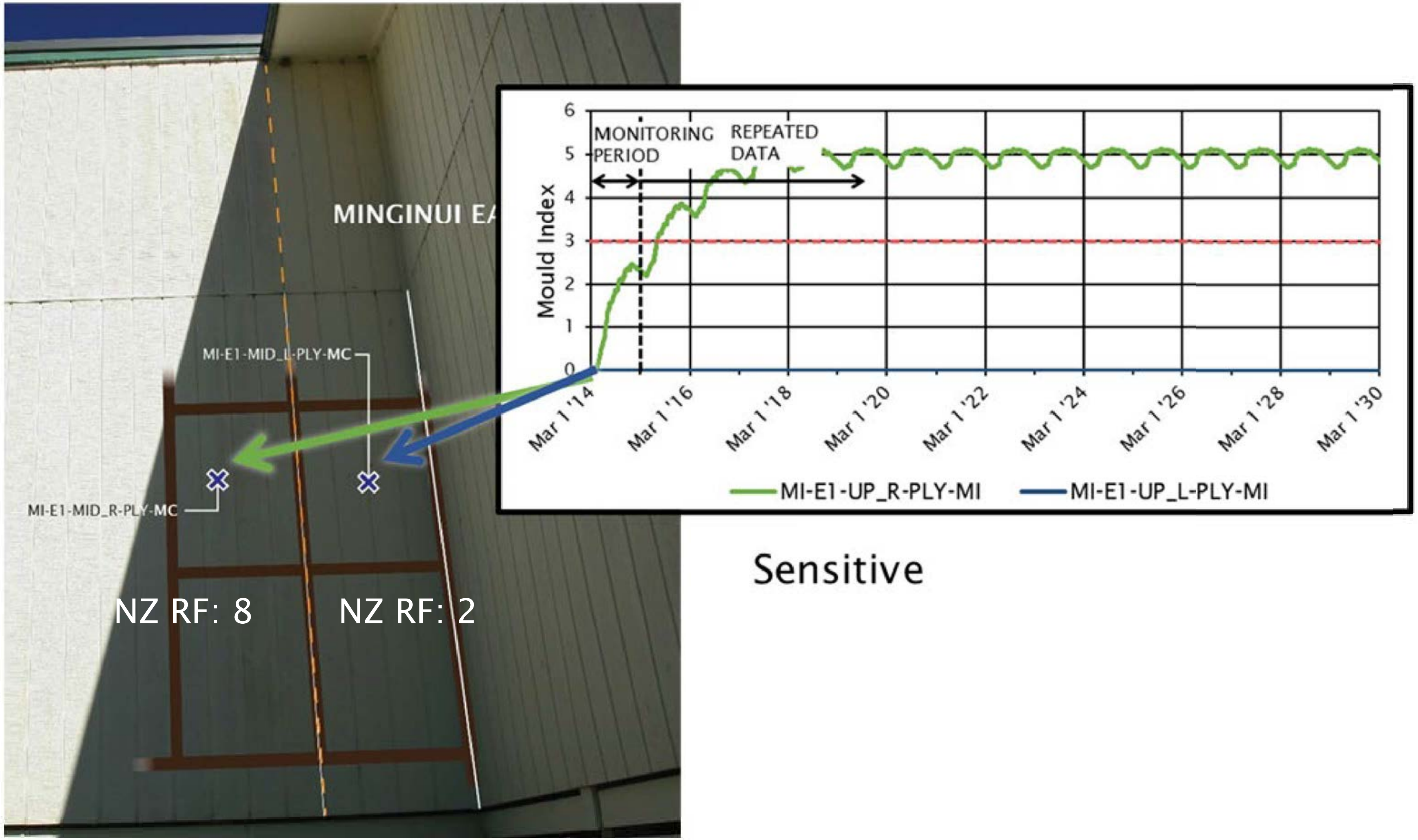
Leakage Location Mould Index



Sensitive/Very Sensitive Mould Resistance

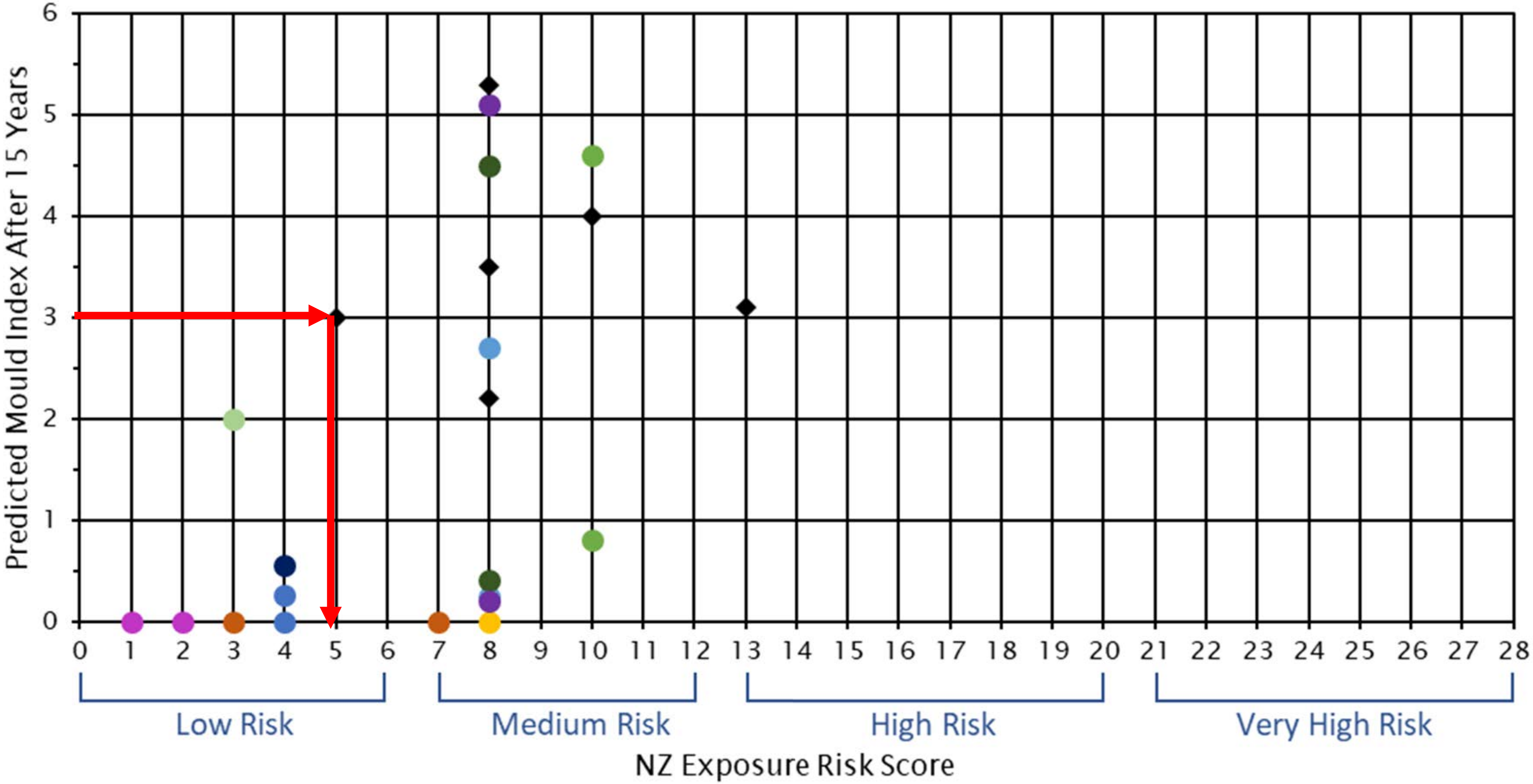
Monitoring Results – Center of Wall (no Leaks)

