Walls and Windows: Claddings, Rainscreen Systems, Thermal and Moisture Performance

Books and Research Reports

Homeowner Protection Office
Cladding
Vancouver: Homeowner Protection Office
2011
Wall cladding is the material or component of the wall assembly that forms the outer surface of the wall and is the first line of protection from the exterior environment (sun, wind, rain and temperature). It is also an important part of the appearance of a building. As with all other exposed portions of the building enclosure (windows, roofs and balconies), regular review and maintenance of the cladding is important to ensure intended performance and appearance.

Homeowner Protection Office,
Rainscreen Walls: Field Monitoring and Performance in Coastal British Columbia
Vancouver: Homeowner Protection Office
2008
Highlights the results of an industry-sponsored program that was performed to verify the long-term performance of rainscreen walls in multi-unit residential construction in British Columbia.

Homeowner Protection Office,
Fenestration Energy Performance: Requirements for Residential Buildings in British Columbia
Vancouver: Homeowner Protection Office
2011
Energy performance requirements for windows, glazed doors and skylights used in residential buildings, and provides a roadmap for compliance. This bulletin will help clarify the building code and BC Energy Efficiency Act requirements and the supporting standards.

Homeowner Protection Office,
Sidewall Venting of Gas Appliances
Vancouver: Homeowner Protection Office
2013
Examines issues surrounding sidewall venting along with current installation requirements and recommendations.

RDH Building Engineering Ltd.
Study of High-Rise Envelope Performance in the Coastal Climate of British Columbia
:
2001
This research project identifies factors contributing to envelope performance problems and successes in non-combustible high-rise residential buildings. The study correlates building

envelope performance with sources of moisture, such as design features, construction of assemblies, and details. Key factors for successful design and construction of the building envelope assemblies and details are identified in this report. The HPO and CMHC are the primary sponsors for this research project.

RDH Building Engineering Ltd.
Performance Monitoring of Rainscreen Wall Assemblies in Vancouver British Columbia February 16, 2007 Edition
:
2007
This project involves measuring and monitoring the performance of rainscreen wall assemblies within new and rehabilitated low, mid and high-rise residential buildings. A total of five buildings in Vancouver, British Columbia were studied. Related measurements (e.g., temperature, wood moisture content, relative humidity, local weather conditions including rainfall, driving rainfall and pressure differences across the walls) were collected and analyzed to assess the effectiveness of rainscreen wall assemblies. This research was co-funded by the HPO, CMHC and BC Housing.

RDH Building Engineering Ltd.
Best Practices for Window and Door Replacement in Wood-Frame Buildings Guide
Burnaby, BC, Canada: Homeowner Protection Office
2013
This comprehensive guide explains best practices for window and door replacement in wood-frame buildings, from single-family homes to multi-unit residential buildings. It‘s intended to help industry meet consumer expectations, provide quality installations and achieve high performance for all types of window and door replacement projects.A valuable reference tool for construction industry professionals, including builders, replacement contractors, window and door manufacturers and others, this 315-page guide:Outlines Building Code requirements for replacement and installation procedures, includes a comprehensive list of installation detailing samples and addresses unique challenges presented by B.C.’s coastal climateThe guide was developed in partnership with the Fenestration Association of BC, BC Hydro PowerSmart and the City of Vancouver. It is available only in a downloadable PDF version
Available at: HPO

RDH Building Engineering Ltd.
Inernational Window Standards
Burnaby, BC, Canada: Homeowner Protection Office
2014
A follow-up study to the Review of Window Energy Rating Procedure in Canada was undertaken to better understand how the rating system used in North America compared to Passive House and ISO fenestration energy rating systems used in Europe. The research identified that the performance measures in North America are more geared towards peak design conditions, whereas the European values are more average values suitable for annual energy simulations. The different calculations methods are leading North American window manufacturers to build narrower gaps between window

panes than in Europe. The findings could help manufacturers to adapt their products for different jurisdictions.
Available at: HPO

Canada Mortgage and Housing Corporation
Understanding Vapour Permeance and Condensation in Wall Assemblies
Ottawa: Canada Mortgage and Housing Corporation
2009
"Polyethylene air/vapour barriers have been used for many decades in the walls of new Canadian homes. This research illustrates where polyethylene is appropriate for this use and where other vapour barrier materials might be preferable. It identifies situations in which performance could be improved, and provides information on general approaches to help mitigate performance concerns."

Anderson, J. M. and J.R. Gill
Rainscreen Cladding: A Guide to Design Principles and Practice
London: Butterworths
1988
"Rainscreen cladding, which was developed in Scandinavia and North America, is an increasingly popular technique used to protect external walls from the effects of heavy wetting and solar radiation. In addition, it serves as a cosmetic element facilitating the use of thermal insulation on the outer face of a wall. This book provides a discussion of the historical development of rainscreen cladding. Basic design principles are reviewed and the factors that must be taken into account when designing and detailing such claddings are explained with practical guidance on avoiding basic mistakes in design and detailing. Selected annotated references and a comprehensive bibliography are also included."
Available at: BCIT, VPL

Brock, L.
Designing the Exterior Wall: An Architectural Guide to the Vertical Envelope
Hoboken, N.J.: John Wiley
2005
"This book presents the basics of building science along with a prescribed set of details that helps the readers to understand why buildings fail and how they can be made more durable through design. Author Linda Brock connects the science and aesthetics of building envelopes through the examination of a variety of construction and cladding types. She features details from real world projects in a variety of climates, successful and unsuccessful case studies, and checklists readers can use on their own projects."
Available at: BCIT, UBC, VPL

Brookes, A.J. and G. Chris
The Building Envelope: Applications of New Technology Cladding
London: Butterworths
1990

"A survey of advanced technology in architecture and building. By means of 33 case studies of recent buildings incorporating new forms of construction throughout the world, the authors clarify, in a highly illustrative fashion, the various advanced forms of construction, and provide an essential database for designers in the field."
Available at: BCIT, VPL, UBC

Brookes, A.J.
Cladding of Buildings Third Edition
London: E & FN Spon
1998
"This updated edition covers the main types of cladding systems in detail and explains methods of production, performance characteristics, applications and methods of assembly, incorporating the latest environmental issues."
Available at: VPL

Brown, W.C.
Construction Innovation
Ottawa: National Research Council of Canada, Institute for Research in Construction
1996
"Sophisticated modeling and measurement techniques developed by IRC will someday be able to produce design guidelines for moisture control in wood-frame houses clad with any exterior finish system, in any climate, and research initiated on behalf of an American client will have long-term benefits for Canadian home builders and consumers."
Available at: BCIT, VPL, UBC, NRC-IRC

Canada Mortgage and Housing Corporation
Predicting Time to Fogging of Insulated Glass Units
Ottawa: Canada Mortgage and Housing Corporation
2001
"Estimating the remaining service life span, or time-to-fogging, of insulating glass units (IGU's) can pose a planning and budgeting problem for building managers and condominium corporations. This research report describes a method for predicting the time-to-failure of IGU's, and suggests ways of improving the predictability of IGU failure. The method entails measuring dew-point temperatures for a sample of identical units; after three sets of measurements are gathered, a time-to-fogging prediction is obtained using a mathematical forecasting model."
Available at: CMHC

