RESEARCH HIGHLIGHT

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Water Penetration Resistance of Windows—Study of Manufacturing, Building Design, Installation and Maintenance Factors

INTRODUCTION

Over the past decade there have been an increasing number of reports of moisture related performance problems in multi-unit residential buildings, particularly in British Columbia. Numerous recent studies have identified fabrication, installation, and maintenance issues associated with windows as a primary contributor to moisture problems in buildings.

Despite the various studies that have identified performance problems associated with windows, and the introduction of new standards to improve quality, windows and window-to-wall interfaces continue to be major contributors to moisture problems in buildings.

The purpose of this study was to determine the primary leakage paths and causes of water penetration associated with windows and the window-to-wall interface. The study represents a comprehensive effort to identify and establish priorities for improving in-service water penetration resistance of windows and the window-to-wall interface. It is considered to be the first step in a process that will help the construction industry better understand the factors that influence water penetration behaviour of windows and window-to-wall interfaces, and more consistently result in installed windows that achieve acceptable performance over the course of anticipated service lives.

The study includes windows and water penetration issues associated with both low-rise wood-frame buildings and high-rise non-combustible buildings. It also includes window-wall technology but does not include curtain wall technology.

A companion project to this study addresses water penetration issues associated with windows in the context of codes, standards and certification processes. The results of that study are reported on separately in a report titled *Water Penetration Resistance of Windows—Codes, Standards, Testing and Certification.*

METHODOLOGY

The assessment of water penetration associated with windows is complicated due to the large number of variables that exist. Not only are there many different window types and manufacturers, there are many potential leakage paths and causes of water penetration to be considered, some unique to particular window types. In addition, windows are installed in a wide variety of wall assemblies with a wide variety of interface details.

The methodology used in the study involved a series of steps:

1. Classification of windows into generic types based on frame material (aluminum, vinyl or wood), and moisture management strategy (face seal, concealed barrier, improved concealed barrier and rainscreen). A total of 10 generic types were identified (see Figure 1).
2. Establishment of primary leakage paths through and around windows and eventual destinations of the intruding water. Six leakage paths were identified (see Figure 2).
3. Development of a comprehensive list of specific issues that may result in leakage. These causal factors were grouped into six general categories; sealants, gaskets and tapes, penetrations, components, window design and selection and quality assurance and control.

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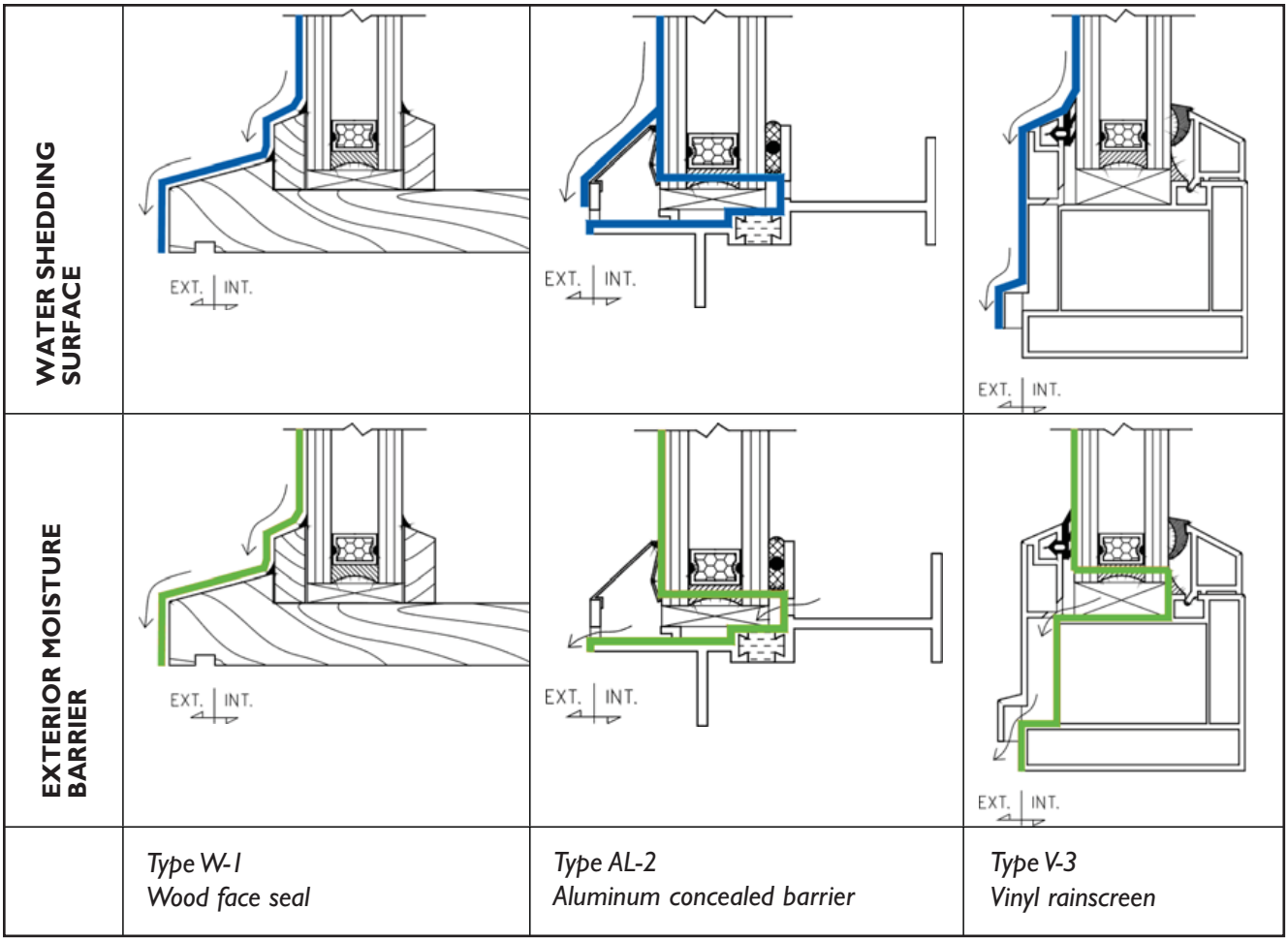


