Drainage Efficiencies of Fiber Cement Panels

ABSTRACT

Building codes now prescribe minimum drainage spaces for distinct cladding types. The intent is to facilitate efficient release of water that has penetrated beyond the cladding. Compliance can also be achieved with drainage efficiencies that are proven through testing in accordance with ASTM E2273, Standard Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish Systems (EIFS) Clad Wall Assemblies. One prevailing assumption is that gap size and drainage efficiency are inexorably linked. However, this notion is challenged by the advent of drainage wraps and other products offering smaller yet efficient drainage spaces. This paper examines drainage efficiencies of full-scale test walls configured with fiber cement panels and gap depths of 10 mm or 1.5 mm. Key considerations, including variances in water application rates and the effects of moisture absorption at drainage interfaces, are discussed. The fate of residual water within the drainage space is further explored with hygrothermal simulations for multiple North American climates.

LEARNING OBJECTIVES

- Discuss methods, criteria, and limitations of ASTM E2273.
- Define the relationships between drainage gap size, drainage efficiency, water absorption, and water application rates.
- Describe key factors that influence drainage efficiencies in standardized testing and real-world conditions.
- Interpret the need for optimized gap size based on climate and proposed wall type.

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Steven Doggett is the founder of Built Environments Inc., a building science research firm with a special focus on resilient enclosure systems. His practice draws from extensive experience with building enclosure failures, particularly those involving air, heat, and moisture transport. He merges this expertise with durable design practices, novel test methods, and advanced simulation techniques. Doggett's primary work centers on research and development of high-performance building products. He is actively engaged in product evaluation, testing and failure analysis, and development of innovative building materials.

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Jarrett Davis has been involved with evolving and facilitating the change of the built environment around the globe, while maintaining the attitude required for high performance construction, design, and execution. He is often found speaking to trade associations, architects and engineers, and frequently lecturing to college classrooms on the building sciences and construction measures. He has been engaged by product manufacturers to develop extensive R&D, testing, and installation manual procedures and systems for acceptance in the construction industry, but you can usually find him in the air teaching his kids how to fly and understanding physics at work.

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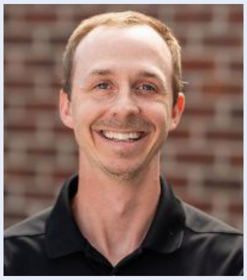

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Working as a technical specialist and project engineer for Built Environments, Mathew Congleton draws upon years of experience in the disaster response industry as an insurance adjuster, loss consultant, and damage appraiser. After personally witnessing the aftermath of catastrophic weather events such as hurricanes, tornados, floods, and wildfires, he understands the vulnerabilities inherent in building structures and the need for resilient design. This firsthand experience, coupled with a degree in construction management, and certifications such as the Insurance Institute for Business & Home Safety Fortified Evaluator designation, has equipped him with a detailed grasp of building science principles.

FIGURE 1. Material degradation due to cladding leaks and poor drainage.

Drainage is a fundamental requirement for proper moisture management of non-barrier wall assemblies. The need for drainage stems all cladding systems leak, whether by design, defect, or the natural weathering of enclosure components. The purpose of drainage is to reduce moisture storage loads, which must be otherwise addressed by much slower processes such as diffusion, capillarity, or evaporation. When the assembly does not drain effectively, moisture may exceed the assembly's storage capacity, leading to degradation and a shortened service life (**Fig. 1**).

A traditional view is that water migrating beyond the cladding is managed by one or more drainage planes, gravity, and a means for unobstructed water egress. In this simplified model, the primary drainage plane is served by building papers or water-resistive barriers (WRBs). The notion of free drainage implies that water flows without impediment in response to gravity alone. This does not occur when cladding is interfaced tightly against the drainage plane.[1,2] Some form of interstitial space is therefore necessary; however, there is little agreement on the minimum size and configuration of drainage spaces. Furthermore, current methods for evaluating the benefits of drainage focus largely on drainage efficiency—the ratio of water expelled from the system to the total amount of water applied. The fates and effects of undrained water are rarely considered and poorly understood.

DRAINAGE SPACE

A drainage space is often referred to as a capillary break, a layer of air that serves to decouple cladding materials from the primary drainage plane. To achieve a perfect decoupling and free drainage, the air space must be sized to prevent water from spanning the gap. Historically, a gap size of 3 mm (1/8 in.)

