Field Monitoring of Wall Vapor Control Strategies in the Pacific Northwest

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ABSTRACT

A twenty-seven month field test comparing the performance of a variety of vapor control layers was conducted in a full-scale test facility in the marine climate of Olympia, WA. The vapor control layers included latex paint on drywall, polyethylene film, Kraft paper, and a variable-permeance polyamide film. One goal of this testing was to compare performance with the most recent building code recommendations. A data acquisition system recorded hourly indoor, outdoor and stud bay temperature and RH measurements as well as wall framing and sheathing moisture contents. The long-term data show seasonal wetting and drying of the assemblies. The latex-paint-only wall exterior sheathing moisture contents were found to be the highest, reaching or exceeding 22% during all three monitored heating seasons. The polyethylene, variable-permeance polyamide film, and Kraft walls had lower moisture contents, with the polyethylene wall being the slowest to wet and also to dry. Visual observations during disassembly at the end of the monitoring revealed minor mold patterns on the exterior sheathing in some of the test sections. The wetting pattern of the sheathing provides evidence that inset stapling results in convective air flow that bypasses the vapor retarder, resulting in condensation and accumulation at the top of the exterior wall sheathing. Recommendations are made to conduct further research on the issue of convective moisture bypass.

Introduction

Vapor retarders are specified in insulated building enclosure assemblies to reduce the risk of moisture-related failures due to the accumulation of diffusion-transported interior-sourced water vapor at cold interstitial surfaces. Recent updates to the building codes (ICC 2007) include more climate-specific recommendations for vapor diffusion control. One region of particular interest is the Pacific Northwest, which is a challenging climate due to its seasonal loading. The mild, wet winters of this region result in high interior dewpoints, increasing the risk of wintertime interstitial condensation.

Therefore, field monitoring research was conducted in a full-scale test facility, comparing the performance of five different vapor control assemblies in otherwise identically-built walls. One goal of this testing was to compare performance with the most recent building code recommendations. Note that this experiment was designed to primarily study vapor diffusion, not the effect of air-transported from or to the interior or exterior; the study was designed to reduce or eliminate this leakage as much as possible. Air leakage can transport moisture at a much higher rate than vapor diffusion alone, and must be addressed in building enclosure design.

One specific topic examined is convective air movement within stud bay cavities, and its linkage with insulation installation defects. The energy and moisture ramifications of this phenomenon are examined.

Background

International Building Code (IBC) Vapor Control Requirements

Many jurisdictions have switched from the regional building codes (UBC, BOCA, SBC) to the International Building Code. However, this single code needs to address requirements for vapor diffusion control in building assemblies in all US climates. The 2006 edition (ICC 2006) removed the requirement of a vapor retarder in warm climates (DOE Climate Zones 1-3; Briggs et al. 2002), and the IRC (International Residential Code) omits the vapor retarder requirement in Zones 1-3, 4A, and 4B.

The 2007 Supplement to the International Codes (ICC 2007) includes approved changes to the 2006 code that will be incorporated into the 2009 International Codes; it has more specific language regarding vapor diffusion control.

First, instead of simply defining a vapor retarder as a material with a dry cup (ASTM E96 Procedure A) of 1 perm (57 $ng/Pa{\cdot}m{\cdot}s^2$) or less, it defines three vapor retarder classes, as proposed by Lstiburek (2004). Example materials in each of these classes are given in Table 1.

- Class I: 0.1 perm or less
- Class II: $0.1 < \text{perm} \leq 1.0$ perm
- Class III: $1.0 < \text{perm} \leq 10$ perm

Second, it provides a more detailed breakdown of vapor control requirements by geographic region. In Zone 4C (Marine), Class I or II vapor retarders are required. However, Class III vapor retarder are permitted in Zone 4C in assemblies with lower risks of moisture accumulation, including ventilated claddings with vapor permeable sheathings (OSB, plywood, fiberboard, gypsum), or insulated sheathings.

It should be noted that Zone 4C (Marine) is distinct from regions with similar temperatures (4A, 4B) due to seasonal moisture behavior. Wintertime exterior dewpoints are higher in 4C than 4A and 4B, due to milder temperatures and seasonal precipitation patterns. This typically results in higher interior relative humidity levels in winter, increasing the risk of interstitial condensation. A survey of interior humidity levels of apartments in Zone 4C is provided by Aoki-Kramer and Karagiozis (2004); they found that the majority of the data were in the 40-60% RH bins.

