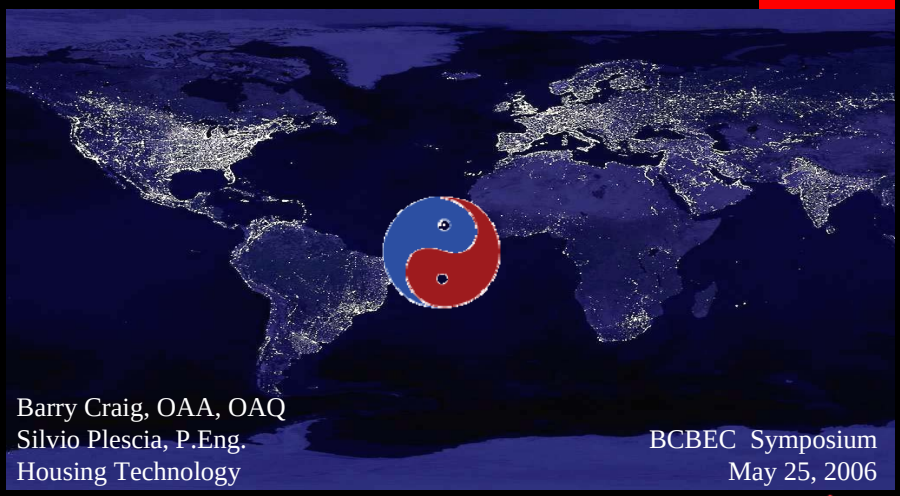
Drainage and Drying: The Yin and Yang of Moisture in Wall Systems



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Housing Technology

BCBEC Symposium
May 25, 2006

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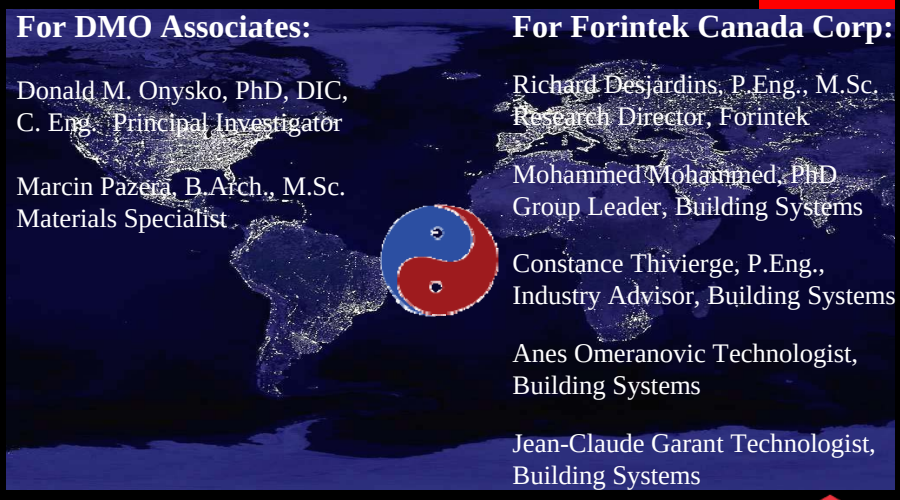
Drainage and Drying: The Yin and Yang of Moisture in Wall Systems



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Jean-Claude Garant Technologist, Building Systems

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Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

"Water, taken in moderation, never hurt anybody."

Mark Twain

"Water ruins everything."

Glenn Allen

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Background

Moisture penetrates all types of siding

Moisture damage in walls is a growing problem across Canada and the US.

The way different sidings manage water isn't well understood

Regulations require capillary breaks or other performance measures in walls

Capillary breaks are difficult to incorporate with some sidings

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Questions

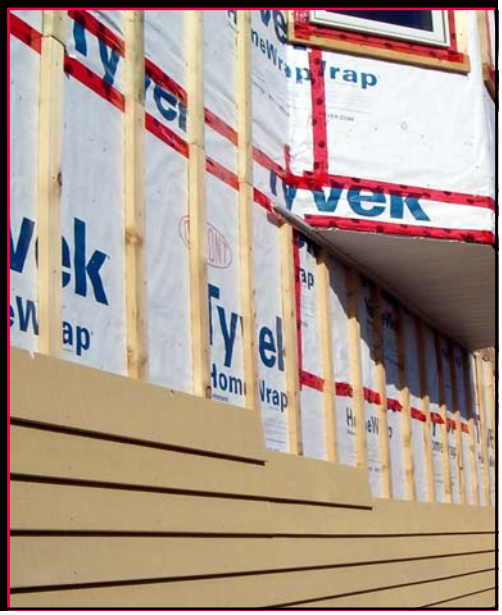
How quickly can water drain through wall systems?

How much water is retained after a wetting event?

Where is the water retained in the wall system?

How quickly does a wall system dry under normal conditions?

How do various capillary breaks affect wetting and drying?



