RESEARCH HIGHLIGHTS

Technical Series 99-117

DRYING OF WALLS WITH VENTILATED STUCCO CLADDING

PARAMETRIC ANALYSIS

Introduction

Moisture destroys wood framing when levels remain high enough to promote fungal growth and decay for long periods. Walls with minimal air leakage, rain penetration and condensation can still have problems if moisture cannot escape. Measures taken to prevent leakage and condensation, and to keep materials dry during construction, are ineffective without adequate provisions for subsequent drying.

Experiments conducted to date with wall systems similar to those most used in the coastal climate of B.C. have shown very slow rates of drying in simulated winter conditions. A drained, ventilated space behind stucco has been suggested as a solution, both to control rain penetration by acting as a rainscreen and to increase drying to the exterior. Laboratory experiments are planned to verify if this effectively promotes drying.

So many variables are involved that it is not simple to design experiments to discover the best strategy for employing a vented space without testing an unreasonable number of cases. The computer model used in the current study permitted a large number of possibilities to be considered. It helped to identify the most important parameters, and predicted the expected performance of particular designs under specified test conditions. This information will be used to design experiments that will validate the model as a design tool, if the predictions are confirmed, without having to test all the possible combinations.

Investigation

The objectives of the study were:

- to study varying vent cavity depth
- to study restriction of vents from the ventilation cavity to the exterior
- to rank, by drying ability, different assemblies subjected to identical simulated steady state winter temperature and humidity conditions.
- to assess drying under these conditions when the vapour barrier is omitted.

In addition, wood and vinyl siding were compared to stucco in a limited number of cases. Over 342 simulations of different walls were conducted. The model used was a modified version of WALLDRY, a program developed for CMHC in 1988, and subsequently modified to account for air infiltration and exfiltration, sorption isotherm algorithms for materials other than solid wood and vapour diffusion properties that vary with moisture content.

The model does not include liquid mass transfer by capillary diffusion. None of the simulations included air leakage. Although variations in resistance to vapour diffusion with different moisture contents are accommodated for some materials, thermal conductivity of materials is assumed constant, irrespective of moisture content. The model has not yet been compared with more comprehensive computer models. However, it has been compared with the field results of walls exposed to climate in the Atlantic provinces and Ontario. The conditions modeled for this report represent winter-like conditions in Vancouver without wetting of exterior surfaces by rain. One must keep in mind that walls that appear to perform well in the simulations (or in the laboratory) might experience problems in summer conditions depending on the climate and indoor conditions.

Test Walls and Conditions

The basic wall simulated consisted of:

- 12.7 mm gypsum board
- 0.15 mm (6 mil-0.006 in.) polyethylene vapour barrier
- 38 x 89 mm framing, at 406 mm centres, all with initial 35 per cent moisture content at the surface and 25 per cent at the core
- glass fibre insulation

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- 12.5 mm OSB sheathing, with initial 25 per cent moisture content
- 2 layers of “30 min.” building paper
- 0 to 38 mm ventilated cavity with various venting arrangements
- 21 mm stucco cladding, permeable or impermeable, with an initial moisture content in equilibrium with the chamber (in most cases around 0.9 per cent).

After initial exploration, a parametric plan was settled upon to answer the following questions:

Assuming the stucco is decoupled from the wall system; that is, the interior surface of the stucco is impermeable and non-absorbent:

1. what is the influence of ventilation cavity depth and ventilation gap dimensions?
2. what is the influence of exterior RH on drying rates?
3. what is the influence of exterior temperature on drying rates?

Assuming the stucco is coupled to the wall system; that is, the stucco is permeable and absorbent:

4. what is the influence of the chamber RH on the drying rates of walls when the stucco is permeable? How much moisture will be removed by diffusion through the wall assembly compared to that by venting?