Convective Flow in Insulated Cavities

Researchers have studied the effect of air movement within insulated cavities on heat transfer through the assembly. Note that this addresses the phenomenon of natural convection within the cavity, not heat loss/gain due to bulk leakage through the assembly (i.e., infiltration/exfiltration). A literature review was compiled by Powell et al. (1989); the research included laboratory measurement of whole-wall R values using hot boxes and computer simulations. Researchers found that convective air flow loops can form within cavities that have a temperature difference imposed on them: air falls on the cold side and rises on the warm side due to thermal buoyancy. These loops can either flow through the insulation, or around the insulation at air space gaps. The magnitude of air movement (and thus heat transfer) is increased by:

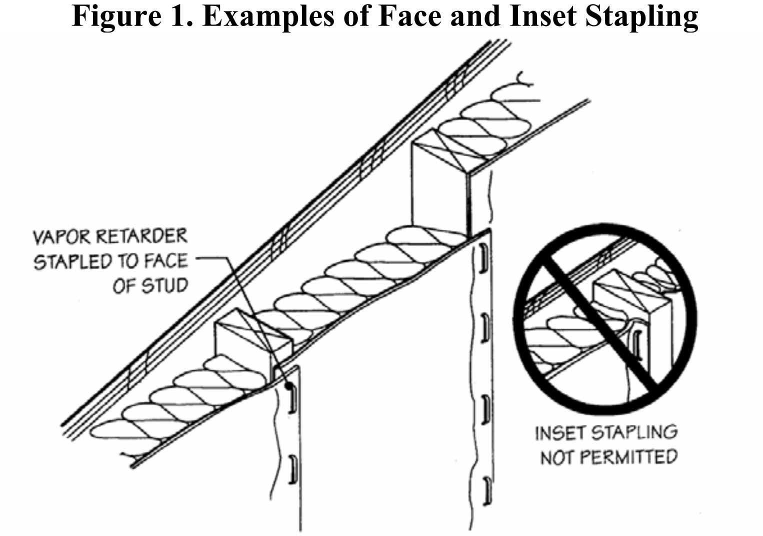
- Lower insulation density (for convection through air permeable insulation)
- Higher temperature difference (ΔT) across the assembly
- The presence on an air space at the face of one or both sides of the insulation, creating a vertical cavity or channel (i.e., significant loss in thermal performance when missing an air barrier in direct contact with insulation surface)
- Greater cavity height (specifically, height to depth ratio of the cavity)
- Gaps at the top and bottom (typical of insulation installation defects), which allow completion of the airflow "loop" around the insulation
- A vertical cavity orientation (i.e., greater penalties seen for wall cavities, compared to sloped or flat roof cavities)

Furthermore, convective air movement in insulated cavities can provide an avenue for moisture flow and redistribution, as examined by Riesener et al. (2004). They studied combined heat, air, and moisture transport using laboratory measurements and simulations, noting that moisture is often deposited and concentrated at the top exterior face of the cavity, due to convective air movement. The sheathing moisture content was greater at this location than predictions of two-dimensional simulations without convective airflow, or one-dimensional calculations.

Inset Stapling of Faced Batt Insulation

Cavity batt insulation is commonly available with a vapor retarder facer (asphalt-coated Kraft paper or foil scrim) laminated to one side. Typical installation methods are face stapling (facer flanges attached to the face of the stud) and inset stapling (flanges attached to edges of studs), as shown in Figure 1 below.

Figure 1. Examples of Face and Inset Stapling



Washington State University Extension Energy Program (2004)

The latter is done as a concession to drywall installers, to allow them to attach panels directly to the studs, and/or to allow the use of adhesive. However, inset stapling results in compression of the insulation and continuous airflow channels on the interior side. Due to these energy impacts, residential new construction demonstration programs and demand side management program specifications in the Pacific Northwest have not allowed inset stapling of batt wall insulation since the 1980s. While there were some early drywall subcontractor complaints, these complaints faded as builders realized that the change was not a significant cost or labor difference, and resulted in improved installed R-value and energy performance. In 1991, the Washington State Energy Code adopted language forbidding the use of inset stapling.

Christian et al. (1998) presented guarded hot box measurements of whole-wall R-values of a variety of wall systems, including wood stick frame and others (steel framing, structural insulated panels, etc.). In the wood frame walls, the researchers incrementally measured the effects of real-world insulation installation defects and interruptions, including an electrical box with wire; "rounded shoulders" (compressed at exterior corners of stud bay), cavity voids (2% of cavity area, located at top and bottom), and inset stapling of the insulation facer. The worst case (adding most of these defects) was a 14% reduction in whole-wall R-value relative to a "perfect" installation; the incremental loss associated with inset stapling alone was roughly 3%. However, the researchers did not find strong evidence of natural convection, which would be evidenced by loss of R-value with increasing ΔT. The maximum temperature difference (ΔT) across the wall was 80° F (44° C or K).

