RESEARCH HIGHLIGHTS

Technical Series 96-214

A Study of the Rainscreen Concept Applied to Cladding Systems on Wood Frame Walls

Introduction

Rain penetration is one of the oldest problems building owners have had to deal with, yet it still occurs all too frequently. The penetration of rain can not only damage interior finishes and materials, but it can also damage the structure of walls themselves. One approach to controlling rain penetration, first introduced in the early 1960s, is the pressure-equalized rainscreen design. The theory of pressure-equalized cladding is that air flows into the cavity behind the exterior cladding equalizing the cavity pressure with the wind pressure and thus, minimizing the force (wind pressure) that causes most rain penetration. Previous research has shown that there is a time lag between the application of the wind load and pressure equalization in the cavity. As a result of this time lag, a pressure difference does occur across the exterior cladding. For the rainscreen concept to be effective, this time lag should be as short as possible. Therefore, when the performance of a rainscreen wall is examined, one of the primary factors considered is time to equalization; the longer the time to equalization, the more rain is likely to penetrate. Another consideration is the load applied to the exterior cladding; the higher the load, the larger the driving force moving rain to the interior.

Research Program

This study was undertaken to better understand and predict pressure equalization performance. The study consisted of three parts. In the first part, the performance characteristics of several rainscreen claddings applied to a wood frame wall were examined in a laboratory. The second part of the study involved an investigation of compartmentalization requirements through the use of a full scale model installed in a wind tunnel. The third part involved the development of a simulation model to predict the pressure equalization performance of various types of exterior cladding and wall systems when subjected to gust loading situations.

Laboratory Testing of Wood-Frame Rainscreen Walls

Test Walls

The exterior claddings studied are shown in Table 1. Each was tested with a sealed polyethylene air barrier (fastened with battens and tape) then with airtight gypsum board, for a total of 12 test configurations. The claddings were mounted on wood framing consisting of 38 mm x 89 mm wood studs on 405 mm centres. The 2.4 m square test walls were mounted in an environmental test chamber with the cladding positioned to the interior of the test chamber (Figure 1). All samples had a measured air leakage rate of less than 0.01 L/m^2•s at a pressure difference of 75 Pa, after accounting for extraneous chamber leakage.

Table 1. Exterior Claddings Tested

1	Vinyl Cladding, Building Paper, Fibreboard
2	Vinyl Cladding, Furring, Building Paper, Fibreboard
3	Vinyl Cladding, Building Paper, Fibreboard, Tyvek, Fibreboard
4	Stucco, K-lath, Building Paper, Fibreboard
5	Stucco, K-lath, Building Paper
6	Brick Veneer, 1"Air Space, Building Paper, Fibreboard