Canada Mortgage and Housing Corporation
Best Practice Guide: Architectural Precast Concrete Walls
Ottawa: Canada Mortgage and Housing Corporation
2002
"This Guide and accompanying CD-ROM is a fully illustrated summary of current information on architectural precast concrete and provides designers with an understanding of the product, recommended design details and site practices. The guide discusses the types of panels, their

manufacture, transport and installation and basic design considerations. The user is then presented with the fundamentals of building envelop performance, as it pertains to precast panels, through to best practice assemblies, details and specifications."
Available at: BCIT, UBC, CMHC

Canada Mortgage and Housing Corporation
Alternative Wall Systems for Low-Rise Housing
Ottawa: Canada Mortgage and Housing Corporation
2002
"An analysis of ten alternative wall systems to raise awareness of different options with Canadian builders and consumers. The wall systems evaluated include: lightweight steel framing, structural insulated panels, insulated concrete forms, post and beam, concrete block, log, stackwall, straw bale, manufactured wood wall and earth wall construction."
Available at: CMHC

Canada Mortgage and Housing Corporation
Water Penetration Resistance of Windows - Study of Codes, Standards, Testing and Certification
Ottawa: Canada Mortgage and Housing Corporation
2003
"Over the past decade there has been an increasing number of reports of moisture related performance problems in multi-unit residential buildings, particularly in British Columbia. This study addresses water penetration issues associated with windows in the context of codes, standards, testing and certification processes. It is one element in a process that will help the construction industry understand the factors that influence water penetration behaviour of window-to-wall interfaces, and more consistently result in installed windows that perform well over the course of their 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."
Available at: CMHC, HPO

Canada Mortgage and Housing Corporation
Water Penetration Resistance of Windows: Study of Manufacturing, Building Design, Installation and Maintenance Factors
Ottawa: Canada Mortgage and Housing Corporation
2003
"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 study represents a comprehensive effort to establish priorities for improving in-service water penetration resistance of windows. It identifies the responsibilities of the various window industry sectors, and makes recommendations for each sector."
Available at: CMHC, HPO

Canada Mortgage and Housing Corporation

Design of Durable Joints between Windows and Walls
Ottawa: Canada Mortgage and Housing Corporation
2003
"The joints between windows (or doors) and the structure of buildings are without doubt the most delicate and most vulnerable. All too often, this is where the first signs of deficiencies in the building envelope appear. This fact sheet contains best practice advice on rain barriers, flashing, perimeter joints, choice of mastic, sizing of joints, shims and anchors, and insulation. Sound joint design is essential to achieving the best possible installation of windows, and the manufacturer's recommendations must always be followed."
Available at: CMHC

Canada Mortgage and Housing Corporation
Best Practice Guide: Exterior Insulation and Finish Systems
Ottawa: Canada Mortgage and Housing Corporation
2004
"EIFS are products that integrate insulation and a 'stucco' like covering, for cladding exterior walls. This sixty-five page technical guide, and extensive appendices, is intended to assist building professionals in proper design and application of EIFS. Following these best practice recommendations promotes satisfactory performance and durability of the products."
Available at: BCIT, UBC, CMHC

Canada Mortgage and Housing Corporation
Best Practice Guide: Glass and Metal Curtain Walls
Ottawa: Canada Mortgage and Housing Corporation
2004
"This Best Practice Guide contains practical information on wall system design and performance for anyone designing, manufacturing or installing curtain wall. This guide covers curtain wall assembly, materials, testing, performance, quality control, specifications and maintenance, with numerous construction details and illustrations. Text and drawings are also included in the accompanying CD ROM, with AutoCAD files of details in DWG and DXF formats."
Available at: BCIT, CMHC

Canada Mortgage and Housing Corporation
Assessing the Impact of Thickness on the Performance of Stucco Cladding
Ottawa: Canada Mortgage and Housing Corporation
2004
"Alberta builders have been using two-coat stucco, rather than the traditional three-coat stucco. This project examined whether there were performance differences between these two types of stucco. Samples were examined for performance in the area of water management and serviceability. The research highlighted a number of factors such as application and drying time that affect overall performance."
Available at: CMHC

Donaldson, B., Ed.

STP 1034: Exterior Wall Systems: Glass and Concrete
Philadelphia, PA: American Society for Testing and Materials
1991
"In recent years the design of exterior walls has incorporated more diverse materials and complex building technology than ever before. The use of metal, glass, stone, concrete, and masonry in the building facade challenges architects, engineers, manufacturers, and contractors to better understand materials and systems. STP 1034 reflects this trend and provides the building industry with information and solutions based on actual building projects. 14 peer-reviewed papers written by experts in the design and technology of exterior wall systems cover design concerns of exterior wall systems; testing and analysis; structural sealant glazing; stone selection; and precast and composite concrete wall systems. Each paper uses case studies to illustrate the successes and failures of exterior wall systems. For architects, engineers, manufacturers, and contractors."
Available at: CMHC, www.astm.org

Drysdale, R.G.
Exterior Wall Construction in High-Rise Buildings
Ottawa: Canada Mortgage and Housing Corporation
1991
"An expert look at problems that can occur with masonry cavity walls and veneer on high-rise buildings with structural frames. It also examines design, construction, supervision, and inspection. Serious in-depth information for architects, builders and developers." [This is one of the most complete texts on anchored brick veneer cladding available to date.]
Available at: BCIT, VPL, CMHC

Malhotra, A.
Best Practice Guide: Brick Veneer Concrete Masonry Unit Backing
Ottawa: Canada Mortgage and Housing Corporation
1997
"This guide provides industry-tested solutions for Brick Veneer Concrete Masonry Unit Backing wall design. Companion CD-ROM includes 24 CAD drawings and specification tables, in metric and imperial measurements."
Available at: BCIT, VPL, UBC, CMHC

Posey, J.B.
Best Practice Guide: Building Technology Brick Veneer Steel Stud
Ottawa: Canada Mortgage and Housing Corporation
1997
"This Best Practice Guide is intended for builders, designers, architects, engineers and specification writers of high-rise and multiple-unit buildings. Topics cover building science issues such as heat flow and thermal bridging, rainscreens, air leakage and water penetration. The quality assurance section looks at prototype testing, inspection and compliance testing. A building envelope checklist in a handy binder is accompanied by a CD-ROM featuring 11 CAD drawings that you can customize for your specific projects."
Available at: BCIT, UBC, CMHC

Ritchie T.
Canadian Building Digests, CBD-21
Ottawa: National Research Council of Canada, Division of Building Research
1961
"Cavity walls provide an important advantage over walls of solid masonry in that they can afford complete protection against rain penetration even when exposed to conditions of severe wetting by wind-driven rain. Under similar conditions rain leakage through solid masonry walls is not uncommon. There are three essential requirements for cavity wall construction: the cavity wall must have a gutter at its base to collect leakage water and drains to direct water out of it; the two parts of the wall must be anchored together with metal ties that are corrosion resistant and adequately strong; the wall must have a cavity free of mortar or other material that may form a water bridge across it. Cavity walls have been used in many countries over a long period of time and have established their excellent performance record under widely varying conditions." [As the construction of cavity walls has changed substantially since this document was published, it is primarily of interest for existing construction and building science issues.]
Available at: BCIT, VPL, UBC, NRC-IRC

