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Cost Effective Basement Wall Drainage Alternatives Employing Exterior Insulation Basement Systems (EIBS)

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Abstract

This paper compares the physical and economic (life cycle) performance of insulation materials placed on the exterior, above and below-grade portions of residential basements, in lieu of non-insulating drainage membranes and drainage layers, combined with internal insulation. The findings are premised on research, field studies and analysis associated with the *Performance Guidelines for Basement Systems and Materials Project* undertaken by the Institute for Research and Construction, National Research Council Canada.

The thermal and drainage performance of several insulation materials installed on the exterior, basement portions of a test house located on the NRCC campus in Ottawa were monitored for a period spanning two heating seasons. In addition to assessing the effective, in-situ thermal resistance of the insulation materials over the study period, the results for drainage effectiveness were also compared with conventional drainage layer and membrane materials commonly used in residential basement construction.

An economic analysis of the exterior basement insulation system (EIBS) applications was also performed to compare their cost effectiveness with interior insulation applications relying on drainage membranes for exterior moisture protection. A comparison of critical considerations pertaining to exterior and interior basement insulation strategies is also presented, along with relevant conclusions based on the testing, energy modelling and economic assessment of EIBS.

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T. J. Kesik and M.C. Swinton, M.T. Bomberg, M.K. Kumaran, N. Normandin, W. Maref

Introduction

This paper stems from the *Performance Guidelines for Basements Systems and Materials* project, carried out through the Institute for Research in Construction, National Research Council of Canada. This multi-phase, government/industry consortium project was initiated in 1996 and is in the final stages of documentation. The project was aimed at improving the performance of residential basements through an integrated series of research and technology transfer initiatives.

In Canada, residential basement performance problems continue to represent a significant proportion of the total defects and failures reported for new houses. Estimates of basement failures have been compiled, but many of the nuisance defects, especially water leakage, remain unreported because in virtually all cases these are repaired by the builder.[1] Recognizing the cost and inconvenience to homeowners associated with water leakage in finished basements, some jurisdictions require a drainage layer or membrane where basements are insulated full height and intended for use as a habitable space. These requirements are often satisfied using an exterior drainage membrane combined with an interior insulation and basement wall finish system. Recent field testing and economic analysis indicate that the use of an exterior insulation basement system with integral drainage capability is equally effective, and may also eliminate many concerns associated with internally insulated basements. However, careful consideration in design and construction must be exercised to achieve the full potential of EIBS technology.

External insulation basement systems were among a range of investigations carried out within the basement guidelines project to assess their moisture control and thermal effectiveness.[2, 3, 4, 5] A fuller discussion of the results of these field investigations is available in *Construction Technology Update No. 36.*[6] Subsequently, the consortium commissioned an economic study to assess the cost effectiveness of a number of basement systems employing a range of moisture protection and thermal insulation strategies, both exterior and exterior.[7] This paper represents the first opportunity to synthesize results from these related studies and to provide a comprehensive discussion of the findings.

Basement Performance: Expectations and Requirements

Canadians are increasingly viewing their basements as potentially livable space and this expectation continues to drive builder marketing and Code requirements for new housing in most, if not all, regions of the country. Fundamental performance requirements for basements have been detailed in earlier work.[8] However, a new development in reconciling expectations and requirements emerged during the early phases of the *Basement Guidelines Project*. It became apparent that in Canada, there exist distinct regional approaches to, and expectations of, basement construction. Ideally, recognition of the diverse use of basements and expectations would be best served by a classification system based on intended use and the intensity, duration and frequency of environmental loads.

Table 1 proposes a basement classification system which reflects the types of basements currently constructed across Canada. The Class A basements (types 1, 2 and 3) represent basements in which all critical control functions for a livable space have been addressed. In many Canadian housing markets, Class A basements are dominant, maximizing the utilization of highly priced land, or adding value to smaller houses where the basement potentially represents nearly half of the livable floor area (e.g., raised bungalows). Class B basements represent conventional practice in many parts of Canada, especially in areas with well-draining soils where the risk of water leakage is of little or no concern. Class C basements represent what was once conventional basement construction up to the 1970s, and continue to be constructed in some parts of Canada where the notion of a livable basement is simply not marketable. Class D basements generally employ engineering design and special measures to deal with chronic flooding or sewer backup events. Class E basements are purely structural foundations which provide no environmental separation. These are typically found in permafrost conditions and also for seasonal dwellings such as cottages which are built on piers, posts or grade beams.