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Agenda

Testing and Measurement

Construction of Test Panels

- EIFS Wall Systems
- Vinyl Wall Systems
- Hardboard, Wood and Cement Board Wall Systems

Drainage, Water Retention & Drying

- EIFS Wall Systems
- Vinyl Wall Systems
- Hardboard, Wood and Cement Board Wall Systems

Conclusions and Next Steps

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Testing and Measurement

•Test set-up

• Instrumentation

• Water flow rate

• Trickle trough

• Environmental conditions

• Moisture content in drainage cavity

• Test program

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Testing and Measurement

Test Set-up

• The purpose of the test was to accurately measure the water retained in each test wall

• Set-up used was composed of three weight-balancing systems

• The weight of the test wall was counterbalanced by other weights using a balance beam

• This allowed the use of a more sensitive load cell

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Testing and Measurement

Instrumentation

- Load cell data acquisition was provided by a compression load cell having a capacity of 35kg
- The load cell was positioned directly under the centre of the bottom plate of each wall
- A ball bearing was installed under the bottom plate of the test wall and rested directly on the load cell bearing plate
- Resolution - 0.2g

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Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Testing and Measurement

Water Flow Rate

- Based on ASTM E2273-03 Standard Test Method for Determining Drainage Efficiency of EIFS
- 8L of water drained into the wall cavity for a 1 hour period
- Water was piped to the trickle trough by an air pressure system
- Water in a glass carboy was constantly weighed during the wetting phase
- The flow rate was calculated and adjusted with a micro valve

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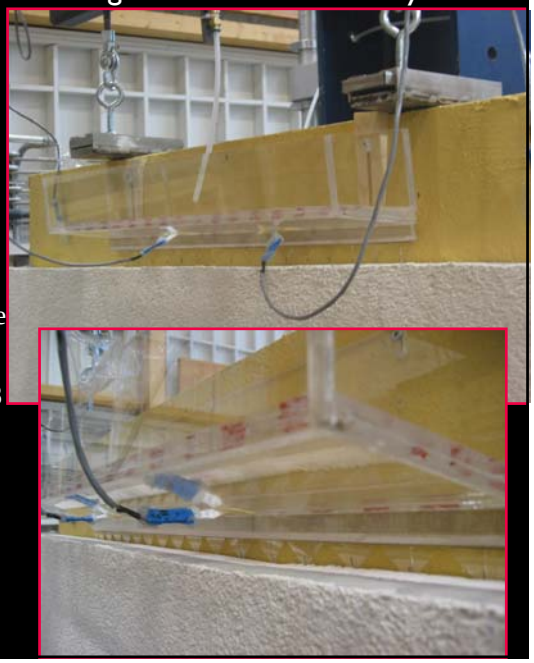
Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Testing and Measurement

Trickle Trough

- Water is delivered to a Plexiglas distribution trough which allows the water to trickle into the cavity
- The trickle trough is 610 mm long and 95 mm wide with a bottom slope of 20%
- 2 mm diameter holes are spaced 38 mm c/c in the bottom corner
- Flow can be directed either to the front or the back surface of the drainage cavity with shims
- A serrated plastic sheet directs the flow to the chosen locations



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Testing and Measurement

Environmental Conditions

- 16 pairs of RH and Temperature sensors monitor the environmental conditions
- 4 sensor pairs are installed on each wall (2 below the trickle trough and 2 placed symmetrically on both sides at the same level)
- Sensors on the wall monitor the exiting air conditions at the top of the drainage cavity
- 4 additional monitoring stations are installed near the test area

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

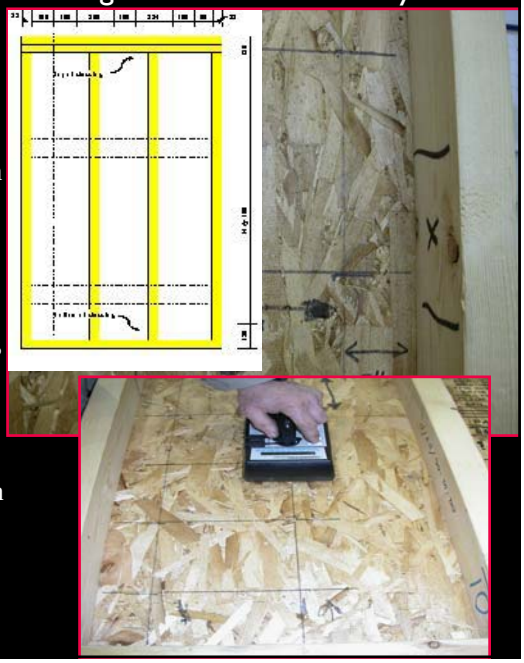
Testing and Measurement

Moisture Content in Walls

• Moisture content was evaluated in a qualitative way using a capacitance Wagner L620 moisture meter

• A series of 90 readings were taken, before the test and after the 48hrs drying phase, on the back of the OSB sheathing surface of each specimen

• Differences in moisture content were computed and contour maps for the retained water were done for each wall



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Testing and Measurement

Test Program

• Three phases to test program:

• Phase 1 Wetting – 8 litres per hour for 1 hour …133ml/min.

• Phase 2 Allow free liquid to drain for 1 hour following wetting phase.

