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FIELD EXPOSURE OF WALLS FACILITY

GENERAL DESCRIPTION

NRC-IRC's Field Exposure of Walls Facility (FEWF) is located in Research House no. 3 at the NRC Montreal Road campus in Ottawa. The facility is used to assist the building industry in developing integrated solutions by providing opportunities for the characterization of the hygrothermal performance of innovative wall systems and retrofit strategies. Researchers can examine the comparative performance of different side-by-side wall assemblies exposed to naturally fluctuating outdoor climate and controlled indoor conditions of relative humidity, temperature and pressure. The data is used to benchmark hygrothermal modeling simulations using hygIRC 1D, and hygIRC-C (3D) for opaque walls. hygIRC-C is also used to assist the design, commissioning and analysis the experiments and results from the FEWF.

Institute/organisation:

National Research Council Canada
Institute for Research in Construction

Contact person:

Dr. Wahid Maref

1200 Montreal Road, Bldg M24

Ottawa, Canada

Tel: 613-993-5709

e-mail: *wahid.maref@nrc-cnrc.gc.ca*

Exact location:

Ottawa, Canada

45° 26' N, 75° 37' W

Overall lay-out

Three test bays in preparation.

The first floor of the West facade of the research house includes a test bay measuring 7.5 m wide by 3.2 m high test. It can accommodate one large specimen or several narrow specimens – typically 3 test bays per experiment – see Figure 1. Each bay is separated thermally with an insulated instrumentation cavity. Each experiment requires the full removal of the test bay and complete reconstruction, and re-instrumentation. Experiments typically last a full year. Wall specimen dimensions are not restricted to one size. Lightweight wood frame walls and massive wall specimens (e.g. insulating concrete form walls) have been studied.

Test bays nearing completion.

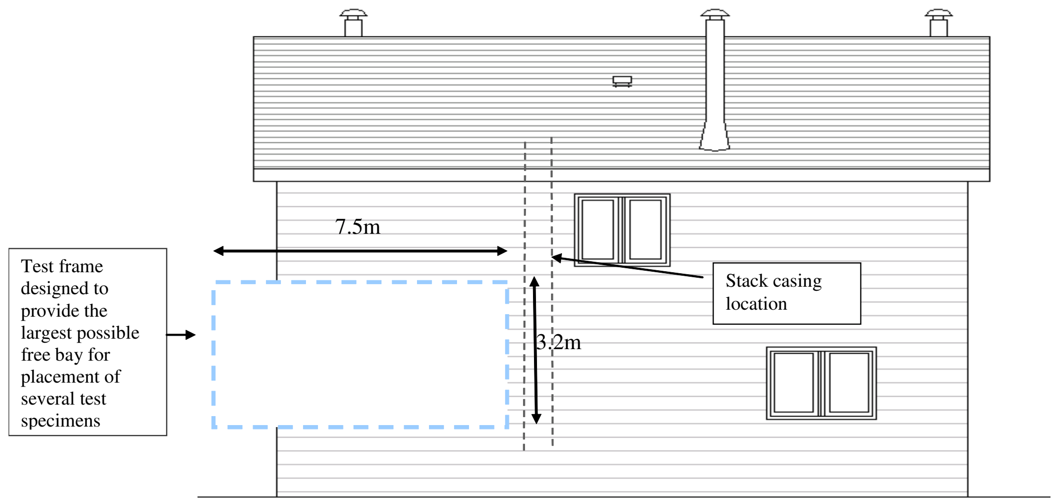
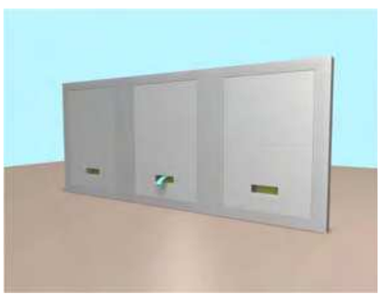


Figure 1. Schematic of the Field Exposure of Walls Facility (FEWF).



Slits in air barrier and wood sheathing allow exfiltration and infiltration.

Inside boundary conditions

To investigate the effects of an increase of indoor humidity levels on moisture content of wood-based materials, an indoor climatic chamber was constructed to introduce high humidity and increased air pressure levels on the interior side of Walls 2 and 3. Wall 1 was kept as a control wall, and exposed to uncontrolled indoor room conditions (i.e. low RH in winter). Pressure, humidity and temperature conditions were regulated and monitored throughout the field trial in the indoor climatic chamber.

Enclosure for control of interior Temperature, RH, and pressure.

