Construction Materials: Air/Vapour Barriers, Membranes, Sealants, Thermal Insulation and Properties

Books and Research Reports

Allen, E. and J. Iano
Fundamentals of building construction: materials and methods
New York: J. Wiley & Sons
2004
"This new edition provides the complete, up-to-date coverage of building construction practices. Using the new International Building Code as its basis, this classic guidebook covers the complete range of construction activities, from excavating and foundations to cladding and interior finishes. It is organized around a detailed treatment of the structural systems most widely used in North America: heavy timber, wood light frame, masonry, steel, light gauge steel, and reinforced and pre-cast concrete. The new edition includes new coverage of green design and energy-efficient construction energies."
Available at: BCIT, UBC

Bomberg, M., Pareza M, Zhang J. and I Haghighat
External Moisture Control: Defining Performance of Water Resistive Barriers
Ottawa: Canada Mortgage and Housing Corporation
2004
"This project examines various aspects of sheathing membrane performance including measuring drainage and moisture retention capability, permeance of weathered materials, and long term performance in context of chemical leaching from stucco or wood-based products. The effect of surfactants, water penetration and weathering was considered, and the findings reveal important design considerations to improve performance of WRB. HPO is part of a research consortium involving CMHC, Concordia University and product manufacturers."
Available at: CMHC, HPO

Canada Mortgage and Housing Corporation
A Commissionable Air Barrier System for the Building Envelope
Ottawa: Canada Mortgage and Housing Corporation
2001
"To improve the housing industry's ability to predict the performance and durability of the air barrier system, a methodology is needed to encourage designers and builders to advance air barrier system design and construction from an art to a science. This research focused on formulating a methodology for the development of a commissionable air barrier system."
Available at: CMHC

Canada Mortgage and Housing Corporation
Composite Masonry Wall Ties
Ottawa: Canada Mortgage and Housing Corporation

2002
"Although buried in walls, steel masonry ties are still exposed to moisture and air which infiltrate the mortar. This leads to their corrosion. Eventually, the ties lose their load-carrying capacity and break. Problems become noticeable only when a number of tiesfail, resulting in visible cracking, bulging or partial collapse of the exterior wall. Even with these visible signs, it is difficult to determine the extent of the problem without removing a large portion of the wall or conducting a tedious local investigation using a borescope. Composite materials, a relatively recent innovation, potentially offer an alternative to stainless steel. This research project was undertaken to develop a prototype masonry tie using composite materials. Several prototypes were developed and tested. The most promising result was an adjustable tie manufactured from glass fiber reinforced polymer composite (GFRPC), which could be used between an exterior masonry veneer and a concrete block backup wall system with a 50-mm air space and 50-mm rigid insulation."
Available at: CMHC

Canada Mortgage and Housing Corporation
Incompatible Building Material
Ottawa: Canada Mortgage and Housing Corporation
2003
"Many types of building materials are needed to construct a house. Occasionally, one material can have a detrimental effect on an adjacent material resulting in premature material degradation. Builders, renovators and building designers need to be awareof this incompatibility issue and better understand how to determine if materials are compatible. Because there is no central registry for recording and sharing incompatibility problems, Canada Mortgage and Housing Corporation and the Canadian Home Builders' Association initiated this research project to help practitioners in the home constructionindustry to become and remain aware of material incompatibility situations."
Available at: CMHC, HPO

Canada Mortgage and Housing Corporation
Testing the Adhesion of Air- Barrier Membranes in Wall Assemblies
Ottawa: Canada Mortgage and Housing Corporation
2005
"One of the critical performance characteristics of air-barrier materials used in wall assemblies is long-term adhesion to the substrate - an air- barrier system must be able to resist peak wind-loads, stack-pressure effects and sustained pressurization loads. This research project evaluated the adhesion performance of air- barrier membrane materials over time and under different conditions and provided a benchmark for membrane-substrate adhesion performance. The membrane systems tested included self-adhesive, torch applied and liquid membrane. Each system was tested with four different substrates under three extreme environmental conditions."
Available at: CMHC

Canadian Wood Council
Wood Reference Handbook: A Guide to the Architectural Use of Wood in Building Construction

Ottawa: Canadian Wood Council
2000
“A wealth of basic information on wood characteristics, wood product properties, connections, structural wood systems, building completion, wood finishes, and fire safety. Minimal information on preservative treatment compared to fire control.”
Available at: Canadian Wood Council