Brown et al. (1993) also studied the effect of installation defects on thermal resistance of mineral fiber (both rock wool and fiberglass) batt insulation at several densities. They created airflow channels at the corners of the insulation (both the interior and exterior sides); in the worst case the area of the channels was 6% of the cross sectional area of the stud bay (roughly 1" x 2" triangle in 2x6 stud bay). With this defect level, a low density batt (0.6 lbs/ft^3 or 9 kg/m^3), and a ΔT of 100° F (55° C or K), a 36% reduction in R-value was measured. Higher insulation densities, smaller defects, and smaller temperature differences all reduced the loss in R-value.

Experimental Setup

Test Site Description

The full-scale test facility was an existing attached carport converted to an enclosed room by the installation of insulated infill walls, as shown in Figure 2.

Figure 2. Test Site, Showing Two Wall Orientations

The site was located in Olympia, WA, a DOE Zone 4C (Marine) climate, with 5531 HDD Base 65° F and 97 CDD Base 65° F. There were two sets of test walls: one (front) facing roughly west (260°), with no solar obstructions, and the other facing roughly south, shaded by tall trees. The space was used as a part time music studio during this research (i.e., intermittent occupancy). The door to the house was normally left open, and an exhaust fan in the test facility was run continuously. This would tend to result in similar dewpoint temperatures in the two spaces. Space heating was provided by a direct-vent propane stove, controlled by a thermostat. Since air conditioning is a rarity in the Pacific Northwest, no cooling system was installed.

Test Walls

Five identical (except for vapor retarder) test sections were built on each orientation, with one assembly per stud bay. The wall construction was (from exterior to interior; see Figure 4):

- 7/16" OSB pre-manufactured panel siding, installed vertically (exterior face is a phenolic resin-saturated primed overlay), with brown painted factory finish (south) or topcoated with grey latex paint (west)
- Spun-bonded polyolefin (SBPO) housewrap
- 2x6 stud framing (single pressure treated bottom plate; ~7'8" total height, 16" o.c. typical) with fiberglass batt insulation
- ½" gypsum drywall with taped seams
- Polyvinyl acetate (PVA) primer and latex paint finish coat (applied 1/1/2004)

When possible, the test bays were kept away from thermal anomalies (corners, doors). The stud bays flanking to the experimental bays were filled with "buffer" panels, using an assembly identical to the adjacent test bay (see Figure 3). These "buffer" panels were not used between test sections due to space and logistical constraints. A foam gasket was installed at the interior face of the cavity to prevent air leakage between stud bay cavities and to the interior. The housewrap was caulked to the stud to prevent lateral air movement between cavities. Penetrations between stud bays and to wiring connections were air sealed.

Figure 3. Test Walls, South Orientation, Pre-Drywall (West Walls Similar)

The vapor control materials compared in this experiment are described in Table 1; it includes the short description used in the text and graphs, and the vapor retarder class.

Table 1: Vapor Control Layer Description and Permeance Data

Vapor Control Layer Description	Short Description	Permeance Perms (gr/h·ft^2·in. Hg)	Vapor Retarder Class (Dry Cup E96 A)
Paper-faced gypsum board w.latex paint (PVA primer & finish coat)	Paint	Dry cup: 2.6-3.5 Perms Wet cup: 18 Perms	Class III
Asphalt-coated Kraft paper (facer on fiberglass batt)	Kraft	Dry cup: 0.4 Perm Wet cup: 0.6-4.2 Perms	Class II
Polyamide-6 (PA-6) (facer on fiberglass batt)	SVR-F	Dry cup: 0.8 Perm Wet cup: 12.2 Perms	Class II
Polyamide-6 (PA-6) film	SVR	Dry cup: 0.8 Perm Wet cup: 12.2 Perms	Class II
Polyethylene (6 mil)	Poly	0.06 Perm (Dry and wet cup)	Class I

Sources: ASHRAE (2005), Kumaran (2002), Gatland (2005), ICC (2007)

Two walls use a vapor control material that is a 2 mil (0.05 mm) polyamide-6 (PA-6) nylon film that is known colloquially as a "smart vapor retarder" ("SVR"). It has a variable permeability, responding to ambient relative humidity. At high relative humidities, the material has a high permeability, allowing drying to the interior, unlike polyethylene. At low relative humidities, it has a low permeability, providing wintertime vapor control. The properties of this material are further discussed by Künzel (2005) and Gatland (2005). Künzel also demonstrated the greater drying available with PA-6 assemblies relative to polyethylene, using both field testing and hygrothermal simulations.

Kraft paper also responds to ambient relative humidity like PA-6, but over a much smaller range. Its wet cup permeability is 0.6-4.2 perms or 34-240 ng/Pa·m·s^2 (ASHRAE 2005), compared to SVR's 12.2 perms (695 ng/Pa·m·s^2).