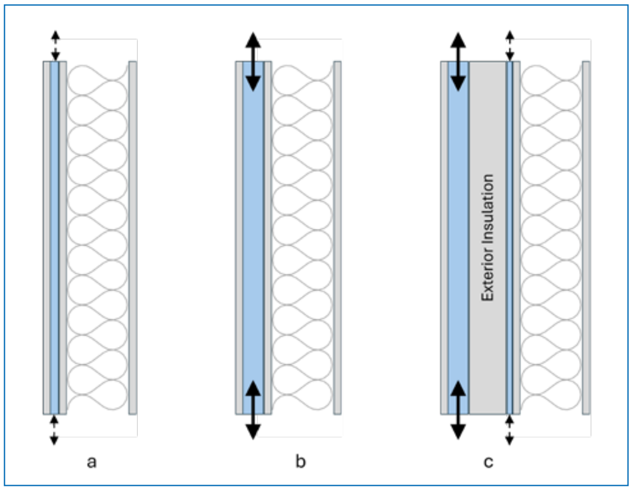

FIGURE 2. (a) Conventional drainage wall; (b) ventilated rain-screen wall; and (c) insulated rain-screen wall.

reflected the limits for capillary suction. Drainage spaces greater than 6 mm (1/4 in.) exceed water's ability to bridge the gap due to the interplay between surface tension and gravity. Accounting for dimensional tolerances achieves what is arguably the most widely cited minimum space, 10 mm (3/8 in.).[3]

Air gaps smaller than 3 mm (1/8 in.), or those otherwise occluded and discontinuous, create constrained or even tortuous paths that are resistant to free drainage. Such spaces rely on head pressure to achieve a desired downward flow. Along these constrained or blocked occluded paths, water may pool or it may be potentially absorbed by building materials, increasing the likelihood of detrimental effects.

Despite seemingly sound rationales for large capillary breaks, research has demonstrated effective drainage can be achieved with much smaller spaces. For example, a study by Straube and Smegal showed that gaps that are less than 1 mm (0.04 in.) may drain even when the space is discontinuous or ill defined, such as interfaces formed between two layers of building paper.[4] The same study demonstrated that gaps ranging from 1 to 9 mm (0.04 to 0.35 in.) offer ample drainage for various cladding types. Results such as these show that a perfect decoupling of the cladding and drainage plane is not necessary. Within the context of modern drainage testing, small spaces work because water within them is pushed by head pressure from above while being pulled by gravity from below.

DRAINAGE WALLS VERSUS RAINSCREENS

Drainage walls and rainscreens are multicomponent enclosures that share the function of removing water that enters beyond the cladding. The former does so with drainage, and the latter incorporates both drainage and appreciably greater ventilation. Most drainage walls have all the components of a rainscreen wall, including cladding, an air space, a drainage plane, and means for water egress. In essence, a drainage wall is a type of rainscreen with limited or negligible ventilation. Drainage walls also lack the ability to appreciably moderate pressure differences, especially when configured with constrained spaces (<3 mm [1/8 in.])

Ventilation within drainage walls relies largely on natural convection or the buoyancy effect. To some extent, air is also exchanged with the exterior environment as air leakage occurs whether by intent or at imperfections in assembly construction. Ventilation rates for unvented drainage cavities typically range from 1 to 5 air changes per hour (ACH).[5] Ventilation increases as drainage spaces become larger and are coupled with exterior air via intentional vent openings. Vented rainscreens provide ventilation rates ranging from 10 to 50 ACH, whereas ventilated rainscreens are designed to vent at rates of 100 to more than 1000 ACH.[5–8]

Differences between drainage walls and rainscreens become more obscured when walls are configured with exterior insulation. By placing an insulation layer over the WRB, an interface is formed that necessitates drainage. Thus, a drainage space and a rainscreen space may coexist within the same assembly. A vented or ventilated space typically occurs outboard of the insulation, and a primary drainage space is formed behind the insulation. The principles discussed herein are therefore applicable to conventional drainage walls as well as insulated rainscreens (**Fig. 2**).

BUILDING CODE REQUIREMENTS

Drainage requirements for exterior cladding first appeared in the 2006 editions of the International Residential Code (IRC), in Section 703.1, and the International Building Code (IBC) in Section 1403.2.[9,10] These early mandates did not specify the means for drainage nor the performance criteria necessary to fulfill the requirements. Model building codes have since refined the drainage requirements for distinct cladding types. For example, the 2009 edition of the IBC included prescriptive drainage requirements for exterior insulation and finish systems (EIFS), as follows:[11]

> *EIFS with drainage shall have an average minimum drainage efficiency of 90% when tested in accordance with the requirements of ASTM E2273 and is required on framed walls of Type V construction, Group R1, R2, R3 & R4 occupancies.*

Similarly, in 2021, the IBC included specific drainage requirements for stucco based on sheathing type and climate zone.[12]