In general:

5. What difficulties will be encountered in the laboratory because of moisture redistribution, when overall weight is used to measure drying?
6. What are the moisture loss distributions in the walls, and the moisture gradients in different elements of the walls?
7. What happens when the ventilation gap at the top is closed?
8. What effect does simulated wind have on drying rates?
9. What difference is there in drying rates when plywood is used instead of OSB?
10. What is the effect of using 38 x 140 mm framing instead of 38 x 89 mm?
11. What is the effect on drying when the polyethylene vapour barrier is omitted?
12. How does the drying of walls with vinyl and wood siding compare with walls clad with stucco?

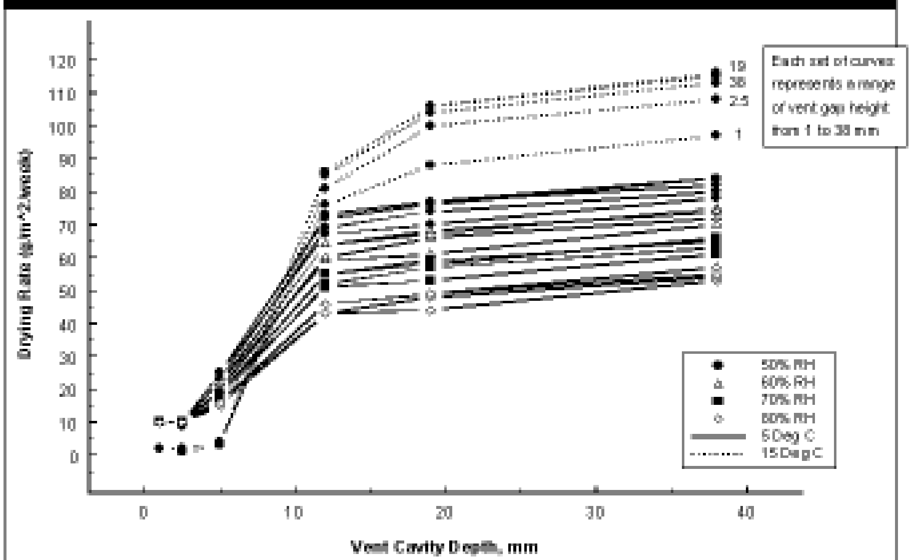
Most simulations were run for 150 days, not enough in most cases to reach equilibrium conditions, but enough to provide predictions for comparison with laboratory results.

The model was also used to predict the effects of different experimental conditions and procedures. Lower temperatures and humidity on the cold side can decrease the time required to conduct an experiment. If validated, the model can then be used to predict drying rates when cold side conditions are more or less favorable for drying. Predicted overall weight loss was shown to be an unreliable indicator of moisture content change of the framing, because of confounding changes in moisture stored in the stucco and other materials.

Findings

The answers to the questions posed are too numerous and detailed to be presented fully in this summary. Some specifics are presented below, and the most important implications are described under the heading “Significance for the Housing Industry”.

Figure 1
Effects of Ventilation Parameters, Exterior RH, & Exterior Temperature on Drying Rate



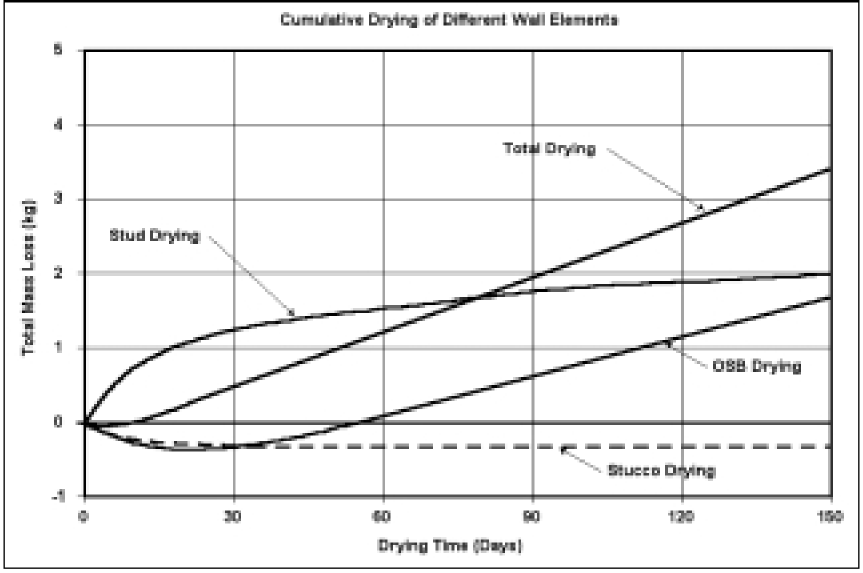
Questions 1, 2 and 3 The effects, with impermeable stucco, of vented cavity depth, vent opening height, chamber relative humidity, and chamber temperature, are shown in Figure 1. Vented cavity depth is more important than any other variable in determining drying rate. Vent opening height is less significant, and the highest drying rate does not always occur when the gap is largest. Increased exterior temperature increases drying rate, but only as long as the cavity is 12 mm or more in depth. Higher exterior relative humidity reduces drying rates.