This paper focuses on class A-3 basements which currently represent the predominant choice among builders and new homebuyers. The class A-3 basement is typically insulated full-height, with services roughed in such that finishing work at a later time can realize a fully livable space within the dwelling. This paper is premised within the context of these contemporary expectations of basements and the latest building science behind their requirements.

CLASS	INTENDED USE	SERVICE CRITERIA	LIMITATIONS/ALLOWANCES
A-1	Separate dwelling unit.	• Satisfies consumer expectations for control of heat, moisture, air and radiation. • Access/egress, fire & sound separation, and fenestration meet all Code requirements. • Separate environmental control system. • Thermal comfort comparable to above-grade storeys of the dwelling.	• Not suitable for flood prone areas, or areas prone to sewer backup. • Basement can be finished with materials that are moisture or water sensitive. • Virtually defect free construction. • Redundancy of critical control measures provided.
A-2	Liveable space (e.g., family room, home office, etc.)	• Satisfies consumer expectations for control of heat, moisture, air and radiation. • Thermal comfort comparable to above-grade storeys of the dwelling.	• Not suitable for flood prone areas, or areas prone to sewer backup. • Basement can be finished with materials that are moisture or water sensitive. • Virtually defect free construction. • Redundancy of critical control measures provided.
A-3	Near-liveable (e.g. unfinished surfaces)	• Satisfies all functions of the basement envelope, except for comfort, and is unfinished (e.g. no flooring, carpet, paint, etc.)	• Virtually defect free construction. • Redundancy of critical control measures provided.
B	Convertible or adaptable basement.	• Satisfies minimum requirements for control of heat, moisture, air and radiation (e.g. no explicit wall drainage layer) • Thermal comfort can be upgraded to same quality as above-grade storeys of the dwelling. (e.g., partially insulated wall)	• Not suitable for flood prone areas, or areas prone to sewer backup. • All structural and interior finishing materials (if any) must recover to original specifications after wetting and drying. • Practically free of defects in free-draining soils where adequate site drainage has been provided. • Normal frequency of defects can be expected otherwise.
C	Basement/cellar - convertible or adaptable at significant future premium.	• Unfinished basement with no intentional control of heat, moisture, air and radiation.	• Practically free of defects in free-draining soils where adequate site drainage has been provided. • Normal frequency of defects can be expected otherwise.
D	Basement serving a dwelling in a flood-prone area, or area prone to sewer backup.	• Class A-1, A-2 or A-3, B or C service criteria may apply.	• Interior finishes capable of withstanding periodic wetting, drying, cleaning and disinfecting.
E	Basement acting as a structural foundation only.	• Acceptable factor of safety for structural performance including frost heaving, adhesion freezing and expansive soils.	• Not intended to be inside the building envelope and no finishing intended. • Floor separating basement and indoors is now the building envelope and must address all functions. • Equipment in basement must be rated to operate outdoors or located in a suitably conditioned enclosure.
Note: Minimum requirements for health and safety are assumed for all of the basement classes listed above. In the case of the Class E basement, only the structural safety requirements are addressed.			

Table 1 Classification of Basements by Intended Use

Moisture Protection and Thermal Performance

Except for structural errors, about 90 percent of all building construction problems are associated with water in some way.[9] This observation continues to apply to residential basements, hence a focus of the EIBS field studies on the moisture protection capability of various insulation materials. Prior to the field studies, anecdotal evidence suggested that properly installed external insulation basement systems provided a level of moisture protection which was comparable to drainage membranes and/or granular layers.

Field investigations were conducted using specimens of various insulation products installed full-height on the exterior basement walls of a test house located on the National Research Council of Canada's Montreal Road Campus. Figure 1 depicts the cross-sections of the test walls which were instrumented and monitored for two heating seasons. In the field studies, seven parameters related to moisture protection and/or thermal performance were investigated, as outlined in Table 2 below.