Centre of Wall Shadowclad Mould Index (Sensitive)



Sensitive

Relatable Risks – Mold vs NZ Risk



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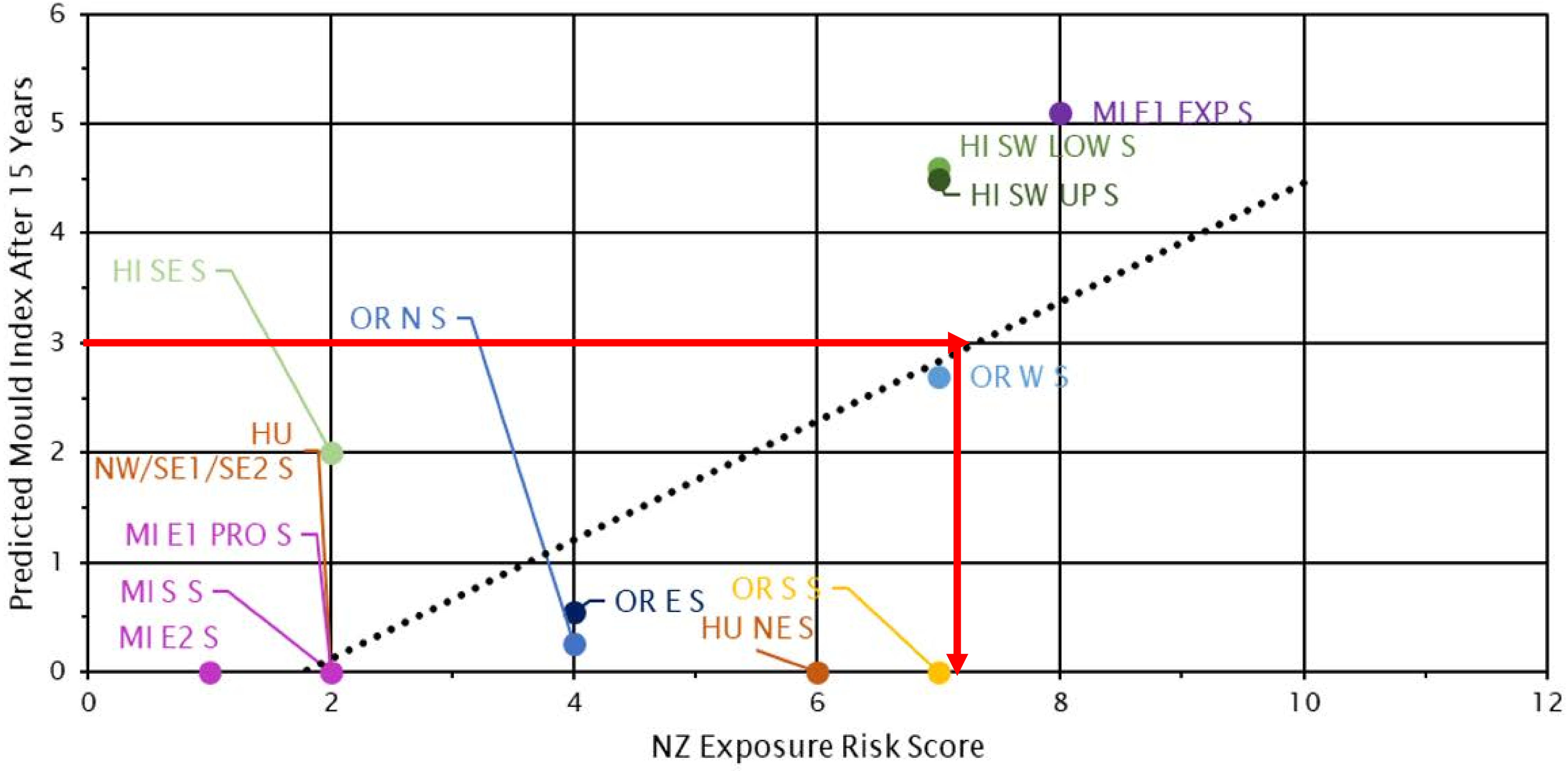
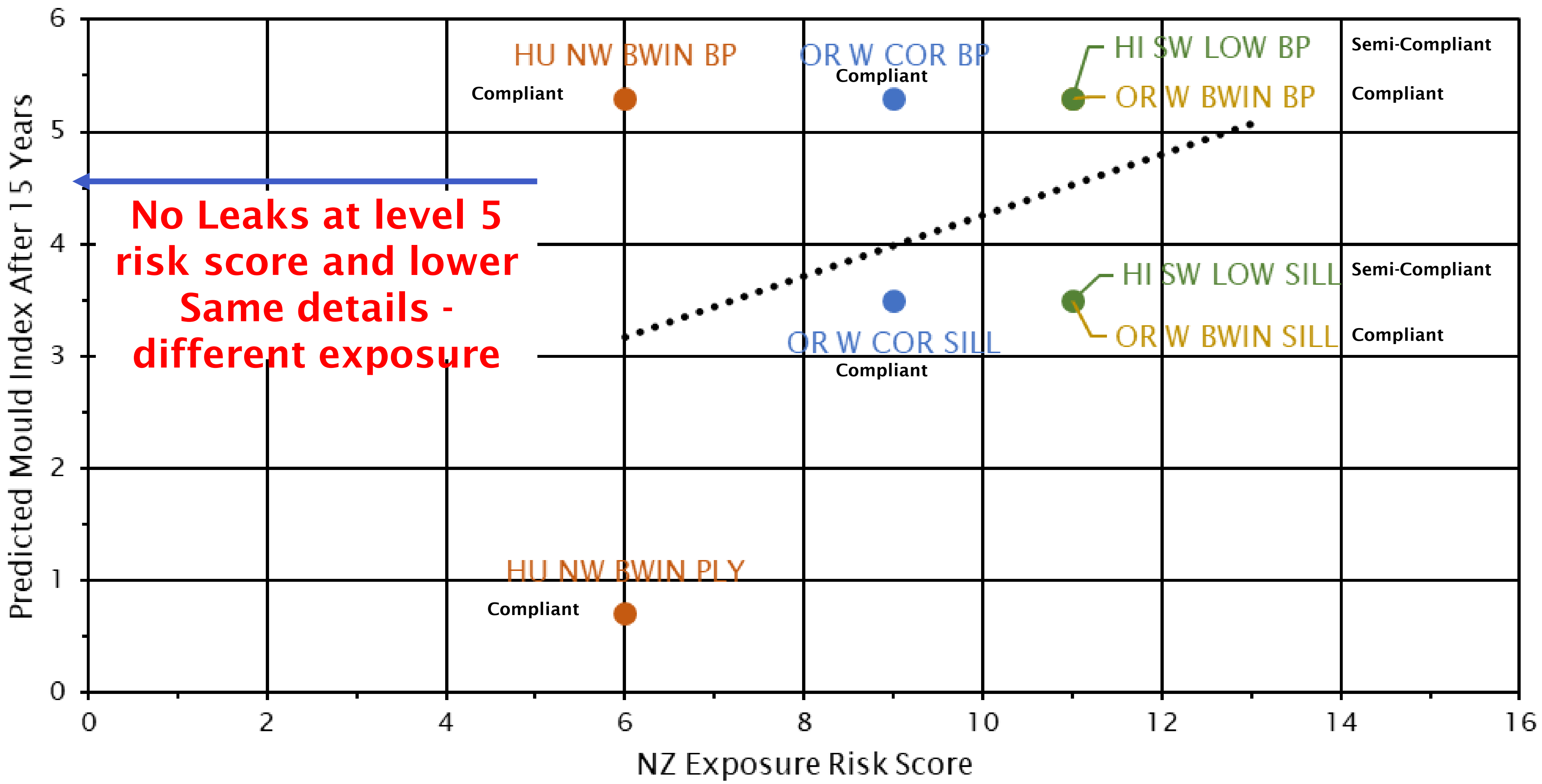
Relatable Risks – Visible Mold VS NZ Risk Score - Cladding Only