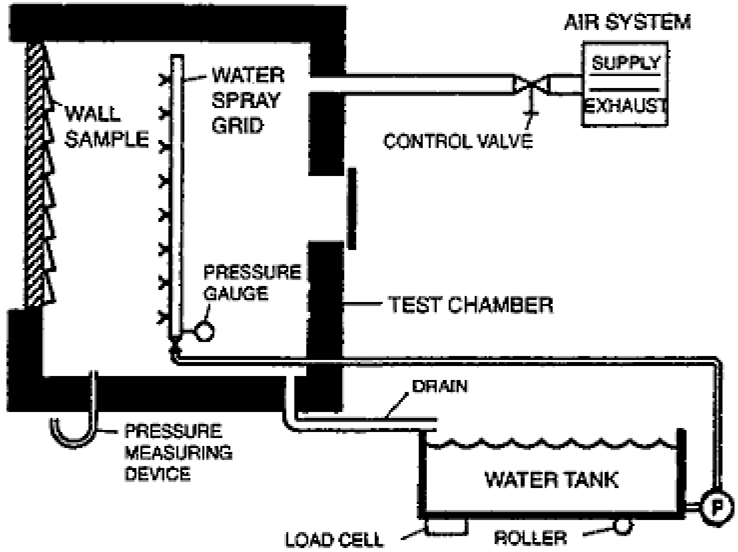

Figure 1. Section Through Test Chamber Showing General Water Leakage Test Setup

Water Test

The water test was adapted from the procedure in ASTM E-331. A rain rack inside the chamber applied water to the test wall at a rate of 5 US gal.hr.ft^2 while the pressure difference across the wall was maintained at 250 Pa. The water to the spray rack was supplied by a high pressure pump and a reservoir located under the chamber (Figure 1). Excess water returned to the reservoir. Load cells were used to record the change in weight of water in the reservoir, indicating the amount of water lost through the test wall. The water test was run for a period of approximately 60 minutes, to allow a steady state condition to be achieved. The air barrier was then changed from airtight to leaky, by unplugging a one-inch diameter hole in the polyethylene or gypsum, to demonstrate the effect on water absorption of a non-pressure-equalized system. The test then continued until steady state conditions were again achieved.

The vinyl-clad wall absorbed less than 0.8 L/min for the duration of the test. The rate of water absorption did not change noticeably when the air barrier was unsealed. This was found to be a result of the fibreboard sheathing and building paper providing much of the resistance to the air pressure; as a result, the space directly behind the vinyl siding between the siding and the sheathing acted as the cavity and the vinyl siding was effectively pressure-equalized throughout the test.

The rate of water absorption of the stucco wall was approximately 0.2 L/min. When the air barrier system was unsealed, a pressure difference of about 150 Pa was noted between the wall cavity pressure and the chamber pressure. However, there was no difference in the rate of rain penetration. It was determined that the water penetration of the stucco wall was limited to the absorption characteristics of the stucco material because there were no cracks or joints for water to penetrate.

The absorption rate for the brick veneer cladding was about 0.53 L/min until the air barrier was unsealed. After unsealing, the absorption rate was well over 1.5 L/min for the first 10 minutes, gradually tapering off to about 0.84 L/min, with an average pressure difference of 130 Pa across the brick cladding. The pressure difference across the cladding was approximately half of the applied load, meaning that the wall was still approximately 50% pressure equalized. But even with that level of equalization, the absorption rate was high, demonstrating the importance of an airtight air barrier and the importance of maintaining a high level of pressure equalization.

Gust Load Tests

Gust loads tests were conducted to investigate the pressure-equalized response of the wall systems. To conduct the gust load tests, a dual chamber test setup was used (Figure 2). The chambers were kept at different pressures, then by rupturing a membrane in the bulkhead between the chambers, a sudden gust of pressure was produced. The tests were undertaken for positive and negative pressures. Various rates of loading were achieved by using various orifice plate sizes.

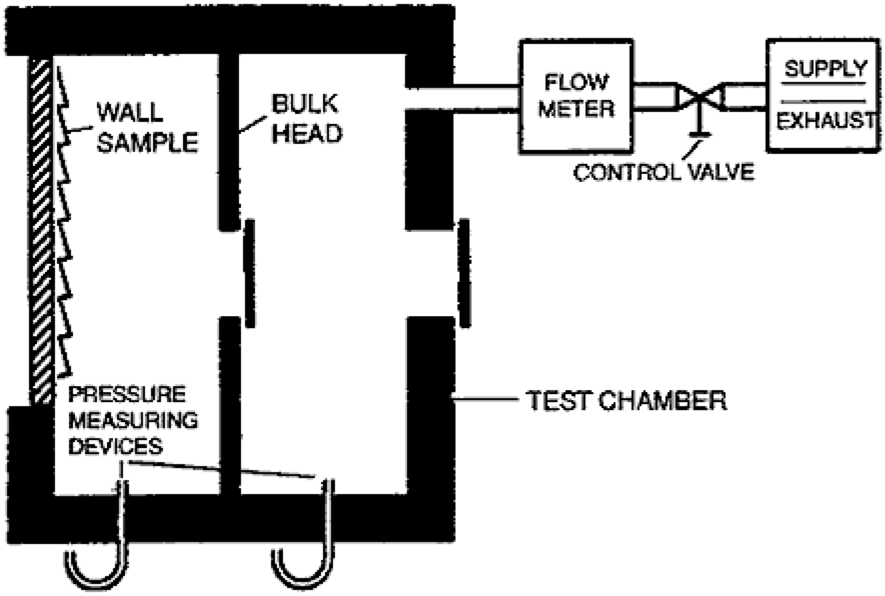

Figure 2. Section Through Test Chamber Showing General Air Leakage and Pressure Equalization Set-up

