IMPORTANT NOTICE

HITEX DIAMOND CAVITY PLASTER CLADDING SYSTEM

Hitex Diamond cavity plaster system (often called by its generic name EIFS) was manufactured between 2003 and 2010 by Hitex Building Systems Limited in response to the 'leaky building' crisis.

Hitex Diamond achieved a number of aims. The diamond cavity provided the first 2 'D's, Drainage and Drying, the undersill trays and detailing achieved better weathertightness the 3rd 'D' called Deflection and builders were requested to use decay resistant framing the 4th 'D' Durability.

During 2003-2005 cavity battens became included in Acceptable Solutions as one way of providing Drainage and Drying. Other detailing introduced better weathertightness and Standards clarified where fungicide treated framing should be used.

This notice is to provide a 'balanced' view. Some people have been obtaining building reports from inspectors and experts unfamiliar with the attributes of plaster claddings like Hitex Diamond Cavity System.

Statement: Hitex had no power over the treatment of the timber framing, or the quality of the many weathertightness detailing like roofs, gutters, soffits, windows, penetrations, garage door openings and finished ground lines. Likewise Hitex has no control over other systems that may also cause leaks like showers, wet areas, decks, plumbing and water pipes. Some buildings had more than one cladding. Hitex has no control over maintenance or alterations that may have been done since the cladding was installed.

Recommendation: It is our strongest recommendation that at a minimum owners, prospective purchasers, building inspectors and experts undertake what is termed 'invasive tests' before making comments on whether the building is 'leaking' or not. Invasive tests are the minimum inspection recommended because it provides the important 'Evidence' in making decisions:

- Whether the framing is adequately treated with an approved fungicide which excludes H1 and UTKD: Despite code changes we still found UTKD as late as 2010
- Are the weathertightness details working properly as if not framing could already be decayed and cause scan and Thermal misses
- Get moisture content readings in winter when rainfall is at peak to determine whether ALL the claddings, roof, gutters, windows and cladding(s) are functioning correctly.
- Has maintenance already been done and if so was the framing checked as it may already be decayed, but now dry because leaks have been fixed?

You cannot assume just because you have had someone inspect the building, or use a scanner or Thermal camera, even if they attest the inspections to have been done to NZS 4306:2005 that you are protected. This is a visual Standard although S4.2 does provide for special purpose reports including weathertightness reports but for some reason inspectors and experts do not invoke this requirement meaning the inspection falls well short of the Standard and protection you expect.

Invasive testing can be done in a way it does not damage the claddings.
Go to www. moisturedetection.co.nz

Microclimate Analysis of In-Situ Hitex Diamond Cavity Wall Constructions (2004/6) Part III

LEAK EVENT

Date: 22 July 2004

1. SUMMARY

This report outlines the microclimate and bottom plate moisture content (MC) analysis of a building wall fitted with Hitex Diamond Cavity cladding during a simulated leak event onto a south-facing wall. Temperature, relative humidity (RH) and timber moisture content (MC) measurements were taken and analysed. The key outcomes were:

- HEALTHY CONDITIONS BEFORE LEAK – Conditions and phenomena observed inside the wall before the leak were very similar to the typical conditions analysed previously in Part II – Typical Conditions. During this time the microclimate was not conducive to mould growth.
- LARGE, IMMEDIATE CHANGE AFTER LEAK OCCURRED - Immediately after the leak occurred, there was significant change in the microclimate inside the wall space. During this time, the recorded level of moisture in the wall air and timber rose. The microclimate was immediately affected as the RH rose from 50% to 80% in 40 mins.
- DRYING OCCURRED – After the leak event, the wall ventilation dried as the moisture levels inside the wall dropped towards its original levels over a 5-day period.
- HEALTHY CONDITIONS AFTER LEAK – Once the moisture in the wall returned to its original level, the conditions and phenomena observed inside the wall were very similar to the original conditions indicating the wall had fully recovered.

2. SUMMARY OF EXPERIMENTAL PROCEDURE

The leak event involved introducing 4L of water onto the bottom plate of the south wall and monitoring. Full details of the procedure followed in this experiment are given in Part I - Procedure. The wall setup, location of hygrothermal probes and MC measurements are summarised in Figure 1 below. The theory used in analysis is based on Holyoake and Holyoake, 2004. Readings were taken from the 28 March to 13 April 2004. through a hole in the gib, resealing the wall and monitoring the air temperature, humidity and timber moisture content (MC).

3. RESULTS

Results for the leak event is broken into 3 specific periods: (1) Typical conditions prior to the leak event (2) Leak event and drying after the rain event (4) Typical conditions after drying.

For the periods, the air temperature and Relative Humidity (RH) measurements are given in *Figure 2* and Figure 3 respectively. The differential between temperature and outside temperature is given in Figure 4. The corresponding vapour pressures (VP) are given in Figure 5. The differentials between VP and outside VP are given in Figure 6. Figure 7 shows the associated dew point temperatures. The differentials between the Dew Point Temperatures to the Outside Temperature are given in Figure 8. The psychrometric wall signatures for the wall during each period are shown in Figure 9. The timber moisture content readings are given in Table 1, and are graphed in Figure 11 and Figure 12.

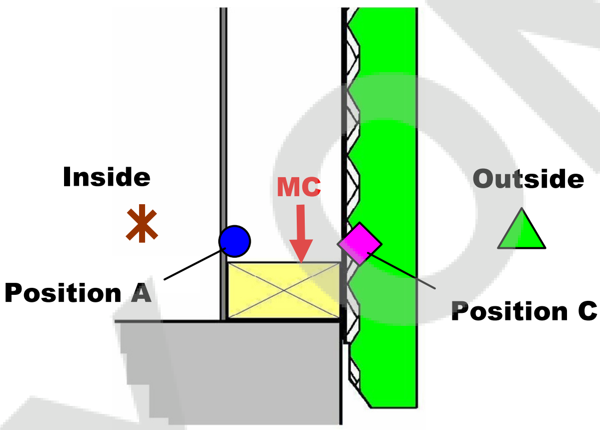


Figure 1 Location of the four hygrothermal probes measuring temperature and Relative Humidity (RH). The location from which MC measurement is taken from is also shown.

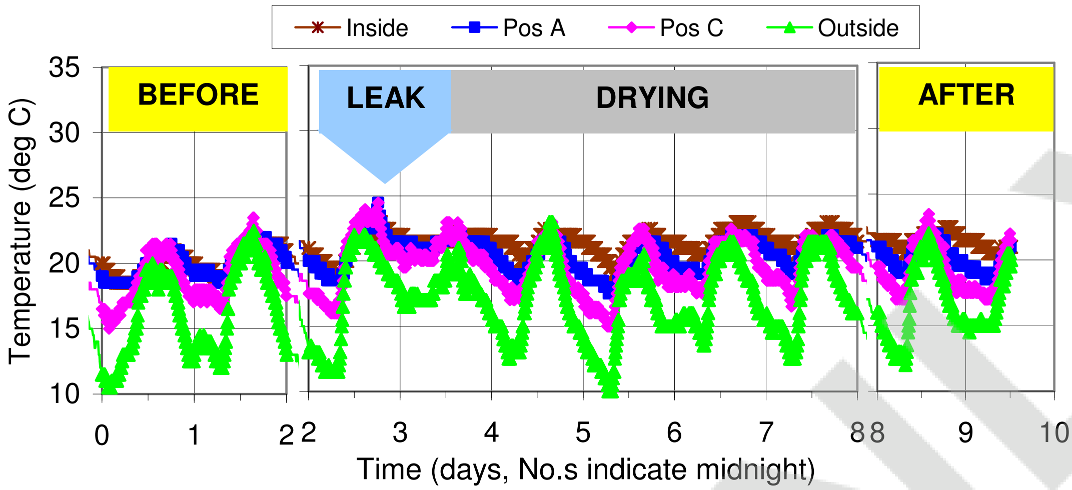


Figure 2 Temperature readings before, during and after rain event

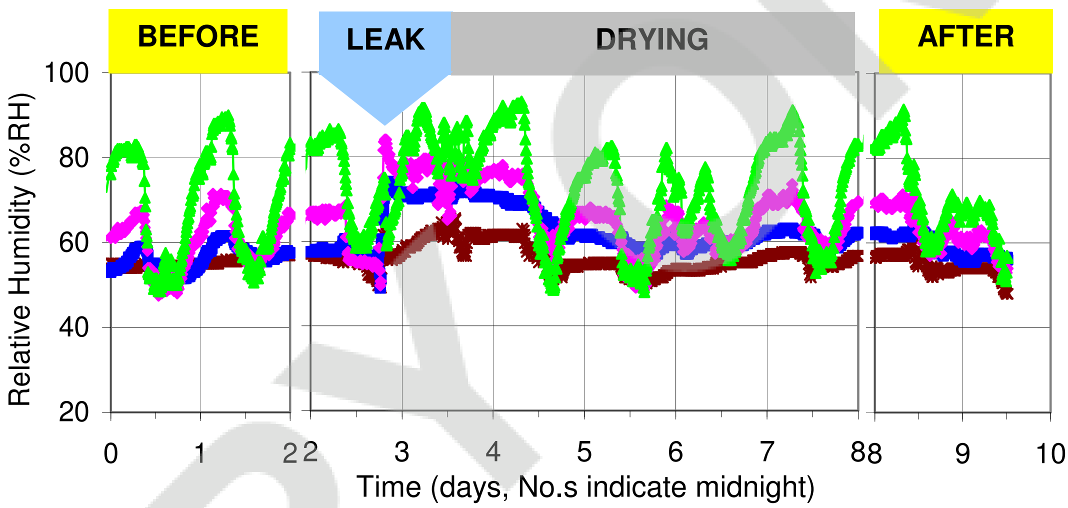


Figure 3 Relative Humidity readings before, during and after rain event

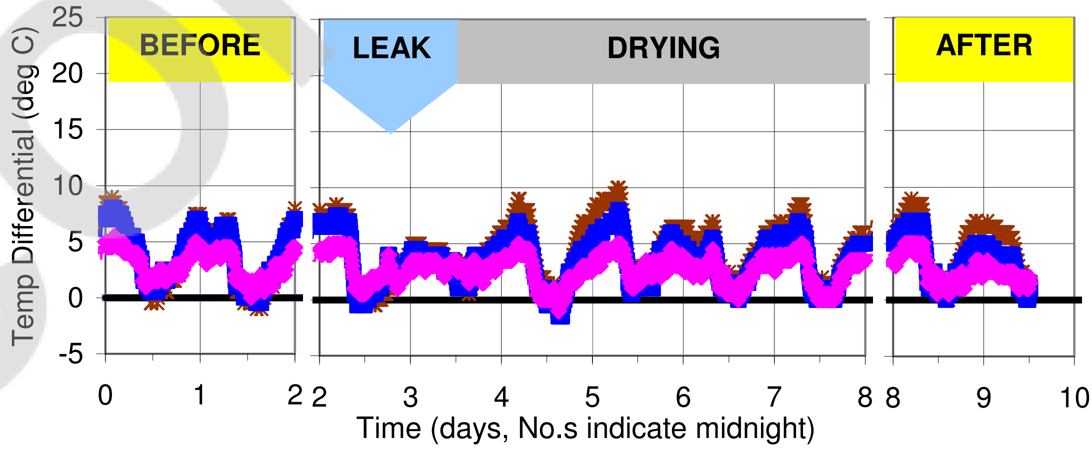


Figure 4 Differential between probe temperature readings and Outside Air Temperature readings