Watts, Andrew
Modern construction facades
New York: Springer
2005
"Modern Construction Facades is a guide for practitioners of architecture as well as structural and environmental engineers who wish to broaden their study beyond the information provided in the Walls chapter of the Modern Construction Handbook. The six chapters in this new handbook examine facades from the standpoint of the primary material used in their construction, from metal to glass, concrete, masonry, plastics, and wood. Each entry explains a specific form of construction and is accompanied by annotated details."
Available at: BCIT

Williams, M. and B. Williams
Manual 16 Exterior Insulation and Finish Systems: Current Practices and Future Considerations
Philadelphia, PA: American Society for Testing and Materials
1994
"With an ever-growing U.S. industry, exterior insulation and finish systems (EIFS) are increasingly recognized as a competitive exterior wall choice along with conventional assemblies of masonry, concrete, metal, and wood. Until now, a comprehensive peer-reviewed sourcebook on EIFS has not been available. ASTM Manual 16 fills this need by bringing together information on EIFS design, application, maintenance, and repair. Four parts cover: EIFS assemblies, system types, components, and fundamentals; System performance criteria and design considerations; System application and inspection; Common system problems; and general maintenance and repair procedures."
Available at: VPL, UBC

Williams, M. F. and R.G. Lampo (editors)
STP 1187: Development, Use, and Performance of Exterior Insulation and Finish Systems
Philadelphia, PA: American Society for Testing and Materials
1995
"This publication contains papers presented at the International Symposium on Exterior Insulation and Finish Systems (EIFS): Performance of EIFS Worldwide, held in Washington DC on 21-24 Sept. 1992. In addition to a history of EIFS, there are papers on material and system performance, standards and building codes, maintenance and retrofit, sealant joints, and new material and system developments."
Available at: BCIT, UBC

Beaulieu, P., Bomberg, M.T. et al.
Final Report from Task 8 of MEWS Project (T8-03) - Hygrothermal Response of Exterior Wall Systems to Climate Loading: Methodology and Interpretation of Results for Stucco, EIFS, Masonry and Siding-Clad Wood-Frame Walls
Ottawa: Institute for Research in Construction, National Research Council Canada
2002
"By 1997, several field surveys in North America had indicated that rain penetration in exterior walls and poor construction detailing contributed to the shortening of the service life of recently built exterior walls of low-rise buildings in climates with high exterior moisture loads. In 1998, IRC/NRC initiated a research consortium with industry partners to develop guidelines for moisture management for exterior wall systems (MEWS) in low-rise residential buildings of North America. Partners represented the wood industry, manufacturers of cladding systems, insulation materials and water resistive barriers as well as building owners and managers. The project was broken down into several tasks, from a review of literature on current construction practice to experimental work in the laboratory and mathematical modelling. The following four types of cladding systems were included in the project: Portland cement plaster (stucco), Exterior Insulation and Finish Systems (EIFS), masonry and siding, over wood-frame construction. This TG8 report is a research document to describe the research approach in some detail (chapter 1), to summarize its application to the four types of wall assemblies (chapters 2 - 5) and to draw general conclusions (chapter 6), based on the observations in chapters 2 - 5."
Available at: NRC-IRC

Boyd, J.M and M.J. Scheffler (editors)
STP 1352: Water Problems in Building Exterior Walls: Evaluation, Prevention, and Repair
Philadelphia, PA: American Society for Testing and Materials
1999
"A unique publication featuring a comprehensive overview of the ways water impacts building envelopes. A diverse range of professionals in related fields have written 22 peer-reviewed papers focusing on the following key areas: Exterior Insulation and Finish Systems - 5 papers examine theoretical, modeling and system design perspectives as well as new system approaches and retrofit alternatives. Moisture Migration, Modeling, and Condensation -- numerous issues such as moisture evaluation and analysis methods and condensation problems in an enclosed swimming pool and ice rink are explored in 4 papers. Masonry Systems - 7 papers address masonry concerns including

mortar bond, foam insulation, alternative water control mechanisms, prefabricated assemblies and flashing and alternative system detailing. Detailing, Testing and Case Studies - An informative and practical view of 6 specific project case studies are presented here."
Available at: VPL, www.astm.org

Brown, W.P. and A.G. Wilson
Canadian Building Digests, CBD-44
Ottawa: National Research Council of Canada, Division of Building Research
1963
"Walls and roofs designed today often incorporate details that have a lower resistance to heat flow than the main construction. In general, these details are thermally weak because high-conductivity structural elements project partly or wholly through materials of lower conductivity; in this Digest they are referred to as 'thermal bridges'."
Available at: BCIT, VPL, UBC, NRC-IRC

Brown, W.C., G.A. Chown, G.F. Poirier, and M.Z. Rousseau
Construction Technology Updates, No. 34
Ottawa: National Research Council of Canada, Institute for Research in Construction
1999
"According to the rainscreen principle, the first line of defense minimizes rainwater passage toward a wall, while the second line deals with water that gets past the first The design characteristics of both lines of defense must take into account the given environmental conditions. For the first line of defense that means reducing the moisture loads, having a watertight facade, and managing the forces (gravity, capillarity, etc.) that drive water through possible holes in the cladding. For the second line of defense, it means intercepting free and bound water and dissipating it."
Available at: VPL, NRC-IRC

Canada Mortgage and Housing Corporation
Seminar: Rain Penetration Control
Ottawa: Canada Mortgage and Housing Corporation

A series of research papers prepared for CMHC including:•An Exploratory Study of the Climatic Relationships Between Rain and Wind, Technical Series 96-208; •Simulation of Wind-Driven Rain and Wetting Patterns on Buildings, Technical Series 96-213; •A Study of Mean Pressure Gradients, Mean Cavity Pressures, and Resulting Residual Mean Pressures Across a Rainscreen for a Representative Building, Technical Series 96-207; •A Study of the Rainscreen Concept Applied to Cladding Systems on Wood Frame Walls, Technical Series 96-214; •Performance of Brick Veneer Steel Stud Wall Systems Subject to Temperature, Air Pressure and Vapour Pressure Differentials, Technical Series 96-211;•A Rainscreen Wall: A Commissioning Protocol, Technical Series 96-238; •Laboratory Investigation, Field Performance and Commissioning of Pressure Equalized Rainscreen Walls, Technical Series 96-236.
Available at: CMHC (Technical Series Research Highlights reports can be downloaded from CMHC website; full research reports available through the Canadian Housing Information Centre)

Canada Housing and Mortgage Corporation
Comparative Analysis of Residential Construction in Seattle, WA and Vancouver, B.C.
Ottawa: Canada Housing and Mortgage Corporation
1999
"An analysis of the similarities and differences in light wood frame residential construction in Seattle and Vancouver, which have similar climates".
Available at: CMHC

Canada Mortgage and Housing Corporation
Envelope Drying Rates Analysis
Ottawa: Canada Mortgage and Housing Corporation
2001
"A research program conducted at Forintek Canada Corp's western lab in Vancouver, Canada has evaluated the relative drying rates of wall assemblies under controlled conditions. The research ranks test wall panels in terms in terms of their relative drying capacities, identifies potential wall locations at greater risk of slow drying (thus requiring enhanced material durability) and derives baseline data which can be used to improve parametric models of wall performance".
Available at: CMHC, HPO, Forintek Canada Corporation