Risk Score & Mould Index – Leak Locations (compliant)



Key Findings from Field Monitoring & Testing

→Primary Failure Causal Factors in order of impact (Visible Mold):

1. Water leakage through “compliant” interface details
2. Exposure to driving rain (overhangs, site, Location)
3. Base-of-panel absorption
4. Centre-of-wall wetting (in exposed areas only)

Phase 2 –Red Herrings and Rebuttals

Taking publications and papers out of context and opining to discredit our methodology.

Defendant Expert Red Herring:

"WUFI is popular despite its inability to provide reasonable predictive outcomes unless used by an experienced and sophisticated user who already 'knows' the correct outcome." *Lstiburek, Ueno, & Musunuru, 2015*

RDH Rebuttal:

Your expert left out the following sentence:
" In fact, despite the sophistication of the numerical analysis, available research is still dominated by experiment. We must still "build it, wet it, and watch it". The observed outcomes are then used to "tune" available models. The field remains phenomenologically based, because there is no widely accepted theory of combined heat and moisture flow ".

The process we have taken in our work for this case is exactly what Lstiburek recommends in this quote. We are sophisticated users who installed monitoring into existing buildings, and we tested them by wetting, monitoring and watching them. With this knowledge we tuned our hygrothermal models so that they were accurate and useful.

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Phase 2 –Red Herrings and Rebuttals

Taking publications and papers out of context and opining to discredit our methodology.

Defendant Expert Red Herrings:

1. *"The outputs from the WUFI software cannot precisely account for all factors in the real world."* [1] (*John Straube, Eric Burnett, "Overview of Hygrothermal (HAM) Analysis Methods" pg. 8)*

2. *The plaintiffs' experts "tampered with their WUFI models by using their monitoring data to manipulate them."*

RDH Rebuttal:

"The gold standard for research-grade studies is to conduct a physical experiment and benchmark the model output results to the physical measurements… Physical testing, supported by modeling, an understanding of building science and building practise is not only an acceptable means of understanding and predicting the behaviour and long-term performance of building enclosures, this combination is the best approach available to science and industry. In this case, RDH's WUFI modelling is backed by the things I have set out above."

RDH

John Straube – Plaintive Expert Opinion Report

Red Herrings and Rebuttals

"Cherry picking" test openings and observations at schools to support their opinions.

Defendants Expert Report confirming excellent field performance when installed correctly

RDH Rebuttal Report showing locations of test openings and simulation results predicting this performance

RDH

Red Herrings and Rebuttals

Performing testing using a nonstandard methodology and making erroneous conclusions.