> *In Moist (A) or Marine (C) climate zones, water-resistive barrier shall comply with one of the following:*
>
> 1. *In addition to complying with Item 1 or 2 of Section 2510.6.1, a space or drainage material not less than 3/16 inch [4.76 mm] in depth shall be applied to the exterior side of the water-resistive barrier.*
> 2. *In addition to complying with Item 2 of Section 2510.6.1, drainage on the exterior side of the water-resistive barrier shall have a minimum drainage efficiency of 90% as measured in accordance with ASTM E2273 or Annex A2 of ASTM E2925.*

The 2021 edition of the IRC included language that is essentially identical to that contained in the 2021 IBC.[13] These requirements remained unchanged for 2024. It should be noted that both IBC and IRC have options for drainage compliance based on drainage efficiency, not gap size per se. Furthermore, neither of these model codes addresses ventilation criteria for the drainage space.

Several North American jurisdictions stipulate specific dimensions for drainage spaces. For example, the National Building Code of Canada requires a 10 mm (3/8 in.) capillary break behind cladding materials.[14] Exception is granted if omission of the gap does not adversely affect the performance of the wall assembly. The 10 mm gap is further prescribed as being vented, but there are no criteria for specific ventilation rates or drainage efficiencies.

Jurisdictions also may accept alternative materials that offer minimum drainage but do not necessarily meet the code-prescribed gap dimensions. Since 2014, the Oregon residential code has required a 1/8 in. (3 mm) drainage space between exterior veneer and the WRB.[15] This requirement is waived for WRB products that meet a minimum 75% drainage efficiency when tested in accordance with ASTM E2273.

ASTM E2273

Standard testing of drainage efficiency is performed in accordance with ASTM E2273, Standard Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish Systems (EIFS) Clad Wall Assemblies.[16] First published in 2003, this standard was originally devised to assess drainage efficiencies of EIFS with drainage., ASTM E2273 has since been adopted as the standard means for evaluating a wide array of drainage systems, including drainage wraps. Other drainage materials such as entangled meshes, formed/textured sheets, and formed battens are evaluated according to Annex A2 of ASTM E2925; the annex methods are substantively identical to those described by ASTM E2273.[17]

The ASTM E2273 test method introduces water into a slot fault positioned at the upper portion of a prescribed 4 ft × 8 ft test assembly. Water is applied by means of two calibrated nozzles at a rate of 106 g/min (0.106 L/min [0.23 lb/min; 3.6 fl. oz/min]) over the course of five 15-minute spray intervals. At each interval, water is collected at the base of the test assembly and weighed. Water collection is continued for 60 minutes following the completed 75-minute application. Efficiency is reported as a percentage based on the ratio of drained water to the total water applied.