Canada Mortgage and Housing Corporation
A Building Envelope Test Hut in Coastal British Columbia
Ottawa: Canada Mortgage and Housing Corporation, research report
2001
"This project examines the feasibility of constructing a building envelope test hut facility in the Lower Mainland to study envelope performance under real conditions in real time. Research partners include HPO, CMHC and BCIT."
Available at: BCIT, CMHC, HPO

Canada Mortgage and Housing Corporation
Air Leakage Characteristics, Test Methods and Specifications for Large Buildings
Ottawa: Canada Mortgage and Housing Corporation
2001
"This research report provided a summary of existing data on airtightness for large buildings and an overview of performance specifications, quality control procedures, test methods and standards."
Available at: CMHC

Canada Mortgage and Housing Corporation
Evaluation of Vapour Diffusion Ports on Drying of Wood-Frame Walls Under Controlled Circumstances
Ottawa: Canada Mortgage and Housing Corporation
2002
"An understanding of how walls manage moisture is a requirement to fully address the leaky condominium problem in British Columbia. Walls require four features for effective moisture

management: deflection, drainage, drying and durability. This report summarizes the findings of an Envelope Drying Rate Analysis (ERDA) experiment."
Available at: CMHC

Canada Mortgage and Housing Corporation
Study of Poured-In-Place Concrete Wall Assemblies in Coastal British Columbia
Ottawa: Canada Mortgage and Housing Corporation
2002
"This study analyzes and documents performance issues associated with Poured-In-Place Concrete Wall Assemblies in the wet coastal climate region of British Columbia. Guidelines are also developed for appropriate design and construction practices. The study investigates the effects of building form, rain penetration control, air leakage control, vapour diffusion control, thermal performance, and concrete construction practices on the performance of Poured-In-Place Concrete Wall Systems."
Available at: CMHC

Canada Mortgage and Housing Corporation
Study of High-Rise Envelope Performance in the Costal Climate of British Columbia
Ottawa: Canada Mortgage and Housing Corporation
2002
"Moisture related problems in high-rise residential buildings have become more common in the coastal climate of British Columbia. This study identifies key factors that contribute to the successful design and construction of building envelope assemblies, interfaces, details and associated mechanical systems."
Available at: CMHC

Canada Mortgage and Housing Corporation
Review of Hygrothermal Models of Building Envelope Retrofit Analysis
Ottawa: Canada Mortgage and Housing Corporation
2003
"CMHC supports research on the durability of building envelope assemblies, with a concern that additions of insulation and air/vapour barriers to existing wall assemblies do not adversely impact their performance. The commercial availability of appropriate computerized hygrothermal modeling tools is thus extremely important to this research. This study revealed that of some 45 such tools known to exist, only a handful met the criteria for general use by architects and engineers in the housing industry. Indeed, only a couple (MATCH and WUFI) were deemed suitable for further research, and all have some limitations."
Available at: CMHC

Canada Mortgage and Housing Corporation
Comparison of Modeled and Monitored Performance of a Wall Insulation Retrofit in a Solid Masonry Building
Ottawa: Canada Mortgage and Housing Corporation
2003

"This project examined the results of adding insulation in 1996 on the inside of the solid masonry walls of a four-storey masonry building in Prince Albert. Many architects and renovators are wary of interior insulation as the practice is thought to increase the likelihood of wall failures due to freeze-thaw cycles. Temperature, relative humidity, thermal flux, and air pressures were monitored on many locations through the building envelope. By all indications, the walls are performing well with none of the aforementioned concerns realized. This is a highly technical fact sheet, dealing with hygrothermal modeling sensitivity, starting moisture content, parging permeance, etc."
Available at: CMHC

Canadian Wood Council
Moisture and Wood-Frame Buildings: Building Performance Series No. 1
Ottawa: Canadian Wood Council
2000
"The bulletin is focused on the control of rainwater penetration in exterior walls, particularly for climates subject to high moisture exposure. The 20-page moisture bulletin provides background for both design professionals and building owners in Canada and the U.S. on moisture issues related to the design and construction of wood-frame buildings. It also provides ideas and solutions to improve the performance of wood-frame buildings, particularly concerning durability and constructability, while communicating the applications of sound building science principles during the design and building phases of construction. Forintek Canada Corp. contributed to the development, editing and review of the bulletin."
Available at: CMHC, Canadian Wood Council

Chown, G.A., W.C. Brown and G.F. Poirier
Construction Technology Updates, No. 9.
Ottawa: National Research Council of Canada, Institute for Research in Construction
1997
"When masonry walls were thick and the materials used quite porous, their very mass absorbed the rainwater and later released it. Eventually, though, walls became thinner and something had to be done to prevent rain penetration. That could be either a face-sealed wall, which in a sense is a rainwater barrier in the form of vinyl or aluminum cladding on the outside wall, or a cavity wall, which consists of one wall just to catch the rain and an adjacent cavity to serve as moisture break. With open rainscreen walls, which reflect current thinking in wall construction, the cladding constitutes the first line of defense. And then there is a second line of defense."
Available at: VPL, NRC-IRC

Derome, D., P. Fazio and G. Desmarais
Impact of Added Insulation on Air Leakage Patterns
Ottawa: Canada Mortgage and Housing Corporation
2001
"This project investigated the impact of added insulation on air leakage patterns through a full-scale laboratory testing. The moisture content and temperature distribution patterns in walls with different air leakage characteristics were monitored when subjected to varying insulating

strategies."
Available at: CMHC

DMO Associates
Drying of Walls with Ventilated Stucco Cladding: A Parametric Analysis
Ottawa: Canada Mortgage and Housing Corporation
1999
"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."
Available at: CMHC

Drysdale, R.G. and M.J. Wilson
Part 5 of the McMaster University Laboratory Test Program on Brick Veneer/Steel Stud Wall Systems
Ottawa: Canada Mortgage and Housing Corporation
1990

Available at: CMHC

Forintek Canada Corporation
Guidelines for On-Site Measurement of Moisture in Wood Building Materials
Ottawa: Canada Mortgage and Housing Corporation
2001
"Builders, inspectors and engineers undertaking moisture measurements on site in many instances do not possess the necessary background for using or interpreting moisture meter readings from wood and wood-based products. Because this judgment is also needed in their interpretation, this document has been prepared to provide both detailed instructions and background information to assist persons involved in these endeavours. The objective of this report is to assist those not fully informed in wood moisture measurement technology and to provide general guidance with respect to measuring wood moisture content in field conditions. The document outlines the types of available moisture meters, a process of how to take moisture readings, where to take moisture

readings and how the moisture readings are corrected for temperature and wood species. In addition, the document will provide a general discussion about steps builders and designers can take minimize construction complications due to moisture."
Available at: CMHC, Forintek Canada Corporation

Garden, G. K.
Canadian Building Digests, CBD-40
Ottawa: National Research Council of Canada, Division of Building Research
1963
"Rain penetration of building walls occurs all too frequently despite advances in building technology. Through-wall or complete penetration may damage building contents as well as cause stains and deterioration of interior finishes; uncontrolled partial penetration, which is less frequently recognized, can permit undesirable quantities of water within the wall."
Available at: BCIT, VPL, UBC, NRC-IRC