It was found that most of the gust pressure is carried by the air barrier, with a low air pressure difference carried by the sheathing and almost no pressure carried by the cladding. However, the brick veneer experienced significantly higher pressures compared to the vinyl-cladding due to the smaller venting area of the brick. The following was also noted:

1. the level of pressure carried by the outer layers increased as the gust rate increased;
2. the level of pressure carried by the air barrier decreased as the air leakage of the wall increased; and
3. there was no significant difference between negative and positive pressure performance for the brick wall, but the pressure carried by the sheathing in the vinyl siding walls was higher for the negative tests.

Compartmentalization Tests

The cavity in a pressure-equalized rainscreen wall must be compartmentalized to prevent the lateral flow of air behind the cladding which may prevent pressure-equalization from occurring. To investigate the air and wind pressure distributions with and without compartmentalization of the cavity, a full-scale model was tested in a wind tunnel at the Boundary Layer Wind Tunnel Laboratory at the University of Western Ontario. The model was square, 1.22 m per side by 1.22 m high, constructed of 38 mm x 89 mm studs at 406 mm on center with vinyl siding over building paper and fibreboard sheathing, and finished with an interior gypsum board air barrier. The corners of the model were constructed to permit easy connecting and disconnecting of the wall cavities, thus allowing various combinations of compartmentalization to be analyzed. The model was instrumented with pressure taps throughout the construction, including in the stud cavity and in the cavity behind the vinyl siding. The model was situated facing the wind and at a 45° rotation to the wind for the following compartment configurations:

1. fully compartmented cavity;
2. continuous cavity through the stud space;
3. diagonal compartments;
4. single windward compartment with other three stud spaces connected; and
5. single leeward compartment with other three stud spaces connected.

When fully compartmented (Figure 3), the wind load was found to be about 2% on the vinyl cladding, 29% on the sheathing, 101% on the gypsum board, 170% on the inside compartment seal (within the stud space), and 213% on the outer compartment seal (in the cavity space). When rotated 45°, there was a slight reduction in the load on the gypsum air barrier and the compartment seals. When the cavity was continuous, the air barrier experienced a maximum wind load of 15%, while the exterior sheathing and building paper supported 150% of the wind load. When rotated 45°, the pressure in the cavities varied less than the normal orientation, but a significant load appeared at the siding compartment seals.