Defendants' expert team constructed and tested 3 samples to NZ 4284 at 300Pa:

Sample 1 - How it should have been built then (compliant + best industry practice)
Sample 2 - How it would be built today (compliant with current installation manual)
Sample 3 - How the schools were built – complete with installation “defects”

Result:

All Samples Passed

Defendants Conclusion:

Cladding is not the problem

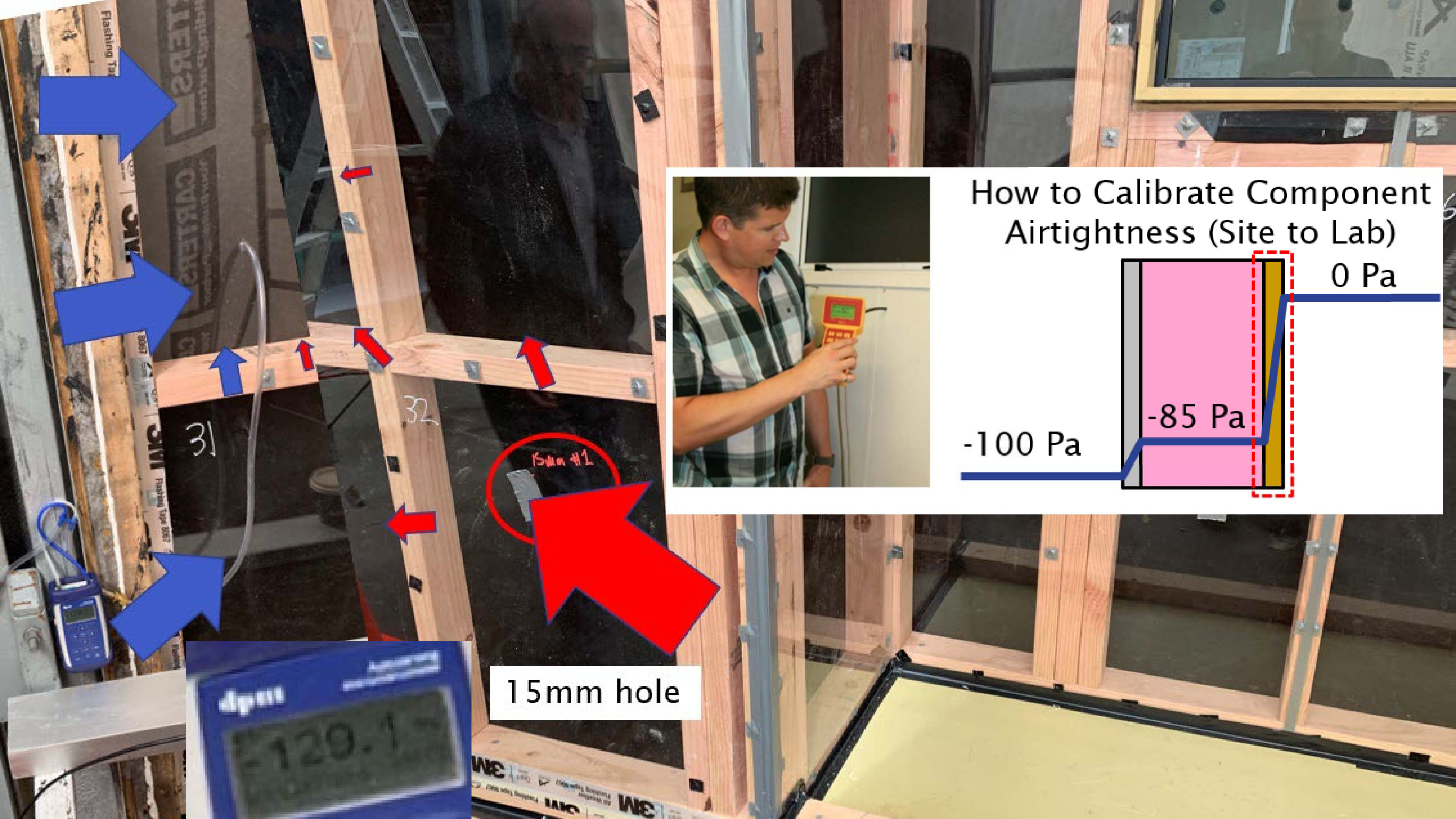
QED or WTF?

RDH

Red Herrings and Rebuttals

Testing using a nonstandard methodology and making erroneous conclusions.

Roofing underlayment used NOT building paper or red "do not get wet" building paper

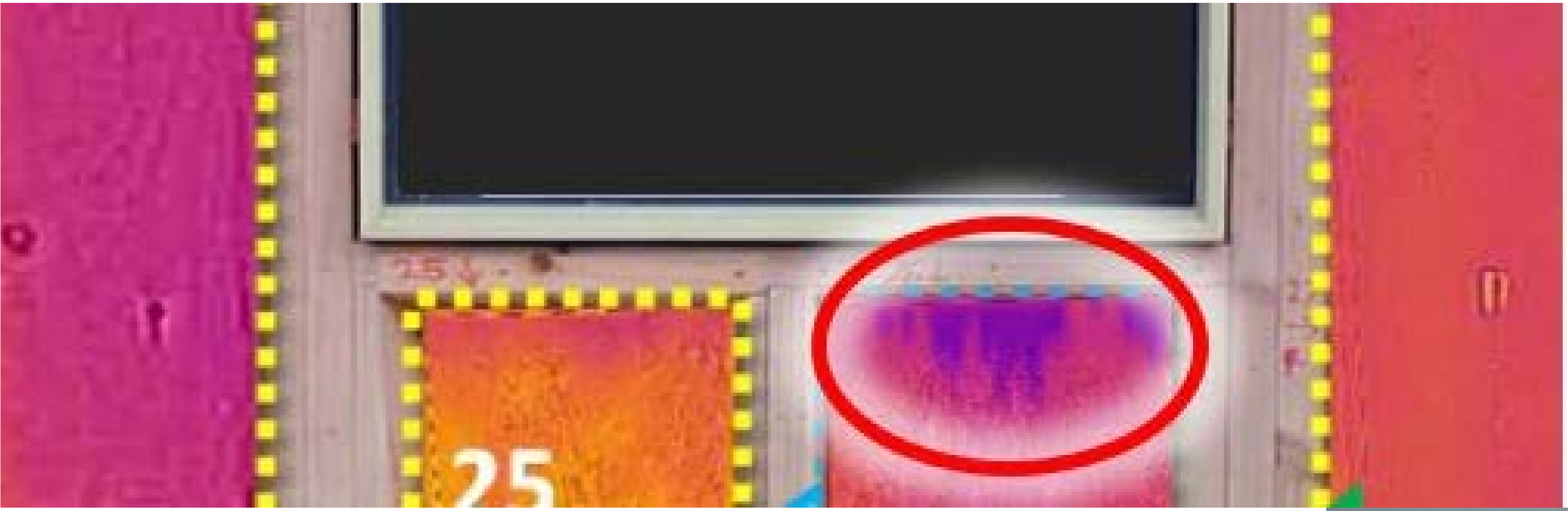

How to Calibrate Component Airtightness (Site to Lab)
0 Pa
-85 Pa
-100 Pa
15mm #1
31
32
15mm hole
-129.1