Hubbs, B. and M. Hircock
Performance Monitoring of Rainscreen Wall Assemblies in Vancouver British Columbia
Ottawa: Canada Mortgage and Housing Corporation, research report
2007
"This project involved measuring and monitoring the performance of rainscreen wall assemblies within new and rehabilitated low, mid and high-rise residential buildings. Five buildings, all located in Vancouver, were monitored. The monitoring program was designed to measure temperature, wood moisture content, relative humidity, local weather conditions including rainfall, wind-driven rain and pressure differences across the walls. The data were analyzed to assess the effectiveness of rainscreen wall assemblies."
Available at: CMHC, HPO

Kerr, Dale D.
Annotated Bibliography on the Rain Screen Principle
Ottawa: National Research Council of Canada, Division of Building Research
1985
"Bibliography No. 45 of the Division of Building Research was to document available literature concerning pressure equalization in the 'open rain screen'. Because the author found little on this subject the bibliography addressed a broader scope including building aerodynamics, joints rain and water penetration, rainfall and climatological date, rain screen principle and pressure equalization, and walls."
Available at: UBC, NRC-IRC

Kubal, M.T.
Waterproofing and the Building Envelope
Boston: McGraw Hill
1993
"Leakage problems in construction are the number one cause of lawsuits. That's why you need Kubal's new Waterproofing the Building Envelope--the first book designed to cover every facet of

waterproofing, from below-grade to above-grade and back down again. It's the only book that explains the critical 90%/1% principle--why 90% of all building leakage is attributable to 1% of a building's area and what you can do about it. It shows you how to select the right materials and systems for a particular project--including sealants, expansion joints, and admixtures--and put them all together so that they function as a waterproof envelope. Included are tips on testing, cleaning, maintenance, and repair--plus coverage of safety and environmental standards."
Available at: VPL, CMHC

Kubal, M. T.
Construction Waterproofing Handbook
New York: McGraw-Hill
2000
"This essential guidebook gives everyone in design, construction, and related consulting industries a complete waterproofing package. Closing the gap left by other publications, Construction Waterproofing Handbook is the choice of envelope consultants, and a project-simplifying blueprint for state-of-the-art construction, waterproofing design, and installation."
Available at: BCIT, UBC, VPL

Kudder/Erdly ed.
STP 1314: Water Leakage Through Building Facades
Philadelphia, PA: American Society for Testing and Materials
1998
"Explores various proven, new, and creative approaches to diagnosing, correcting, preventing, and repairing water leakage in walls. Everyone from the architect to the technician who installs the final linear foot of joint sealant, has a critical role in the success or failure of building walls. STP 1314 reflects the latest developments on how the industry deals with these problems. Provides you with: a clearer understanding of performance requirements; refined techniques for diagnostic and quality assurance procedures; broadened perspectives on certain issues, including durability; and a focus on detail and design. 22 peer-reviewed, comprehensive papers, are divided into the following sections: design, repair, case studies, testing and quality control."
Available at: BCIT, CMHC, www.astm.org

Latta, J.K. and G.K. Garden
Canadian Building Digests, CBD-36
Ottawa: National Research Council of Canada, Division of Building Research
1962
"Determination of the thermal gradient throughout a building element that separates two environments that have different properties is the first step toward designing problem free walls. Information pertaining to thermal bridges, psychometry, moisture migration, rain penetration and differential air pressures is also necessary for optimum design."
Available at: BCIT, VPL, UBC, NRC-IRC

Lstiburek, J. and J. Carmody

Moisture Control Handbook: New, Low-rise, Residential Construction
Oak Ridge: U.S. Department of Energy
1991
"A general primer on moisture control, the first three chapters deal with mold, moisture movement, wetting, and drying. The following chapters apply the concepts previously outlined and give examples for specific moisture control in three basic U.S. climate zones. The three climate conditions discussed are those requiring cooling, heating, and mixed."
Available at: BCIT

Lstiburek, J. and J. Carmody
Moisture Control Handbook: Principles and Practices for Residential and Small Commercial Buildings
New York: Van Nostrand Reinhold
1993
"This handbook deals almost exclusively with moisture and water management. Some of the areas covered, including illustrations, are moisture movement, wall assemblies in various climates, moisture control practices in various climates, case studies/moisture problems that create mold, odor, roof decay and condensation, peeling paint on wood trim and hardboard panel problems."
[This text is a revised edition of the Moisture Control Handbook by the same authors published by the U.S. DOE in 1991. It focuses primarily on light wood frame for small buildings.]
Available at: BCIT, VPL, CMHC

Malhotra, A.
Best Practice Guide: Flashings
Ottawa: Canada Mortgage and Housing Corporation
1998
"This guide and companion CD-ROM provides architects, engineers, designers and builders with a general understanding of the principles and best practices in design and construction on flashings…. includes information about materials and installations, controlling forces, directing water flow, surface tensions and capillary action, and builder-designer checklists."
Available at: BCIT, VPL, CMHC

Maurenbrecher, A.H.P.
Construction Technology Updates, No. 23
Ottawa: National Research Council of Canada, Institute for Research in Construction
1998
"Enjoying the low maintenance of masonry along with its long-term durability requires that particular attention be paid to those building details that help prevent or divert concentrated flows of water from exterior masonry walls. The careful installation of flashing, overhanging copings or caps, drips, eaves troughs and downspouts, among several other details, can prevent staining, efflorescence, and biological growth on the masonry. Mere unsightliness, one could say. But drenched masonry, given a few freeze-thaw cycles, soon begins to spall, and worse, leads to corrosion of ties."
Available at: VPL, NRC-IRC

Morrison Hershfield Limited
Study Of the Rainscreen Concept Applied to Cladding Systems on Wood Frame Walls
Ottawa: Canada Mortgage and Housing Corporation
1990
"Rain penetration is one of the oldest problems building owners have had to deal with, yet it still occurs all too frequently. The penetration of rain cannot only damage interior finishes and materials, but it can also damage the structure of walls themselves. One approach to controlling rain penetration, first introduced in the early 1960s, is the pressure-equalized rainscreen design. The theory of pressure-equalized cladding is that air flows into the cavity behind the exterior cladding equalizing the cavity pressure with the wind pressure and thus, minimizing the force (wind pressure) that causes most rain penetration. Previous research has shown that there is a time lag between the application of the wind load and pressure equalization in the cavity. As a result of this time lag, a pressure difference does occur across the exterior cladding. For the rainscreen concept to be effective, this time lag should be as short as possible. Therefore, when the performance of a rainscreen wall is examined, one of the primary factors considered is time to equalization; the longer the time to equalization, the more rain is likely to penetrate. Another consideration is the load applied to the exterior cladding; the higher the load, the larger the driving force moving rain to the interior."
Available at: CMHC

Morrison Hershfield Ltd.
Survey of Building Envelope Failures in the Coastal Climate of British Columbia
Ottawa: Canada Housing and Mortgage Corporation
1996
"The purpose of this study was to correlate building envelope performance problems which are currently being experienced in low rise wood frame residential buildings in the coastal climate of the BC Lower Mainland, with sources of moisture, and design and construction features. This study has facilitated the identification of key aspects of the design, construction, and operations and maintenance processes leading to the problems, which in turn provides the construction industry with focal points for the development of solutions to the current problems. Chapter 4 has 12 specific conclusions and Chapter 5 contains 8 specific recommendations."
Available at: BCIT, VPL, UBC, CMHC