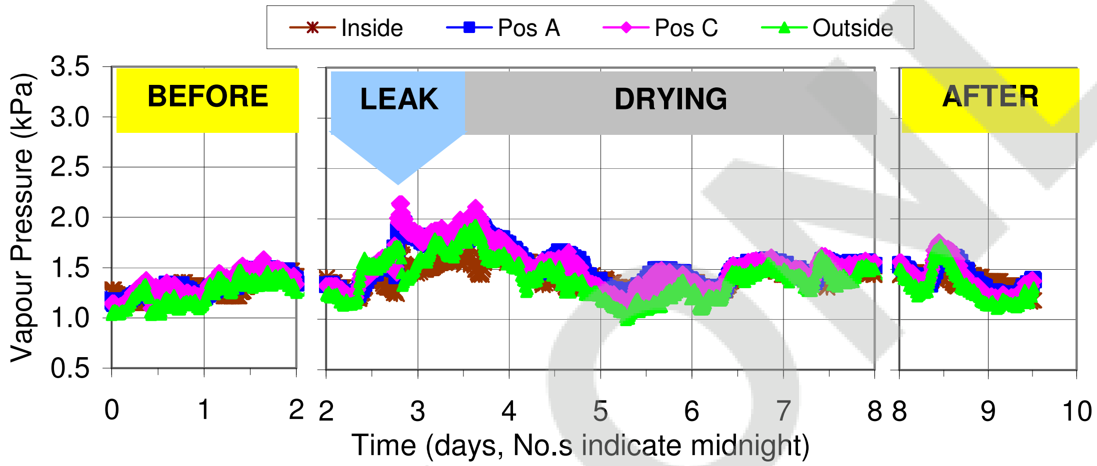


Figure 5 Vapour Pressure values

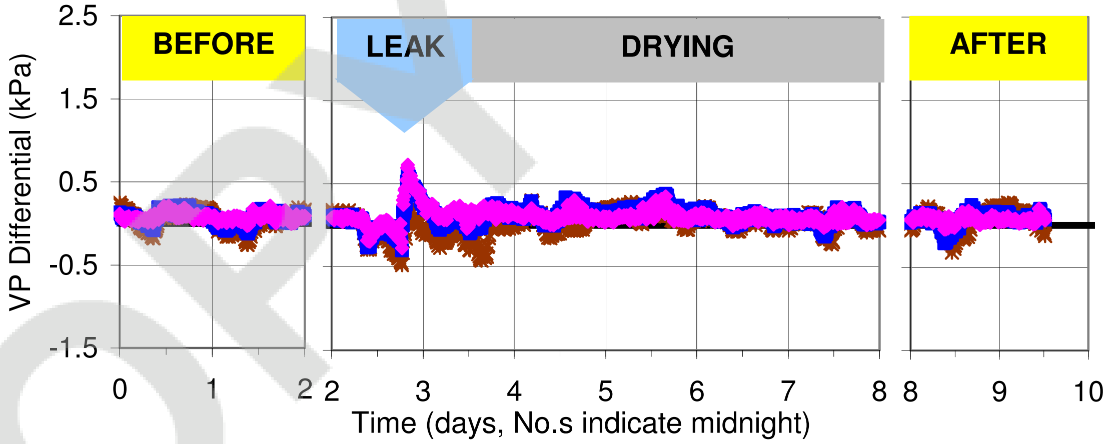


Figure 6 VP Differential between probe VP values and outside air VP

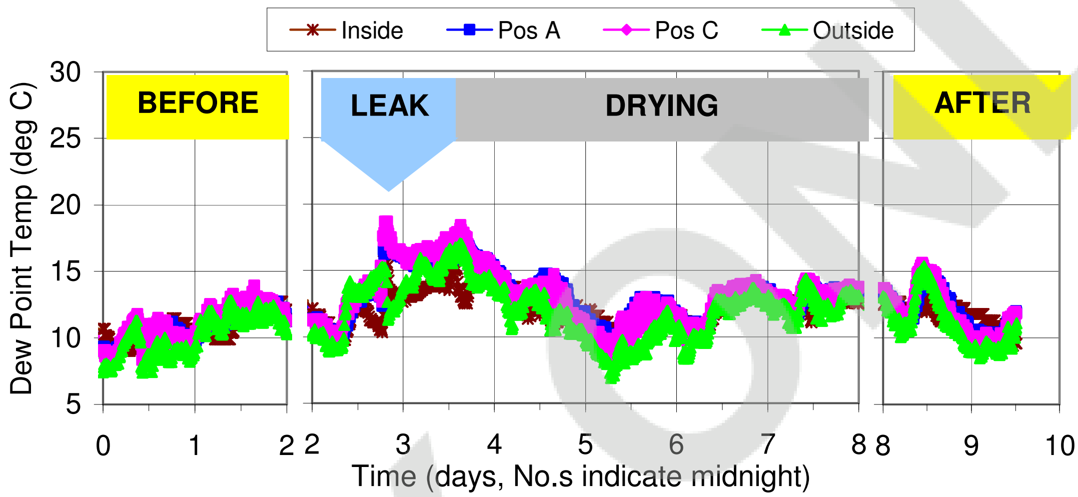


Figure 7 Dew Point Temperature points

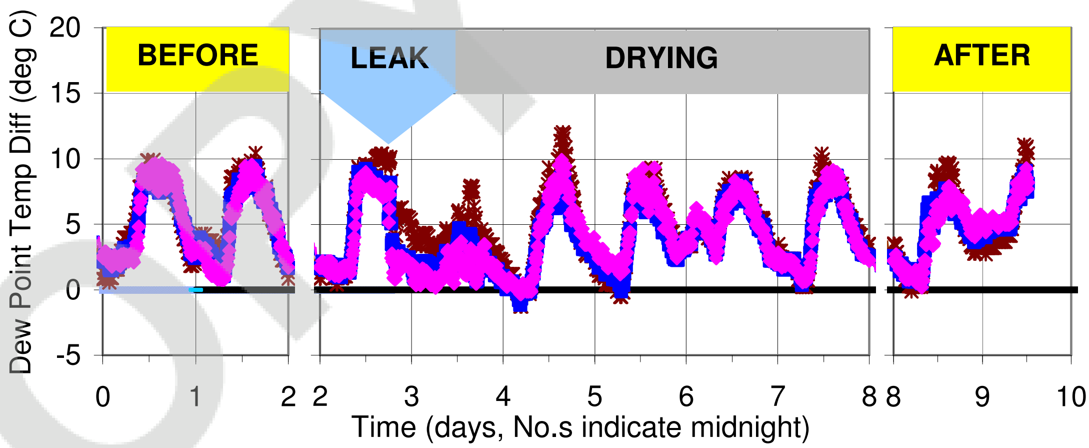


Figure 8 Differential between Dew Point Temperature and Outside Temperature readings

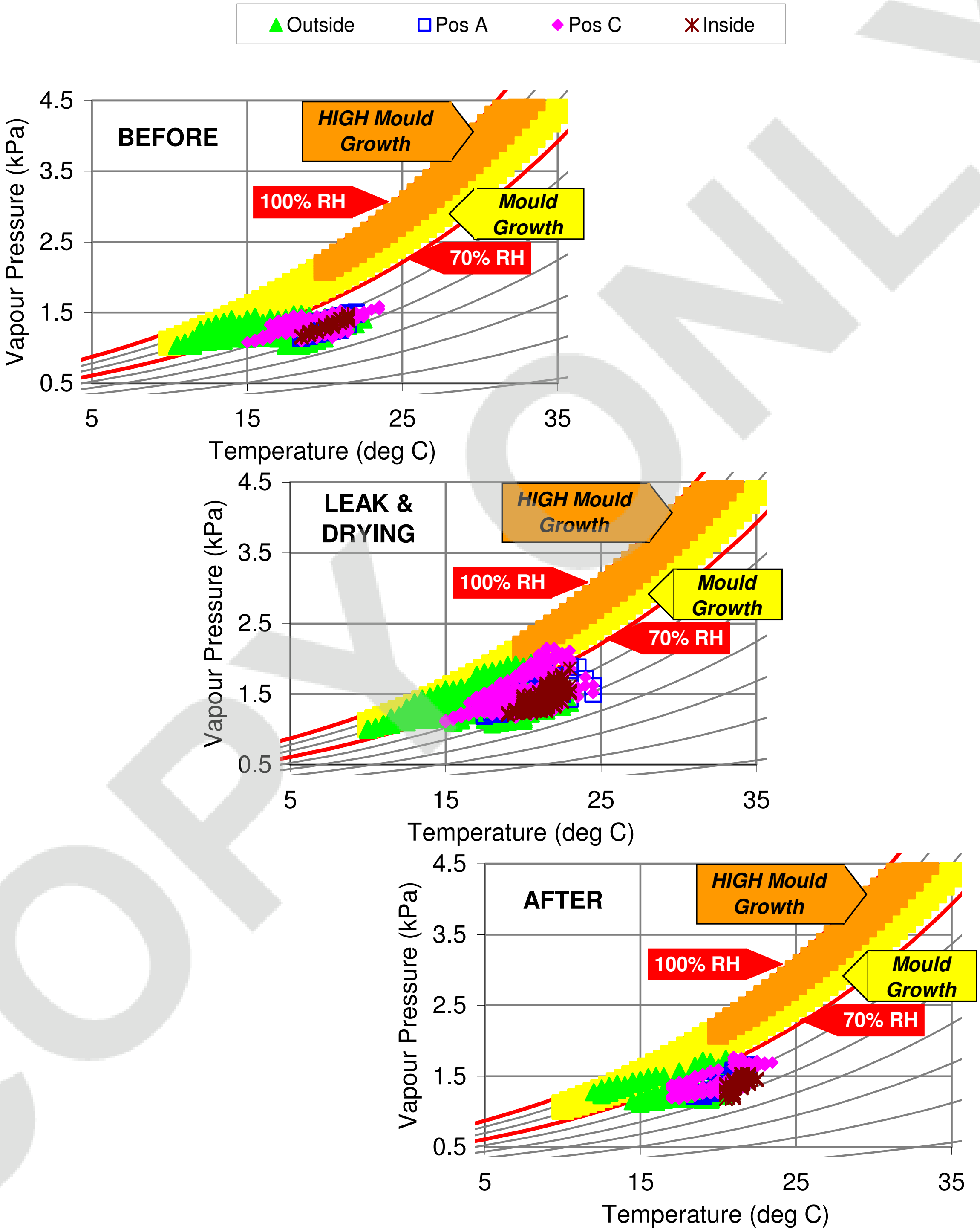


Figure 9 Psychrometric Wall Signatures for the 3 stages during the leak event

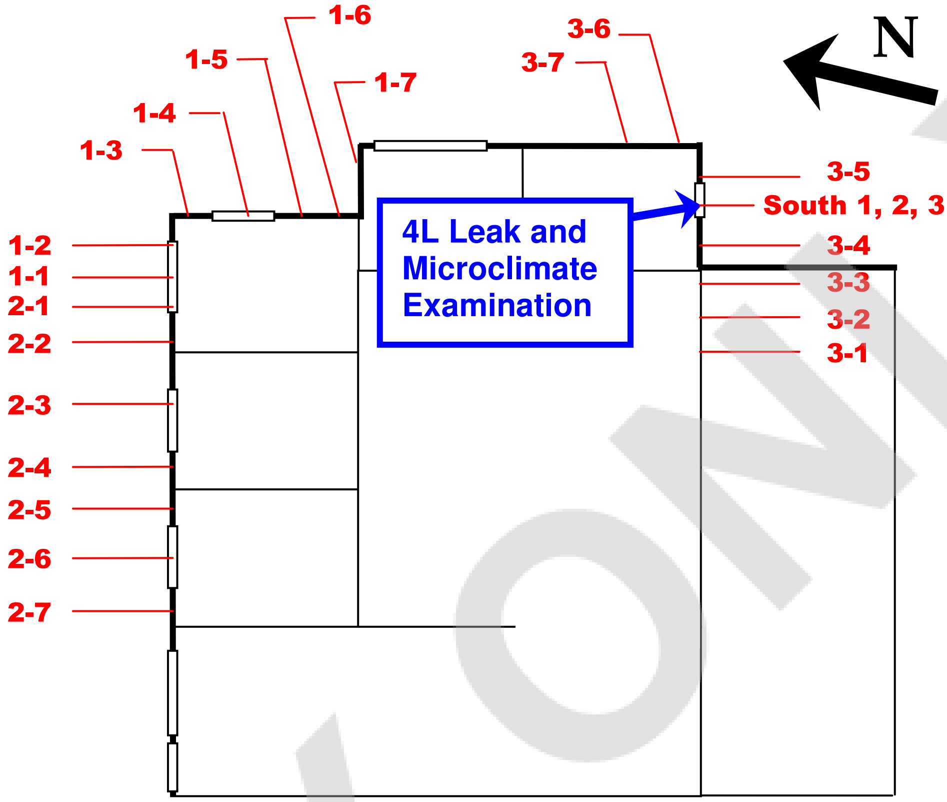


Figure 10 Location of Moisture Detection Unit (MDU) probes installed in the Hitex factory offices located on bottom plate.

Table 1 Bottom Plate Timber MC% readings taken

Date	16 March 04	17 March 04	21 March	23 March 04
Day	Day 2	Day 3	Day 5	Day 7
Period	BEFORE	LEAK	DRYING	AFTER
Pin	MC%	MC%	MC%	MC%
3-1	16.1	16.2	16.0	15.9
3-2	15.2	16.2	15.6	15.2
3-3	16.5	18.0	17.1	16.6
3-4	16.8	17.9	17.4	16.9
South 1	16.1	34.3	20.1	18.8
South 2	16.5	31.5	21	19.8
South 3	16.2	34.2	20.4	18.8
3-5	11.7	14.3	13.7	13.2
3-6	14.7	15.8	15.3	15.0
3-7	15.8	16.0	16.0	15.9

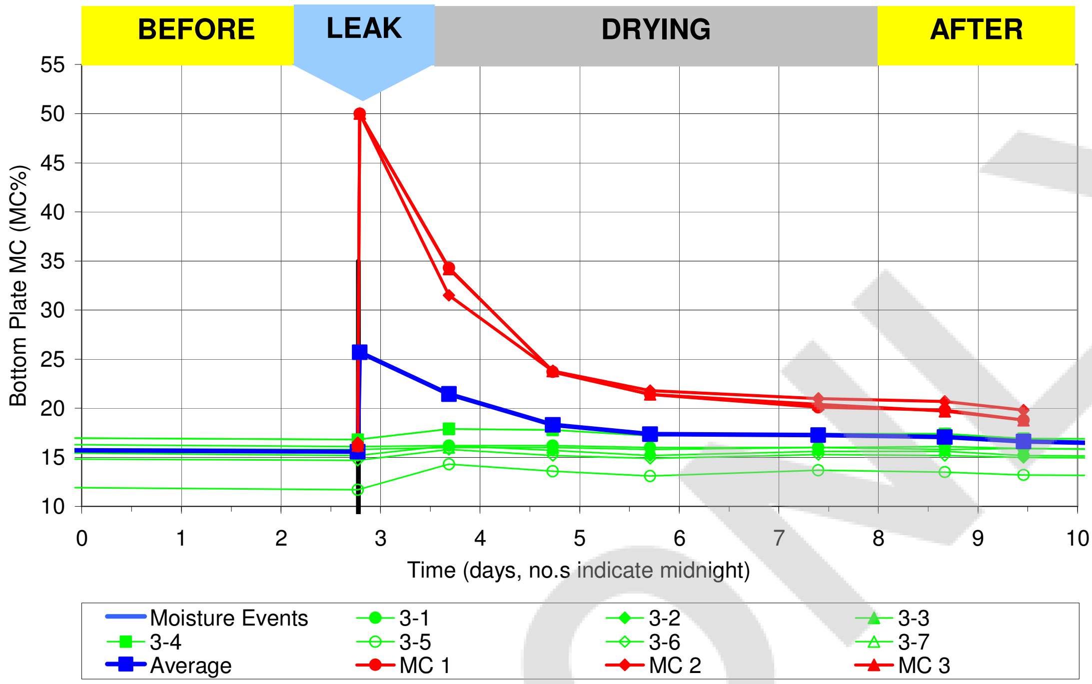


Figure 11 Bottom Plate timber MC readings over time

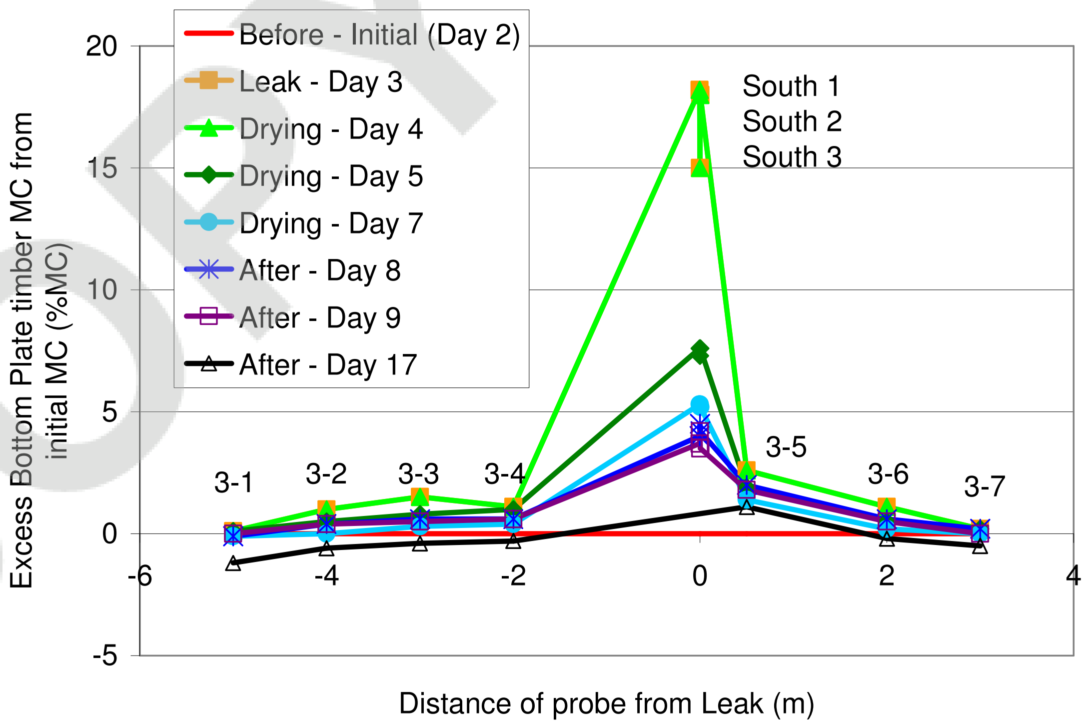


Figure 12 Bottom Plate MC distribution over time

4. DISCUSSION

General observations of the above figures:

(a) Conditions and phenomena observed inside the wall before the leak are very similar to the typical conditions analysed previously in Part II – Typical Conditions.