Question 4 With permeable stucco, drying rates increase substantially overall, compared to stucco materials or systems that prevent drying by diffusion through the stucco.

Question 5 In an experiment, the stucco may be in equilibrium with the laboratory conditions where the wall was stored. Then, when exposed to the test chamber conditions, the test wall faces a new set of environmental conditions, and an increase in weight may occur as the wall reaches equilibrium with the new conditions. This can be seen in Figure 2 where the stucco starts out with a low moisture content and gets wetter by transfer of moisture from the wall behind and the atmosphere of the chamber. The total mass of the wall increases for a time before a net moisture loss is registered. This can confound interpretation of weight loss from the sensitive elements of the wall unless they can be determined independently of overall weight loss.

Question 6 As drying proceeds, moisture gets redistributed within the wall. Warmer elements dry rapidly at first, but the sheathing and stucco increase in moisture content. The sheathing eventually dries as moisture is removed from the wall, but the stucco arrives at a moisture content in balance with the moisture in the cavity air and exterior air (with a constant rate of diffusion of moisture through the stucco as long as total drying rate remains constant). In the 150 days of drying shown in Figure 2, only the studs lose enough moisture for their rate of drying to tail off.

Figure 2
Drying with Permeable Stucco, 19 mm Cavity, Exterior at 5 deg C & 70% RH



Question 7 While closing off the top of the cavity reduces drying by ventilation, even a small (1mm) gap at the top is beneficial in assisting removal of moisture from the wall.

Question 8 The simulated wind actually reduced the drying rate. Wind-induced flow through the ventilation cavity lowered the air temperature and increased the RH, reducing drying potential by ventilation. Because of the low (and steady) pressure difference from bottom to top (1 Pa) the flow was laminar and relatively slow. Turbulent flow in the cavity and fluctuating winds might promote drying.

Question 9 The interpretation and analysis of the simulations comparing the drying potential of OSB and Plywood sheathed wall systems is complicated by the initial sheathing moisture contents. Starting with 25 per cent moisture content on a dry weight basis in the sheathings, the higher dry mass of the OSB results in more moisture load in the sheathing than that of plywood. At the end of a five-month simulation under neutral pressure and no wind, the sheathing in a plywood sheathed wall was drier than in an OSB sheathed wall, and so was the wood framing. With more moisture to be removed, more time is required to reach the same moisture level. This may not hold for all plywoods and all OSB, however, since the properties of these products may vary from what was assumed.

Question 10 If the initial moisture contents of the framing are the same, a 38 x 140 mm framed wall will contain 57 per cent more moisture than a 38 x 89 framed wall because of the larger volume. In the conditions simulated, the inner surface of the sheathing increased in moisture content for 20 days, at which time it reached saturation. It remained saturated for another 70 - 80 days before starting to dry again, not reaching the initial 25 per cent moisture content even after 150 days. Overall (through the entire thickness) the sheathing gained moisture for about 100 days, although the studs, the outer surface of the sheathing, and the overall wall assembly lost moisture continuously from the beginning. With 38 x 89 framing, the pattern of drying is similar, but the maximum moisture content of the inner surface of the sheathing is less, and it returns to initial moisture content sooner.