Morrison Hershfield Ltd.
Stucco-Clad Wall Drying Experiment, Vancouver, British Columbia
Ottawa: Canada Mortgage and Housing Corporation
1999
"Walls that have cavities with drainage, venting, and appropriate detailing of penetrations are more effective at keeping rainwater out of walls than face-sealed walls without cavities. Once water has entered a wall, however, walls using construction similar to the tested specimens will not dry quickly enough to prevent damage, with or without a cavity. Some change other than the introduction of the cavity is required to improve drying."
Available at: CMHC

Mukhopadhyaya, P., M.K. Kumaran, F. Tariku, and D. van Reenen
Final Report from Task 7 of MEWS Project-Long-Term Performance: Predict the Moisture Management Performance of Wall Systems as a Function of Climate, Material Properties, etc. Through Mathematical Modelling
: Institute for Research in Construction, National Research Council Canada
2003
Report#: IRC-RR-132"This document is one of the major outcomes from the consortium project called MEWS (Moisture Management in Exterior Wall Systems), carried out at the Institute for Research in Construction (IRC) of National Research Council (NRC), Canada. This report deals with the parametric analyses of four different types of wall assemblies in a building envelope. The four types of walls considered are (1) Stucco walls, (2) EIFS walls, (3) Masonry walls, and (4) Siding walls. The parametric analysis was done using IRC's hygrothermal modelling tool hygIRC. hygIRC is a 2-dimensional numerical modelling tool specifically developed for research purposes and it is continuously evolving at the IRC/NRC. The utility and reliability of hygIRC outputs have been established through laboratory measurements and benchmarking exercises."
Available at: NRC-IRC

Poirier, G.F., W.C. Brown and M.Z. Rousseau
Reprinted in Building Envelope Performance and Durability, an IRC technical seminar held in 11 cities across Canada.
:
1995

Available at: NRC-IRC

Quirouette, Richard
Laboratory Investigation and Field Monitoring of Pressure Equalized Rainscreen Walls
Ottawa: Canada Mortgage and Housing Corporation
1996
"The pressure equalized rainscreen wall is an advanced approach to rain penetration control. While the rainscreen principle is sound conceptually and the qualitative attributes have been applied to various wall and window designs, there is little information on the quantitative aspects of its performance. This project was commissioned by CMHC and Public Works Canada (PWC) to advance the development and application of the rainscreen principle to a higher level of design and construction technology. This report examines the first area of interest, the measurement and monitoring of rainscreen field performance. It includes a laboratory exploration of the wetting and drying of rainscreen cavities, the development of a field monitoring method, and the monitoring of 2 rainscreen systems in the field."
Available at: VPL, UBC, CMHC

Ritchie, T.
Canadian Building Digests, CBD-2
Ottawa: National Research Council of Canada, Division of Building Research
1960

“The problem of efflorescence on unit masonry walls is an old one which has been studied for a great many years. Several factors may influence the occurrence of efflorescence in a particular case, but there must be salts in the masonry to be taken into solution by water and then deposited on the surface as the moisture dries. The movement of the solutions within masonry is controlled to some considerable extent by seasonal weather, and efflorescence is usually a "cold weather" problem. Possible sources of the salts of efflorescence have been described; these include the masonry materials used, the mortar, units and backing, as well as "outside" contaminants such as ground water. Design features of a building which prevent excessive wetting of the masonry and prevent contamination of "clean" parts from those containing salts of efflorescence are desirable. Precautionary measures against efflorescence should therefore include the selection of materials with a low content of the salts of efflorescence and, equally important, the overall designing of a building to protect masonry from excessive wetting.” [It is important to note that the presence of efflorescence is a symptom, not the problem. It is an indication of excessive moisture traveling through the masonry wall. The efflorescence problem should not be addressed until the underlying source of moisture has been determined and corrected.]
Available at: BCIT, VPL, UBC, NRC-IRC

Ritchie, T.
Canadian Building Digests, CBD-6
Ottawa: National Research Council of Canada, Division of Building Research
1960
“Rain penetration of walls of unit masonry is a common problem, which may arise for several reasons. When units and mortar are not completely bonded together penetration may occur at the interface. In addition, when permeable units are used, leakage may take place through them. Structural cracks form yet another path for rain penetration. In the design of a building consideration should be given to the possibility of stresses being set up in the masonry from differential movements of various parts of the building. When possible, the movements should be accommodated without stressing the masonry, in order to avoid cracking. Suitable design of a building for rain resistance also calls for the provision of adequate flashings and of complete caulking at wall openings. In construction of the masonry, particularly [fired clay] brick masonry, steps can be taken to obtain complete bonding between unit and mortar and thus prevent interface leakage. Cavity wall construction affords a means of obtaining resistance to rain penetration and walls of this type have come into extensive use where severe exposure to rain has caused leakage problems in solid walls. Treatment of a masonry wall affected by rain penetration requires "plugging" of the openings between mortar and unit, and in addition, often a treatment of the face of the unit. For very permeable units, it may be necessary to apply stucco; in other cases, paint or colourless water-repellent coatings may be sufficient. Filling of structural cracks, renewal of caulking, and repair of defective drains and flashings are a necessary part of the treatment of damp walls. [All coatings applied to the outside face of the masonry should be permeable to water vapour to decrease the possibility of condensation within the wall. Substantial development in permeable coatings has occurred since the publication of this document.]
Available at: BCIT, VPL, UBC, NRC-IRC

Rousseau, J., R.L. Quirouette, M.Z. Rousseau and G. Handegord
Proceedings for the Building Science Insight '83 Conference
:
1983
"Since 1973, there has been a significant change in construction practices and particularly in relation to insulation levels and airtightness of the building envelope. While thermal upgrading of the building envelope is undeniably the correct route, it is also linked to the moisture control performance of any wall or roof system. Increased airtightness also has several important implications. Notwithstanding the quality of the indoor air, there will be a natural tendency for almost all new and retrofitted houses to operate at a higher indoor humidity level than the normal."
Available at: BCIT, VPL

Rousseau, M.Z., G.F. Poirier and W.C. Brown
Construction Technology Updates No. 17
Ottawa: National Research Council of Canada, Institute for Research in Construction
1998
"If the pressure in the air chamber behind the rainscreen is less than the pressure in front of it, rain is actually driven into the air chamber, which is, of course, undesirable. Through pressure equalization, this pressure difference is eliminated. A rainscreen wall has vent holes through which air can flow quickly to achieve pressure equalization. Two types of pressures - static and dynamic - have to be considered when calculating the size of the vent holes. Also, the pressure in an air chamber is not constant across the facade of a wall. That needs to be considered in their placement."
Available at: VPL, NRC-IRC

Schwartz, T.A. (editor)
STP 1107 Water in Exterior Building Walls: Problems and Solutions
Philadelphia, PA: American Society for Testing and Materials
1991
"This Special Technical Publication focuses on the myriad of problems caused by water within exterior walls. Papers from an ASTM Symposium held in Dearborn, Michigan during October 1990, delineate both the problems and their solutions."
Available at: VPL, UBC, CMHC