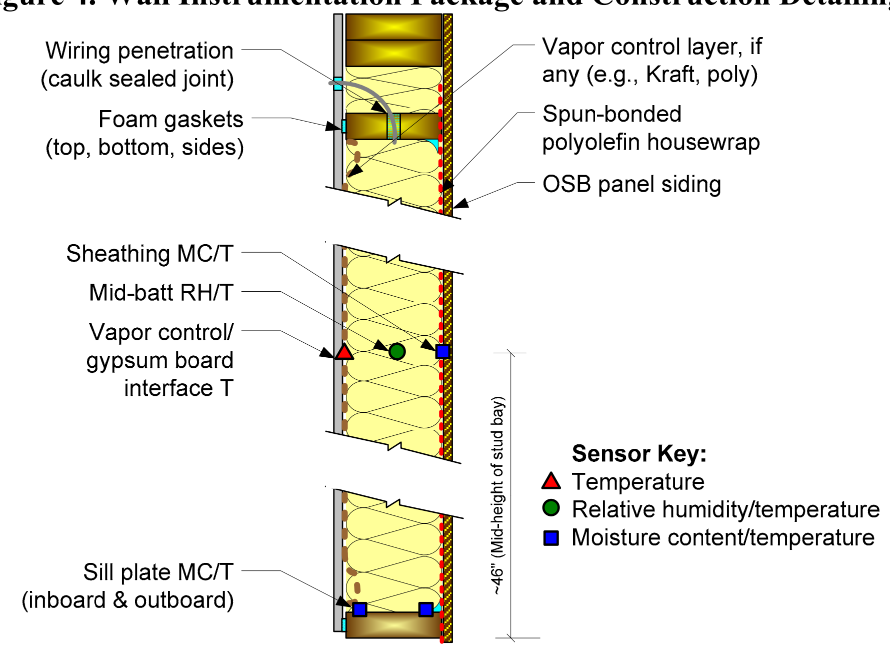
The Kraft paper and PA-6 with facer ("SVR-F") bays were all installed with inset stapling of the facer, as per the directions of the manufacturer.

The south-facing test walls before the installation of drywall are shown in Figure 3 above; the west orientation has a similar setup.

Instrumentation Package

Each wall was instrumented with wood moisture content (MC) sensors (electrical resistance pins), temperature (T) sensors (0.2ºC accuracy thermistors), and capacitance-based relative humidity (RH) sensors (2% NIST traceable) in multiple locations, as per the methodology described by Straube et al. (2002). Sensor locations are shown in Figure 4. Indoor and outdoor temperature and relative humidity were also recorded.

Figure 4. Wall Instrumentation Package and Construction Detailing

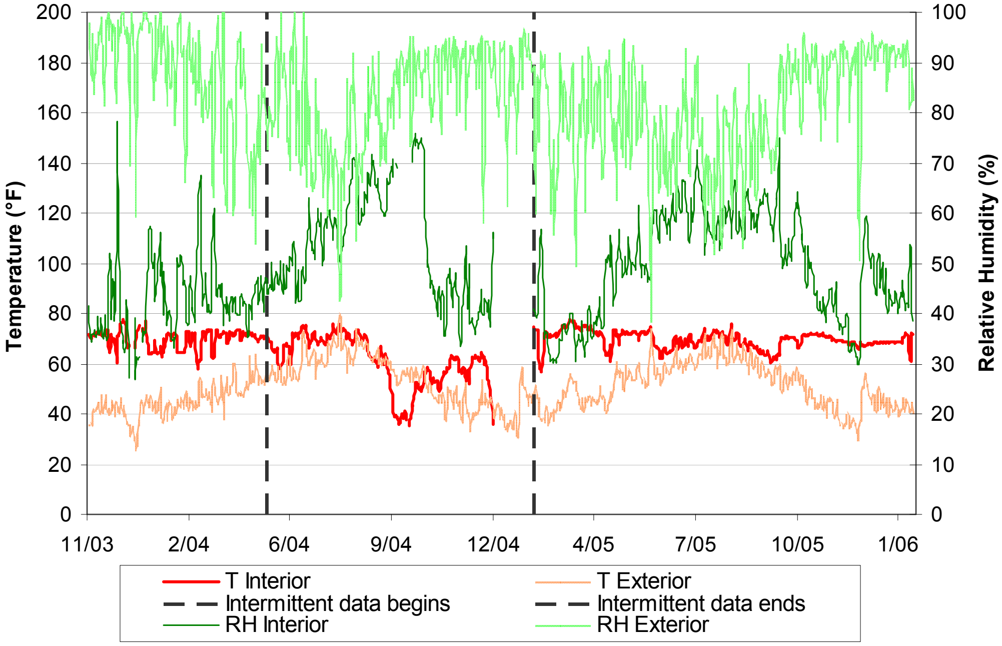


Results

Boundary Conditions

The interior and exterior temperature and humidity conditions (daily averages) are shown in Figure 5 below. Outdoor temperatures were slightly warmer than historical averages, with a lowest recorded hourly temperature of 22.3° F (-5.4° C), compared to the 99.6% wintertime design temperature of 18.0° F (-7.8° C). The 99.6% condition for the monitored data was 27.9° F (-2.3° C).