Question 11 Drying of the wall with no interior vapour barrier (polyethylene sheet or vapour retardant paint on gypsum board) was substantially faster than drying of the same wall with a vapour barrier; more than twice the amount of moisture left the wall assembly. At the end of 150 days of simulation, the 'no-poly' wall showed that the studs had dried to near equilibrium at around 12 per cent, the inner surface of the sheathing had dried to equilibrium at around 14 per cent, and the stucco had begun to dry in comparison with the 'poly' wall which showed 15 per cent in the studs, 23 per cent moisture content on the inside surface of the sheathing and relatively no drying in the stucco. The 'no-poly' simulation also showed that during the initial stages of drying, the inside of the sheathing increased in moisture content for less than 10 days before reaching it's initial moisture content of 25 per cent again in comparison with 120 days required by the 'poly' simulation.

Significance for the Housing Industry

Pending validation of the model by comparing laboratory test results with model predictions, the conclusions stated here should be helpful to designers in devising walls that can dry after getting wet, before decay takes over. While not all of these predictions will be tested, if the model accurately predicts laboratory observations, it will be reasonable to assume that the untested predictions are valid. The significant findings are:

- Vent cavity depth is more important than any other variable considered, including the size of vents. Drying is substantially reduced in the absence of a cavity between the back of the stucco and the sheathing membrane.

- Drying rates under steady-state conditions are higher when drying can occur by diffusion through the stucco in addition to venting. If the stucco is finished with an impermeable coating, or separated from the cavity by an impermeable backing, drying rates by diffusion are reduced.
- Complete closure at the top of the vented cavity slows drying considerably, however a gap of as little as 1 mm is sufficient for drying rates to approach those that would occur with top and bottom vents of equal area.
- Elimination of the interior vapour barrier greatly accelerates initial drying, provided that interior painting is delayed. (However, subsequent problems with leakage or condensation might arise, since the vapour barrier protects the back of the drywall from moisture in the stud space.)
- Vinyl siding will retain moisture in the wall longer than permeable stucco. However the predicted result might be different with better characterization of the effective leakage characteristics of vinyl siding. (It was modeled without considering the venting effects of edge details, venting at top or bottom, vent holes, joints, or pumping action when wind flexes the siding).
- Painted wood siding with back priming applied in direct contact with the sheathing membrane retards drying as much as vinyl. In addition, the siding itself will eventually become wet enough to cause deterioration, under the conditions simulated. Drying of the wall was good when wood siding was applied to strapping, with the resulting cavity vented to the exterior at the bottom, and with minimal venting at the top. The siding then remains dry as well.
- The rate of flow of moisture from the wall is controlled by the sheathing. Plywood sheathed walls probably dry more rapidly than OSB sheathed walls, based on published material properties. However, since the actual properties of OSB vary from one manufacturer to another, it may not be possible to firmly generalize this conclusion.
- Initial moisture in walls framed with 38 x 140 mm studs takes longer to escape than from walls framed with 38 x 89 mm studs having the same moisture content based on the dry weight (because there is more moisture in the lumber to begin with).
- While drying is underway, the interior face of the sheathing will be much wetter than the exterior face, with a steep moisture content gradient through the thickness. There will also be vertical moisture gradients in the sheathing due to the manner that moisture escapes at the top of the ventilation space, if there is one.
- Under the simulated laboratory test conditions, wind retarded drying, because the temperature in the vented cavity was lower, reducing the drying potential between the cavity and the exterior. This may change under real weather conditions due to local heating by sunlight and by venting.
- Finally, it must be kept in mind that the simulations have been run under steady-state conditions. The drying performance of wall assemblies under actual weather conditions may vary.

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Research Report: Drying of Walls with Ventilated Stucco Cladding: A Parametric Analysis March 31, 1999

Research Consultant: DMO Associates

A full report on this project is available from the Canadian Housing Information Centre at the address below.

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