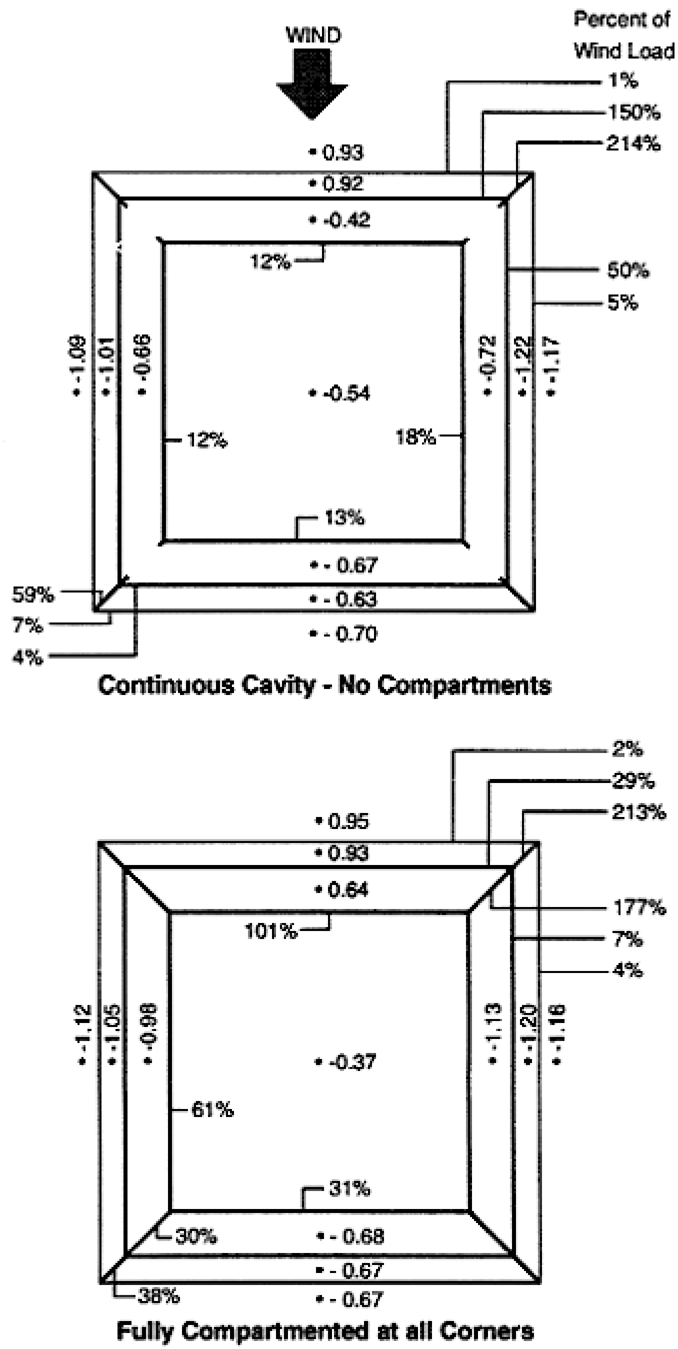

Figure 3. Results of Compartmentalization Tests with Wind at a Zero Degree Angle to Front Face

When the cavity was divided diagonally, the cladding load was less than 20% of the full wind load in all cases. The loads on the compartment seals were large except when the wind direction was in line with the sealed compartments.

There was no effect on the adjacent cavities when only the rear elevation was compartmentalized. When only the front elevation was compartmentalized, the sheathing and air barrier exhibited a high load while the remainder of the elevations exhibited a lower pressure difference from outside to inside.

The results of the test confirm that compartmentalization of the wall cavities tends to transfer the pressure load to the air barrier system. Also of note was that the test results indicate that compartment seals should be designed to withstand loads in excess of two times the winddesign load. In the non-compartmentalized test, the pressures were dissipated around the cavities which would tend to entrain moisture.

Simulation Model
This study undertook to develop a simple mathematical model that simulates the pressure equalization performance of a rainscreen wall. The model was developed using the basic gas laws for pressure, temperature and volume. It was designed to predict the cavity pressure and time response of the cavity for various gust load rates and magnitudes. The parameters used for the simulation of a particular wall type included: the vent area, the air barrier leakage area, the volume of the cavity, the stiffness of the air barrier and the stiffness of the cladding. The computer program which was developed, called RAIN, is available on disk from CMHC*.

The model was validated by comparing its results to the measured performance of a glass and metal curtain wall system. While there was a noted difference in the slope of decay between the measured and the simulated results, the peak loads and time to equalization were approximately the same under similar loading conditions.

To demonstrate the use of the program and the effect of changing the input parameters, a number of example simulations involving rapid depressurization were executed using parameters typical of a brick veneer wall, with the following results:

1. increasing the initial volume significantly increased both the peak load on the cladding and the time to equalization (Figure 4);
2. increasing the flexibility of the cladding reduced the peak load on the cladding but increased time to equalization;
3. increasing the flexibility of the air barrier increased both the peak load on the cladding and the time to equalization;
4. increasing the vent area (cladding leakage) reduced both the peak load and the time to equalization; and
5. increasing the leakage through the air barrier decreased the peak load and slightly increased the time to equalization (in a pressure buildup condition, leakage through the air barrier would have the reverse effect).