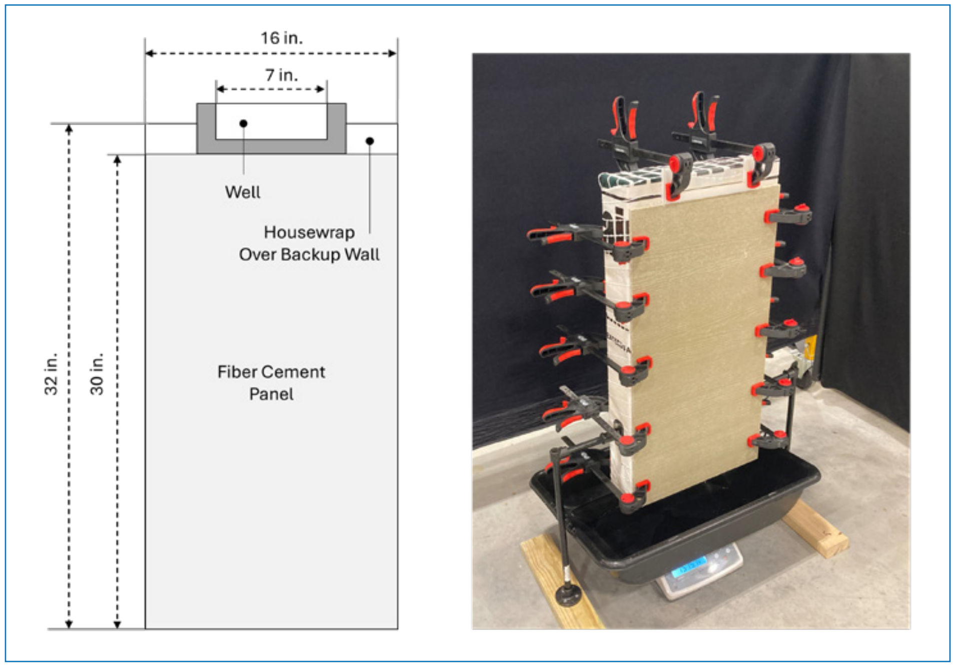

FIGURE 3. Benchtop drainage assembly. *Note: 1 in. = 25.4 mm.*

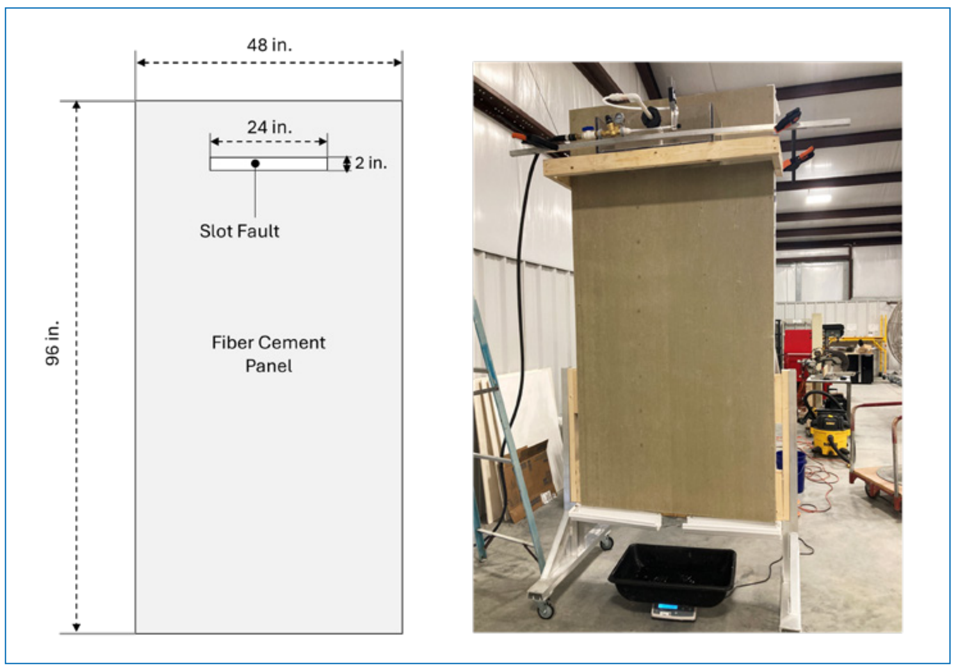

FIGURE 4. Full-scale drainage assembly. *Note: 1 in. = 25.4 mm.*

STUDY DESIGN

The study reported herein had three primary objectives. The first was to compare drainage efficiencies of walls clad with fiber cement panels having 1.5- or 10-mm (0.06 or 0.375 [3/8] in.) capillary breaks. Drainage testing incorporated benchtop and full-scale assemblies evaluated in accordance with ASTM E2273. We chose medium-density fiber cement panels based on their simple planar interface, potential for water absorption, and common use in residential and commercial construction. Selected gap sizes represent typical reliefs of drainage wraps (1.5 mm) and

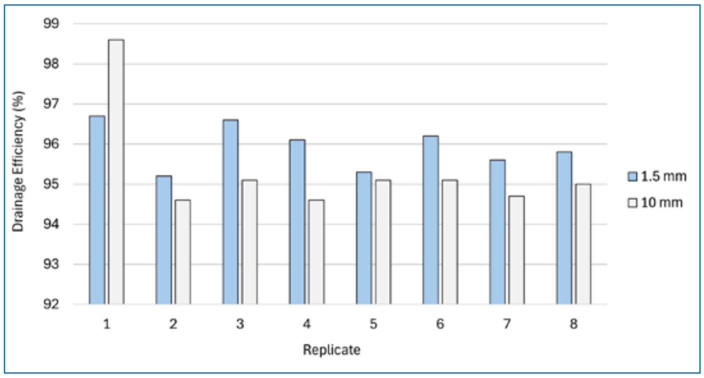

FIGURE 5. Drainage efficiencies of benchtop assemblies. *Note: 1 mm = 0.039 in.*

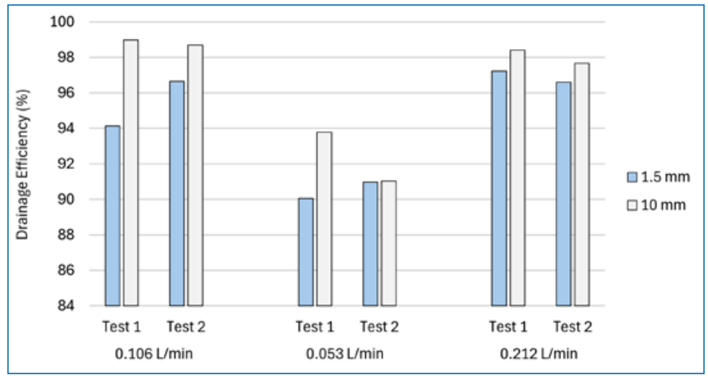

FIGURE 6. Drainage efficiencies of full-scale assemblies. *Note: 1 mm = 0.039 in.*

conventional practices involving larger drainage spaces (10 mm).