Scott, D.L.
Building Research Note, 210
Ottawa: Division of Building Research, National Research Council of Canada
1984
"This note documents wall moisture problems in two buildings located in Atlantic Canada. A brief description of the construction details is supplemented by photographs taken during cladding removal which record the nature and extent of rain-induced damage."
Available at: NRC-IRC

Trechsel/Bomberg (editor)
STP 1039 Water Vapor Transmission through Building Materials and Systems: Mechanisms and Measurement
Philadelphia, PA: American Society for Testing and Materials
1989
"Round robin data, case histories, and panel discussions on the moisture in walls and roofs. 15 peer-reviewed papers cover mechanisms, field observations, and measurement. For those engaged in research on moisture movement and concerned with material properties relating to water vapor transmission."
Available at: BCIT, CMHC, www.astm.org

Treschel, Heinz R. (editor)
Manual 18: Moisture Control in Buildings
Philadelphia, PA: American Society for Testing and Materials
1994
"Brings together in one volume important data and applicable state-of-the-art relating to moisture problems in buildings: their diagnosis, prevention, and rehabilitation. This desktop reference gives the reader information on how to design and maintain moisture-resistant buildings and how to investigate and correct moisture problems in existing buildings. It addresses residential, commercial, and institutional buildings in all North American climatic zones. Part 1, Fundamentals, provides fundamental information and data relating to moisture control and the effects of moisture on buildings. Part 2, Applications, discusses the application of related technologies to prevent or solve moisture problems in buildings. Part 3, Construction Principles and Recommendations, gives guidelines and recommendations for designing and constructing new buildings and for increasing the moisture resistance of existing buildings. Part 4, Implementation, provides insights into the various mechanisms for implementing moisture control strategies."
Available at: BCIT, UBC

Treschel, Heinz R. (editor)
Manual 40: Moisture Analysis and Condensation Control in Building Envelopes
Philadelphia, PA: American Society for Testing and Materials
2001
"This unique new manual provides an introduction to moisture analysis in buildings and examines the necessary technical background for conducting moisture analysis as an integral part of building design. For the building practitioner without a deep knowledge in hygrothermal analysis, it offers a basic understanding of the mechanisms involved in moisture movement, condensation, and accumulation, as well as the tools for conducting analysis on simple building walls and roofs. For the intermediate and expert in moisture analysis, it adds recent state-of-the-art information on weather data, material properties, and an overview of single and multidimensional analysis models."
Available at: VPL, CMHC, www.astm.org/

Waugh, Joseph

Moisture in Atlantic Housing
Ottawa: Canada Mortgage and Housing Corporation
1994
"Although information about preventing and dealing with moisture problems exists in a number of publications and from a number of sources, a need has been identified to develop information targeted to the residential construction industry in the Atlantic Region. This manual attempts to meet this need by providing information about the causes of moisture-related problems and about construction techniques designed to prevent these problems."
Available at: VPL, UBC, CMHC

Canada Mortgage and Housing Corporation
Performance Evaluation of Retrofitted Solid Masonry Exterior Walls
Ottawa: Canada Mortgage and Housing Corporation
2007
"This research project includes the testing and assessment of the results of a preliminary performance evaluation of nine existing buildings which had recently undergone an insulation retrofit of their solid masonry walls. While the results of the computer modeling of both the original and the retrofit wall assemblies demonstrated conditions favourable to increasing the rate of condensation in the wall assemblies, a physical examination of the majority of the walls did not reveal evidence of deterioration. The report speculates that the insulating of the exterior solid masonry walls may not result in deterioration when the retrofit approach involves the installation of suitable air and vapour barrier."

Canada Mortgage and Housing Corporation
*Monitored Thermal Performance of ICF Walls in MURBs *
Ottawa: Canada Mortgage and Housing Corporation
2007
"These days, builders, owners and developers of multi-unit residential buildings are on the lookout for ways to reduce the cost of construction and building energy consumption. Insulating concrete forms (ICF), which can be used in constructing the walls of multi-unit residential buildings, provide respectable thermal resistance, minimized thermal bridging and airtight construction. These advantages should lead to lower heating and cooling energy consumption, increased comfort and reduced space-conditioning systems capacity requirements. This research report provides quantitative performance-monitoring data and analysis on ICF walls that highlight the benefits of this construction system."

Canada Mortgage and Housing Corporation
Residential Solar Mass Wall Analysis for Canada
Ottawa: Canada Mortgage and Housing Corporation
2007
"Passive solar heating offers great promise for reducing the use of conventional heating fuels in Canadian houses. This study explores the performance of one type of passive solar heating system. the mass wall. Mass walls hold the promise of being able to provide passive solar heating in situations in which direct gain is not suitable, but the results of the study are not favorable

for Canada."

Articles

None

Ali M. Memari. 2012. Comparative Study of Multi-Hazard Performance of Different Wall Systems Used in Single-Family Dwelling Construction. *Forensic Engineering 2012 San Francisco, California*

Ali, M. Memari. 2012. Comparative Study of Multi-Hazard Performance of Different Wall Systems Used in Single-Family Dwelling Construction. *Forensic Engineering 2012 San Francisco, California*

Broniek, J.. 2010. Detailed Modeling Study on How Different Assemblies Affect Comfort Conditions in Zero-Energy House Designs. *Proceedings of Thermal Performance of Exterior Envelopes of Whole Buildings XI Florida, USA*
Available at: Public Libraries of B.C., ASHRAE

Chan, H. Y.; Zhu, J.; Riffat, S.. 2012. Solar facade for space cooling. *Energy and Buildings* 0: 307-319
Available at: BCIT, UBC

Charles J. Russo; Amy S. Graver; Michael L. Brainerd. 2012. Investigation and Remedial Strengthening of Deteriorated Masonry Walls. *Forensic Engineering 2012 San Francisco, California*

Christensen, Dane. 2010. Thermal Impact of Fasteners in High-Performance Wood-Framed Walls. *Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference Clearwater Beach, Florida*

Delgado, J M P Q; Ramos, N M M; Freitas, V P De; Barreira, E. 2010. Numerical Simulation of Exterior Condensations on Façades : The Undercooling Phenomenon. *Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference Clearwater Beach, Florida*

Derakhshan, H.; Griffith, M.; Ingham, J.. 2013. Out-of-Plane Behavior of One-Way Spanning Unreinforced Masonry Walls. *Journal of Engineering Mechanics* 4: 409-417
Available at: BCIT, UBC

Desta, Tadiwos Zerihun; Roels, Staf. 2010. Experimental and Numerical Analysis of Heat, Air, and Moisture Transfer in a Lightweight Building Wall. *Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference Clearwater Beach, Florida*

Doya, Maxime; Bozonnet, Emmanuel; Allard, Francis. 2012. Experimental measurement of cool facades' performance in a dense urban environment. *Energy and Buildings* 0: 42-50
Available at: BCIT, UBC

Ehlinger, L.. 2011. Brick Veneer. *Journal of Performance of Constructed Facilities* 6: 479-484
Available at: BCIT, UBC

Farmer, Matthew C.; Gerns, Edward A. . 2010. Design and Use of Expansion Joints in New and Existing Clay Masonry Wall Systems. *journal of ASTM International*
Available at: UBC, Public Libraries of B.C.