Canada Mortgage and Housing Corporation
High-Performance Stucco for Housing
Ottawa: Canada Mortgage and Housing Corporation
2007
"This research project, a collaboration between NRC-IRC and CMHC, was conducted in an effort to improve the moisture performance characteristics of stucco cladding by modifying existing stucco design mixes and testing new materials. The experimental work was carried out in two phases. Phase I established the basic moisture-transport properties, water-vapour permeabilities and water-absorption coefficients of four stucco materials currently used in Canada. In phase II, researchers tested four trial high-performance stucco materials having lower water-absorption coefficients but higher water-vapour permeabilities than the base-case stucco materials tested in Phase I."

Canada Mortgage and Housing Corporation
Relationship Between Moisture Content and Mechanical Properties of Gypsum Sheathing
Ottawa:
2007
“This research assessed the relationship between moisture content (MC) and the mechanical properties of various gypsum-based sheathing and determined whether or not the mechanical properties of gypsum sheathing could be rehabilitated by drying it out once it has been wetted.”

D.L. Cassens, W.C. Feist, B.R. Johnson and R.C. DeGroot
Selection and Use of Preservative Treated Wood
Madison: Forest Products Society
1995
“An excellent guidebook for those contemplating using treated wood in a project”.
Available at: Canadian Wood Council

Hall, C. and W. Hoff
Water Transport in Brick, Stone, and Concrete
New York: Spon Press
2002
“This publication provides a unified description of the transport process involving saturated and unsaturated flow in inorganic building materials and structures. The book emphasizes fundamental physics and materials science, mathematical description and experimental measurement as a basis for engineering design and construction practice. Water Transport in Brick, Stone and Concrete brings together in a unified manner current information and guidance on a complex subject.

Durability of much of the built infrastructure depends on how water reacts with the construction material concerned, yet the underlying science of deterioration processes is not yet well understood. This book, by the two leading researchers in the field, will provide a central point of reference for the future."
Available at: UBC

Handegord G.O. and K.K. Karpati
Canadian Building Digests
Ottawa: National Research Council of Canada, Division of Building Research
1973
"Most joints on the exterior of buildings require some form of seal to prevent or minimize the passage of water, water vapour, air, or contaminants. Such seals are usually provided by special flexible materials that bridge the opening and maintain close contact with the separated components, at the same time accommodating in themselves whatever movements take place under the conditions of service." [Many improvements and innovations have occurred with sealants since this document was published in 1973.]
Available at: BCIT, VPL, UBC, NRC-IRC

Institute of Research in Construction
Air Barrier Systems for Walls of Low-rise Buildings: Performance and Assessment
Ottawa: National Research Council
1997
"This publication is intended to help designers and building officials understand air barrier performance, code requirements, and testing and assessment methods. Manufacturers will also be able to use the guide to develop appropriate air barrier materials and systems. The 1995 National Building Code (NBC) includes a number of important changes to air barrier system requirements that reflect the industry's evolving knowledge, experience, and practices. The publication reviews the 1995 National Building Code requirements for air barrier systems and explains how the new requirements and new knowledge will likely affect the design of different wall types in low-rise buildings. It also provides advice on how to extend the information to high-rise buildings. Specifically, the publication deals with air barrier systems and their performance, air leakage, and the relationship between air barrier systems and vapour barriers."
Available at: NRC-IRC

Institute of Research in Construction
Deterioration of Concrete: Symptoms, Causes, and Investigation
Ottawa: National Research Council
2000
"This monograph provides a guide to the construction practitioner who wants to recognize and assess the degradation that has occurred in the concrete elements of a structure. It outlines how to: 1) detect deterioration; 2) understand the causes; and 3) evaluate the condition of the structure. The first half of the publication focuses largely on problems that arise in the use of concrete and on conditions under which concrete deteriorates. In the second half, tests for evaluating concrete structures are described (destructive and non-destructive test methods, and

microscopic and instrumental analyses), and the methodology for an investigation is set out clearly."
Available at: NRC-IRC