(b) Immediately after the leak occurred, there was significant change in the microclimate inside the wall space. During this time, the recorded level of moisture in the wall air and timber rose.

(c) After the leak event, the wall dried as the moisture levels inside the wall returned to its original levels over a 5-day period. During the drying period, the RH in the wall reduced to below 70% within 3 days. The vapour pressure in the wall reduced over time to original levels of 1-1.5kPa. There was risk of condensation during the first two days, but none after that. The timber MC readings returned to near original conditions.

(d) Once the moisture in the wall returned to its original level, the conditions and phenomena observed inside the wall were very similar to the original conditions indicating the wall had fully recovered.

5. REFERENCES

Holyoake, K. M. & Holyoake, B. D., "*In-Situ Building Wall Microclimate Investigation*", Proceedings of Joint SCENZ/FEANZ/SMNZI Conference, Waikato University, 2004, pp112-117, ISBN 0-476-00748-8

Microclimate Analysis of In-Situ Hitex Diamond Cavity Wall Construction (2004/6) Part IV

RAIN EVENT

Date: 22 July 2004

1. SUMMARY

This report outlines the microclimate and bottom plate moisture content (MC) analysis of a building wall fitted with Hitex Diamond Cavity cladding during a simulated rain event for the north wall. Temperature, relative humidity (RH) and timber moisture content (MC) measurements were taken and analysed. The key outcomes were:

- HEALTHY CONDITIONS BEFORE RAIN – Conditions and phenomena observed inside the wall before the rain event were very similar to the typical conditions analysed previously in Part II – Typical Conditions. During this time the microclimate was healthy and not conducive to mould growth.
- AIR-BORNE MOISTURE INGRESS DURING RAIN EVENT - During the rain event, there was significant change in the microclimate inside the wall space. During this time, the recorded level of moisture in the wall air and timber rose. The microclimate was affected as the RH rose from 50% to 80% in 12 hours.
- DRYING AFTER RAIN – After the rain event, the wall ventilation dried as the moisture levels inside the wall returned to its original levels over a 5-day period.
- HEALTHY CONDITIONS AFTER RAIN – Once the moisture in the wall returned to its original level, the conditions and phenomena observed inside the wall were very similar to the original conditions indicating the wall had fully recovered.

2. SUMMARY OF PROCEDURE

The rain event occurred from the 28 March to 13 April 2004. The rain event involved spraying 35000L of water onto the cladding surface and monitoring the air temperature, humidity and timber moisture content (MC) during the period. The wall setup, location of hygrothermal probes and MC measurements are summarised in Figure 1 below. Full details of the experimental procedure followed are in Part I - Procedure. The theory used in analysis is based on *"In-Situ Building Wall Microclimate Investigation"* by Holyoake and Holyoake, 2004.

3. RESULTS

For the four periods, the air temperature and Relative Humidity (RH) measurements are given in Figure 2 and Figure 3 respectively. The differential between temperature and outside temperature is given in Figure 4. The corresponding vapour pressures (VP) are given in Figure 5. The differentials between VP and outside VP are given in Figure 6. Figure 7 shows the associated dew point temperatures. The differentials between the Dew Point Temperatures to the Outside Temperature are given in Figure 8. The psychrometric wall signatures for the wall at each stage are given in Figure 9. The timber moisture content readings are given in Table 1 and their locations are given in Figure 10.

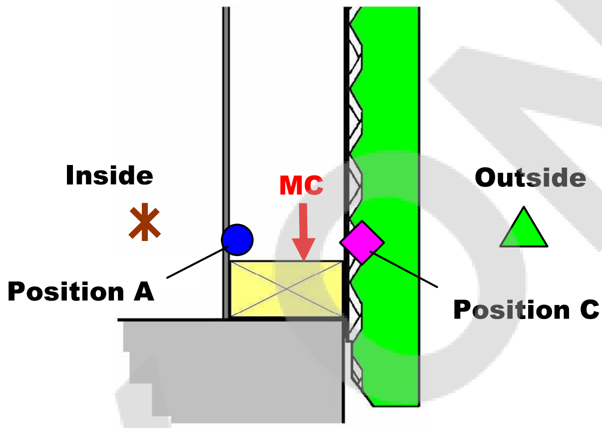


Figure 1 Location of the four hygrothermal probes measuring temperature and Relative Humidity (RH). The location from which MC measurement is taken from is also shown.

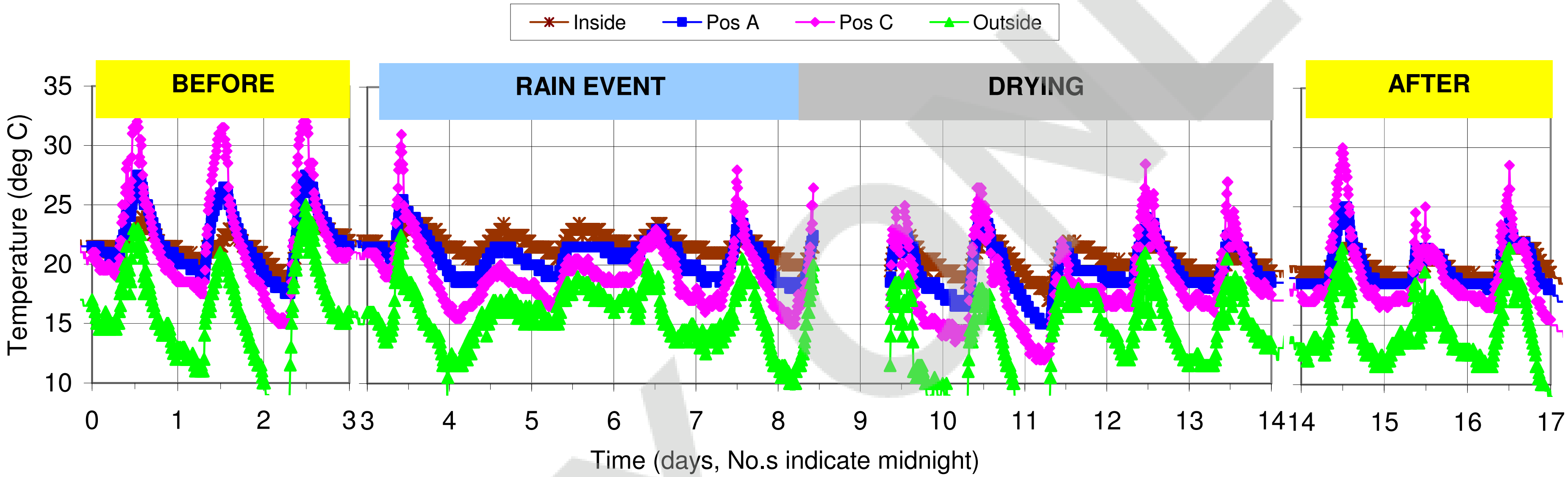


Figure 2 Temperature readings before, during and after rain event

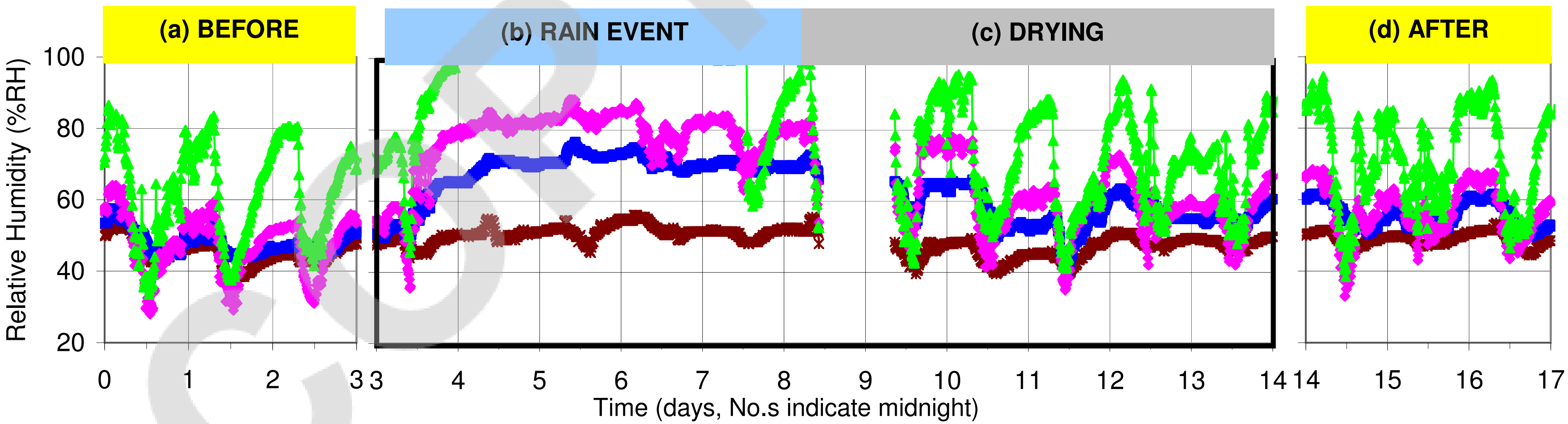


Figure 3 Relative Humidity readings before, during and after rain event

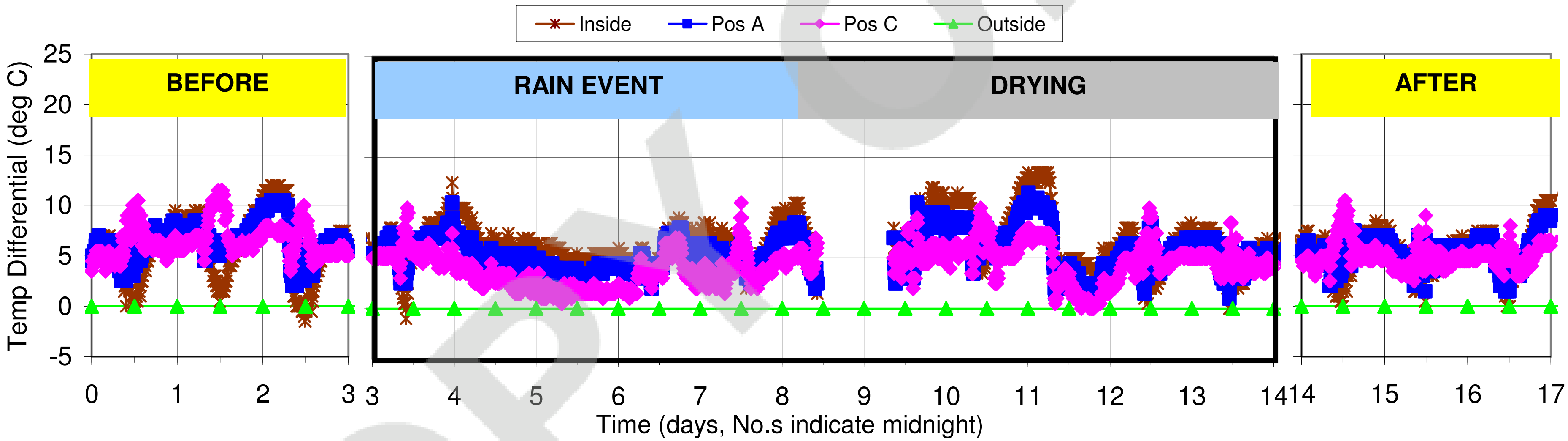


Figure 4 Differential between probe temperature readings and Outside Air Temperature readings