Our second aim was to evaluate potential water absorption by fiber cement panels that interface with drainage spaces. Here, we relied on two approaches, including static ponding and gravimetric measurements of panels used in our benchtop studies.

Lastly, we sought to compare wetting and drying potentials of fiber cement panels configured with the same gap sizes used in our drainage studies. These analyses used one-dimensional hygrothermal simulations for the purpose of determining the effects of climate and gap size on overall wall performance.

DRAINAGE EFFICIENCIES

Test assemblies used in this study are illustrated in **Fig. 3 and 4**. Both assembly types were factory-primed 5⁄16-in. (7.9-mm) fiber cement panels installed over code-accepted WRBs, 3⁄4 in. (19 mm) oriented strand board (OSB) sheathing, and 2 in. × 4 in. (51 × 102 mm) wood framing. Selected drainage spaces of 1.5 and 10 mm (0.06 or 0.375 [3⁄8] in.) were achieved with either a commercially available drainage wrap or 10 mm vertically applied high-density polyethylene (HDPE) battens. For benchtop testing, cladding was clamped to the backup wall to facilitate removal and weighing of cladding panels. Full-scale assemblies employed cladding fastened in accordance with the manufacturer's installation instructions.

The benchtop apparatus was scaled to one-eighth of the standard test assembly. Water application rates were also reduced accordingly to approximately 0.014 L/min (38 fl. oz/min). Three different flow rates were employed for full-scale testing, including the standard rate of 0.106 L/min (3.6 fl. oz/min), 0.053 L/min (1.8 fl. oz/min; 50% decrease), and 0.212 L/min (7.2 fl. oz/min; 100% increase). Small-scale testing involved 8 test replicates for each drainage gap and the single-flow condition, for a total of 16 tests. Full-scale testing employed 2 replicates for each drainage space and each flow rate, for a total of 12 tests.

Drainage efficiencies for the eight benchtop replicates are summarized in **Fig. 5**. No significant differences were observed for the two gap conditions, which yielded efficiencies ranging from 95% to 98%. Mean drainage efficiencies for the 1.5-mm and 10-mm (0.06 and 0.375 [3⁄8] in.) gaps were 95.9% and 95.4%, respectively. Approximately 23 to 77 g (0.8 to 2.7 oz) of water remained within the test assemblies either as water adhered to drainage surfaces or as water absorbed by the fiber cement panels.

Full-scale testing employing standard flow conditions revealed drainage efficiencies that were unchanged from those determined by our benchtop studies (i.e., 95%–98%). In **Fig. 6**, we report drainage efficiencies for each replicate and corresponding water application rate. Both gap conditions met the minimum 90% drainage criteria set by ASTM E2273 for all three flow conditions. In most instances, the 10-mm (3⁄8-in.) battens offered only minor improvement over the 1.5-mm (0.06-in.) drainage wrap.

Our results further show that flow rates and corresponding head pressures play important roles in wall drainage. For example, drainage efficiency was reduced to approximately 91% when water application rates were decreased by half; this finding was due largely to reduced head pressures. Any further reduction would likely result in test failures, especially for smaller gaps. When the application rate was doubled, drainage efficiencies remained unchanged from those determined under standard flows. We therefore expect that a further increase in flow will result in little or no difference as efficiency approximates 100%. This finding supports the premise that current standards favor displacement (i.e., head pressure) over the dynamics of space, surface tension, and gravity (i.e., free drainage). As flow rates increase, the effects of displacement are more pronounced. Conversely, the quotient of stored water is diminished.

Lower drainage efficiencies resulting from reduced flow rates are consistent with findings obtained from our prior unpublished work. When application rates for 1.5-mm (0.06-in.) gaps were reduced from 0.106 to 0.01 L/min (3.6 to 0.34 fl. oz/min), drainage efficiencies decreased to approximately 63% to 84%. Based on these earlier findings and the results presented herein, we conclude that lower flow rates are more challenging and are therefore less likely to meet standard drainage criteria. The application rate employed by ASTM E2273 most likely reflects the near-minimum displacement necessary to reliably achieve 90% efficiency, regardless of gap size.