Figure 5. Interior and Exterior Temperature and Relative Humidity



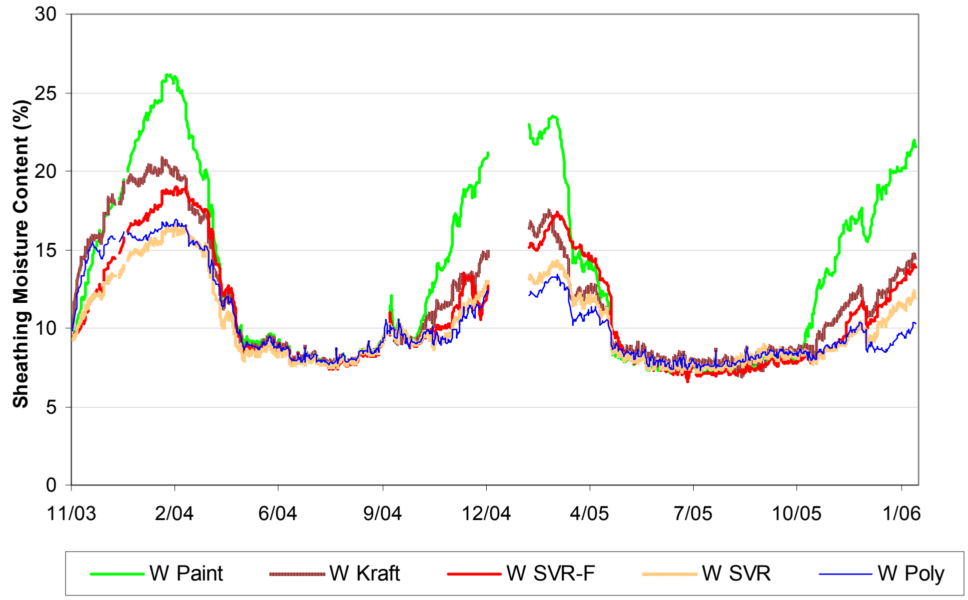
The interior temperature shows anomalous behavior during the fall and winter of 2004, falling below exterior conditions, and dropping to near freezing indoors. Based on occupant feedback and other recorded data, these results were found to be intermittent and unreliable. The occupants definitely did not see near-freezing conditions indoors, and further data from a nearby weather station confirmed these anomalies. Ignoring the "intermittent data" period, interior temperature averaged 70° F (61-78° F ±2σ).

Interior relative humidity had significant portions of the year above 60% (19% of hours); this is significantly higher than interior humidity levels observed by Aoki-Kramer and Karagiozis (2004) in nearby Seattle.

Test Wall Data

Daily average data is shown in the figures below for the measured period; it includes 2-½ winters, which are the critical periods for interstitial condensation. The sheathing moisture content (west walls shown in Figure 6) cycles seasonally, reaching its peak in winter and drying in summer.

Figure 6. Sheathing Moisture Content for West Walls (Mid-Height)



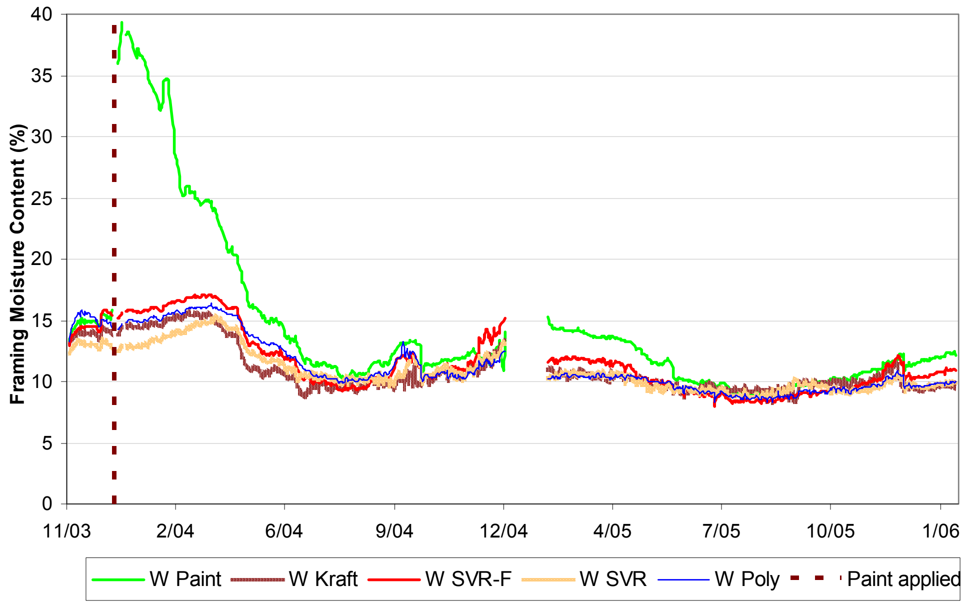
The latex paint walls clearly have the highest moisture contents, with peaks in the 20-25+% MC range; the south walls act similarly and are not graphed here due to space constraints. The remaining walls exhibit drier behavior, rarely rising above 20% MC; a typical threshold given for mold growth on wood is roughly 20% MC for several weeks. During the summer, all walls dry to very safe moisture content levels (less than 10% MC); it is difficult to distinguish between them during this period.