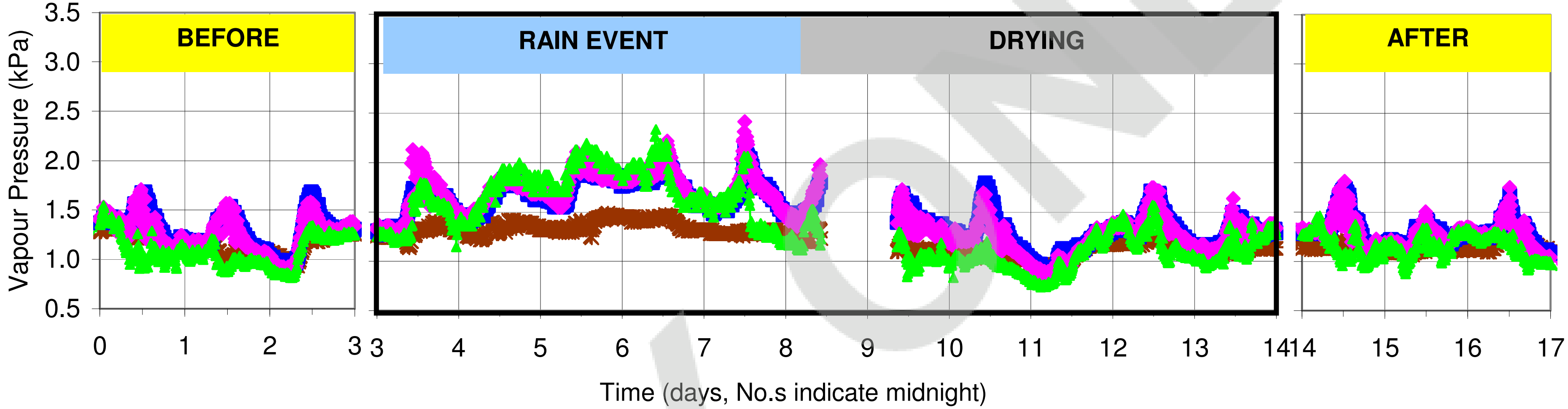


Figure 5 Vapour Pressure values

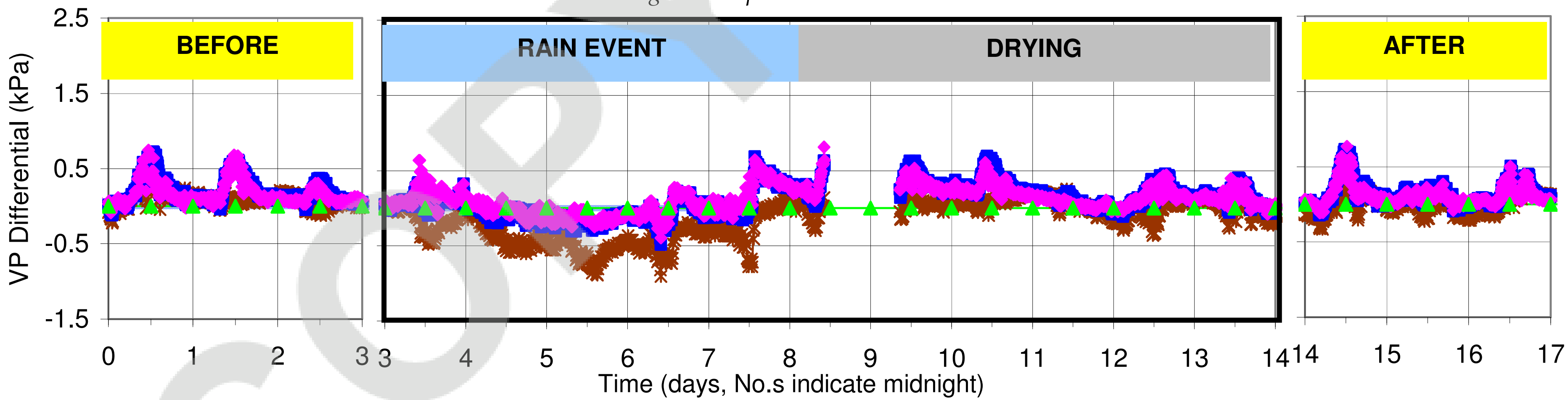


Figure 6 VP Differential between probe VP values and outside air VP

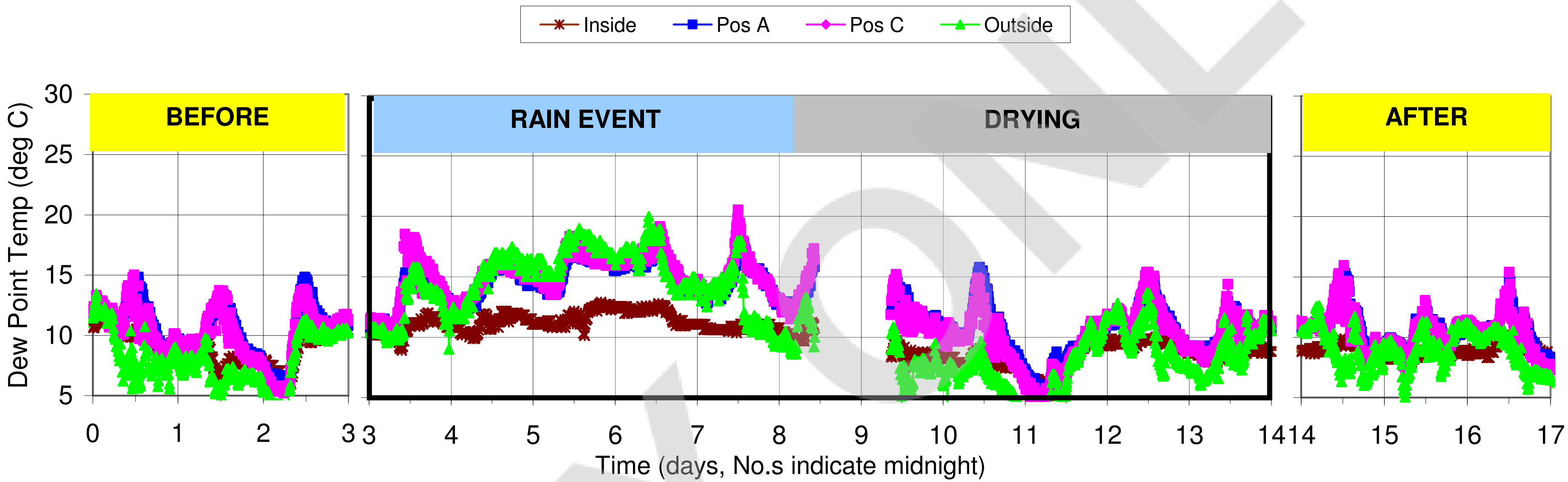


Figure 7 Dew Point Temperature points

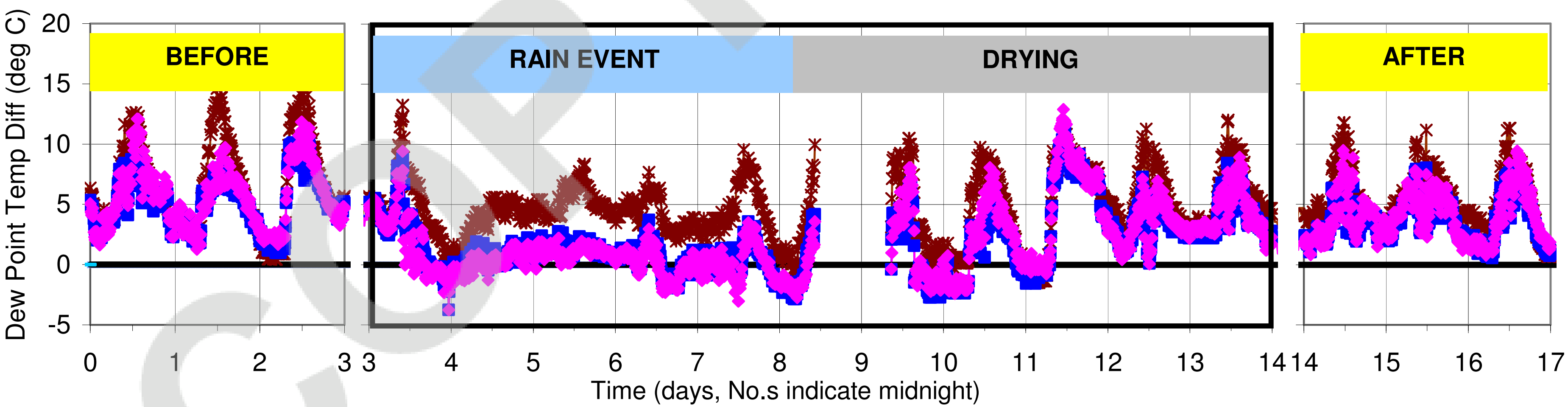


Figure 8 Differential between Dew Point Temperature and Outside Temperature readings

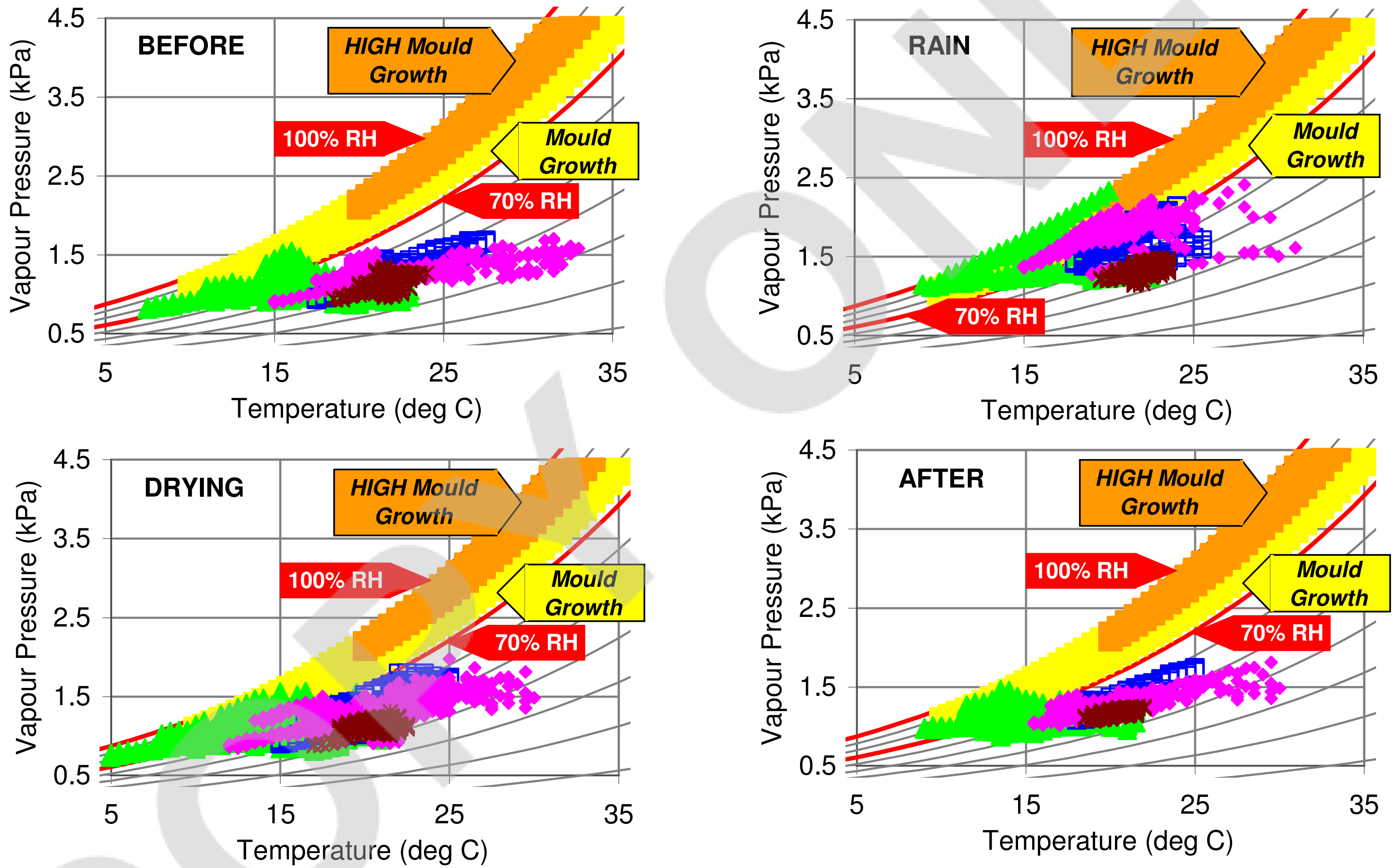


Figure 9 Psychrometric Wall Signatures for the 4 stages during the rain event

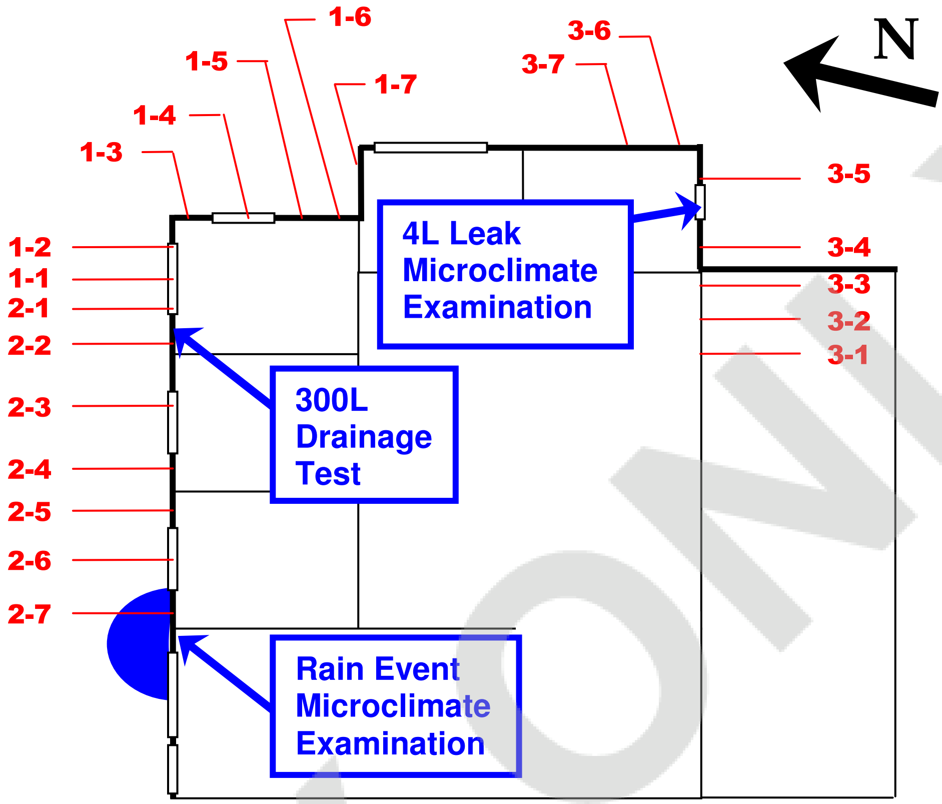


Figure 10 Location of Moisture Detection Unit (MDU) probes installed in the Hitex factory offices located on bottom plate.

Table 1 Bottom Plate Timber MC% readings taken

Date *Day*	*31 March 04* *Day 3*	*3 April 04* *Day 6*	*5 April 04* *Day 8*	*6 April* *Day 9*	*13 April 04* *Day 16*
Period	*BEFORE*	*RAIN*	*End of RAIN*	*DRYING*	*AFTER*
Pin	*MC%*	*MC%*	*MC%*	*MC%*	*MC%*
1-1	13.9	15.1	-	-	-
1-2	14.3	15.3	-	-	-
1-3	16.3	16.5	-	-	-
1-4	15.0	15.3	-	-	-
1-5	14.0	14.5	-	-	-
1-6	15.6	16.0	-	-	-
1-7	16.6	17.1	-	-	-
2-1	12.6	14.1	13.5	13.2	12.5
2-2	15.5	16.3	15.0	13.5	14.9
2-3	14.7	15.7	14.6	14.0	14.4
2-4	15.8	16.7	16.2	15.6	15.8
2-5	16.4	18.5	18.4	17.1	16.8
2-6	14.7	21.4	21.2	19.2	16.5
2-7	15.3	20.9	20.3	18.5	16.6

4. DISCUSSION

This document should be read in conjunction with Part II – Typical Conditions, which discusses the phenomena present in walls during typical conditions. The below discussions will focus on the changes that occur due to the rain event.