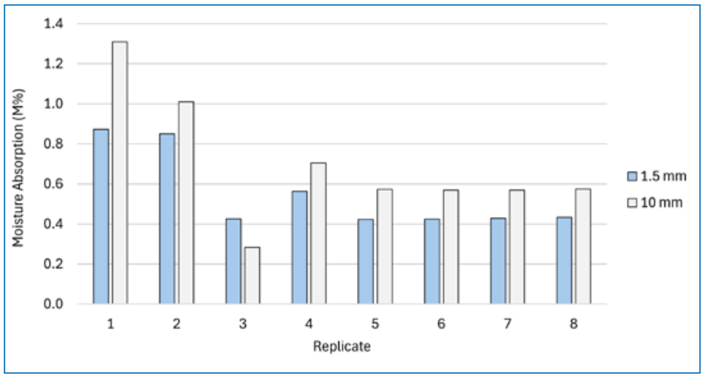

FIGURE 7. Water absorption by fiber cement panels. Note: 1 mm = 0.0394 in.

Reduced application rates are also more indicative of real-world conditions. For example, Boardman and Glass demonstrated infiltration rates of 0 to 0.028 L/min (0 to 946.8 fl. oz/min.) for vinyl siding under pressure differentials ranging from 17 to 48 Pa (0.002 to 0.007 psi).[18] Even lower infiltration rates have been shown for EIFS installed with intentional cracks (0.007–0.008 L/min at 0 Pa [0.24–0.27 fl. oz/min at 0 psi]).[19] Curtainwalls exhibit infiltration rates of 0.05 to 0.07 L/min at 0 Pa (1.7 to 2.7 fl. oz/min at 0 psi) and 0.069 to 0.077 L/min at 600 Pa (2.33 to 2.6 fl. oz/min at 0.09 psi).[20] Under low pressure differentials, the only conditions that exceed 0.106 L/min (3.6 fl. oz/min) are those associated with extreme fault conditions, open-jointed claddings, or absorptive claddings such as stucco and brick.[21]

WATER ABSORPTION

These findings, as well as those of others, show that 100% drainage efficiency is not possible as some quantity of water is always stored within the system.[1,4] Unreleased water remains as films or droplets adhered to drainage surfaces. Water is also absorbed by interfacing materials. In these evaluations, the WRBs and HDPE battens were not absorptive, leaving only the fiber cement cladding as the sole absorptive material.

Benchtop studies showed that approximately 5% of the applied water was stored within test assemblies, equating to 53 g (1.9 oz) or 171 g/m^2 (5 oz/yd^2). Of the undrained portions, 18% to 85% (10–45 g [0.4–1.6 oz) was absorbed by fiber cement panels, representing 0.28% to 1.32% on a panel weight basis. A more conservative estimate was obtained with static ponding tests, which demonstrated 2% water absorption over 2.5 hours—the period corresponding to drainage testing and the associated 60-minute post-flow collection.

Panels installed over the drainage wrap absorbed less water than panels installed over the 10-mm (3⁄8-in.) battens (**Fig, 7**). This outcome was unexpected due to tighter interfaces associated with the 1.5-mm (0.06-in.) gap. We attribute this discrepancy to differences in drainage patterns as well as selective water absorption at untreated panel edges. For the 10-mm gaps, the applied water flowed freely across a limited surface area corresponding to the width of the application well. As a result, there were continuous exposures near the center of each test panel. In contrast, the drainage wrap dispersed water into smaller, discrete streams; thus, panel surfaces were less prone to repeated or continuous exposure.

Untreated cut edges of benchtop panels also served as routes for water absorption. For tests involving 10-mm (3⁄8-in.) battens, water application wells were slightly offset outward, increasing edge exposure and hastening water absorption. Considering these findings, cut edges in full-scale assemblies were primed to comply with the manufacturer's installation instructions.

Fastener penetrations in full-scale assemblies served as another route for localized water absorption. This condition was particularly apparent for walls configured with the drainage wrap where water bridged the gap at fastener shanks (**Fig, 8**). In contrast, fasteners applied through the 10-mm (3⁄8-in.) gaps also penetrated the HDPE battens and were therefore partially sealed.

HYGROTHERMAL ANALYSES

The efficacy of drainage, in terms of overall wall performance, is best gauged not by the amount of water forced into an orifice and subsequently expelled but rather by the fate of water that is left undrained. The assumption that a 10-mm (3⁄8-in.) space is inherently superior to a 1.5-mm (0.06-in.) space is invalid; in fact, the same amount of water is stored regardless of gap size. Likewise, the belief that a 10-mm space is better vented is also flawed; venting is substantively improved only when the assembly is designed and constructed to do so—a condition not required by building codes.