Franco, Irving Montanar. 2007. Efficacy of Light Shelves: Passive, Dynamic, and Automatic Devices Related to Light and Thermal Behavior. *Thermal Performance of Exterior Envelopes of Whole Buildings X International Conference Florida, U.S.A.*

Frenette, Caroline D; Beauregard, Robert; Derome, Dominique. 2007. Multi-Criteria Evaluation Framework of Factory-Built Wood-Frame Walls. *Thermal Performance of Exterior Envelopes of Whole Buildings X International Conference Florida, U.S.A.*

Gjinolli, A. E., J. J. Vogt . 2007. Building envelope and structural performance of wood structural panels under climate loads. *Proceedings of the 11th Canadian Conference on Building Science and Technology Conference Banff, Albert*

Gratia, E. and A. De Herde . 2007. Greenhouse effect in double-skin facade. *Energy and Building* 39(2) : 199-211
Available at: BCIT, UBC

Gustavsen, Arild; Goudey, Howdy; Arasteh, Dariush; Uvslokk, Sivert; Talev, Goce; Jelle, Bjorn Petter; Kohler, Christian. 2010. Experimental and Numerical Examination of the Thermal Transmittance of High Performance Window Frames. *Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference*

John Straube,; Jonantan Smegal, . 2010. High R Wall Systems. *Building Enclosure Science & Technology Conference (BEST2) Portland, OR*

Kimball J. Beasley. 2012. Latent Building Facade Failures. *Forensic Engineering 2012 San Francisco, California*

Koo, J.; So, H.; Hong, S. W.; Hong, H.. 2011. Effects of wallboard design parameters on the thermal storage in buildings. *Energy and Buildings* 8: 1947-1951
Available at: BCIT, UBC

Kosny, J., W. Miller, et al.. 2010. Dynamic Thermally Disconnected Building Envelopes—A New Paradigm for Walls and Roofs in Low-Energy Buildings. *Proceedings of Thermal Performance of Exterior Envelopes of Whole Buildings XI Florida, USA*
Available at: Public Libraries of B.C., ASHRAE

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Available at: UBC

Kozem Silih, E.; Premrov, M.. 2010. Analysis of timber-framed wall elements with openings. *Construction and Building Materials* 9: 1656-1663
Available at: UBC

Kramer, Michael Aoki; Hubbs, Brian; Finch, Graham; Teetaert, Jason. 2010. Monitoring of Historic Structures for Whole-Building Improvements. *Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference*

Kvande, T. and K.R. Lisø . 2009. Driving-rain protective design of parapet flashing. *Proceedings of the 4th International Building Physics Conference: Energy Efficiency and New Approaches Istanbul, Turkey*

Lacasse, M.A. et. al.. 2009. Assessing the effectiveness of wall-window interface details to manage rainwater - selected results from window installation to a wall sheathed in extruded polystyrene . *Journal of ASTM International* 6 (9): 1-43
Available at: UBC, NRC-IRC

Langmans, J., M. D. Paepe, et al.. 2010. Feasibility of Using Wind Barriers as Air Barriers in Wood Frame Construction. *Proceedings of Thermal Performance of Exterior Envelopes of Whole Buildings XI Florida, USA*
Available at: Public Libraries of B.C., ASHRAE

Liu, Di; Zhao, Fu-Yun; Wang, Han-Qing. 2011. Passive heat and moisture removal from a natural vented enclosure with a massive wall. *Energy* 5: 2867-2882
Available at: UBC

Lourenco, P.; Medeiros, P.. 2013. Learning from Failure of a Long Curved Veneer Wall: Structural Analysis and Repair. *Journal of Performance of Constructed Facilities* 1: 53-64
Available at: BCIT, UBC

Lstiburek, J. W. 2008. The perfect storm over Stucco. *ASHRAE Journal* 50(2): 38-40+42-43.
Available at: BCIT, UBC

Lstiburek, J. W. . 2007. Face-lift for old buildings. *ASHRAE Journal* 49(9): 80-83
Available at: BCIT

Maheri, MahmoudR; Motielahi, F.; Najafgholipour, M. A.. 2011. The effects of pre and post construction moisture condition on the in-plane and out-of-plane strengths of brick walls. *Materials and Structures* 2: 541-559

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Mark Lawton,. 2010. Troubleshooting in Design of Construction Details, Walls. *Building Enclosure Science & Technology Conference (BEST2) Portland, OR*

Martin, K.; Escudero, C.; Erkoreka, A.; Flores, I.; Sala, J. M.. 2012. Equivalent wall method for dynamic characterisation of thermal bridges. *Energy and Buildings* 0: 704-714
Available at: BCIT, UBC

Mas, Angeles; Gutierrez, Javier; Gil, Enrique; Gil, Alba; Galvan, Vicente. 2011. Design and construction recommendations to improve impermeability in rainscreen walls built with natural stone coverings. *Construction and Building Materials* 4: 1753-1761
Available at: UBC

McFarquhar, Dudley . 2012. The Role of the Building Facade - Curtain Walls. *Building Enclosure Science & Technology Conference (BEST3) Atlanta, GA*

Michael A. Lacasse ; Steven M. Cornick ; Denis Richard ; Khaled Abdulghani ; Thibaut Hilly ; Brian Kyle . 2008. A GIS-Based Framework for the Evaluation of Building Façade Performance and Maintenance Prioritization. *11DBMC International Conference on Durability of Building Materials and Components Istanbul, Turkey*

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Petrie, Thomas W; Atchley, Jerald A; Childs, Phillip W; Desjarlais, André O. 2007. Energy Savings for Stucco Walls Coated with Cool Colors. *Thermal Performance of Exterior Envelopes of Whole Buildings X International Conference Florida, U.S.A.*

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Available at: UBC

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Rousseau, M. Z. and K. J. Trischuk . 2008. Key elements for proper repointing of older masonry.

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Available at: BCIT, UBC

Samant, Swinal. 2011. Atrium and its adjoining spaces: a study of the influence of atrium façade design. *Architectural Science Review* 4: 316-328
Available at: UBC

Seferis, P.; Strachan, P.; Dimoudi, A.; Androutsopoulos, A.. 2011. Investigation of the performance of a ventilated wall. *Energy and Buildings* 9: 2167-2178
Available at: BCIT, UBC

Silva, A.; Dias, J. L.; Gaspar, P. L.; de Brito, J.. 2011. Service life prediction models for exterior stone cladding. *Building Research & Information* 6: 637-653

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Torres, Isabel; Freitas, Vasco Peixoto de. 2010. The influence of the thickness of the walls and their properties on the treatment of rising damp in historic buildings. *Construction and Building Materials* 8: 1331-1339
Available at: UBC

Trimble, B. E. . 2013. Design of unique landscape walls and their use in building facades. *12th Canadian Masonry Symposium Vancouver, BC*

Umeno, Tetsuya; Hokoi, Shuichi. 2012. Field survey on ventilation volume in vented air space of exterior walls. *5th International Building Physics Conference (IBPC) Kyoto, Japan*

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Yesilata, Bulent; Bulut, Husamettin; Turgut, Paki. 2011. Experimental study on thermal behavior of a building structure using rubberized exterior-walls. *Energy and Buildings* 2â€“3: 393-399
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Air/Vapour Barriers, Membranes, Sealants

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