Temperature – during the rain event, the wall temperature fluctuations reduced in magnitude significantly. All monitored temperatures shifted closer together. During the drying event the temperature maximums were reduced. This could be due to excess energy required for evaporation.

Relative Humidity – During the rain event, the RH experienced a large increase in the wall and outside. The RH in the wall increased to between 70-90% during the rain. This increase in RH made the timber exposed to this environment start to absorb more moisture. When drying, the RH levels in the wall shifted back to original conditions between 40-70% within 4 days. This shift caused the timber to release the water it absorbed during the high RH period.

Vapour Pressure – The vapour pressure in the wall and outside increased over a period of 3-4 days during the rain, moving from 1.0-1.5kPa to a maximum of almost 2.5kPa. The increase in the outside vapour pressure is due to the rain. The vapour pressure in the wall increased because of the ventilation connection between the wall and outside air. Air in the wall interchanges with air from outside and so the wall vapour pressure followed the outside vapour pressure.
During the drying event the outside vapour pressure was lower than the wall VP. This allowed the wall to dry out. The wall VP was kept high from water evaporating from the wetted timber

Dew Point Temperature – The Dew Point Temperature in the wall and outside rose significantly during the rain period. This is due to the increase in VP in those locations. This increased the chances of condensation during the rain, which is shown by the negative values in Figure 8.

Psychrometric Wall Signatures – The wall before the rain did not support mould growth. The rain event increased the VP and RH which caused the microclimate in the wall to support mould growth, and in some cases high mould growth. After drying the microclimate returned to the original values and therefore 5 days after the rain event stopped, the wall microclimate did not support mould growth.

Bottom Plate Timber MC – Before the test, all MC readings of the bottom plate was below 18%. The MC of the wall rose during the rain, and lowered during the drying, showing the drying was effective. After the drying, the MC readings returned to pre-experiment values.

5. REFERENCES

Holyoake, K. M. & Holyoake, B. D., "*In-Situ Building Wall Microclimate Investigation*", Proceedings of Joint SCENZ/FEANZ/SMNZI Conference, Waikato University, 2004, pp112-117, ISBN 0-476-00748-8

RESEARCH

Case Study – Drainage Test

of Cavity Construction Methods

Summary

Two cavity walls were constructed: one using HITEX Diamond with its integral cavity and the other a fibre-cement cladding with a 20-mm battened cavity. Four litres of water was dripped behind the claddings into the cavities over a 34 minute period to simulate a leak. Water that drained from the walls was collected and measured.

Results:

- HITEX Diamond Cavity system provided total drainage of all water (except a couple of drops) inserted into the wall.
- The fibre cement cavity system absorbed 700mL of the 4000mL water inserted (17.5% absorption).
- In the fibre cement system, the 700mL of water was absorbed into the rear of the fibre cement sheets and the timber battens.

Method

The aim of the test was to determine the efficiency of the drainage planes from two cavity construction systems in shedding introduced water (ie do they drain – and how well). The drainage test was performed on request by Phil Saunders on behalf of the Waikato Building Consents Group. Concern has been voiced that the proposed changes to the Building Regulations includd prescriptive cavities but no verification method to determine performance or a benchmark of acceptability.


Test Walls: (left) fibre cement with 20mm battened cavity system and (right) Hitex Diamond with integral cavity.

Wall Setups

The two wall systems tested were:

- HITEX Diamond Cavity system
- Fibre cement system on Harditex with a 20mm battened cavity.

The battened cavity system was chosen as the control and built as best as it could from the descriptions contained in E2/AS1 of the BIA discussion documents published in 2003. Both walls were timber-framed with Carters Thermocraft Cover-Up building paper. Both walls were not plastered so water could be detected on the exterior and the panels could be easily removed.

Dyed Water Drip Fed into Cavity

The drainage test simulated a leak by introducing 4L of blue-dyed water into the top of the two walls between building paper and cladding. A drip tray was inserted into the wall cavities (shown in photos with panels removed in re-enactment) to introduce water uniformly. 4x1 Litre bottles were used to drip water, over 34mins at a near-constant rate (approx. 7 L/hr), into each wall. Water dripped from one bottle at a time. Bottles were constantly monitored to ensure water flow rate was identical in both walls.



Drained Water Collected

Any water drained from each wall was collected and drained by a tray (left) into a 5L jug (centre) during and after water was inserted until no more dripped out. The panels were then removed (right) for a visual inspection to see whether the drainage was complete.



Limitations

This test is assuming an ideal wall situation, with no rips or tears in the building paper. This test also takes no account of building paper diffusion. It is performed over a short period of time (34mins) so the amount of diffusion possible is greatly reduced.

RESULTS

The Hitex Diamond with integral cavity showed superior drainage with all 4 Litres of water drained from the wall (0% retained). The fibre cement cladding with 20mm battened cavity drained 3.3L of the total 4L, retaining 700mL (17.5% retained).

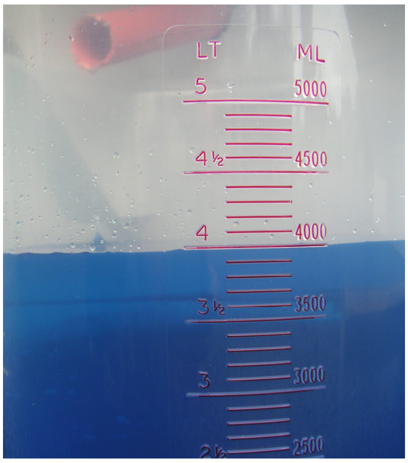
Fibre Cement 20mm Battened-cavity System

The fibre cement 20mm battened cavity system absorbed 700mL of the 4000mL water inserted. In the fibre cement system, 700mL of water was absorbed by the fibre cement sheets and 20mm timber battens. The photo below shows the internal face of the removed fibre cement panel.

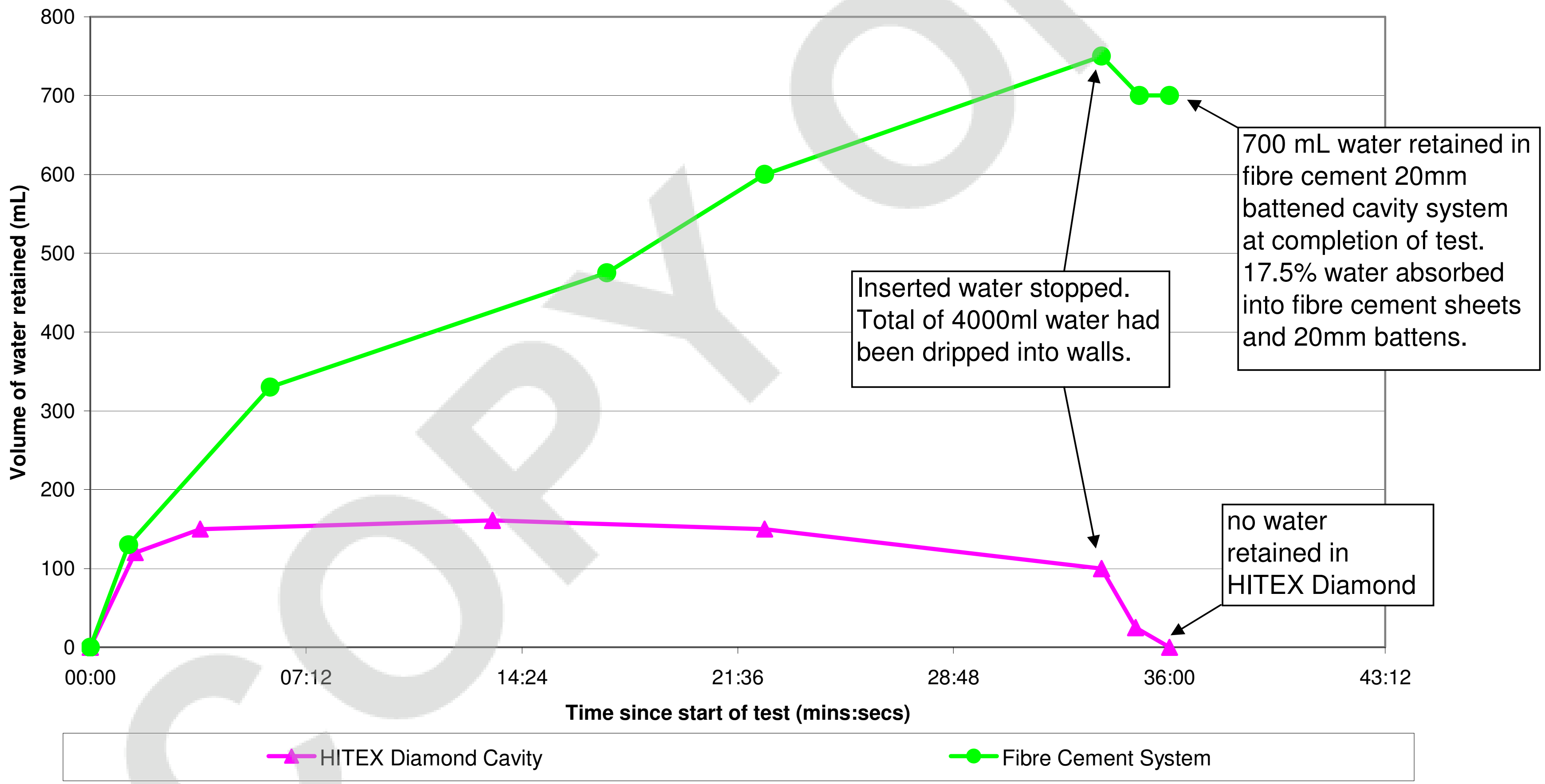
It was noted that water drains by gravity and makes contact with the building paper, cladding and battens. In the photos both the vertical and horizontal battens are damp. Water absorbed through the fibre cement panel onto the front bottom edge (bottom).

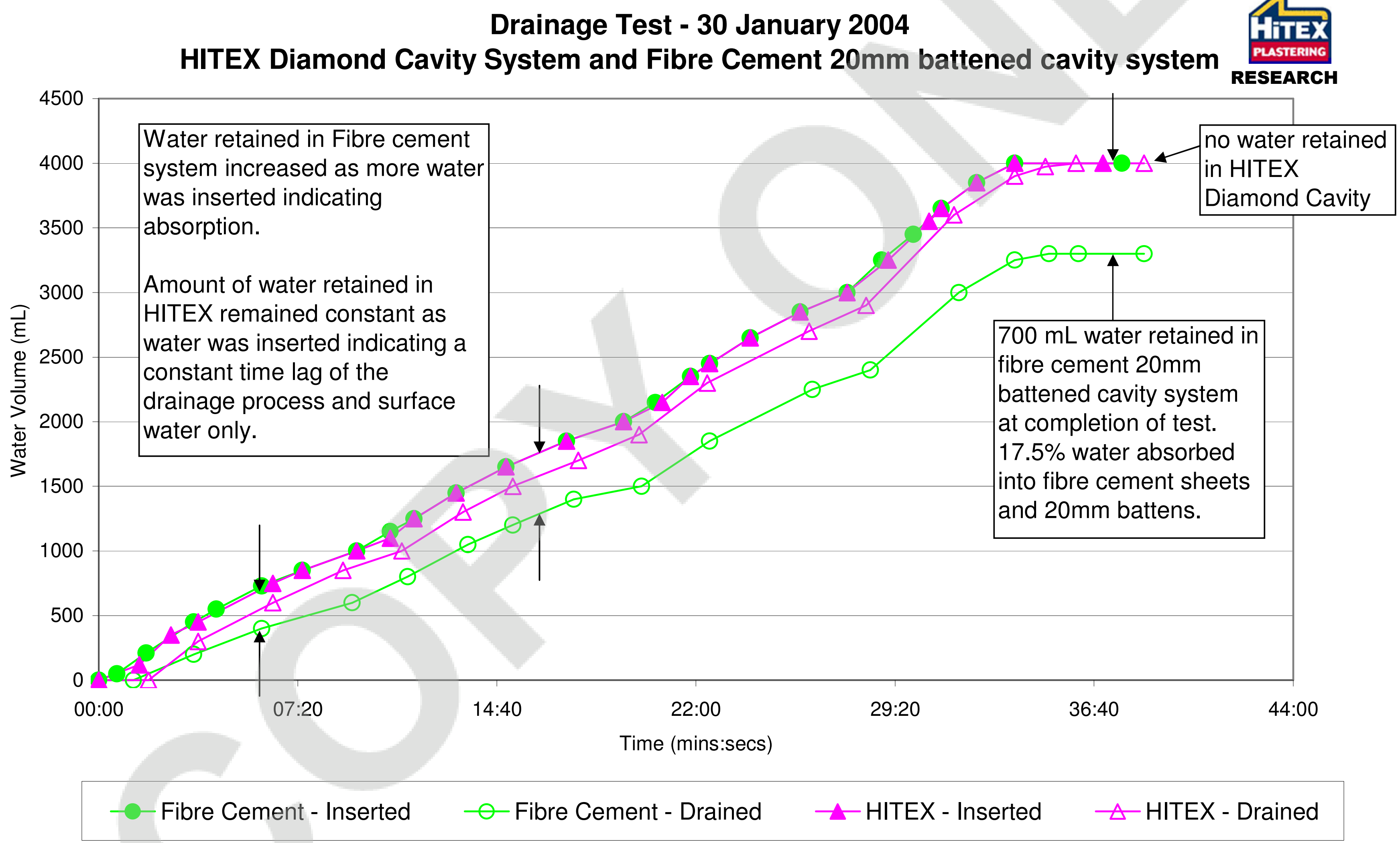
Hitex Diamond with Integral Cavity

The HITEX Diamond cladding with integral cavity provided total drainage (4L) of all water (except a couple of drops) inserted into the wall. No water absorbed into the Diamond Cavity polystyrene. The below photo (below left) shows several water droplets unable to drain due to surface tension in the water and were left suspended on the diamond grooves.