Institute for Research in Construction

Ottawa: National Research Council Canada
2003
Report#: RR-110"This report summarizes the findings of MEWS Task Group 3 on the Properties of the following building materials. 1. Oriented Strand Board 2. Plywood 3. Brick 4. Mortar 5. Stucco 6. Wood fiberboard 7. Composite wood siding 8. Water resistive barrier 9. Exterior grade gypsum board 10. EIFS base and finish coats and 11. Spray polyurethane foam. The properties that have been experimentally determined include: 1. Thermal conductivity of the dry material as a function of temperature 2. Water vapour permeability/permeance as a function of relative humidity 3. Equilibrium moisture content as a function of relative humidity/suction 4. Moisture diffusivity as function of moisture content 5. Water absorption coefficient 6. Air permeability/permeance. The main purpose of this investigation was to provide representative material properties as inputs for IRC's hygrothermal model hygIRC."
Available at: NRC-IRC

Kumaran, M. K., J. Lackey, et al.
ASHRAE research project 1018-RP
Ottawa: Institute for Research in Construction, National Research Council of Canada
2002
"This report presents results from a set of hygrothermal tests that were systematically carried out on many building materials that are currently used in North America. The materials include several wood based products, several species of wood, masonry products, cladding materials, sheathing membranes, insulation products, one limestone, a prier and a latex paint and a vinyl wallpaper. The properties that were determined include thermal conductivity, equilibrium moisture content, water vapour permeance or permeability, water absorption coefficient, moisture diffusivity and air permeance or permeability."
Available at: NRC-IRC

Maurenbrecher, A.H.P.
Construction Technology Updates No. 7
Ottawa: National Research Council of Canada, Institute for Research in Construction
1997
"Metal ties are the interfaces, so to speak, between the masonry and the framing of a building. Keeping the interfaces intact keeps the system intact. This may sound a bit like a cliché, until, of course, the sound of collapsing masonry cladding drowns it out. Keeping the interfaces intact or rather, ensuring the durability of metal ties, depends on the materials used, the conditions to which they are exposed and the care with which they have been installed. These measures and more are all aimed at preventing corrosion. For example, the choice of material is closely linked to the thickness and completeness of the layer of zinc galvanizing a metal tie."

Available at: VPL, NRC-IRC

Newtown, C.T.
Roofing, Flashing and Waterproofing
: Taunton Press
2005
"This book presents the basic principles to waterproof residential structures properly to protect them from water intrusion and to prevent call-backs for flashing or roofing failures."
Available at: VPL

O'Connor, T.F. (editor)
STP 1069 Building Sealants: Materials, Properties, and Performance
Philadelphia, PA: American Society for Testing and Materials
1990
"Major concerns of the sealant industry -- the use of sealants for structural sealant glazing; identification and quantification of the effects of movement on sealants; continuing laboratory investigation of sealant performance under various environmental factors; and the in service performance of sealants -- are addressed in this peer-reviewed publication from ASTM. For sealant manufacturers, glazing contractors, architects, building owners, waterproofing contractors, curtain wall contractors, sealant testing laboratories, and glass fabricators."
Available at: BCIT, VPL, UBC

Parise, C.J. (editor)
STP 1168 Science and Technology of Building Seals, Sealants, Glazing, and Waterproofing
Philadelphia, PA: American Society for Testing and Materials
1992
"Progress and developments in the technology of building seals, sealants, glazing, and waterproofing. Papers cover: Problems and research related to movement of sealants during cure, Structural sealant glazing, Sealants immersed in water, Factors affecting the design of joint seals in exterior insulation finish systems (EIFS), The state-of-the-art relative to insulating glass edge seals, A case history retrofit to a building deck waterproofing failure."
Available at: UBC, CMHC

Articles

A.S. Smith, ; F. Verhelst, ; C. Denayer,; R. Givens,. 2013. Hydrated lime additions to cement mortars; quantifying the benefits to mortar durability in masonry structures. *12th Canadian Masonry Symposium Vancouver, BC*

Abahri, K.; Belarbi, R.; Trabelsi, A.. 2011. Contribution to analytical and numerical study of combined heat and moisture transfers in porous building materials. *Building and Environment* 7: 1354-1360
Available at: BCIT, UBC

Agoua, Eusebe; Allognon-Houessou, Elisabeth; Adjovi, Edmond; Togbedji, Bovis. 2013. Thermal conductivity of composites made of wastes of wood and expanded polystyrene. *Construction and Building Materials* 0: 557-562
Available at: UBC