As example the different walls were subjected to varying indoor conditions of relative humidity and pressure during the winter season. Four periods were selected for intensive analysis (labeled A to D respectively), as described in Table 1. To explore the potential for wetting and drying when varying the degree of air leakage across the wall assembly, the specimen air leakage characteristics were modified during testing to represent two levels of increased leakiness as compared to a perfectly airtight assembly.

Condition	Indoor Climatic Chamber		Opening in the air barrier system and drywall	Test period (2007)	Range of Outdoor T (°C)
	Pressure (relative to room air)	RH			
A	0 Pa	70%	None	11 Feb – 18 Feb	-24.5 to -3.3
B	5 Pa	50%	6 X 400 mm	22 Feb – 24 Feb	-14.3 to -4.6
C	5 Pa	~30%	3 X 400 mm	16 Mar – 17 Mar	-10.0 to -4.4
D	0 Pa	50%	3 X 400 mm	8 Apr – 15 Apr	-6.4 to 6.3

Table 1. Example of test schedule of different indoor and outdoor conditions.

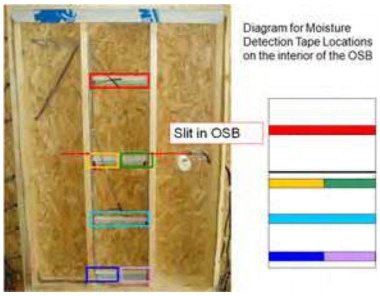
Outside boundary conditions

A rain gauge measuring the quantity of rainwater deposition in one area of the exterior face of the exterior siding is in place as well. Ambient outdoor parameters including temperature, relative humidity, wind speed and direction are measured by means of a weather station located 30 m from the research house.

Special limitations / possibilities

This flexible state-of-art research house enables not only evaluate the in-situ hygrothermal performance of exterior wall assemblies that have different wall assembly techniques, insulation systems and air and vapour barrier approaches, but enables as well comparison of various heating and ventilation strategies while evaluating energy usage and the quality of the resulting indoor environment. It also allows side-by-side rooms comparison in term of energy conception and thermal comfort. Automated 3-D indoor environment measurement systems (robots) are used to sample spatially distributed indoor environment parameters. The walls are exposed to the indoor conditions of the house and therefore will offer an opportunity to investigate interactions between wall moisture performance and indoor conditions produced by the various heating and ventilation systems.

DATA ANALYSIS



Moisture detection strips to track the path of condensation at the inner surface of the wood sheathing.

Typical equipment within test wall

Several monitoring instruments were used to characterize hygrothermal response in the different layers of the wall assembly. The middle stud cavity was designed to be the focus of the study, with the stud cavities on either side acting as a buffer zone. For this reason the majority of instrumentation was located in the middle stud of each wall, as shown in Figure 2. The instrumentation was deployed at four heights (Figure 3), with most sensors concentrated in the large area below the gap in the exterior sheathing - where it was assumed moist air exfiltration would lead to wetting.

Pressure sensors installed in the test specimens measured the differential air pressure between the pressure taps, at locations shown in Figure 2, and the ambient room pressure. Pressure taps were located in the top half of the middle stud cavity, 254 mm (10 in.) above the gap in the exterior sheathing.

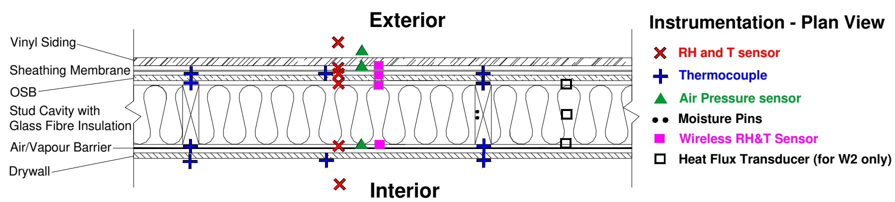
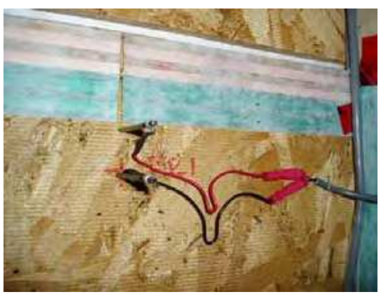


Figure 2. Plan view of wall cross section



Surface moisture detection destection strips and moisture pins.

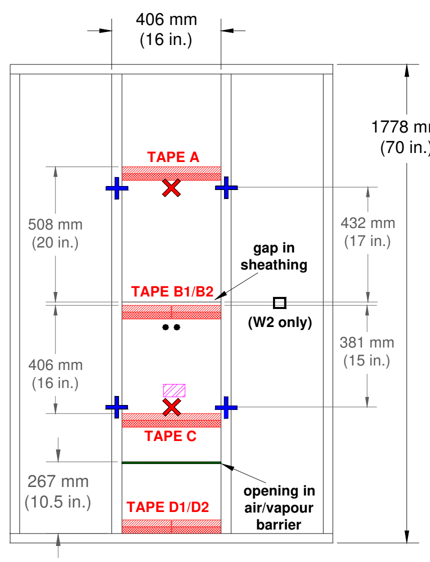


Figure 3. Liquid moisture detection strips.