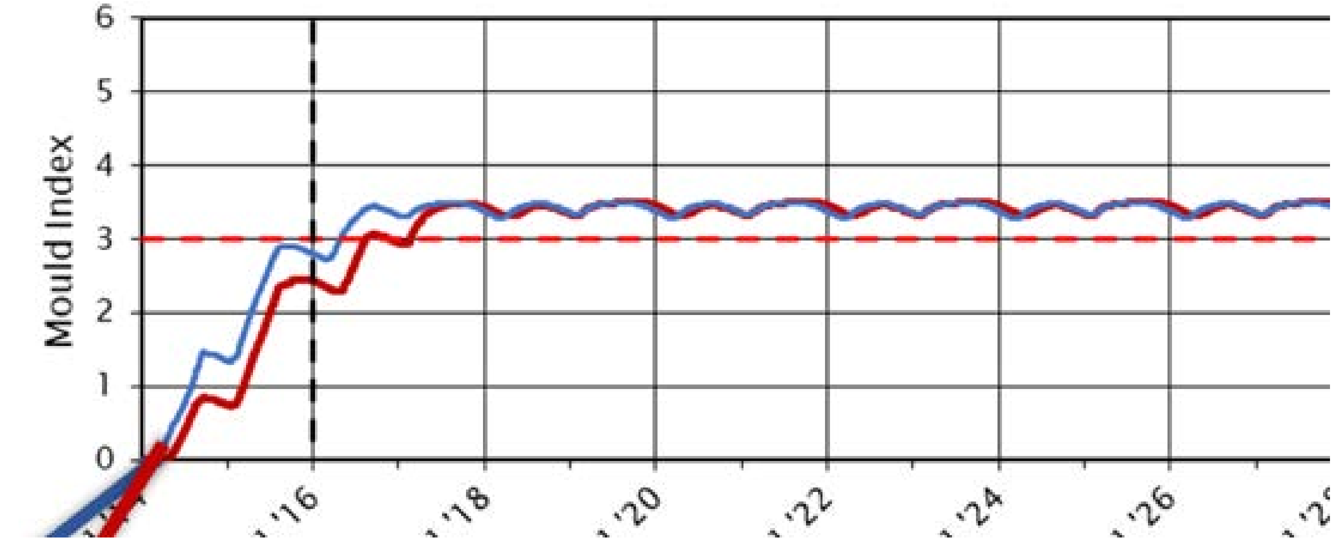

24
25
26
27
34
37
35
36
44
45
46
47
42
49
3M


3M
24
25
26
27
34
37
35
36
44
45
46
47
42
15mm
49
40

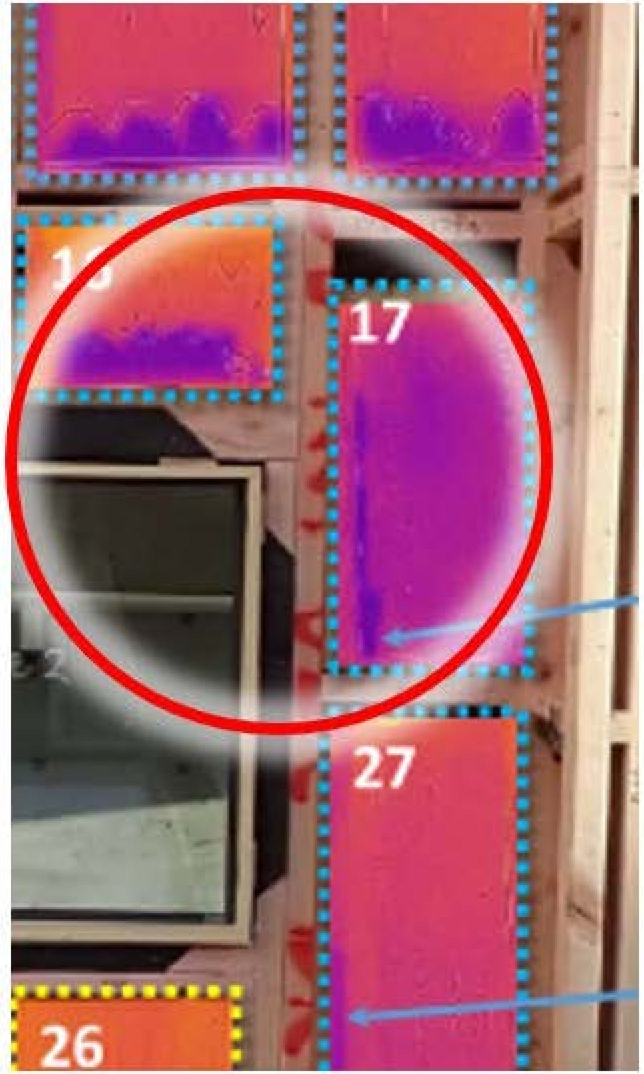
Defendants Report -Thermographic scan after water testing Sample 2