Figure 1 Examples of generic window types based on frame type and moisture management strategy

4. An assessment for each window type of:

a) The likelihood of a particular leakage path occurring

b) The level of consequential damage that may occur as a result of leakage

c) The likely causal factors contributing to particular leakage paths

d) The potential of various sub-sectors of the construction industry (window design, manufacturing, installation etc.) for correcting causal factors

5. Development of conclusions and priorities with respect to causal factors, leakage paths, and industry sector impact for each window type and recommendations for addressing water penetration issues.

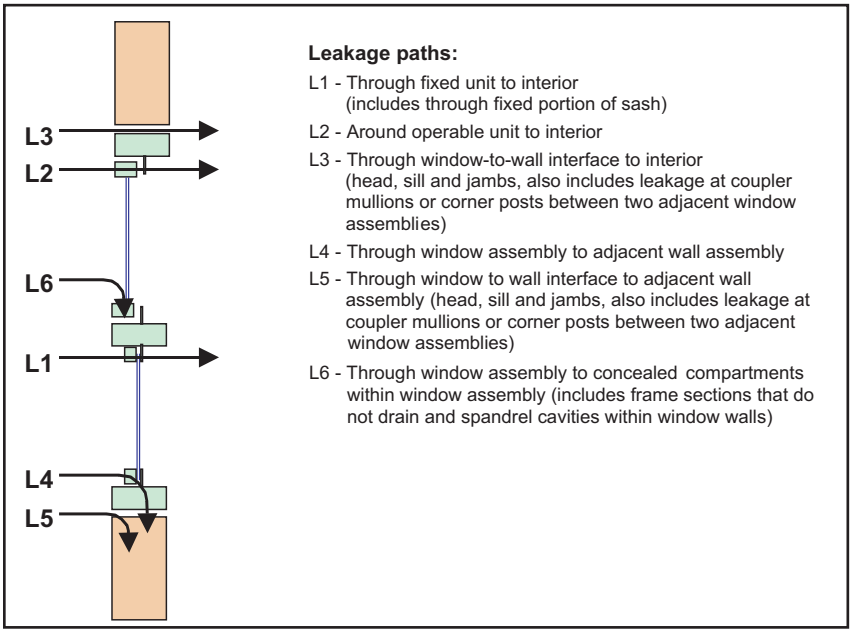


Figure 2 Possible window leakage paths

Table 1 Step four assessments carried out by construction industry sub-sectors

Industry sub-sector	Responsibility
Manufacturing • Window manufacturers	Window product design, including materials, fasteners and anchors, glazing retention systems. Quality control during manufacture.
Testing and certification • Testing agencies	Verification that window products (and in some cases installation) meet specified performance criteria.
Building & interface design and field review • Architects • Envelope consultants	Development of prescriptive and performance specifications. Control of some aspects of exposure conditions through design of building form and window location. Design and documentation of installation and interface details.
Installation • Glazing contractors	Window installation Shop drawings
Maintenance and renewals • Building owners • Maintenance contractors	Cleaning Adjustment of hardware Sealed unit replacement, sealant replacement