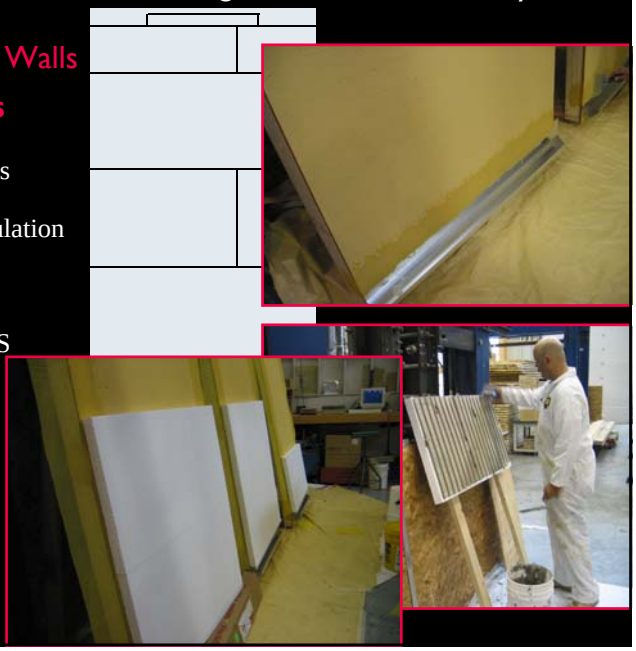
• Phase 3 – Drying of retained water for 48 hours.

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

EIFS Wall Systems

- Wall/cladding assemblies
- Joint layout for EPS insulation
- Stainless steel gutter
- Adhesive ribbons on EPS
- EPS applied to substrate



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

Wall/Cladding Assemblies

Number of Test Walls								Total No. of Walls to be Tested
Siding or Cladding Type	No. of Sets of Wall Tests 3 per set	WRB	Location of Water Entry	Drainage Cavity				
				Ribbons Adhesive	Proprietary Drainage Mats	Batten Straps	Direct Applied	
EIFS	2 3	LA-WPB LA-WPB	F/B Center	6 (repeat) 9				6 9
Vinyl siding	1	C/P	center				3	3
Hardboard siding	1	P	C/F/B		2**		1***	3
Wood siding	2	P	C/F/B		2**	1**	2*	5
Cementitious siding	1	C/P	center				2	2

C/P – Cellulose or Polyolefin

* One Bevel- One Shiplap

** All Shiplap

*** Bevel Spline

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Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

EIFS Wall Systems

- Edge reinforcement, finish coat
- 3 completed samples from one manufacturer

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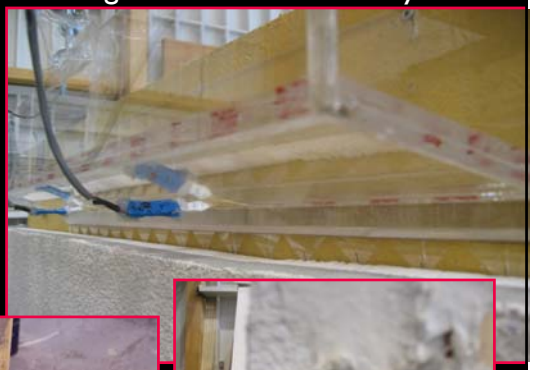
Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

EIFS Wall Systems

- Trickle trough
- Gutter
- Water collection



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

Vinyl Wall Systems

- Vinyl profile 1: double 4.5” Horizontal, direct applied over 15 lb. building paper
- Vinyl profile 2: double 4.5” Dutch lap, direct applied over SBPO sheathing membrane
- Vinyl profile 2: double 4.5” Dutch lap, direct applied over 15 lb. building paper

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

Vinyl Wall Systems

- Metal gutter at bottom of wall
- Vinyl starter strip over water resistant barrier (WRB)
- Vinyl starter strip

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

Vinyl Wall Systems

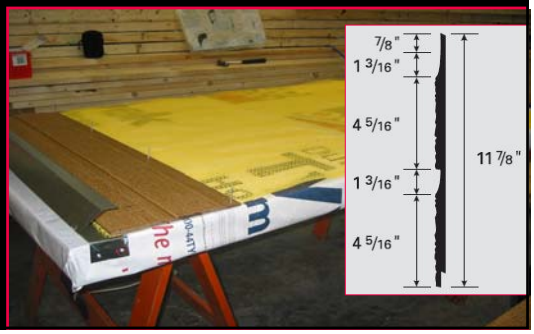
- Vinyl siding direct applied over WRB
- Sealant at both edges of specimen
- Edges taped
- Trickle trough installed

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

Hardboard Wall Systems

- Wall 1: Hardboard siding profile 1 (direct applied) with SBPO
- Wall 2: Hardboard siding profile 2 (direct applied) with drainage mat (type 1) and SBPO
- Wall 3: Hardboard siding profile 2 (direct applied) with drainage mat (type 2) and SBPO