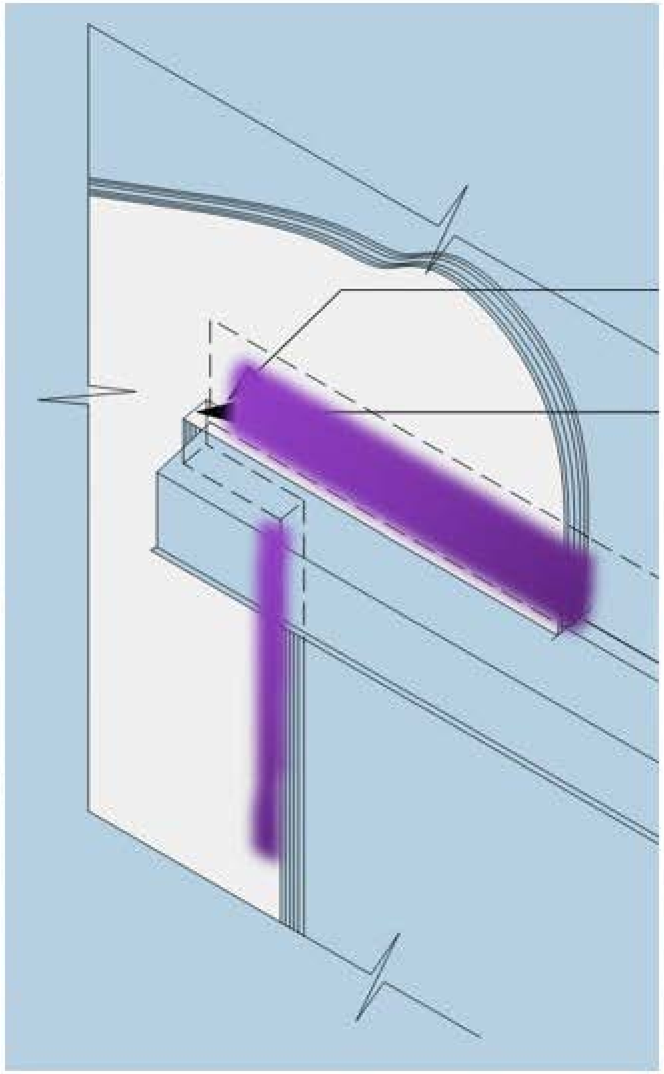
Rebuttal – Thermography Analysis





Rebuttal - Thermography Analysis





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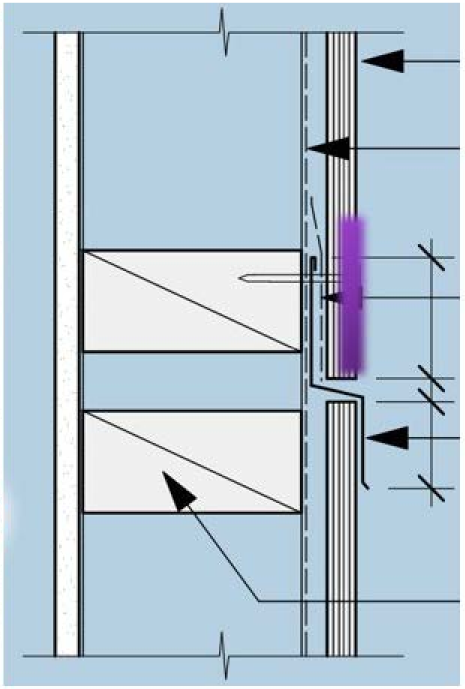

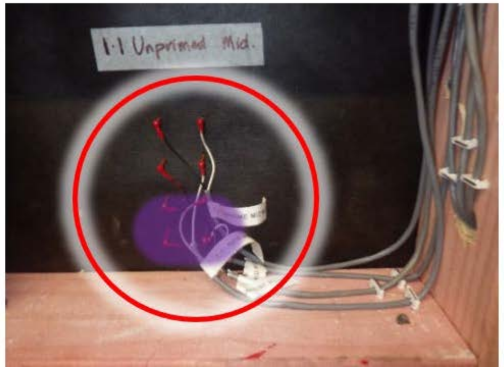

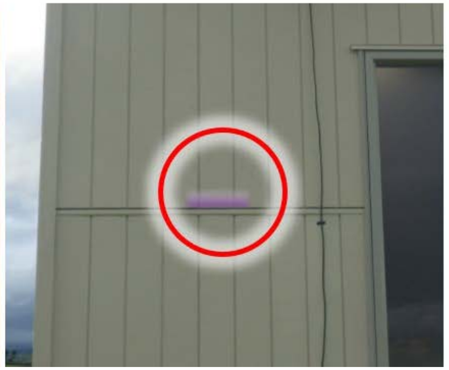

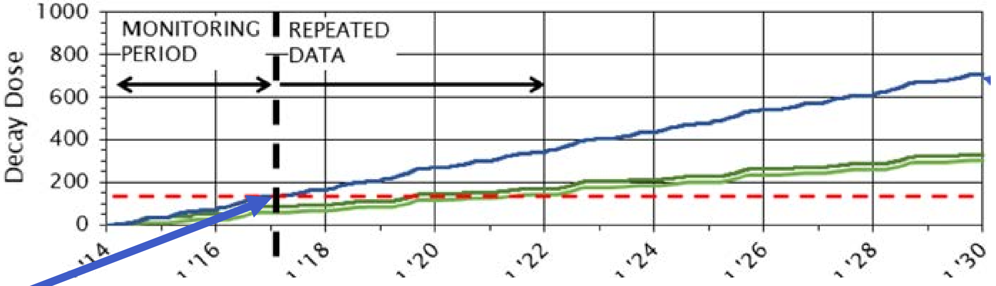

Defendants Expert Testing (Pass?)
RDH Test Hut Monitoring Results
RDH 2D WUFI Simulation (3 months)
RDH Field Investigation

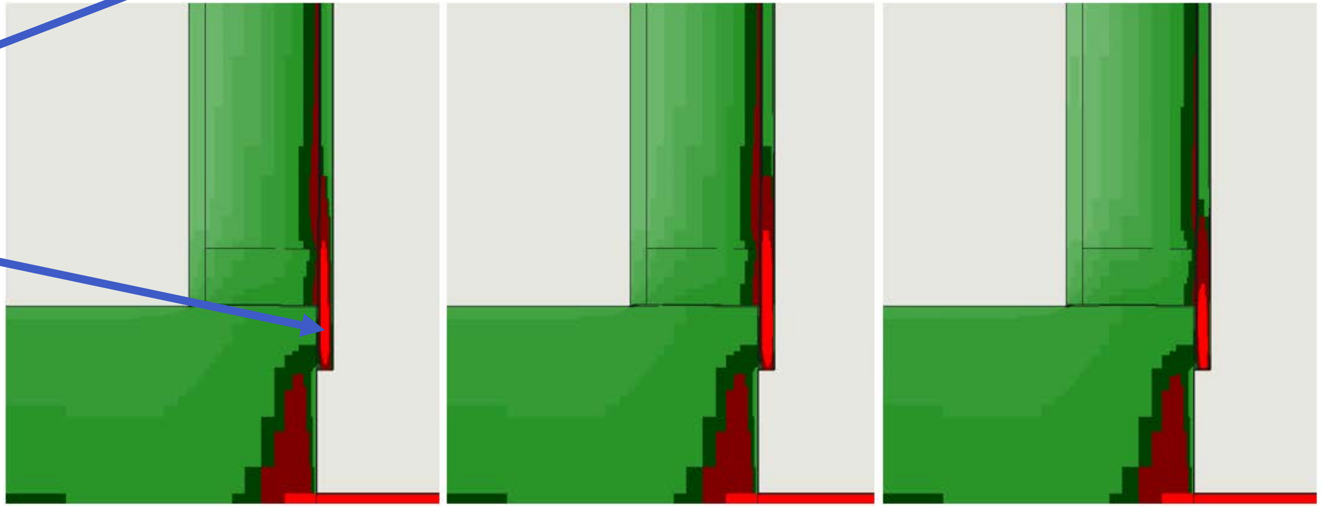

Figure 3.29 Test Hut Sheet "W" Unpainted face/edge (left), unpainted edge (centre) and painted edge (right) predicted RH distribution after the first 3-months of modelling from April to July.