The first winter has a noticeably higher peak MC than the remaining winters; this behavior is seen in parallel in all walls. This could be due to drying of construction moisture; also, the first winter had colder temperatures than the following winters, which would increase moisture contents and condensation risk.

The outboard sill plate moisture content measurements are plotted in Figure 7; they show a similar pattern in terms of seasonal behavior and relative ordering of walls.

However, the sharp spike peaking to almost 40% MC in the latex paint wall is quite noticeable; a similar spike was also seen in the south paint wall, peaking at roughly 36%. This step discontinuity was coincident with the priming and painting of the test walls; it was also during a period of cold weather. Therefore, it seems plausible that painting the walls introduced enough moisture to the latex paint wall to cause condensation in the cavity, and perhaps rundown of accumulated moisture to the sill plate. This would be especially likely given the construction of the wall: the spun-bonded polyolefin housewrap is non-hygroscopic (i.e., water-repellent), and would reduce storage of moisture on the OSB by absorption and/or surface tension.

Figure 7. Sill Plate Moisture Content for West Walls (Outboard Side)



The inboard side sill plate moisture contents were mostly in the 10-15% MC range and only showed small seasonal variations. Since these moisture contents are well within the safe range, they are not plotted.

Disassembly and Inspection

At the conclusion of the experiment in early February of 2006, the test walls were disassembled, and the materials and surfaces were examined for evidence of moisture-related damage. Some liquid water condensation was visible on the SBPO housewrap, concentrated near the top plate of certain stud bays (SVR-F, Kraft). In addition, minor mold growth and spotting was seen on the housewrap; the spotting was coincident with MC levels of 15% and higher, when measured with a handheld resistance-based moisture content meter.

Additional moisture content measurements were taken to understand the spatial distribution of wall sheathing moisture contents; the results are shown for the west walls in Figure 8. The latex paint wall shows high (roughly 20%) MCs throughout: this is consistent with the measured data shown in Figure 6. The polyethylene and SVR (film layer) all have consistently low MCs, also matching collected data. However, the PA-6 wall with an inset-stapled facer ("SVR-F") shows significant moisture accumulation at the top of the wall cavity (18-20% MC), relative to the mid-height measurements (~15%). The Kraft wall shows intermediate moisture contents (14-16% MC).

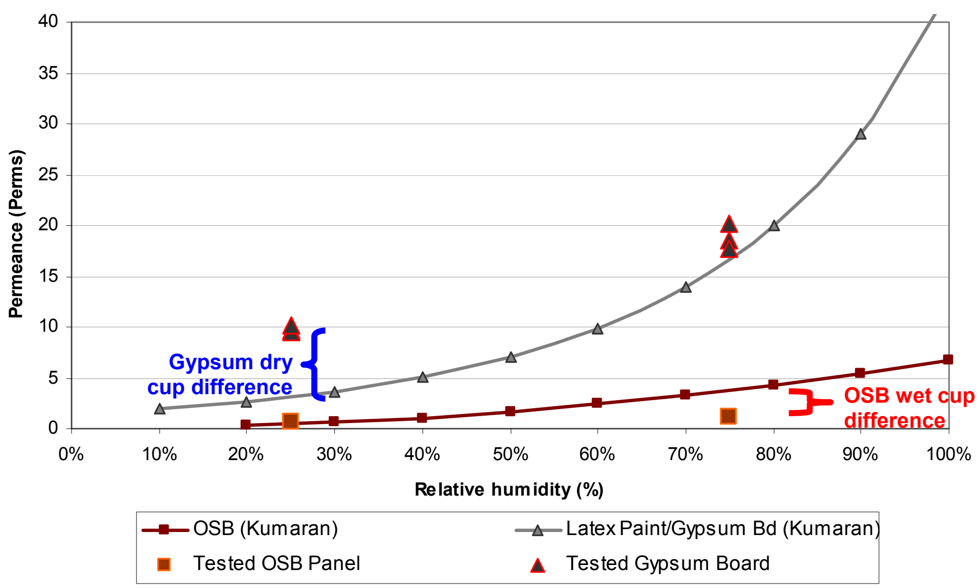
In the South walls, similar patterns were observed; the SVR-F and Kraft walls both show noticeable increases in moisture content at the top of the wall cavity.