Heat flux transducers.

Additionally, researchers deploy sensors of moisture content of wood-based materials and liquid moisture detectors on the surface of building materials in different internal layers of the wall specimens.

Accuracy and logging resolution

All sensor data is recorded at a 15-minute interval. Temperature was measured with an accuracy of ±0.1°C, while relative humidity measurements were accurate to ±0.5% The uncertainty of the heat flux measurements was ± 5%

Instrument	Manufacturer	Model	Measurement Range	Accuracy
Thermocouple (Type T)	Omega	TT-T-24-SLE	Max 200°C	±0.1°C
Relative Humdity	HoneyWell	HIH 3602C	0-100%	±0.5%
Heat Flux	HukseFluxUSA Thermal Sensors	PU11-T & PU32-T	-2000 to 2000 w/m^2	±5% of readings
Pressure Sensors	Setra	0.25"WC and 2.5"WC	Max 0.25" WC and 2.5"WC	±1% full scale

Table 2. Instrumentation accuracy.

Analysis of the data

The experimental methodology and instrumentation provided substantial insight into the hygrothermal performance of wall assemblies under varying conditions. The deployment of water detection tape proved valuable in confirming or not the presence of surface water at different layers through the wall when temperature and humidity conditions were favorable for condensation. The resulting wealth of data will aid in benchmarking numerical models, and in characterizing the response of the exterior walls to heat, air and moisture transfer.

EXAMPLES OF PREVIOUS STUDIES

Since 2006 the FEWF has been used to study side-by-side hygrothermal performance of wall assemblies. The most of the study focused on the effects of the different envelope characteristics on interstitial moisture accumulation. Examples of previous studies are:

1. Year 1 (2006-2007) Commission the facility by monitoring three identical test specimens of traditional construction (2x6) through Fall, Winter and Spring.
2. Year 2 (2007-2008) Partnership with Canada Mortgage and Housing Corporation (CMHC) and Natural Resources Canada (NRCan) to investigate the effects of two energy retrofit strategies on the wetting and drying potential of wall assemblies.
3. Year 3 (2008-2009) Partnership with FPInnovation (Forintek) to investigate the effects of the interior air/vapour barrier polyethylene membrane on the wetting and drying potential of wall assemblies and extending the project with CMHC & NRCan for one retrofit strategy.

4. Year 4 (2009-2010) Partnership with CMHC & NRCan to investigate the dynamic heat transmission characteristics through Insulated Concrete Form (ICF) wall assemblies over a full year cycle of weather exposure.
5. Year 5 (2010-2011) Project to Test the Next Generation Envelope Systems (i.e. Vacuum Insulated Panel) in partnership with CMHC and NRCan.

6. Year 6 and beyond Investigate the performance of wall specimens of different innovative designs based on industrial collaboration/partnership.

MAINTENANCE / COLLABORATION

Personnel involved

The Research House is maintained by Technical staff and Managed by Research Officers of the National Research Council Canada's Institute for Research in Construction (NRC-IRC) from two programs: Indoor Environment (IE) and Building Envelope and Structures (BES).

International collaboration

There is currently no specific international collaboration. The facility is currently used in partnership with industry and with other Canadian Government Agencies.

Envelope Environmental Exposure Facility (EEEF)

Twin Houses at the Canadian Centre for Housing Technology

Link with other devices

The study of hygrothermal behaviour of building envelopes under real climatic conditions as performed in the FEWF is one of the facilities of the Heat, air and Moisture Performance of Envelope (HMPE) group. In addition to the field measurements HMPE investigates specific aspects of thermal behaviour of wall systems in the Guarded Hot Box apparatus as well at the Environmental Exposure Envelope Facility (EEEF) climatic chamber and Dynamic Wall Test Facility (DWTF) for water penetrations. In these facilities, the building envelope is subjected to controlled boundary conditions (Interior and Exterior). This will give better insight of the interstitial condensation and hygrothermal performance. The measurements are used to benchmark the State-of-The-Art hygrothermal CFD package tool hygIRC-C developed by NRC-IRC. For whole-house energy and moisture assessment studies, the team also collaborates with the Canadian Centre for Housing Technology (CCHT), operated as a partnership between National Research Council Canada, Canada Mortgage and Housing Corporation and Natural Resources Canada.