Aigbomian, Eboziegbe Patrick; Fan, Mizi. 2013. Development of Wood-Crete building materials from sawdust and waste paper. *Construction and Building Materials* 0: 361-366
Available at: UBC

Akers, S. A. S.. 2010. Cracking in fibre cement products. *Construction and Building Materials* 2: 202-207
Available at: UBC

Alavez-Ramirez, R.; Chinas-Castillo, F.; Morales-Dominguez, V. J.; Ortiz-Guzman, M.. 2012. Thermal conductivity of coconut fibre filled ferrocement sandwich panels. *Construction and Building Materials* 0: 425-431
Available at: UBC

Ashori, Alireza; Tabarsa, Taghi; Sepahvand, Sima. 2012. Cement-bonded composite boards made from poplar strands. *Construction and Building Materials* 1: 131-134
Available at: UBC

Awad, Ziad K.; Aravinthan, Thiru; Zhuge, Yan. 2012. Investigation of the free vibration behaviour of an innovative GFRP sandwich floor panel. *Construction and Building Materials* 0: 209-219
Available at: UBC

Ayrilmis, Nadir; Akbulut, Turgay; Dundar, Turker; White, Robert H.; Mengeloglu, Fatih; Buyuksari, Umit; Candan, Zeki; Avci, Erkan. 2012. Effect of boron and phosphate compounds on physical, mechanical, and fire properties of woodâ€“polypropylene composites. *Construction and Building Materials* 0: 63-69
Available at: UBC

Berdahl, P., H. Akbari, et al. . 2008. Weathering of roofing materials - An overview. *Construction and Building Materials* 22(4): 423-433
Available at: UBC

Boucher, C.. 2010. Air Barrier Assembly Testing to Replicate Real World Conditions. *Proceedings of Building Enclosure Science and Technology (BEST2) Conference Portland, USA*
Available at: HPO, BCIT

Bucher, Charles Jr. 2012. Dating Twentieth-Century Buildings by Means of Construction Materials. *APT Bulletin* 2/3: 71-76
Available at: UBC

C. M. R. Dias ; H. Savastano Jr. ; Vahan Agopyan ; Vanderley M. John . 2008. Effects of Wet and Dry Cycles on the Performance and Microstructure of Asbestos-free Fiber Cement. *11DBMC International Conference on Durability of Building Materials and Components Istanbul, Turkey*

Cannavale, Alessandro; Fiorito, Francesco; Manca, Michele; Tortorici, Giovanni; Cingolani, Roberto; Gigli, Giuseppe. 2010. Multifunctional bioinspired sol-gel coatings for architectural glasses. *Building and Environment* 5: 1233-1243
Available at: BCIT, UBC

Cerdeira, F.; Vazquez, M. E.; Collazo, J.; Granada, E.. 2011. Applicability of infrared thermography to the study of the behaviour of stone panels as building envelopes. *Energy and Buildings* 8: 1845-1851
Available at: BCIT, UBC

Derome, Dominique; Rafsanjani, Ahmad; Patera, Alessandra; Sedighi-Gilani, Marjan; Dressler, Martin; Carmeliet, Jan. 2012. The role of water in the behavior of wood. *5th International Building Physics Conference (IBPC) Kyoto, Japan*

Finch, G., B. Hubbs, et al.. 2010. Moisture Transport by Osmotic Flow through Waterproofing Membranes— Toward the Development of Osmosis-Resistant Membranes. *Proceedings of Thermal Performance of Exterior Envelopes of Whole Buildings XI Florida, USA*
Available at: Public Libraries of B.C., ASHRAE

Furmaniak, Sylwester. 2012. The Alternative Model of Water Vapour Sorption in Porous Building Materials. *Transport in Porous Media* 1: 21-23
Available at: BCIT, UBC

Gaffner, Dan. 2007. The Moment for Measuring Moisture Diffusivity of Porous Building Materials. *Thermal Performance of Exterior Envelopes of Whole Buildings X International Conference Florida, U.S.A.*

Gaggino, Rosana. 2012. Water-resistant panels made from recycled plastics and resin. *Construction and Building Materials* 0: 468-482
Available at: UBC

Gutierrez-Gonzalez, S.; Gadea, J.; Rodriguez, A.; Junco, C.; Calderon, V.. 2012. Lightweight plaster materials with enhanced thermal properties made with polyurethane foam wastes. *Construction and Building Materials* 1: 653-658
Available at: UBC