Figure 8. Moisture Content Distribution in West Test Walls

Vapor Permeability Testing

After the decommissioning and disassembly of the experiment, vapor permeability tests (ASTM E96; dry cup and wet cup) were conducted on the painted gypsum board and the OSB panel siding product. Permeance data are critical to understanding the wall behavior, and are used as inputs for hygrothermal modeling. Six gypsum board and four OSB panel samples were tested. The results are plotted in Figure 9, with the published data for gypsum board with latex paint and typical (non-faced) OSB (Kumaran et al. 2002).

Figure 9. Vapor Permeance of Painted Gypsum Board & OSB Panel Siding



The test results at wet cup conditions for painted gypsum board are similar to published data. However, at dry cup conditions—closer to the wintertime operating conditions—the tested permeance is much higher, averaging 9.8 perms (compared to 3.1 perms in the literature). Although the tested specimen would meet requirements for a Class III vapor retarder, it was much higher than expected.

No manufacturer's permeability data was found for the OSB panel siding, which necessitated this testing. It was found that dry cup permeance is similar to 7/16" OSB sheathing. However, at wet cup conditions (typical wintertime conditions), the panel siding is much less permeable (1.1 perms) than OSB sheathing (3.8 perms). The in-service conditions experienced by the panel siding is similar to wet cup conditions. The CCMC report (CCMC 2006) on this product suggests that it might have a low permeance, although it does not state a value. The report gives the warning: "The location and installation of elements with low air permeance and low vapour permeance require special consideration to avoid moisture-related deterioration."

The combination of these two permeability measurements and the high interior humidity means that the latex paint wall operated under very adverse conditions, with a greater risk of interstitial condensation.

Analysis

Overall Performance of Vapor Control Materials

The overall performance of the tested vapor control materials in a Zone 4C climate under the given test conditions are described below.

- Latex paint (Class III vapor retarder) did not provide acceptable performance under these conditions, allowing moisture accumulation in the wall. This was evidenced by sustained high sheathing moisture contents, as well as minor mold spotting on the interior side of the housewrap, and visible condensation during wintertime disassembly. However, the monitored data show that the sheathing dries to levels similar to the other walls during the summer. In addition, during disassembly there was no sign of any decay or structural damage. As discussed above, the paint layer used here was much more permeable (10 perms) than materials tested in the literature (3 perms), and the sheathing much less (under 1 perm) than normal. Both of these factors lowered the chances of success of this assembly. It is important to realize that this wall assembly does not meet the requirements for allowing a Class III vapor retarder in Zone 4C (as discussed in the 2007 Supplement to the International Codes). To use a Class III vapor retarder in this climate zone, a more permeable sheathing (e.g., standard OSB, plywood, gypsum) and a ventilated cladding would be required.

- Asphalt-coated Kraft paper-faced batts (Class II vapor retarder) provided adequate vapor resistance to give good wintertime performance. Wintertime moisture contents were moderate but well within the safe range, and the material allows drying to the interior. There was some evidence for convective airflow bypass (see below), but moisture contents were within safe ranges.

- Polyamide-6 "Smart Vapor Retarder" (SVR and SVR-F) (Class II vapor retarder), when applied as a film layer, had excellent performance. Sheathing moisture contents remained within safe ranges throughout the winter, and the material allows drying to the interior. However, the faced version of this product, despite having identical permeance characteristics, showed higher moisture contents, especially at certain locations in the stud bay. This convective looping issue is discussed below.

- Polyethylene (Class I vapor retarder) had low wintertime sheathing moisture content levels. There was some indication of greater moisture content during the summers, due to elimination of drying to the interior. This was seen at the interior side sill plate MCs; and was not seen in other walls. However, all moisture contents remained well within safe levels in these test walls.

Convective Looping and Inset Stapling

The distribution of moisture content measurements in the stud bay revealed that inset stapled batt walls typically had elevated moisture contents at the top of the wall, relative to mid-height (the location of data logger sheathing measurements). This was evidenced in both test and non-test (buffer) bays. In two cases (West SVR-F and South SVR-F buffer), sheathing moisture content levels at the top of the stud bay were equal to those seen in the latex paint-only wall (18-20% MC).