Drainage Test - 30 January 2004
HITEX Diamond Cavity System and Fibre Cement 20mm battened cavity system
Volume of water present in walls during and after drainage test





Drainage Test - 30 January 2004
HITEX Diamond Cavity System and Fibre Cement 20mm battened cavity system
Water retained in Fibre cement system increased as more water was inserted indicating absorption.
Amount of water retained in HITEX remained constant as water was inserted indicating a constant time lag of the drainage process and surface water only.
no water retained in HITEX Diamond Cavity
700 mL water retained in fibre cement 20mm battened cavity system at completion of test. 17.5% water absorbed into fibre cement sheets and 20mm battens.
Water Volume (mL)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
00:00
07:20
14:40
22:00
29:20
36:40
44:00
Time (mins:secs)
Fibre Cement - Inserted
Fibre Cement - Drained
HITEX - Inserted
HITEX - Drained

Hitex Diamond Cavity Performance Figures:

Drying Rate

Laboratory Results

The below laboratory experiments prove Hitex Diamond cladding allow drying to occur.

Source: An Investigation of Water Transport from Building Walls, University of Auckland, Bryan Holyoake 2003

P 19-20:

Experiment 5 the average moisture content of the timber dropped from 30% to 14% in 13 days. Experiment 9 experienced similar rates of drying when heated. Heating significantly increases the rate of drying. During times of no heating, experiment 11 showed much slower rates of MC loss than the other two experiments. Experiment 11 showed that heating (0.1-2.1 days) greatly increased the MC loss rate experienced by the timber.

Table 1 Summary of experiments performed on total system simulation chamber

Expt. #	Period	Cladding Material	Heating Regime	Air agitation
5	14 days	HITEX + FrameGuard	Constantly heated	No
6	7 days	FrameGuard	Constantly heated	No
7	15 days	HITEX	Constantly heated	No
9	8	HITEX + FrameGuard	days 0-0.4 unheated 0.4-7.4 heated 7.4-8.5 unheated	No
11	14	HITEX + FrameGuard	Days 0-0.1 unheated 0.1-2.1 heated 2.1-14 unheated	Days 0-11.1: No 11.1- 14: occasionally.
12	7	HITEX + FrameGuard	unheated	

Table 5 Mass drying rates of selected experiments as a function of wood MC

Mass Loss Rate (g/hr)

MC%	14-16	16-18	18-20	20-22	22-24	24-26	26-28	28-30	30-32	32-34	34-36	36-38	38-40	40-42
Timber														
FrameGuard II				0.54		0.98	0.83	1.83			3.44		3.96	7.22
Black Building Paper				0.44	0.32	0.76	0.73	1.20		1.90	3.68	6.62		
Cover-Up										0.15	0.26			
Thermofoil			0.17	0.41	0.75	0.79	1.47		2.60		4.61	6.10		
Bare Timber L21, L42			0.25	0.35	0.84	1.69	3.63	6.27						
Chamber														
Experiment 5	1.10	2.22		2.46		3.59								
Experiment 6	2.48		4.29	6.02					8.78					
Experiment 7	1.28	1.56	1.68	3.26	2.13			3.88						
Experiment 9					0.10	0.66	1.02							
Experiment 11							0.34	2.55	4.63					

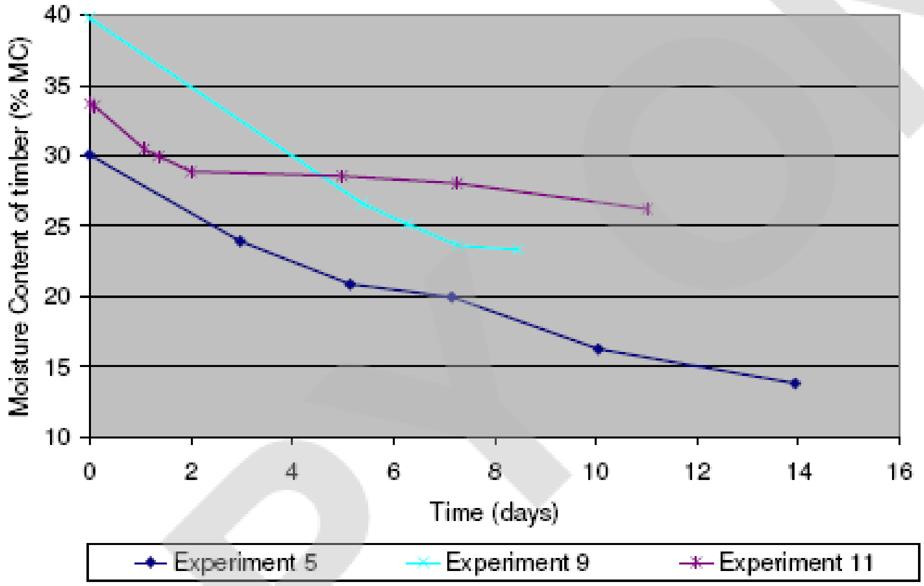


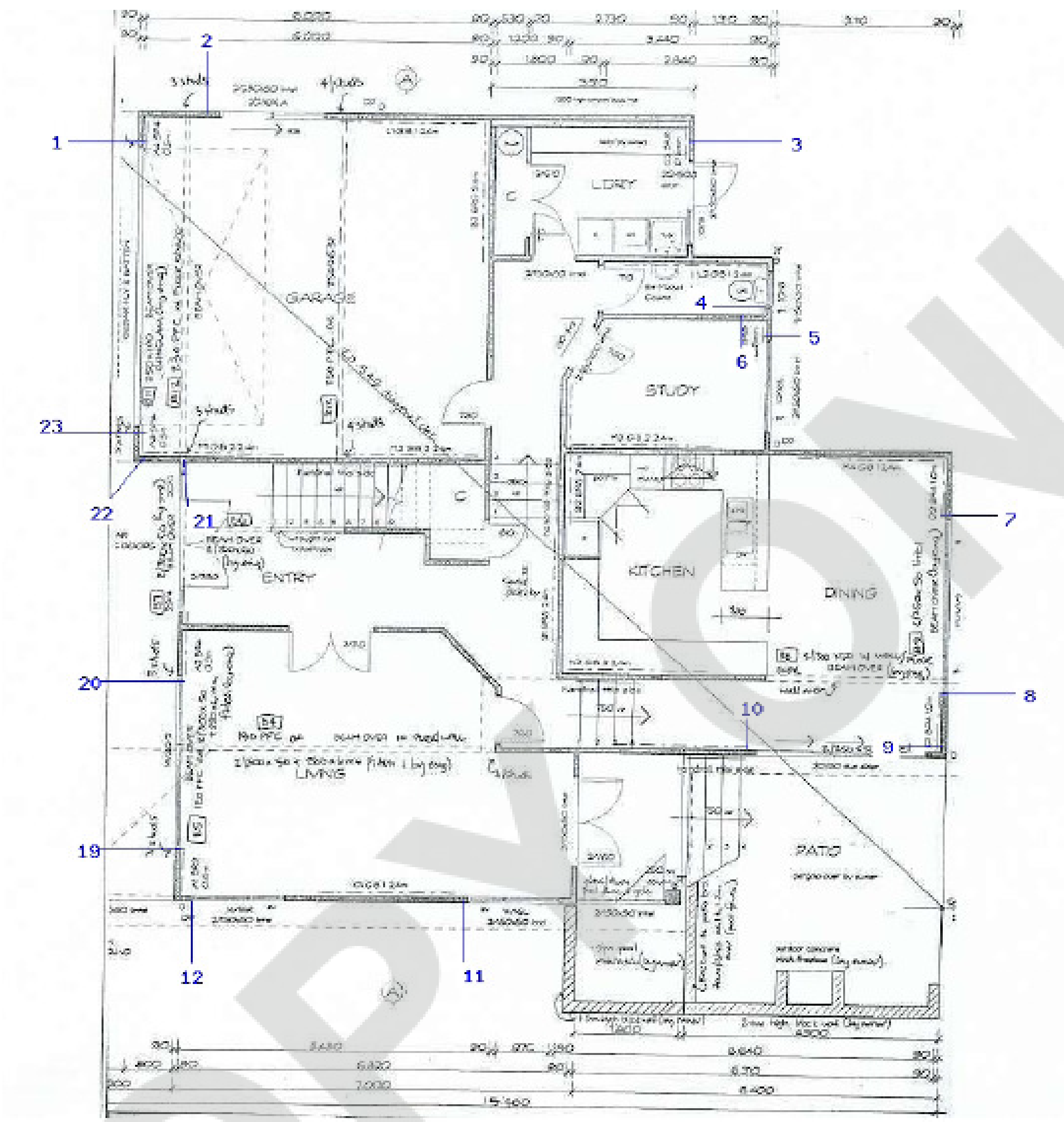
Fig. 11 Timber moisture content in a simulated wall environment clad with FrameGuard and HITEX Diamonds.

On-site Moisture Content readings from Mdu Probes support this position:

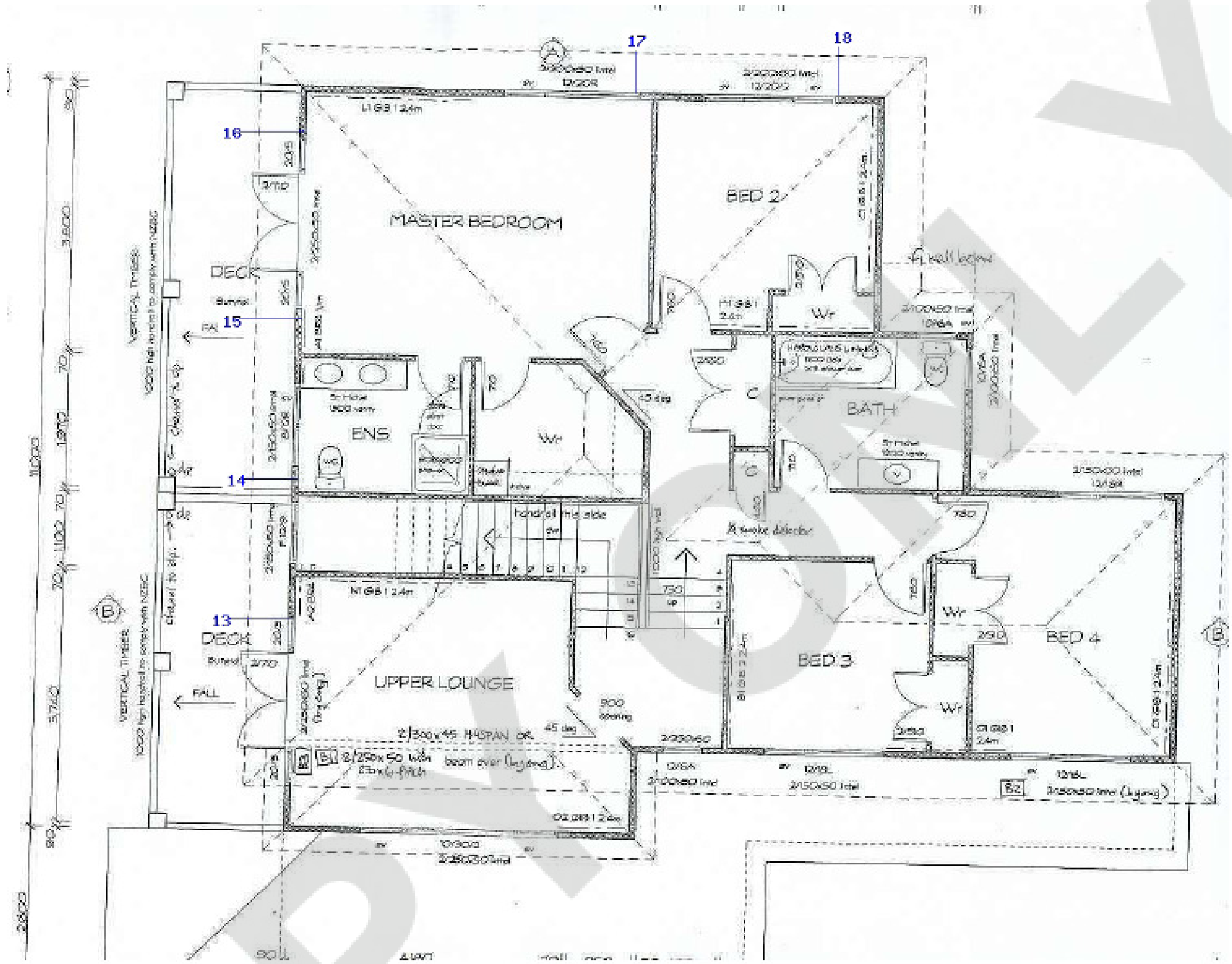
Source: House 129 clad in Hitex Diamond.