The step four assessments were carried out by team members and by representatives of each of the construction industry sub-sectors (see Table 1) involved in window manufacturing, interface design and field review and installation.

Data collected during the assessment stage was compiled and summarized in table format for each of the 10 window types. Figure 3 illustrates a typical summary table and provides explanation of the information presented.

CONCLUSIONS

General

- The dominant leakage path based on frequency of occurrence was identified as L5 (through window-to-wall assembly interface to adjacent wall assembly). Based on an assessment of risk of consequential damage both L4 (through window to adjacent wall assembly) and L5 can be considered to be high risk. Relatively minor variation exists between window types with respect to leakage paths.
- A wide range of causal factors were found to contribute to leakage activity. It is not possible to reach conclusions related to the prevalence of certain causal factors since they can only be considered in the context of particular leakage paths.
- The two industry sectors that appear to have the most significant opportunities to impact positively on the performance of windows are the Manufacturing sub-sector, and the Design and Field Review sub-sector. This finding reflects the fundamental influence that the window as a manufactured assembly has on performance, as well as the influence of the Design and Field Review sub-sector on the dominant leakage paths associated with the window-to-wall interface.

Manufacturing

- Quality control is the focal point for the manufacturing sector in achieving improvements in a range of causal factors. However, because of limitations in the manufacturing process, achieving perfection is not possible and alternative solutions may be preferable, for example sub-sill drainage capacity may be a more effective solution than an attempt to achieve watertight mitre joints in window frames.
- Particular window types are often used in exposure conditions beyond their capability for durable performance, despite the fact that appropriate windows are available.

Testing and certification

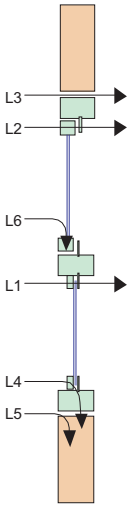
- The A440 B rating performance criteria does not address the dominant leakage paths. Nor does the standard appropriately address microclimate effects such as building form, overhangs, or local terrain.
- There is no certification system in place that addresses the water penetration performance of installed windows. A certification program could have a positive impact on performance.

Building & interface design and field review

- The design and field review sector has the greatest potential to address causal factors that contribute to the dominant leakage paths.
- All window types have a high risk of water penetration due to causal factors related to window-to-wall interface.
- A key factor in addressing the dominant leakage paths and improving window performance is the provision of sub-sill drainage capability.

Leakage path and causal factor combination results in high relative risk rating for this window type

CAUSAL FACTORS FOR MEDIUM AND HIGH RELATIVE RISK RATINGS	LEAKAGE PATHS FOR MEDIUM AND HIGH RELATIVE RISK RATINGS		POTENTIAL IMPACT OF SECTOR				
CAUSAL FACTORS	MEDIUM	HIGH	Manufacturing	Testing & certification	Building & interface design and field review	Installation	Maintenance & renewal
1.01 Between fixed frame members		L4	3	2		1	
1.02 Between couplers (fit)		L4	3	2	1	2	
1.03 Perimeter exterior moisture barrier seal	L3	L4 L5	1	2	3	2	2
1.09 Seepage around thermal break	L4		3	2	1	2	
1.11 Seal at fasteners		L4 L5	3	2	1	2	
3.03 Electrical cable		L4 L5	1	2	3	2	1
3.04 Security hardware	L4	L5	1	2	3	2	1
4.05 Poor seal between vent adapter and frame	L4		3	2	1	1	
4.06 Lack of slope on head flashing	L3	L5	2	2	3	2	
4.07 Lack of slope on sill flashing		L5	2	2	3	2	
4.08 No end dams on head flashing	L3	L5	2	2	3	2	
4.09 No end dams on sill flashing	L3	L5	2	2	3	2	
4.10 No head flashing		L5	2	1	3	2	
4.11 No sill flashing		L5	2	1	3	2	
4.12 Wall exterior moisture barrier discontinuities at window perimeter	L3	L4 L5	1	1	3	3	1
4.13 Screw spline blocking drainage path	L4		3	2	1	1	
4.16 No slope on window frame sill to encourage drainage	L4		3	2	1	1	
6.01 Window will work with very diligent QA/QC in plant or installation but it is not done	L3	L5	3	2	2	3	
6.02 Not implementing measures that were necessary to achieve rating in test	L4	L5	2	2	2	2	