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

Hardboard Wall Systems

• Wall 1 was tested only once while walls 2 and 3 (with drainage mats) were tested twice (once on the back and once on the front surface of the drainage cavity)

• For wall 1 water was simply allowed to drip behind the top course through the 4 mm space provided at the top edge of the siding (similar to vinyl walls)

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

Wood Wall Systems

• Wall 1: Wood siding profile 1 (direct applied) with SBPO

• Wall 2: Wood siding profile 2 (direct applied) with drainage mat (type 3) and SBPO

• Wall 3: Wood siding profile 2 (applied on furring) with SBPO

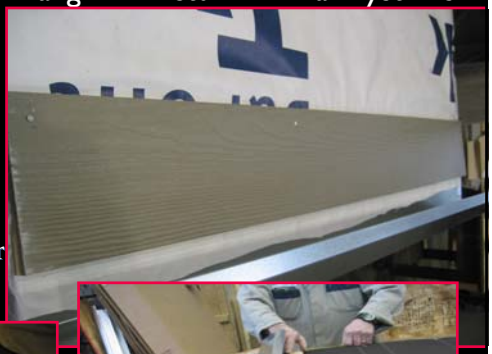
Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Construction of Test Walls

Cement Board Wall System

• Wall 1: Cementitious siding profile 1 (direct applied) with SBPO

• Wall 2: Cementitious siding profile 1 (direct applied) with black building paper (15 lbs)



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention & Drying

EIFS Wall Systems

• Water retention values and curves

• Observations

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

EIFS Wall Systems

Water retention - Initial, WRB, EPS

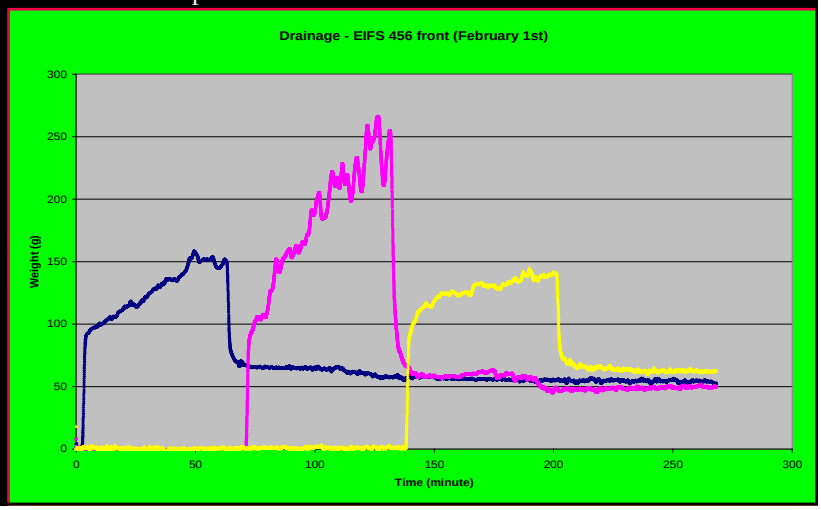
Test Series	Manufacturer	Wall #	Wall Designation	Location of Trickling	Retained Water (g)		
					1-hr	2-hr	48-hr
Lowest Initial Retention	A	1	A-4	Initial WRB EPS	267 215 239	196 139 165	86 101 153
	B	2	B-1	Initial WRB EPS	102 117 188	30 24 47	8 61 42
	C	3	C-1	Initial WRB EPS	282 235 119	189 109 54	115 51 34
Highest Initial Retention	A	4	A-1	Initial WRB EPS	807 178 152	744 54 61	574 19 46
	B	5	B-4	Initial WRB EPS	504 134 150	385 35 59	223 0 31
	C	6	C-3	Initial WRB EPS	348 419 141	305 95 63	292 28 44

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

EIFS Wall Systems

Water retention - Offsets represent 70 min. interval between tests

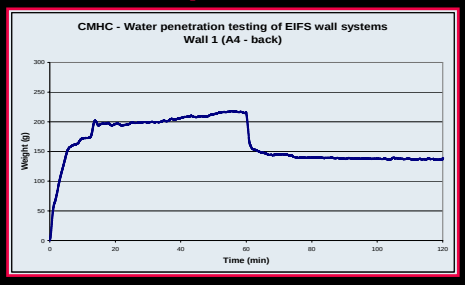


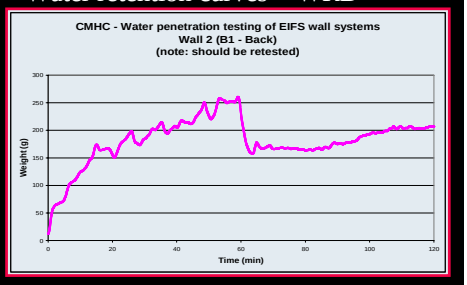
Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