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Bonus: No Non-Disclosure Agreement

LAW

2

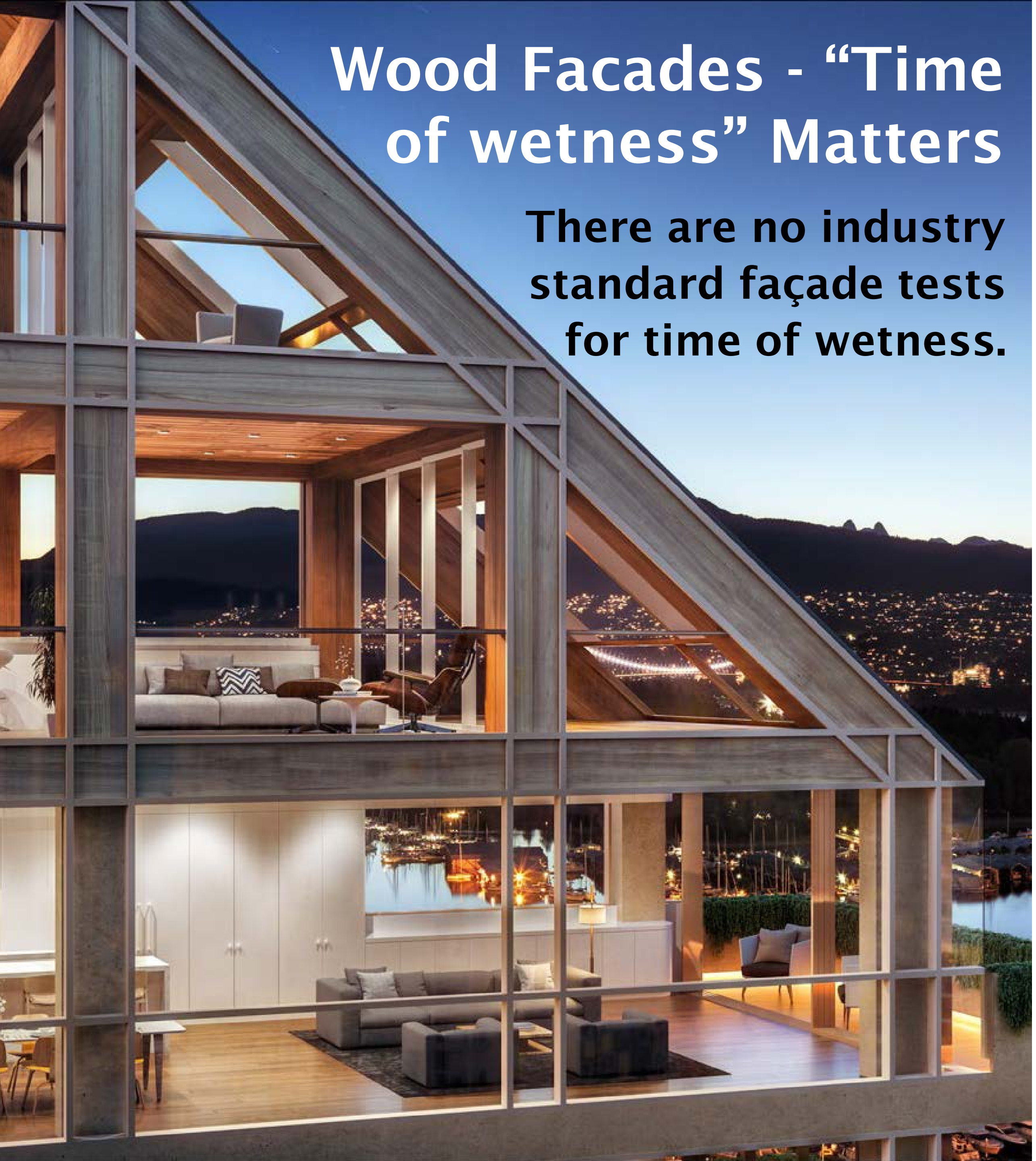
Carter Holt Harvey settles billion dollar leaky schools case

The terms of the settlement with the Ministry of Education are unknown.


moray
SUPERCAB
RDH

Wood Facades - “Time of wetness” Matters

There are no industry standard façade tests for time of wetness.