LEAKAGE PATHS:

L1 - Through fixed unit to interior
L2 - Around operable unit to interior
L3 - Through window to wall interface to interior
L4 - Through window assembly to adjacent wall assembly
L5 - Through window to wall interface to adjacent wall assembly
L6 - Through window assembly to concealed compartments within window assembly

RELATIVE RISK RATING[1] =

Risk of consequential damage x frequency of occurrence x leakage path applicability
(18 to 27 = High, 12 to 17 = Medium, 0 to 11 = Low

POTENTIAL IMPACT OF SECTOR

Degree to which a particular sector may be able to influence a causal factor to improve performance.
(0 no effect, 1 minor , 2 moderate, 3 major)

Leakage path and causal factor combination results in medium relative risk rating for this window type

Industry sector that is perceived to have potential for major influence on causal factor to improve performance

Figure 3 Summary table of step four assessments for window types

[1] See section 2.6 of *Water Penetration Resistance of Windows—Study of Manufacturing, Building Design, Installation, and Maintenance Factors*, Canada Mortgage and Housing Corporation, 2002, for description of the individual assessment parameters.

Installation

- The installation sub-sector has little control over many issues that impact the performance of the installed window. In larger multi-unit residential buildings a design team is involved in the project. The installer typically installs a window manufactured by others in accordance with interface details provided by others. The focus therefore is on trade training, improved quality control and effective identification of manufacturing and design issues for resolution in conjunction with other sectors. In smaller Part 9 buildings, the role of the installer is actually expanded since they usually determine the details to be used. The installer may need to have greater understanding of the design strategy and details of water penetration for these smaller buildings, further emphasizing the need for trade training.

Maintenance and renewals

- With certain window and installation types, the nature and frequency of required maintenance is considered unreasonable.
- Those undertaking maintenance and renewal activities are often unaware of strategies and details for water penetration control.

Recommendations

- Consideration of micro exposure conditions must become an explicit consideration of the establishment of exposure classification.
- Performance expectations for water penetration resistance for different window types, based on a rational exposure classification system, including the durability of that performance level, need to be mandated.
- A 'Best Practice Guide' for windows should be developed that integrates not only the recommendations developed in this report with respect to effective water penetration control, but all other performance issues associated with window specification, selection, interface design and maintenance and renewals.
- Maintenance and renewal plans should be developed on a building specific basis. Plans should describe the design strategy, function of components and materials, in addition to the frequency, procedures and materials to be used in undertaking the maintenance and renewal activities.
- The manufacturing sub-sector has a general need to increase focus on quality control, which should include in-plant water penetration testing.
- Manufacturers have to focus on the design of the entire installed window and take a more active role in the installation of their products.
- The Manufacturing sub-sector, in collaboration with the Building & Interface Design sub-sector, must provide realistic maintenance and renewal recommendations for their products for the intended service life of the product.
- A water penetration testing protocol needs to be developed and mandated for the installed window that also reflects building specific conditions. This could be done as part of the installation section of current A440 standard series (A440.4).
- There is a need for the Building & Interface Design sub-sector to increase their focus on interface detailing, considering continuity of all of the critical barriers, as well as durability, and maintenance and renewals issues. A key component of this focus on interface detailing is to provide some redundancy in the installed assembly to allow for the understanding that it is not possible to achieve perfection in the manufacturing and installation process. Sub-sill drainage should be provided for all windows.

Related and reference documents

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7. *Windows*, CSA Standard A440-00, Canadian Standards Association
8. *User Selection Guide to CSA A440-00*, Windows, Special Publication A440.1, Canadian Standards Association
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11. *Water Penetration Resistance of Windows—Study of Manufacturing, Building Design, Installation, and Maintenance Factors,* Canada Mortgage and Housing Corporation, 2002

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CMHC undertook this study in partnership with the Homeowner Protection office and the British Columbia Housing Management Commission.

Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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