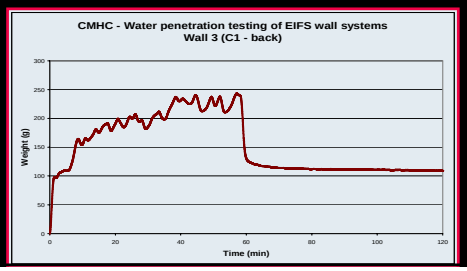
Drainage, Water Retention and Drying

EIFS Wall Systems

Water retention curves - WRB





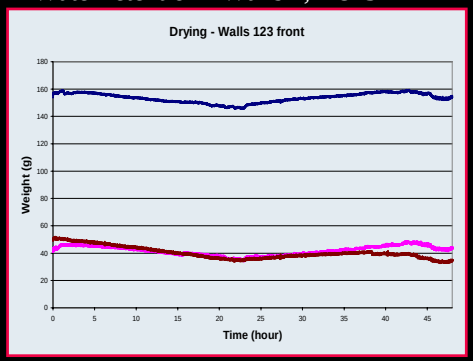


Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

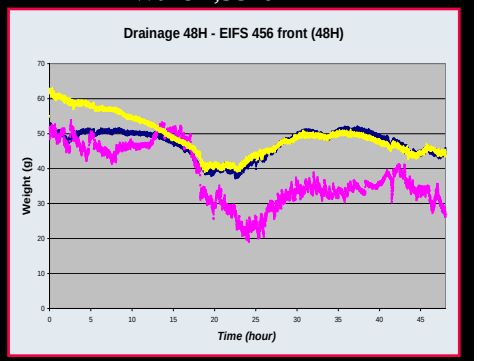
Drainage, Water Retention and Drying

EIFS Wall Systems

Water retention - Walls 1, 2 & 3



Walls 4,5& 6



48-Hr. Drying Curves – EPS

- Note different vertical scales

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

EIFS Wall Systems

Observations

• Water retention at both 2-hr and 48-hr times was usually less that when originally tested by trickling in the middle of the drainage gap

• Water retention did not appear to have taken place in joints as was expected.

• Despite having been selected for their different original performance, this difference was not reflected in the tests conducted at this time.

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention & Drying

Vinyl Wall Systems

• Water retention values and curves

• Observations

• Moisture mapping

• Observations of moisture mapping

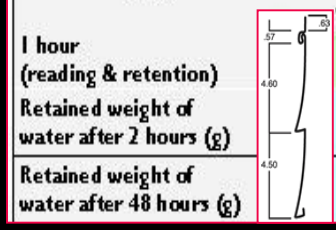
Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

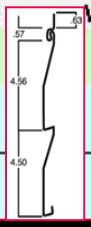
Drainage, Water Retention and Drying

Vinyl Wall Systems

Water retention - Walls 1, 2 and 3

Time	Wall 1 Vinyl–P1-BP	Wall 2 Vinyl–P2-SBPO	Wall 3 Vinyl–P2-BP
1 hour (reading & retention)	698	500	327
Retained weight of water after 2 hours (g)	364	236	224
Retained weight of water after 48 hours (g)	283	130	135





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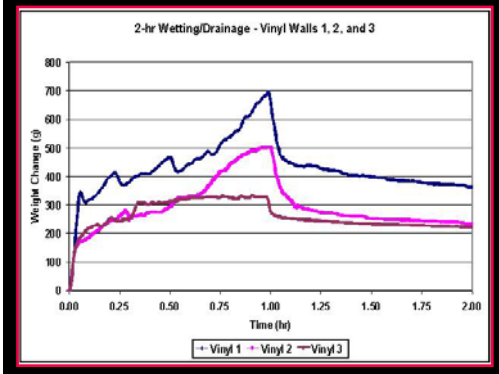
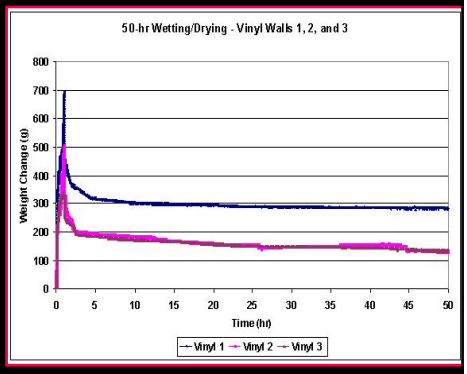
Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Vinyl Wall Systems

Water retention curves - 2 hrs, 48 hrs - Walls 1, 2 & 3





- Vinyl 1: double 4.5" Horizontal, direct applied over 15# black paper
- Vinyl 2: double 4.5" Dutch lap, direct applied over SBPO sheathing membrane
- Vinyl 3: double 4.5" Dutch lap, direct applied over 15# black paper

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Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Vinyl Wall Systems

Observations

- Water immediately started to drain out of the small drainage holes below the first course of siding
- Most of the water drained through the holes at the first joint
- Some water ended up on the floor and on the bottom part of the specimen (sill plate)
- Some water leaked out through the sealed edges