• **Five insulation products:** 1) moulded expanded polystyrene (EPS) Type 1 2) moulded expanded polystyrene (EPS) Type 2 3) medium density spray-polyurethane foam 4) semi-rigid mineral fibre intended for exterior application to basement walls 5) semi-rigid glass fibre intended for exterior application to basement walls • **Two installation approaches for the insulation products.** 1) in direct contact with the soil below grade 2) wrapped (but not sealed) in two layers of polyethylene • **Three joining techniques for the insulation products:** 1) butt joints 2) ship-lap joints 3) continuous spray foam	• **Two approaches to relieving water pressure on the inner side of the insulation boards:** 1) grooves 2) no grooves • **Two approaches for mounting the above-ground protective cover (fibre-cement board):** 1) vertical Z-bars 2) horizontal Z-bars • **Two grading schemes:** 1) sloped away from the wall at a 5% slope (good landscaping practice) 2) sloped towards the wall at a 5% slope (poor landscaping practice) • **Two approaches with respect to the weeping tile gravel underneath the backfill:** 1) Protected by filter cloth over the gravel 2) Unprotected

Table 2 Summary of Parameters Investigated in IRC Field Studies

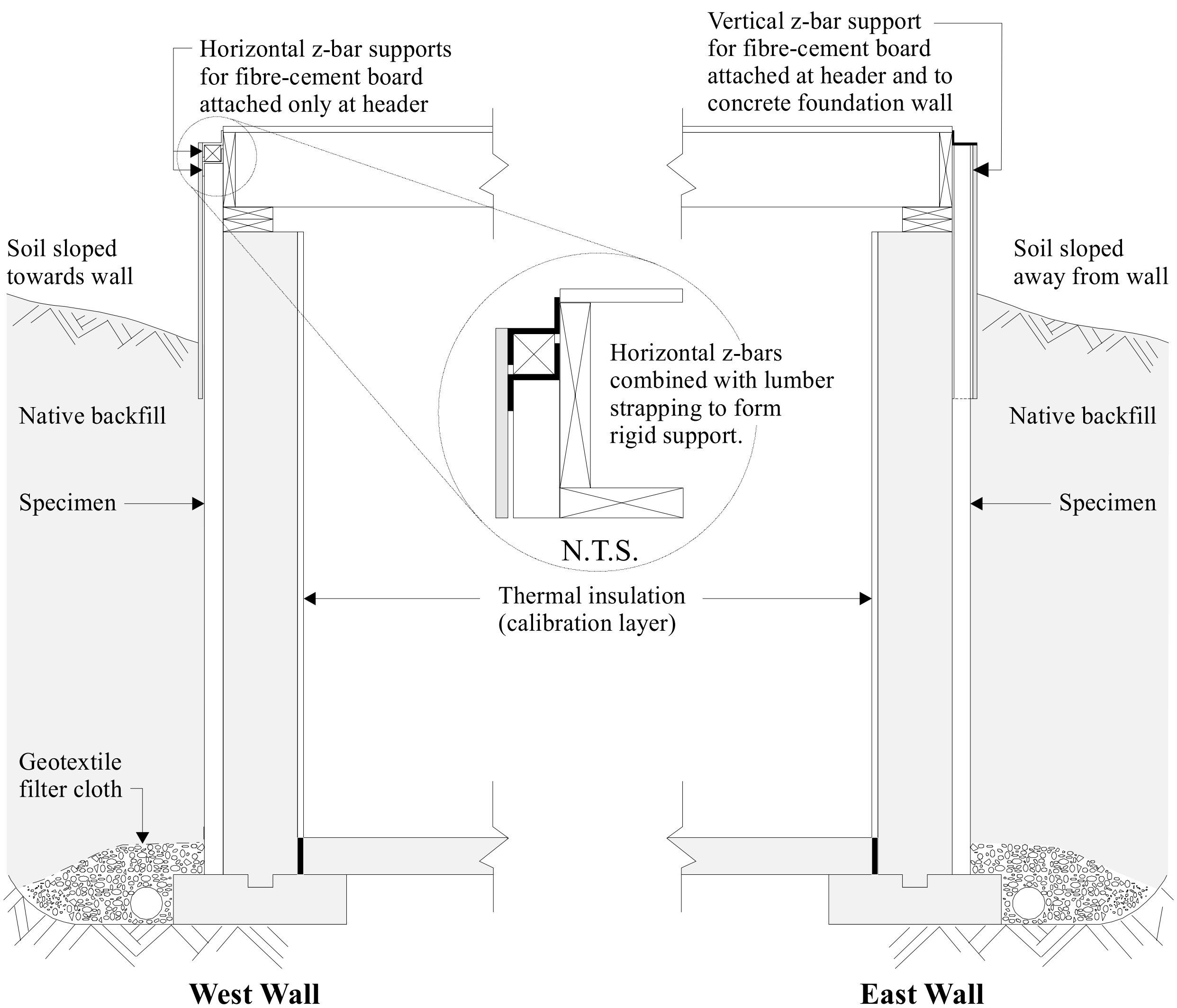


Figure 1 Wall Sections Used in EIBS Field Testing

Moisture Protection Capability

The moisture protection investigations revealed a number of significant findings:

1. **Insulation Materials** - All of the insulation materials provided acceptable levels of moisture protection, provided the joints between materials were continuous.
2. **Drainage Channels** - Researchers investigated two different specimens, each wrapped in two layers of polyethylene, forming smooth surfaces with no drainage spaces. They found that in both cases, the specimens promoted water movement at the outer surface so that the water did not penetrate the basement wall system. It may be concluded that outboard drainage spaces are not required to protect against the ingress of bulk water. A continuous "first line of defence" proved to be equally effective, hence drainage spaces may be deemed redundant.

3. **Joints** - All joint types between rigid and semi-rigid board insulation materials performed acceptably. Some movement of water can be expected between the joints, but the lack of hydrostatic build-up apparently keeps the water from migrating to the back of the board and into the concrete wall.