RELEVANT LITERATURE

General literature about the test facility:

- Client Report "Evaluating The effects of Two Energy Retrofit Strategies For Housing on The Wetting and Drying Potential of Wall Assemblies", W. Maref, M. Rousseau, M.A. Armstrong, W. Lei, M. Leroux and M. Nicholls, Nov 2009, PP 1-118.
- Client Report "The dynamic heat transmission characteristics through Insulated Concrete Form (ICF) wall assemblies over a full year cycle of weather exposure", W. Maref, H. Saber, M.A. Armstrong, M.Z. Rousseau, C. Thivierge, G. Ganapathy, M. Nicholls, F. Lalumiere and K. Abdulghani, 2011.
- Client report "Effects of the Interior Air/Vapour Barrier Polyethylene Membrane on the Wetting and Drying Potential of Wall Assemblies", W. Maref, M.Z. Rousseau, M.A. Armstrong, C. Thivierge, G. Ganapathy, M. Nicholls, F. Lalumiere and K. Abdulghani, 2011, PP 1-100

Literature on previous measuring campaigns:

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- **Hygrothermal Response of Different Wall Assemblies to Water Ingress**, C. Thivierge, W. Maref, M. Armstrong, G. Ganapathy, M. Nicholls and M.Z. Rousseau, Submitted to 13th Canadian Conference of Building Science and Technology, May 2011, Winnipeg, Canada.
- **Field Monitoring of Wetting and Drying in Wood Frame Wall Assemblies in Cold Climate**, W. Maref, M. Armstrong, M.Z. Rousseau, C. Thivierge, M. Nicholls and W. Lei, Submitted to 13th Canadian Conference of Building Science and Technology, May 2011, Winnipeg, Canada.
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- **Field monitoring of energy-retrofitted wall assembly in cold climate: impact of the vapour permeance of exterior retrofit insulation on the flow of moisture in wood-frame wall** Maref, W.; Armstrong, M.M.; Rousseau, M.Z. ASHRAE Seminar no. 48 on

"Solving Moisture Problems Created by Energy Efficient Design" (Albuquerque (NM) USA 2010-06-30)

- **Effect of the air and vapor permeance of exterior insulation on the flow of moisture in wood frame walls in a cold climate** Armstrong, M.M.; Maref, W; Rousseau, M.; Lei, W.; Nicholls, M.ICBEST 2010 - International Conference on Building Envelope Systems and Technologies (Vancouver, Canada 2010-06-27)
- **A field monitoring investigation of the effect of adding different exterior thermal insulation materials on the hygrothermal response of wood-frame walls in a cold climate** Maref, W.; Armstrong, M.M.; Rousseau, M.Z.; Lei, W. BEST2 Conference (Building Enclosure Science & Technology) (Portland, (OR), USA 2010-04-12) pp. 1-15.
- **Workshop on Moisture Management and Energy Rating in Building Envelopes / Part II : Effects of two energy retrofit strategies on the wetting and drying potential of wall assemblies** Maref, W.; Armstrong, M.M.; Rousseau, M.Z. 12th Canadian Conference of Building Science and Technology (Montreal, QC 2009-05-06)
- **A field monitoring study of interstitial condensation in wood-frame walls in cold climate** Armstrong, M.M.; Maref, W.; Rousseau, M.Z.; Lei, W.; Nicholls, M. 12th Canadian Conference on Building Science and Technology (Montréal, Quebec 2009-05-06) pp. 1-12.
- **Effects of exterior insulation retrofit on moisture accumulation in wood-frame exterior walls (Poster)** Rousseau, M.Z.; Maref, W.; Leroux, P.; Armstrong, M.M. pp. 1. 2008-10-01
- **Recent experiments conducted in NRC-IRC moisture management facility** Rousseau, M. Z.; Maref, W.; Armstrong, M.M.; Lei, W.; Nicholls, M. *Construction Innovation,* 13, (3), pp. 7. 2008-09-01 Complete citation
- **Étude sur la performance hygrométrique des murs menée dans une installation d'essais à l'IRC-CNRC** Rousseau, M. Z.; Maref, W.; Armstrong, M.M.; Lei, W.; Nicholls, M. *Innovation en construction,* 13, (3), pp. 7. 2008-09-01
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- **Ventilation and wall research house** Maref, W.; Ouazia, B.; Reardon, J.T.; Rousseau, M.Z. Performance of Exterior Envelope of Whole Buildings X Conference (Clearwater, Florida 2007-12-01) pp. 1-8. 2007-12-01
- **New field testing facility at NRC-IRC offers opportunities for wall performance assessment** Maref, W.; Rousseau, M.Z. *Solplan Review,* (135), pp. 18-19. 2007-07-01
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