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Vinyl Wall Systems

Observations

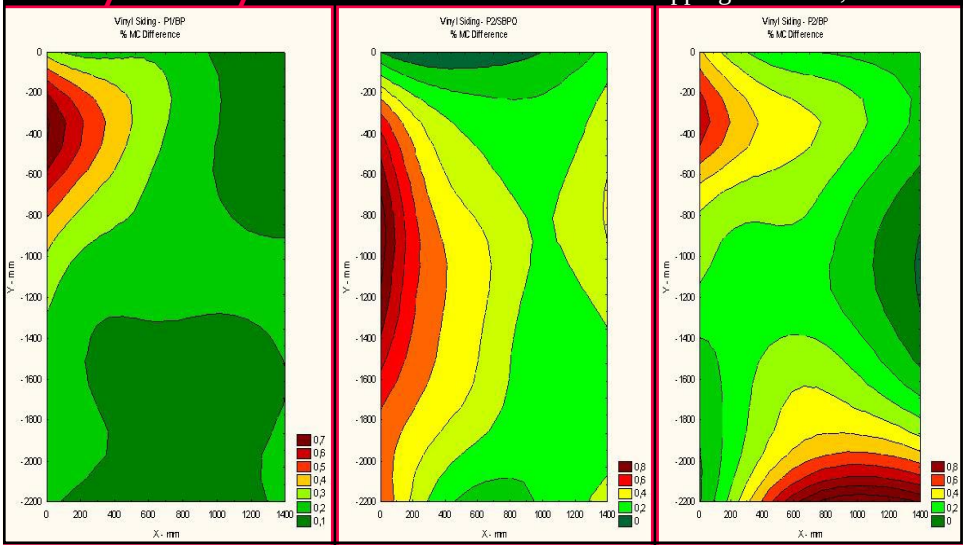
- Leaked water wetted bottom corner of panel
- All walls demonstrated similar moisture loss
- Exterior water on the siding was wiped off and weighed after the 2 hrs wetting/drainage phase
- Drying rate for wall 1 was under 1g/hour
- Drying rate for walls 2 and 3 was 1.5g/hour
- When walls were dismounted from test frame, some free water that was held by the siding drained out on the floor

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Vinyl Wall Systems

Moisture Mapping – Walls 1, 2 & 3



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Vinyl Wall Systems

Observations of Moisture Mapping

- Readings for moisture mapping were taken before the wetting/drainage phase and after the 48hrs drying phase
- Differences in MC were higher at the first course of siding
- The maximum difference in moisture content observed for all three walls was around 0.8 %
- Only 1 wall showed a difference in MC at the bottom of the wall

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Hardboard, Wood and Cement Board Wall Systems

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention & Drying

Hardboard Wall Systems

- Water retention values and curves
- Observations

•Wall 1: Hardboard siding profile 1 (direct applied) with SBPO

• Wall 2: Hardboard siding profile 2 (direct applied) with drainage mat (type 1) and SBPO

• Wall 3: Hardboard siding profile 2 (direct applied) with drainage mat (type 2) and SBPO

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Hardboard Wall Systems

Water Retention - Walls 1, 2 & 3 - Water directed to WRB

Time	Wall 1 H1/DA/SBPO	Wall 2 H2/Mat1/SBPO	Wall 3 H2/Mat2/SBPO
1 hour (peak reading)	372	368	446
Retained weight of water at 2 hours (g)	117	231	284
Retained weight of water after 48 hours (g)	35	156	229

Water Retention - Walls 1, 2 & 3 - Water directed to back face of siding

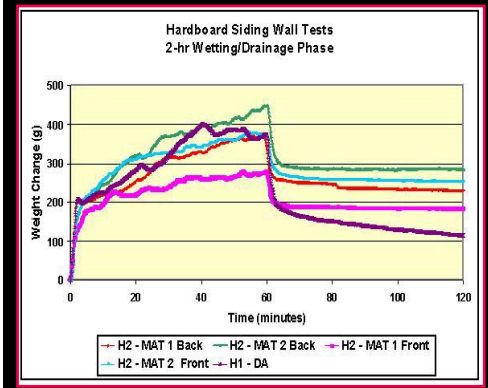
Time	Wall 1 (retest) H1/DA/SBPO	Wall 2 H2/Mat1/SBPO	Wall 3 H2/Mat2/SBPO
1 hour (peak reading)	383	276	371
Retained weight of water at 2 hours (g)	130	183	254
Retained weight of water after 48 hours (g)	0	109	221

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

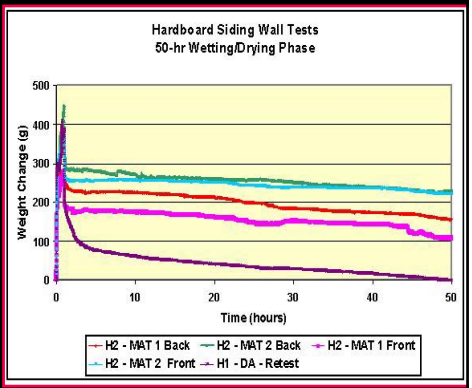
Drainage, Water Retention and Drying

Hardboard Wall Systems

Water Retention Curves - 2 hr



48 hr



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention & Drying

Hardboard Wall Systems

Observations

• Some of the water drained out below the first course of siding and down face of siding