Hansen, E. J. d. P. and E. Brandt. 2010. Timber-Frame Walls: Feasible with a Damaged Vapor Barrier?. *Proceedings of Thermal Performance of Exterior Envelopes of Whole Buildings XI Florida, USA*
Available at: HPO, BCIT

Hass, Philipp; Wittel, FalkK; Mendoza, Miller; Herrmann, HansJ; Niemz, Peter. 2012. Adhesive penetration in beech wood: experiments. *Wood Science and Technology* 1-3: 243-256
Available at: UBC

Hernandez, Roger; Caceres, Claudia. 2010. Magnetic Resonance Microimaging of Liquid Water Distribution in Sugar Maple Wood Below Fiber Saturation Point. *Wood and Fiber Science* 3: 259-272

Janssen, H. and G. A. Scheffler . 2009. Dynamic effects in porous media flow: exploratory modeling. *Proceedings of the 4th International Building Physics Conference: Energy Efficiency and New Approaches Istanbul, Turkey*

Joblonka, M., A. Karagiozis, et al.. 2010. Innovative Passive Ventilation Water-Resistive Barriers— How Do They Work?. *Proceedings of Thermal Performance of Exterior Envelopes of Whole Buildings XI Florida, USA*
Available at: Public Libraries of B.C., ASHRAE

Kourkoulis, S. K.; Ganniari-Papageorgiou, E.. 2010. Experimental study of the size- and shape-effects of natural building stones. *Construction and Building Materials* 5: 803-810
Available at: UBC

Kuljich, Svetka; Cool, Julie; Hernández, RogerE. 2013. Evaluation of two surfacing methods on black spruce wood in relation to gluing performance. *Journal of Wood Science* 3: 185-194
Available at: UBC

Lam dos Santos, J. P.; Rosa, L. G.; Amaral, P. M.. 2011. Temperature effects on mechanical behaviour of engineered stones. *Construction and Building Materials* 1: 171-174
Available at: UBC

Landry, Veronic; Blanchet, Pierre; Zotig, Luciano; Martel, Tommy. 2013. Performance of exterior semitransparent PVDF-acrylic coatings. *Journal of Coatings Technology and Research* 1: 37-46

Li, Min; Wu, Zhishen; Chen, Meirong. 2011. Preparation and properties of gypsum-based heat storage and preservation material. *Energy and Buildings* 9: 2314-2319
Available at: BCIT, UBC

Liu, Zhe; Ye, Wei; Little, John C.. 2013. Predicting emissions of volatile and semivolatile organic compounds from building materials: A review. *Building and Environment* 0: 7-25
Available at: BCIT, UBC

Lstiburek, J. W.. 2010. Exterior spray foam. *ASHRAE Journal* 52(11): 36-47
Available at: BCIT, UBC

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Modified gypsum compounds: An ecological-economical choice to improve traditional plasters. *Construction and Building Materials* 0: 591-596
Available at: UBC

Mendoza, Miller; Hass, Philipp; Wittel, FalkK; Niemz, Peter; Herrmann, HansJ. 2012. Adhesive penetration of hardwood: a generic penetration model. *Wood Science and Technology* 1-3: 529-549
Available at: UBC

Miniotaite, Ruta. 2012. Influence of moisture sorption on deformations of building materials. *5th International Building Physics Conference (IBPC) Kyoto, Japan*

Morton, J. H.; Cooke, T.; Akers, S. A. S.. 2010. Performance of slash pine fibers in fiber cement products. *Construction and Building Materials* 2: 165-170
Available at: UBC

Mukhopadhyaya, P., S. D. G. II, et al.. 2010. Accelerated Aging Performance Evaluation of “Smart Vapor Retarder. *Proceedings of Thermal Performance of Exterior Envelopes of Whole Buildings XI Florida, USA*
Available at: Public Libraries of B.C., ASHRAE

Mukhopadhyaya, Phalguni; Normandin, Nicole; Kumaran, M Kumar; van Reenen, David; Lackey, John; Tariku, Fitsum. 2007. Hygrothermal Properties of Exterior Claddings, Sheathing Boards, Membranes, and Insulation Materials for Building Envelope Design. *Thermal Performance of Exterior Envelopes of Whole Buildings X International Conference Florida, U.S.A.* 1: 1-13