These observations provide strong evidence of convective airflow due to inset stapling, resulting in moisture transport within the stud bay. Outward vapor diffusion through the painted drywall introduces interior moisture to the vertical channels formed between the facer and the drywall. These channels provide a clear airflow path; a convective loop can form, bypassing the vapor retarder at the top of the wall and depositing condensation on the top portion of the stud bay sheathing, as seen in field results. Note that only a small gap is required at the top and bottom of the insulation to allow convective airflow: Brown et al. (1993) reported that gaps less than 1 mm (1/32") wide allow these loops to form between air spaces on both sides of insulation.

It is unlikely that these results are due to one-dimensional vapor diffusion through the gaps at the edges of the batt facers, as shown by the spatial moisture content patterns. Specifically, no moisture deposition was seen at the bottom of any of the inset-stapled stud bays.

It is worth noting that two vapor retarder materials that were detailed as air barriers (polyethylene and PA-6 film) resulted in assemblies with excellent performance (very low sheathing moisture contents). These vapor retarder materials were installed overlapping the foam gaskets on the face of the stud, so they would have been very airtight. It is uncertain whether their performance is solely due to their vapor retarding characteristics, or also due to this detailing.

Note that in this research, we did not see evidence of convective looping within the cavity insulation in bays that did not have inset stapling. As noted in the literature (Powell et al. 1989), convective loops are more likely with these air gaps, and less likely if an air barrier is placed in direct contact with the insulation. If significant convective looping were occurring within the insulation, there would have been greater deposition of moisture at the top portion of the latex paint cavity to due air movement. Instead, MC levels were, if anything, slightly lower at the top of the wall (edges of cavity). One might conjecture that these surfaces were slightly warmer, due to thermal bridging of the framing.

Furthermore, given (a) the mild climate (maximum observed ΔT of 47° F/26.3° C), (b) careful installation of the insulation (cut to cavity size, not compressed), and (c) air barrier/

compartmentalization efforts, convective looping within the insulation (as opposed to around the insulation, in the air channels) would be relatively unlikely. It appears that under this set of conditions, the density of this fiberglass batt is sufficient to prevent significant convection.

The temperature data were examined to see if there was a discernable difference in the inset stapled bays; no differentiation could be made on either interior or exterior sides of the cavity, in either orientation. A strong temperature difference was not expected to be found. First, the portions affected by convection would likely be localized at insulation deficiencies at the edges (particularly the top) of the stud bay. Temperature monitors were located at the mid height/center of stud bay specifically to avoid the thermal anomalies of edges. Figures in the literature (Riesener et al. 2004) show the distortion of isotherms concentrated at the top and bottom of the wall cavity.

Conclusions and Further Work

The interpretation of these field monitoring results should account for the test conditions and their effects on increasing or decreasing the risk of interior-sourced condensation-related failure. Weather was warmer than climate normals (resulting in lower risk), but interior relative humidities were higher than typical, and the exterior sheathing/cladding was less permeable than typical assemblies (both resulting in higher risk). Under these conditions, a Class III vapor retarder (latex paint) did not provide acceptable performance, showing high sheathing moisture contents, condensation, and some mold growth.

Two Class II vapor retarders (Kraft-faced batt and PA-6) provided acceptable performance, if the vapor control layer is not bypassed by convective airflow. Both of these materials allow drying of incidental moisture to the interior, if interior conditions are at a lower dewpoint than the assembly cavity.

A Class I vapor retarder (polyethylene) provided acceptable performance as well in these walls. Although an increase in sill plate wood moisture content was seen in the summer due to an inward vapor gradient, it was well within the safe range. However, the use of a completely impermeable vapor control layer such as polyethylene eliminates drying to the interior; moisture sources could include inward vapor drives from saturated reservoir claddings, and the drying of incidental water leakage. The effects of including or omitting polyethylene in building assemblies have been reported by Wilkinson et al. (2007).

Convective airflow loops appear to be linked to the inset stapling of faced batts. High sheathing moisture content levels were found at the top of the cavity of these inset stapled batts, supporting this contention. Therefore, in addition to the documented energy penalty associated with inset stapling, bypass of vapor control layer due to air channels is additional reason why this practice should be discontinued and explicitly disallowed in energy building codes.

It will be worthwhile to conduct further research on the bypass of the vapor control layer by convective air looping in inset stapled batt insulation, if it will help end or mitigate this practice. An experiment can be designed to look at this specific phenomenon, with instrumentation at specific areas of interest. The sensitivity to installation factors, such as the size of the gap at the top of the insulation, can be examined. Furthermore, it can be determined if simple detailing changes, such as adding an air barrier at the top of the stud bay cavity, might eliminate this problem.

Acknowledgements

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