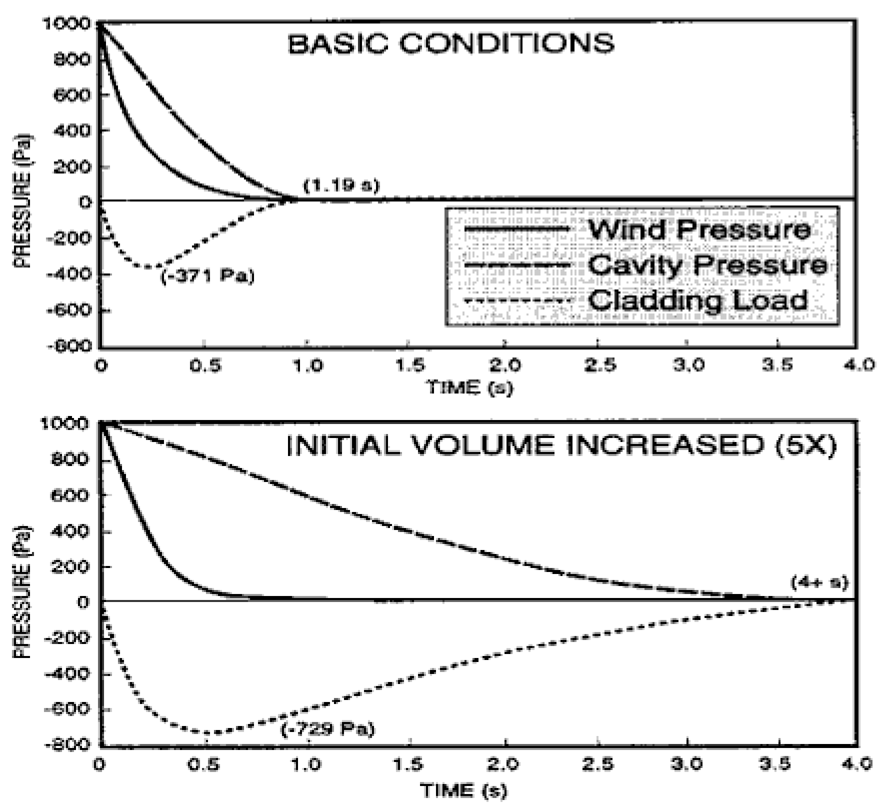

Figure 4. Pressure Equalization Graphs

Implications for the Housing Industry

The rainscreen wall concept was demonstrated as a viable solution to water penetration control, particularly in the case of brick veneer walls. Also demonstrated was the importance of an airtight air barrier and compartmentalization. An unexpected observation was the airtightness and structural support provided by the fibreboard sheathing and building paper in the vinyl-clad and stucco wall systems. This result points to the need to consider the air permeability of all construction materials in the performance of a rainscreen wall design.

The dynamic load testing illustrated that the air barrier must be designed to carry the full wind load pressures and that due consideration must be given to the gust strength factor. It was also found that whether a wall was negatively or positively pressurized from a gust, the loads on the air barrier and other components of the wall are approximately the same.

Through the computer simulations, the stiffness of the cladding and air barrier were found to have a significant effect on the distribution of gust wind loads. It is recommended that the air barrier be as stiff as possible and that the cladding should have a lesser stiffness than the air barrier to minimize the pressure difference across the cladding.

* ***To download a copy of the RAIN computer disk, click HERE at CMHC at (613) 748-2013.***

Project Manager: Jacques Rousseau

Research Report: *A Study of the Rainscreen Concept Applied to Cladding Systems on Wood Frame Walls*

Research Consultant: Morrison Hershfield Limited

A full report on this research project is available
from the Canadian Housing Information Centre.