Nejad, Mojgan; Cooper, Paul. 2011. Exterior wood coatings. Part-2: Modeling correlation between coating properties and their weathering performance. *Journal of Coatings Technology and Research* 4: 459-467

Nejad, Mojgan; Cooper, Paul. 2011. Exterior wood coatings. Part-1: Performance of semitransparent stains on preservative-treated wood. *Journal of Coatings Technology and Research* 4: 449-458

Plagge, Rudolf; Scheffler, Gregor; Nicolai, Andreas. 2007. Experimental Methods to Derive Hygrothermal Material Functions for Numerical Simulation Tools. *Thermal Performance of Exterior Envelopes of Whole Buildings X International Conference Florida, U.S.A.*

Rutila, Dean A.; Klein, Kenneth A.; Normandeau, Matthew J.. 2012. Principles of Design and Installation of Below-Grade and Building Deck Waterproofing in 2010. *Journal of ASTM International*
Available at: UBC, Public Libraries of B.C.

Sadique, Monower; Al Nageim, Hassan; Atherton, William; Seton, Linda; Dempster, Nicola. 2012. A new composite cementitious material for construction. *Construction and Building Materials* 0: 846-855
Available at: UBC

Scheffler, Gregor A; Plagge, Rudolf. 2010. Introduction of a Drying Coefficient for Building Materials. *Thermal Performance of the Exterior Envelopes of Whole Buildings XI International Conference*

Seo, Janghoo; Kato, Shinsuke; Ataka, Yuji; Yang, Jeong-Hoon. 2010. Influence of Environmental Factors on Performance of Sorptive Building Materials. *Indoor and Built Environment* 4: 413-421
Available at: UBC

Sokoll, T. and A. F. Jacob . 2007. In-situ moisture detection system with a vector network analyser. *Measurement Science and Technology* 18(4) : 1088-1093
Available at: UBC

Subalakshmi, Palani; Saraswathy, Velu; Sivasankaran, Shyamala Kumari. 2012. Hydraulicity of mineral admixtures in cement blends. *Construction and Building Materials* 0: 648-653
Available at: UBC

Sun, De-lin; Yu, Xian-chun; Liu, Wen-jin; Sun, De-bin. 2010. Laminated Wood-Ceramics Prepared from Beech Veneer and Phenol Formaldehyde Resin. *Wood and Fiber Science* 4: 474-479

T. Yates ; A. Mauko . 2008. Freeze Thaw Susceptibility of Natural Stone â€“ Characterization of the Mechanical Strength and Microstructure During Frost Cycling. *11DBMC International Conference on Durability of Building Materials and Components Istanbul, Turkey*

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Available at: UBC

Tkaczewska, E.; Mroz, R.; Toj, G.. 2012. Coal-biomass fly ashes for cement production of CEM II/A-V 42.5R. *Construction and Building Materials* 1: 633-639
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Available at: UBC

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Available at: UBC

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Available at: UBC

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Available at: UBC

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Available at: Public Libraries of B.C., ASHRAE

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Available at: UBC

Xu, Jinxia; Zhang, Changkuan; Jiang, Linhua; Tang, Li; Gao, Guofu; Xu, Yunpu. 2013. Releases of bound chlorides from chloride-admixed plain and blended cement pastes subjected to sulfate attacks. *Construction and Building Materials* 0: 53-59
Available at: UBC

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Available at: UBC

Zhao, Feng-qing; Liu, Hong-jie; Hao, Li-xia; Li, Qian. 2012. Water resistant block from desulfurization gypsum. *Construction and Building Materials* 1: 531-533
Available at: UBC

Zhu, Yu; Yang, Yingzi; Yao, Yan. 2012. Autogenous self-healing of engineered cementitious composites under freeze-thaw cycles. *Construction and Building Materials* 0: 522-530
Available at: UBC

Zivica, Vladimir; Palou, Martin T.; Krizma, Martin; Bagel, Lubomir. 2012. Acidic attack of cement based materials under the common action of high, ambient temperature and pressure. *Construction and Building Materials* 0: 623-629
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Air/Vapour Barriers, Membranes, Sealants

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Available at: VPL

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Available at: UBC

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Available at: HPO, BCIT

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