Probe	Timber VCR		Timber Strength		Scan	Moisture Content (% MC)							
	Inner	Outer	Inner	Outer	Inner	Inner	Outer						
#	19 Oct 2004	19 Oct 2004	19 Oct 2004	19 Oct 2004	19 Oct 2004	19 Oct 2004	#	19 Oct 2004	18 Nov 2004	23 Apr 2005	18 Sep 2006	25 Sep 2006	27 Sep 2007
1	-	-	-	-	-	-	6	17.9	13.2	10.1	11.1	14.0	11.2
2	-	-	-	-	-	-	6	21.9	13.9	10.3	11.0	12.7	11.0
3	-	-	-	-	-	-	6	21.5	17.2	14.6	12.8	15.8	14.9
4	-	-	-	-	-	-	6	26.8	19.8	15.0	15.2	18.3	15.6
5	-	-	-	-	-	-	5	24.7	18.4	12.6	-	16.1	14.0
6	-	-	-	-	-	-	6	32.2	20.5	14.1	13.7	15.1	13.1
7	-	-	-	-	-	-	6	22.9	16.7	13.3	13.6	16.9	13.8
8	-	-	-	-	-	-	6	26.3	17.2	10.3	12.1	15.5	13.2
9	-	-	-	-	-	-	6	26.6	15.9	10.9	12.8	14.0	12.1
10	-	-	-	-	-	-	6	21.6	14.8	11.9	8.8	14.6	12.9
11	-	-	-	-	-	-	6	24.2	15.9	10.7	11.8	14.0	11.8
12	-	-	-	-	-	-	6	20.1	13.8	11.0	11.7	13.7	12.1
13	-	-	-	-	-	-	6	18.4	11.2	8.2	10.4	11.8	11.5
14	-	-	-	-	-	-	6	15.4	11.7	9.1	10.6	10.9	9.6
15	-	-	-	-	-	-	6	16.1	12.8	9.3	10.9	13.0	9.2
16	-	-	-	-	-	-	6	15.2	12.4	9.5	10.5	12.6	9.9
17	-	-	-	-	-	-	6	17.8	11.6	8.6	9.5	12.5	10.4
18	-	-	-	-	-	-	6	15.8	12.8	10.2	11.1	12.9	10.8
19	-	-	-	-	-	-	4	-	-	13.2	11.1	11.5	11.5
20	-	-	-	-	-	-	4	-	-	12.9	11.1	11.4	11.4
21	-	-	-	-	-	-	4	-	-	12.6	10.3	10.5	10.2
22	-	-	-	-	-	-	4	-	-	11.4	10.8	11.1	10.3
23			-	-	-	-	4	-	-	13.7	10.3	10.5	9.7

Next reading is due in March 2008



Ground Level | Probe Locations | 19 Oct 2004



Level 2 | Probe Locations | 19 Oct 2004

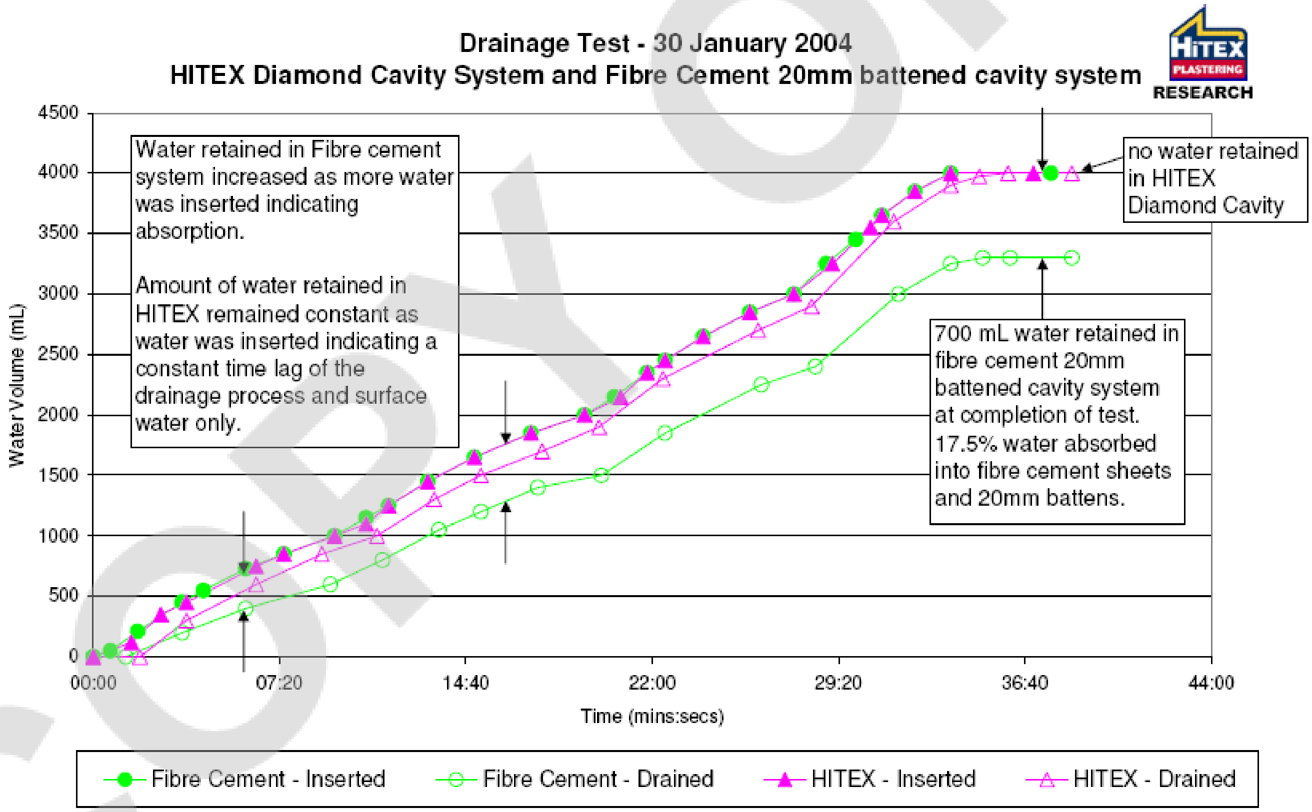
Drainage Efficiency
The below test compares Hitex Diamond Cavity with Fibre Cement battened cavity E2/AS1:

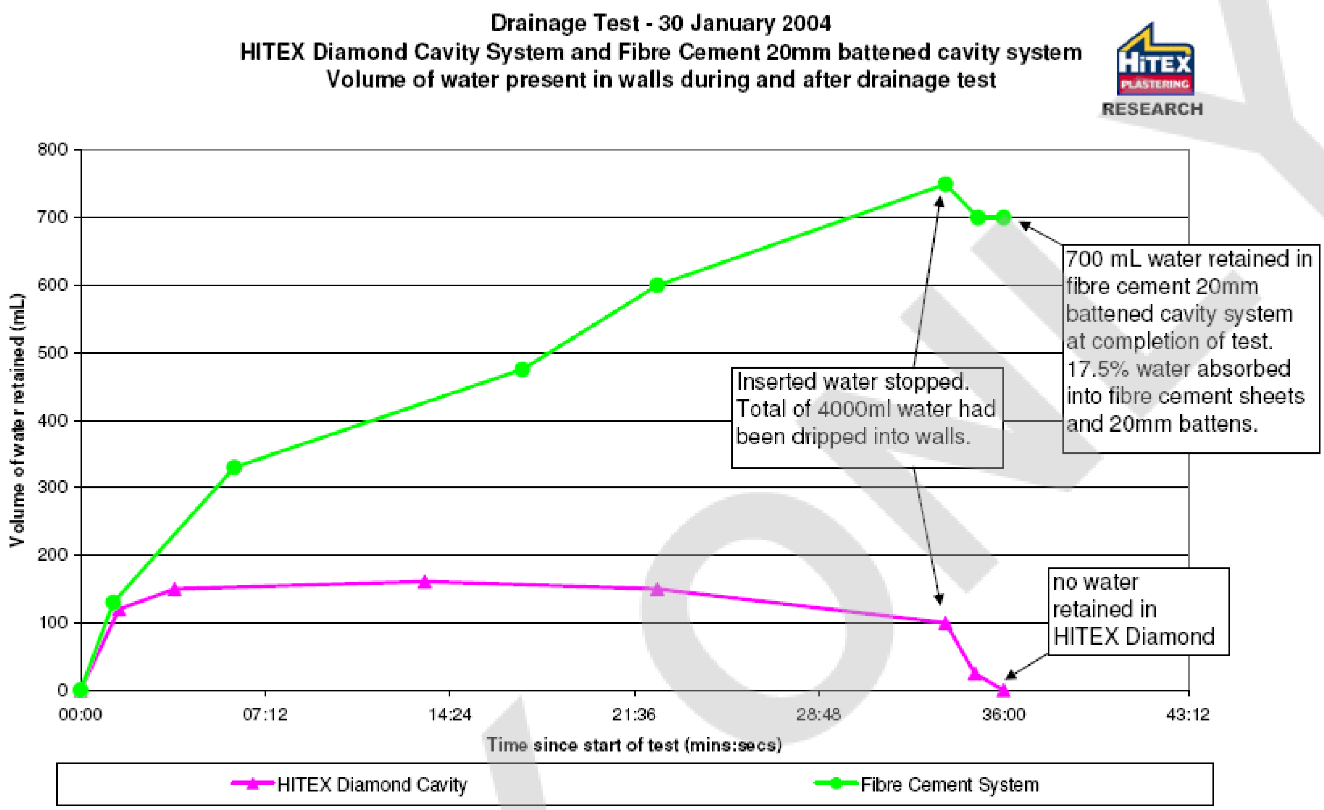
Source: Hitex Case Study – Drainage Test – Of Cavity Construction Methods. Performed January 2004.

Two cavity walls were constructed: one using HITEX Diamond with its integral cavity and the other a fibre-cement cladding with a 20-mm battened cavity. Four litres of water was dripped behind the claddings into the cavities over a 34 minute period to simulate a leak. Water that drained from the walls was collected and measured.

Results:

- HITEX Diamond Cavity system provided total drainage of all water (except a couple of drops) inserted into the wall.
- The fibre cement cavity system absorbed 700mL of the 4000mL water inserted (17.5% absorption).
- In the fibre cement system, the 700mL of water was absorbed into the rear of the fibre cement sheets and the timber battens.





Drainage Test - 30 January 2004
HITEX Diamond Cavity System and Fibre Cement 20mm battened cavity system
Volume of water present in walls during and after drainage test
RESEARCH
Volume of water retained (mL)
800
700
600
500
400
300
200
100
0
00:00
07:12
14:24
21:36
28:48
36:00
43:12
Time since start of test (mins:secs)
700 mL water retained in fibre cement 20mm battened cavity system at completion of test. 17.5% water absorbed into fibre cement sheets and 20mm battens.
Inserted water stopped. Total of 4000ml water had been dripped into walls.
no water retained in HITEX Diamond
HITEX Diamond Cavity
Fibre Cement System

IN-SITU BUILDING WALL MICROCLIMATE INVESTIGATION

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Abstract: The microclimates in four in-situ building walls were investigated. Measurements of temperature, and relative humidity (RH) and timber moisture content (MC) were taken. It was found the two external insulation finishing system (EIFS) walls have conditions that do not support mould growth and that the two stucco walls have conditions ideal for mould growth. It was found that in-situ wall microclimate analysis is a useful indicator to measure the suitability of conditions for mould growth, and timber MC alone is not sufficient. It is concluded that for a wall to effectively manage moisture, the wall must have an RH below 70%, the vapour pressure can interact with the outside and the dew point temperatures inside the wall is always below the outside temperature. Of the walls tested, only EIFS wall 1 showed these characteristics.

Keywords: Microclimate, mould, humidity, moisture, building wall.

1. Building Walls Deteriorate due to Mould Growth

Building walls are deteriorating due to mould growths and this is resulting in loss of durability and public health concerns. Moulds grow when there is a suitable microclimate. This paper reports on investigations into the microclimate in in-situ timber wall cavities as part of ongoing research to develop a wall cladding that can effectively manage moisture and result in a durable and healthy wall free of mould growth.

2. In-Situ Wall Microclimate Knowledge Insufficient

There is a lack of knowledge on the microclimates of building walls in-situ. The majority of previous research has been performed on computer models and test rigs. For example the Moisture Management and Exterior Wall Systems (MEWS) research program in Canada investigated the ingress of moisture into building walls, its effects and the drying out process following moisture ingress using computer modelling [1,2,3]. Computer modelling can only be used as a comparison tool to support decision-making and not to quantify absolute performance [4]. Work performed at the University of Auckland with test rigs investigated wall microclimates and the mechanisms controlling the movement of moisture. It also showed moisture levels were highest in the bottom plate compared to other sections of a building. [4,5]. This paper focuses on the microclimates present in in-situ walls.

3. Microclimate for Mould Growth

Generally, the rate of growth of moulds increases as the RH and temperature increases [5]. In the absence of preservatives, mould spores will germinate in a RH well in excess of 90%; in all probability a film of free water is required, at least briefly, but once germination has occurred, growth will continue at RH as low as 70% [5,6,7]. Inevitably buildings are exposed to rain during construction allowing mould spores to germinate. The germinated spores will later grow given the right RH conditions. Common moulds grow with a RH above 80% and rot forming and toxic moulds have considerable growth when the RH is above 95% [6,7]. The required conditions for mould growth are generalised in Fig 1 on the psychrometric chart.

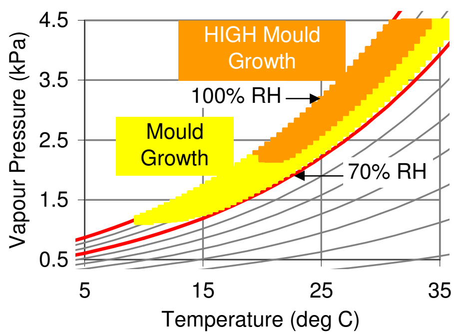

Fig 1: Psychrometric Chart of Mould Zones

4. Relationship Between Air RH and Building Elements MC

There is a relationship between Air RH and the moisture content (MC) of building elements. Any building element exposed to an atmosphere of constant temperature and RH will eventually reach a stable MC, referred to as the "equilibrium moisture content" (EMC). In experimentation, the EMC in sample timber was not reached after 6 days exposure to laboratory conditions [9]. However, for a given MC in a closed system, the authors found air RH adjusted to the predicted RH within minutes. Fig 2 gives the generalised EMC curves for the main building elements used in this study.

In an open system this EMC-RH relationship can be used to predict the movement of moisture. When a system is affected from an outside influence, moisture is absorbed or desorbed between the air and material in an attempt to maintain equilibrium.

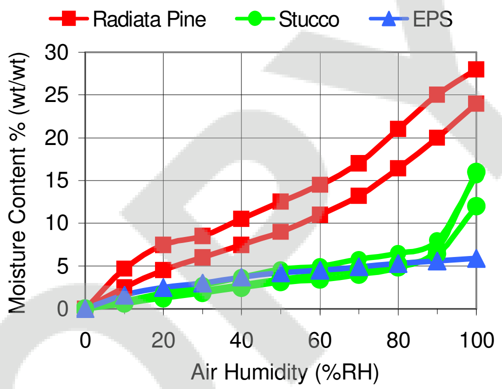

Fig 2: EMC-RH relationship [1,10]

5. In-Situ Walls Investigated

Four in-situ north-facing building walls in houses around Auckland were investigated during summer between January and March 2004 in typically sunny conditions. PT1000 Class A temperature sensors and HC101 humidity sensors were placed on the bottom plates of the walls (Fig 3) to monitor the microclimate with the exception of wall 2, which was monitored on the first floor. The temperature and RH were recorded at 10-minute intervals over a period of 4 days. Timber MC measurements via inductance probes were taken from the bottom plates directly underneath the probe locations at the beginning of the test to find the maximum MC range present. Wall 2 timber readings were taken from the first floor plate. The four different walls investigated were:

- **Wall 1:** external insulation finishing system (EIFS) clad wall with integral 10mm deep ventilated drained cavity. Subject to earlier research at University of Auckland [8,9]. Exposed to full sun.
- **Wall 2:** EIFS clad wall with no cavity. Semi-shaded wall.
- **Wall 3:** Stucco clad wall with no cavity. Exposed to full sun.
- **Wall 4:** Stucco clad wall with no cavity. Wall wet due to moisture ingress. Semi-shaded wall.