• High initial retained water probably stored in drainage mats

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention & Drying

Wood Wall Systems

• Water retention values and curves

• Observations

•Wall 1: Wood siding profile 2 (direct applied) with SBPO

• Wall 2: Wood siding profile 1 (direct applied) with drainage mat (type 3) and SBPO

• Wall 3: Wood siding profile 2 (applied on 19mm wood battens) and SBPO

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Wood Wall Systems

Water Retention - Walls 1, 2 & 3

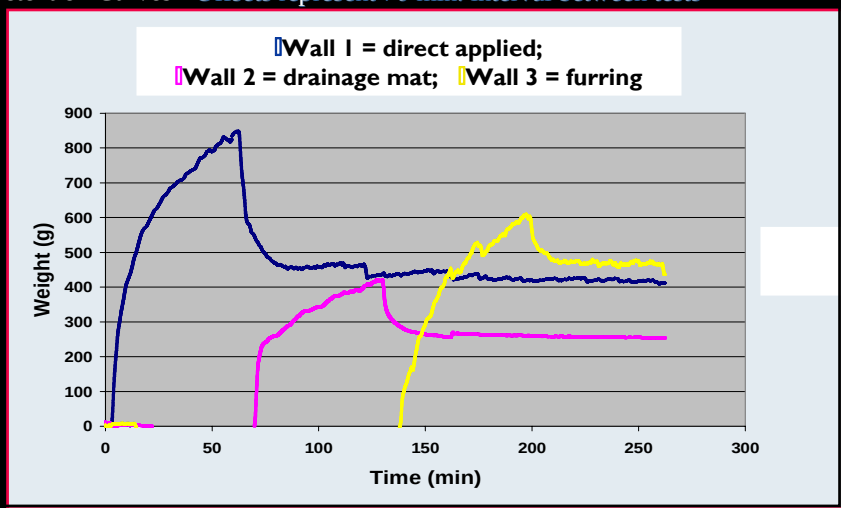
Time	Wall 1 W2/DA/SBPO	Wall 2 W1/Mat3/SBPO	Wall 3 W2/battens/SBPO
1 hour (peak reading)	842	415	603
Retained weight of Water at 2 hours (g)	426	260	467
Retained weight of water after 48 hours (g)	294	123	0

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Wood Wall Systems

Water Retention Curves - Offsets represent 70 min. interval between tests



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Wood Wall Systems

Observations

- Water drained out through first siding joint and down face of siding
- 1 hr water retention high
- 2 hr water retention substantial
- 48 hr water retention low

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Cement Board Wall Systems

- Water retention values and curves
- Observations

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying
Cement Board Wall Systems

Water Retention - Walls 1& 2

Time	Wall 1 Fiber Cement/DA/SBPO	Wall 2 Fiber Cement/DA/BP
1 hour (peak reading)	412	284
Retained weight of water at 2 hours (g)	340	197
Retained weight of Water after 48 hours (g)	50	0

- Wall 1: Fibre cement board (direct applied) with SBPO
- Wall 2: Fibre cement board (direct applied) with 15# building paper

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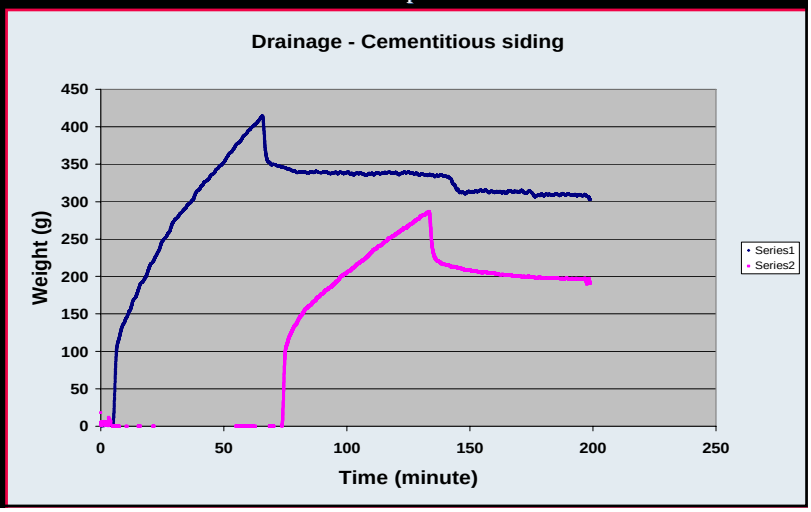
Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying
Cement Board Wall Systems