To further test the efficacy of gap size, we performed one-dimensional hygrothermal modeling to simulate wetting and drying within drainage gaps. Although this type of modeling does not directly evaluate the dynamics of water drainage, it does assess the effects of moisture infiltration behind the cladding as fractions of wind-driven rain. In this manner, the infiltration loads simulate water applied into the slot fault of a standard drainage test. The influence of gap size and assumed ventilation rates can be assessed in relation to climate and building orientation.

We used the computer software model WUFI® Pro 7.0 to perform 5-year simulations for 15 climate locations.

FIGURE 8. Water absorption at fastener penetrations.

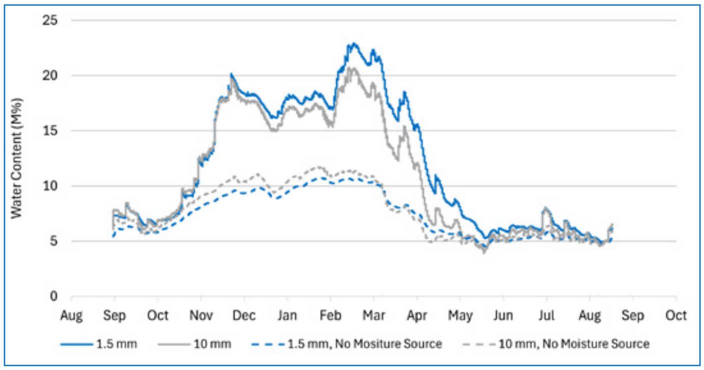

FIGURE 9. Water content of fiber cement panels for a typical simulated year in Vancouver, British Columbia. *Note: 1 mm = 0.0394 in.*

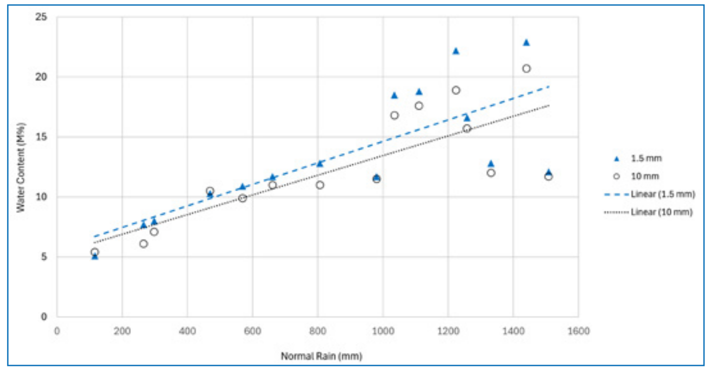

FIGURE 10. Peak water content of fiber cement panels. *Note: 1 mm = 0.0394 in.*

Analyses assumed a low-rise building with a framed wall enclosure configured with 5/16 in. (7.9 mm) fiber cement cladding, 1.5- or 10-mm (0.06 or 0.375 [3/8] in.) air gaps, polyolefin house wrap, and ½-in. (12.7-mm) plywood sheathing. The remaining wall assembly included 5½-in. (139.7-mm) batt-filled stud cavities and ½-in. interior gypsum. An interior vapor retarder was incorporated where appropriate for a given climate.

Boundary conditions were assigned the default surface transfer coefficient for interior air films; whereas wind-dependence was selected for exterior surfaces. Absorptivity was designated as 0.6 without radiative overcooling. Additional diffusion resistance was modeled as latex paint applied to exterior and interior boundaries.

Rain loading was calculated according to ASHRAE Standard 160, *Criteria for Moisture-Control Design Analysis in Buildings*, using the building height option of <10 m (32.8 ft).[22] Building orientation was varied based on climate location and prevailing wind directions, with the intent of demonstrating worst-case scenarios for wind-driven rain loads. Corresponding exposure and deposition factors were 1.0 and 0.5, respectively.

In accordance with ASHRAE 160, assumed moisture infiltration within the drainage space was simulated with a total wind-driven fraction of 1%. This fraction was further segregated into two equal portions (0.5%) applied to the WRB and interfacing fiber cement. This approach accounts for the fact that water is deposited onto both surfaces—a condition demonstrated by drainage testing for both gap sizes. Free water saturation was selected as the source term cutoff, relegating unreleased moisture to assumed drainage. Ventilation rates for the 1.5- and 10-mm (0.06 and 0.375 [3/8] in.) air gaps were 1 ACH and 20 ACH, respectively. The chosen air change rates reflect the model's lower limit for cavity walls (1 ACH) and the upper limit for vented spaces (20 ACH). The rate of ventilation for the 10-mm gap represents a generous assumption, as assemblies built to code generally lack the necessary vent openings to achieve this rate.