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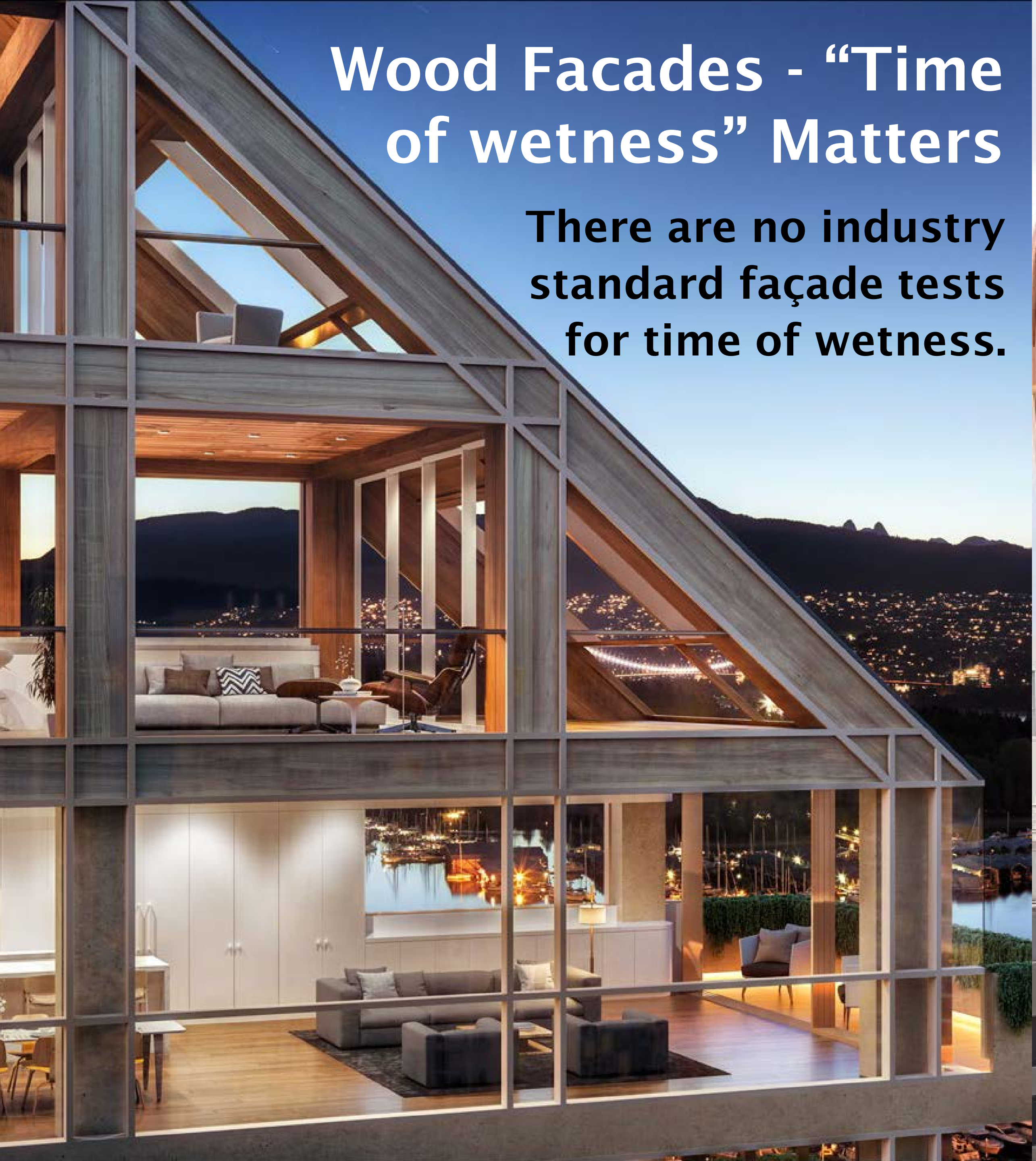

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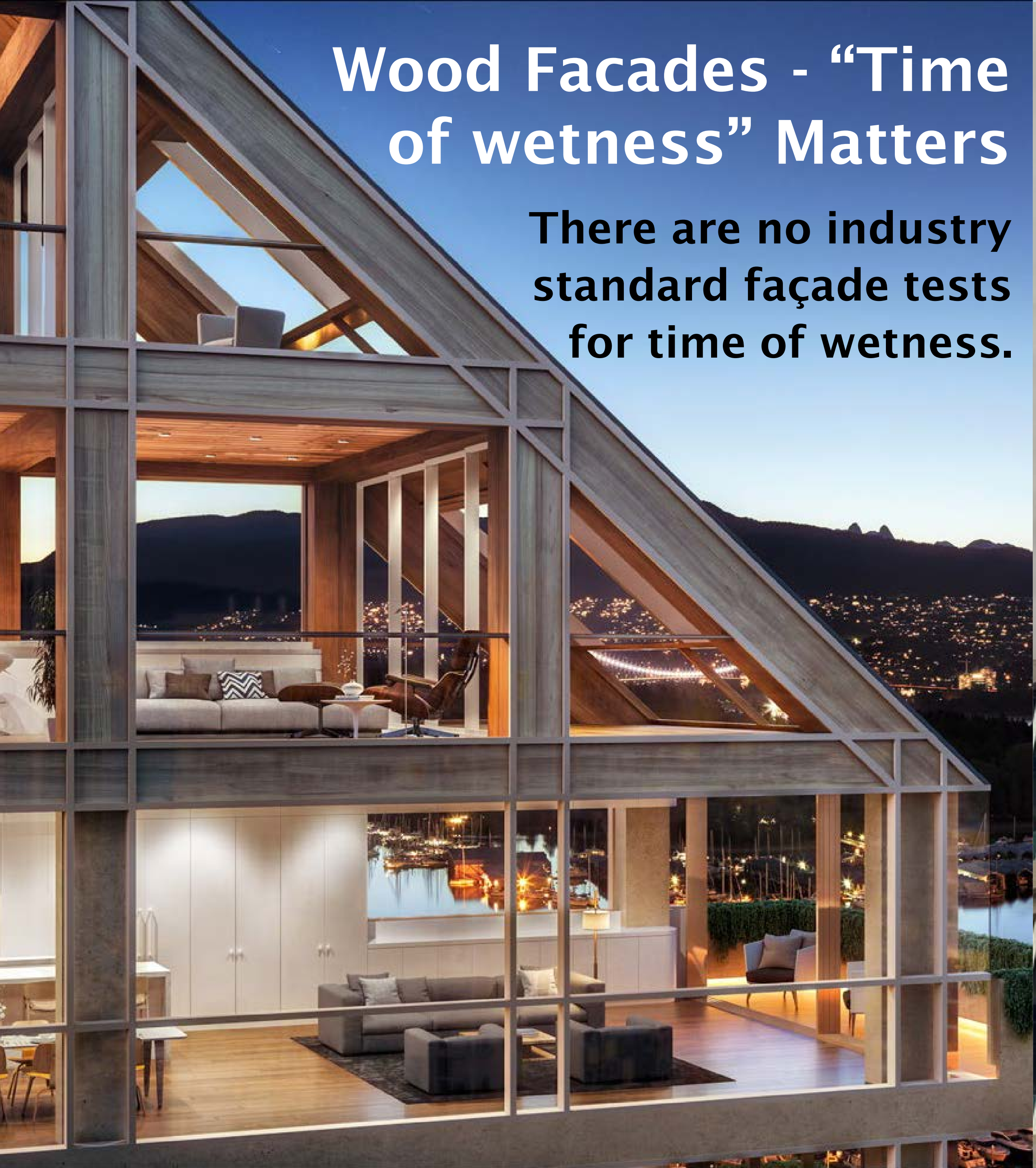


Accoya

Accoya = Acetylated Radiata Pine

RDH Wood Cladding Weathering Study Observations

INTERNAL USE

FEBRUARY 5TH , 2024 UPDATE

Graham Finch, Dipl.T., M.A.Sc., P.Eng.
Principal, Senior Building Science Specialist

Marc Imrich, B.A.Sc., EIT
Building Science Engineer (EIT)

Time of Wetting – Good vs Bad

Good – Warm, dry and protected by the building enclosure ☺

Bad – exposed to weathering ☹

Discussion + Questions

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Learn more at
rdh.com

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