Water Retention Curves - Walls 1 & 2 - Offset represents 70 min. interval



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention and Drying

Cement Board Wall Systems

Observations

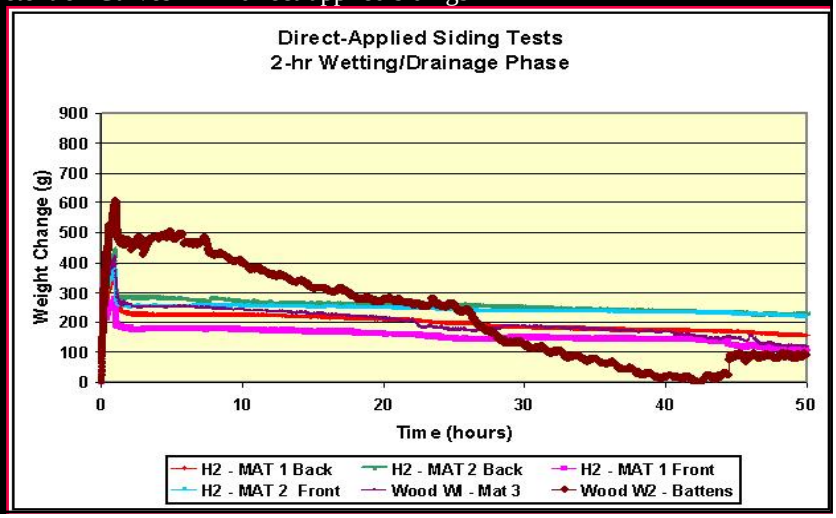
- Water drained out through first joint and down face of siding
- High initial retained water drained out almost completely by 48 hrs

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention & Drying

Direct Applied Wall Systems

Water Retention Curves – All direct-applied sidings



Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Drainage, Water Retention & Drying

All Wall Systems

Mat'l	#	Description	1 Hr gram	2 Hr gram	48 Hr gram
EIFS	1	Middle of drain space	267	196	86
EIFS	2	"	102	30	8
EIFS	3	"	282	189	115
EIFS	4	"	807	744	574
EIFS	5	"	504	385	223
EIFS	6	"	348	305	292
EIFS	1a	On WRB	215	139	101
EIFS	2a	"	117	24	61
EIFS	3a	"	235	109	51
EIFS	1b	On EPS	239	165	153
EIFS	2b	"	188	47	42
EIFS	3b	"	119	54	34
EIFS	4a	On WRB	178	54	19
EIFS	5a	"	134	35	0
EIFS	6a	"	419	95	28
EIFS	4b	On EPS	152	61	46
EIFS	5b	"	150	59	31
EIFS	6b	"	141	63	44

Mat'l	#	Description	1 Hr. grams	2 Hr. grams	48 Hr. grams
Vinyl	1	P1/DA/BP	698	364	283
Vinyl	2	P2/DA/SBPO	500	236	130
Vinyl	3	P2/DA/BP	282	189	115
Hard board	1	H1/DA/SBPO	372	117	35
Hard board	2	H2/Mat1/SBPO	368	231	156
Hard board	3	H2/Mat2/SBPO	446	284	229
Hard board	1a	H1/DA/SBPO	383	130	0
Hard board	2a	H2/Mat1/SBPO	276	183	109
Hard board	3a	H2/Mat2/SBPO	371	254	221
Wood	1	W2/DA/SBPO	842	426	294
Wood	2	W1/Mat3/SBPO	415	260	123
Wood	3	W2/Baten/SBPO	603	467	0
Cement Board	1	DA/SBPO	412	340	50
Cement Board	2	DA/BP	284	197	0

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Conclusions

- Laboratory conditions were sufficiently steady for drying of non EIFS walls
- Direct applied sidings leaked out through the joints and the water didn't drain all the way to the bottom of the wall
- Direct applied cement board siding showed high water retention at 2-hrs, but less than direct applied wood siding.
- Drying rate was high for most of the systems tested
- EIFS wall systems showed lowest water retention at 2-hrs.

CMHC SCHL

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Conclusions

• Over 90% of 8kg water drained through all samples during 1 hr wetting

• Water retained at 1 hr was between 842g (wood direct applied over SBPO) and 102g (EIFS)

• Water retained at 2 hrs was between 467g (wood on furring) and 24g (EIFS)

• Water retained at 48 hrs was between 294g (wood direct applied over SBPO) and 0 (EIFS, hardboard, wood on furring, cement board)

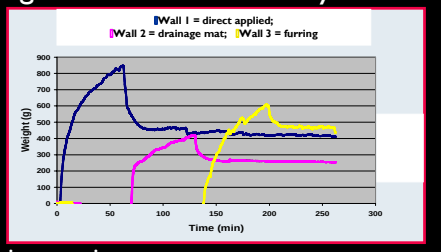
• We don't know exactly where water is retained in the wall system or whether this will cause a problem

• Drying rates were between 0.8 g/hr and 1.5 g/hr at 20°C and 50% RH

• Drainage mats & furring stored water in the short term but dried rapidly

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems

Next Steps



Measure how wall systems respond to successive wetting events

Determine how much water expected to enter wall systems during wetting events

Accurately measure and locate water in wall systems following a wetting event

Measure the effect of vapour and air permeability of sidings on the drying of walls

Model how quickly walls dry during different climate conditions (high humidity, fog)

Determine how much ventilation is needed to accelerate drying of wall systems in different climate conditions

Determine how much water can be safely stored in wall systems

Drainage and Drying: The Yin and Yang of Moisture in Wall Systems