Interior climates were modeled as simplified sinusoidal curves with temperature variances of 20°C to 22ºC (36°F to 39.6°F) and 40% to 60% relative humidity. Exterior climates were modeled as ASHRAE Year 3. It should be noted that key materials, including the cladding and plywood sheathing, were partitioned as two layers to better resolve the density-dependence of predicted moisture contents, which were ultimately converted to, and expressed as, mass percent.

Preliminary analyses showed that drainage-gap performance was best measured by water content within the interfacing layer of fiber cement. Furthermore, outcomes for all climates and both gap conditions revealed no evidence of moisture accumulation in other material layers. Although cladding moisture levels was largely influenced by exterior conditions, they were also notably affected by infiltration loads placed directly against the interior cladding surface. Moreover, such loads result in short-term and long-term moisture storage that is not accounted for by exterior climates alone. For example, in **Fig. 9**, we compare simulated moisture contents for assemblies with and without applied moisture infiltration. The 1% infiltration load clearly affects wall performance more than gap size and assumed ventilation rates.

Figure 10 presents peak moisture contents for all 15 climates as a function of corresponding normal rain. These outcomes demonstrate that moisture content is moderately correlative with total rainfall (R2 = 0.60 [1.5 mm] and 0.64 [10 mm]). Of particular interest was the finding that gap size and corresponding ventilation rates had limited influence on overall wall performance. In most instances, the primary determinants were climate or the mere presence of moisture infiltration (**Fig. 9 and 10**). The influence of gap dimension was more pronounced for marine and cool humid climates that receive greater than 1000 mm (39 in.) of rainfall annually. In these instances, the results support the use of larger drainage gaps with higher ventilation rates.

CONCLUSION

This study highlights several important outcomes and limitations concerning drainage testing. First, we conclude that small drainage spaces such as

1.5 mm drain as well as larger gaps when evaluated in accordance with ASTM E2273. This premise holds true even at the reduced water application rate. We assert that the standard flow rate specified by ASTM E2273 is too high, as doubling it yields no substantive change and reducing it by half lowers drainage efficiency for both gap conditions. The standard reflects a bias toward higher drainage efficiencies that are obfuscated by the influence of displacement and predicated on the perception that 90% efficiency indicates better performance. In other words, a benchmark of 90% is perceived more favorably than one of 80% even though the lower application rate yields the same moisture storage. A proposed flow rate of 0.035 L/min (1.18 fl. oz/min)—or one-third of the flow rate employed by ASTM E2273—would better represent infiltration resulting from real-world fault conditions. Furthermore, most buildings experience a wide range of defects over the course of their service lives; some yield higher infiltration rates whereas others may yield significantly lower rates. It would seem obvious that a standard should account for smaller, more common faults yielding lower infiltration loads rather than larger ones that are arguably less common and notably less rigorous.

Water absorption by the interfacing cladding can markedly influence drainage efficiency. Our research shows that moisture absorption by fiber cement panels accounts for up to 85% of the stored moisture or roughly 4% of the total applied water. Although this moisture appears to be safely stored in all but the most extreme climates, this conclusion may not hold true for other types of claddings or other test conditions. Research into methods for further reducing moisture absorption may be worth pursuing to improve drainage and cladding durability.

Mandates for 10-mm (3⁄8-in.) gaps are fundamentally flawed if criteria for minimum ventilation rates are not also prescribed. As shown here, expectations that 10-mm gaps drain and dry substantively better than smaller gaps are not necessarily correct even when higher ventilation rates are assumed. In some instances, significant improvements in moisture control require a ventilated space—a condition not required by model building codes. Our results support the prevailing thought that buildings in marine or cool, humid climates would benefit from larger, effectively vented drainage gaps. However, for most climates, it is the mere presence of moisture, not the size of the drainage space, that determines whether a wall will sustain water-related damage.

Lastly, our findings expose an important conundrum in modern design practices. While model building codes and jurisdictions embrace drainage mandates, they do not adequately address the interface between exterior insulation and the drainage plane (**Fig, 1c**). A larger drainage gap, or one that is notably ventilated, would compromise thermal performance. If mandates assume that walls are best served by larger vented spaces, how do we justify much smaller spaces between exterior insulation and the drainage plane? No matter how much water is addressed by the outboard rainscreen, the primary drainage space is the one adjacent to the WRB—the point from which walls are flashed and the last resort for preventing air-induced intrusion. Drainage at the insulation-WRB interface is best managed by small drainage gaps that drain effectively while preserving thermal performance. The 1.5-mm (0.06-in.) space can effectively achieve this objective. Further research is therefore necessary to better understand drainage efficiencies and drying potentials in spaces that are thermally isolated from the outboard rainscreen cavity.

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