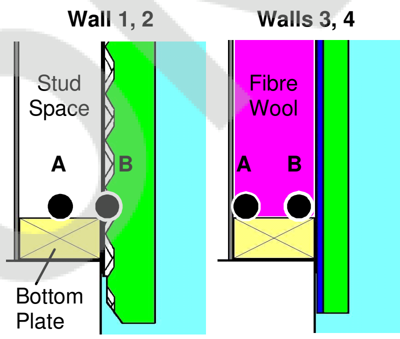

Fig 3: Position of instruments inside wall. Note Wall 2 has no cavity.

6. Temperature, RH measurements

The temperature and RH measurements provided the data for microclimate analysis. As an example of the data gathered for each wall the temperature and RH plots for wall 1 and 3 are given in Figs 4 and 5 respectively. The time axis begins at midnight on the first day.

In Fig 5 there is a gap in data for wall 3 on day 2 for 5 hours due to the equipment being accidentally turned off by the homeowner.

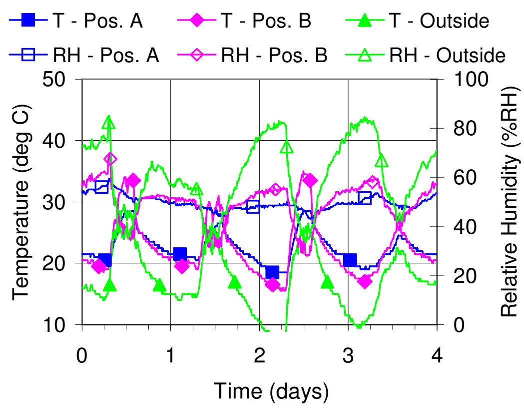

Fig 4: Wall 1 Temp and RH Plots

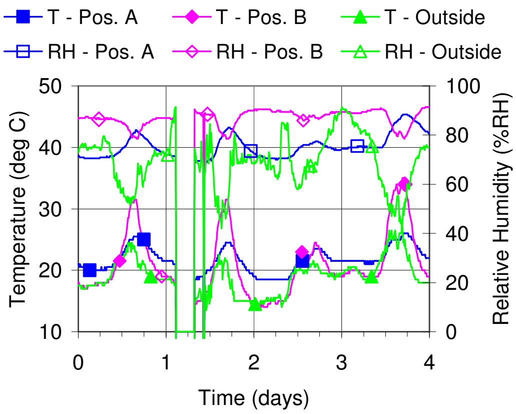

Fig 5: Wall 3 Temp and RH Plots

7. Temperature

Results showed that the temperatures in all wall microclimates follow the diurnal cycle and energy equilibrium is never reached. This increases the complexity and difficulty of analysis. The wall temperatures peak in the afternoon after sun exposure due to radiant heat being absorbed on the cladding surface. Position B in the monitored walls reached higher temperatures than Position A and the outside due to this radiant heat. Position B in walls 1 and 3 recorded the maximum temperatures during the tests at 35°C in the afternoon.

8. RH and Mould

The RH of the microclimates in the four walls is given in Fig 6.

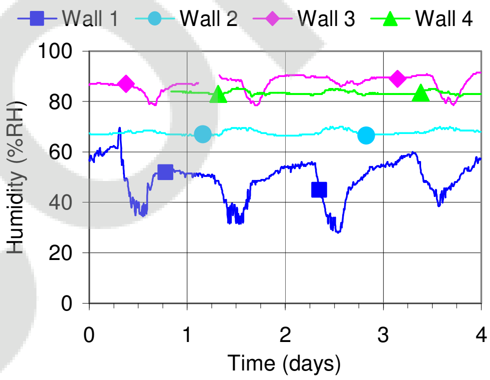

Fig 6: RH of Walls in Position B

The RH in wall 1 fluctuates during the diurnal cycle (28-69%). Walls 2, 3 and 4 have a comparatively steady RH. Walls 1 and 2 always have a RH below 70% RH. Walls 3 and 4 consistently have a RH above 80%. Walls 3 and 4 are in the mould growth zone above 70% RH.

Site observations found mould growth in wall 4 had advanced to the stage of timber rot even though the house was only 3 years old. Wall 3 timber is 8 years old and has not shown visible signs of rot. It is suspected that this process has been delayed because the timber has been boric treated.

9. Vapour Pressure Differential

The differentials between the wall microclimate vapour pressures (VP) at position B and the outside air are given in Fig 7. The outside air VP typically remained between 1-1.5 kPa.

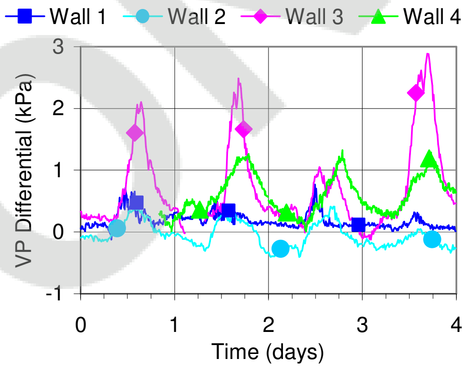

Fig 7: Pressure Differential between Position B and outside vapour

EIFS wall 1 has a VP differential close to or just above zero with minimal fluctuation. Non-ventilated EIFS wall 2 and stucco walls 3 and 4 have a VP differential that fluctuates over a day. The fluctuation in VP differential in walls 2, 3 and 4 shows the absence of an effective moisture release mechanism from the wall to the exterior environment.

10. Moisture Content Variations

The MC measurements taken of the bottom plates beside the probes of the four walls are shown in Table 1, and include the average air RH found during the monitoring period.

Table 1: Timber MC of Bottom Plates and air RH (Position B)

	MC(%)			RH(%)
	Median	*Max*	*Min*	*Ave*
Wall 1	16.1	16.8	15.3	49.4
Wall 2	19.1	21.9	16.3	67.8
Wall 3	16.7	18.5	15.7	87.0
Wall 4	24.0	58.9	21.0	83.5

Table 1 shows the MC readings of the bottom plate vary within a given wall and the range of this variance changes between walls. As an illustration, wall 4 MC readings and their locations are shown in Fig 8. It shows large variations occurring within small distances and moisture is concentrated directly next to the cladding. The 58.9% reading indicates that liquid water must have been present since the maximum timber MC at 100% RH is 28%.

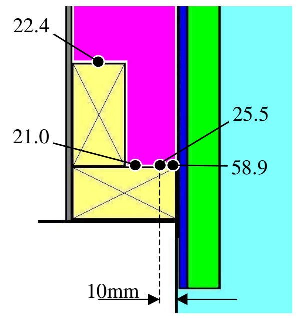

Fig 8: Timber MC Measurements in Wall 4

Fig 9 plots the measured MC and average microclimate RH readings at Position A or B on the EMC-RH relationship (Fig 2) to determine if the MC is in equilibrium with the wall microclimate RH.

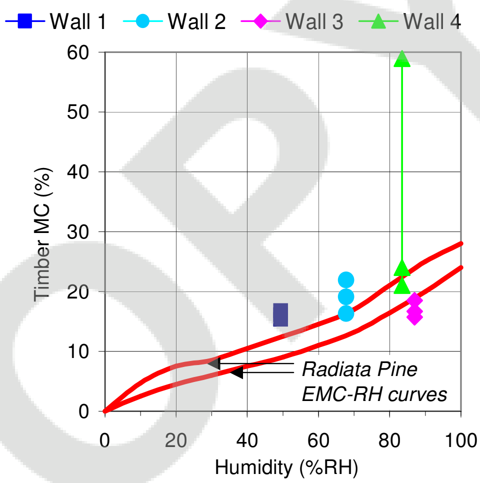

Fig 9: MC-RH readings plotted on EMC-RH relationship for Radiata Pine (Fig 2)

Fig 9 show the MC and RH are not in equilibrium and do not have a definitive relationship. This is due to the timber requiring a consistent environment for over 6 days. However conditions are not constant as the temperature conditions inside the walls are continuously fluctuating with the diurnal cycles.

11. Wall Psychrometric Signatures

Figs 10-13 illustrate the wall 'psychrometric signatures' for walls 1-4 respectively.

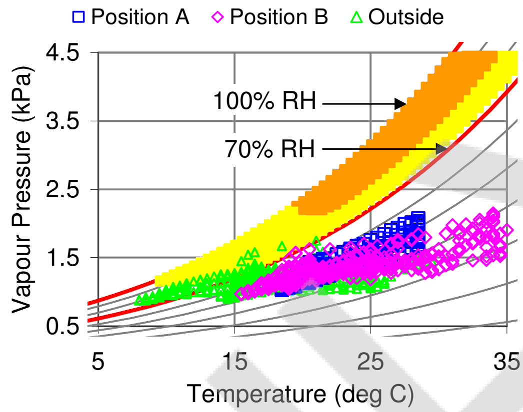

Fig 10: Wall 1 Psychrometric Signature

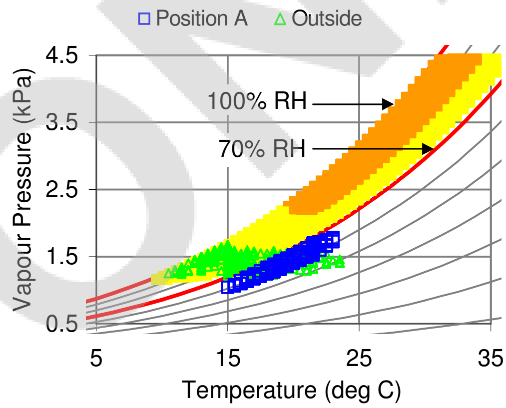

Fig 11: Wall 2 Psychrometric Signature

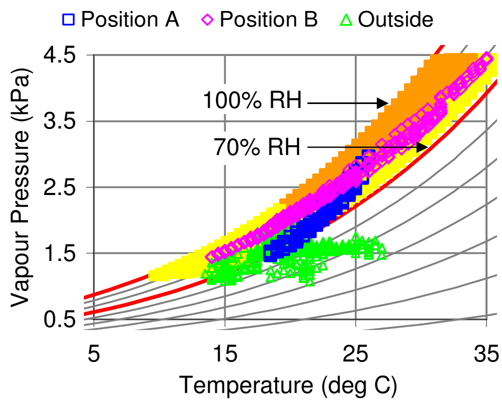

Fig 12: Wall 3 Psychrometric Signature

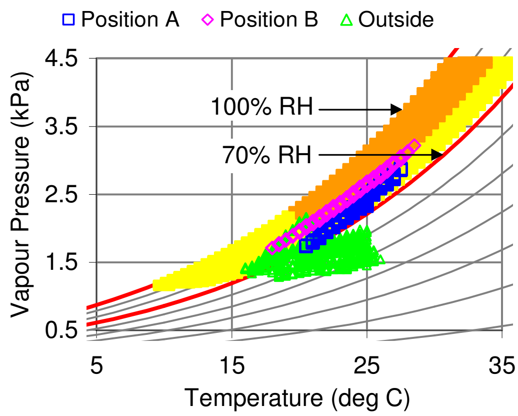

Fig 13: Wall 4 Psychrometric Signature

For each wall, the wall signature plots all temperature and RH measurements taken over the 4-day period as a 'signature' on the psychrometric chart. These plots further illustrate walls 3 and 4 have a microclimate inside the mould growth zone and walls 1 and 2 do not.

These wall signatures summarise the complex relationships of temperature, RH and VP of the wall microclimates. The signatures appear to be identifiably unique to each wall and its moisture loading conditions. Further, the moisture movement characteristics of the microclimate can be inferred. From this, the ability of the wall to handle excess moisture can be assessed.

Figs 11, 12 and 13 show that in the non-ventilated walls, the microclimate VP rises and falls along a constant RH line as temperature changes. In comparison, Fig 10 shows the ventilated wall 1 does not follow a constant RH line.

This phenomenon indicates that in the non-ventilated walls, as the temperature of the microclimate changes, the VP adjusts to maintain a consistent RH based on the EMC-RH relationship of the building elements it is in contact with. In ventilated wall 1 this relationship is not followed as the VP build-up is released to the outside environment, showing there is an interaction between the VP in the wall and the outside. If there was ingress of moisture into wall 1, this mechanism allows airborne moisture to egress and the wall to dry. Since wall 2 does not show this interaction, this drying ability is not available.

12. Dew Point Temperature Approach

The differentials between the outside temperatures and dew point temperatures at position B for walls 1, 3 and 4 and position A for wall 2 are given in Fig 14.

Fig 14 shows the EIFS walls 1 and 2 always have a positive temperature differential, whereas stucco walls 3 and 4 have periods of negative differential and condensation may occur. The source of the liquid water shown in the 58.9% MC reading in Fig 8 may be condensation.

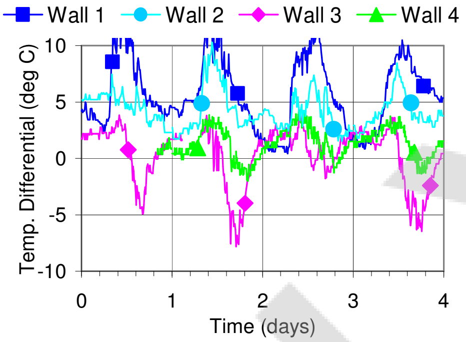

Fig 14: Outside Air to Dew point Temperature Differentials in wall

13. Microclimate Analysis Conclusions

The in-situ wall microclimate is an absolute indicator of the health of a wall. It can predict the potential for mould growth in the wall and hence its durability.

The variability of timber MC readings shown in Fig 8 raises questions on the reliability and accuracy of using single MC measurements to check whether the conditions inside the wall are suitable for mould growth or not. Timber MC alone is not a sufficient indicator of a wall's durability, especially when the wall moisture loading increases above a MC of approximately 16-18%.

For a wall to effectively manage moisture and result in a durable and healthy wall free of mould growth, all of the following microclimate characteristics need to be exhibited:

- RH below 70% at levels not conducive to mould growth.
- Wall VP interacting with outside VP showing there is potential for drying following ingress of moisture.
- dew point temperature always below outside

EIFS wall 1 showed all these characteristics whereas stucco walls 3 and 4 showed none of these.

The wall microclimate interactions are so complex and variable, in-situ measurements are perhaps the best way to accurately show what is happening in a building wall. Engineers wishing to advance the design of building walls should perform a full microclimate analysis as a verification method to prove the durability of the wall.

14. References

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