4. **Hydrostatic Pressure Relief** - The provision of channels or grooves on the inboard surface of board insulation materials to relieve hydrostatic pressure build-up between the insulation and the foundation wall does not appear necessary. Apparently, the roughness of the wall (typically cast-in-place concrete) performs this function implicitly.
5. **Grading** - Monitoring indicated that when grading slopes away from the above-grade foundation wall, a large proportion of rain water and snow melt are diverted away from the basement. Conventional backfill and grading practices, which were emulated in the field studies, were found to be inadequate over the study period. The initial grading of a 5% slope away from the building was eventually transformed into a slope toward the basement due to soil subsidence. This suggests that positive grading sloped away from the building combined with the proper placement and compaction of backfill are critical to basement moisture protection strategies.
6. **Protection of Gravel Over Weeping Tile** - Examination of drainage pipes on both sides of the test house basement indicated both pipes were free of sedimentation. Hence it was not possible to confirm or deny the effectiveness of filter cloth to prevent the sedimentation of weeping tile.

Redundancy and Multi-Functionality in Moisture Protection Strategies

Within the building science community, it is now generally accepted that the “perfect barrier” approach to moisture protection, which depends on a single material and flawless workmanship, is generally less reliable than a “systems” approach which incorporates redundant measures employing multi-functional materials to compensate for material imperfections and workmanship.

Redundancy in moisture protection, which is also referred to as a “first line” / “second line” of defence approach, is a systems concept analogous to structural redundancy where failure of one member or component is compensated for by other adjacent or connected members and components.

Multi-functionality is a materials concept which defines the capability of a material to perform more than one critical control function. For example, the test specimens of insulation demonstrated the control of heat transfer and moisture migration. The foundation walls provided resistance to structural loads and a reasonable measure of moisture resistance when combined in a redundant arrangement with the exterior insulation.

External basement insulation systems are founded on redundancy and multi-functional materials which employ the following moisture management strategy:

1. **Shedding/Conveyance** - shedding and conveying water away from the building through provision of grading which is sloped away from the building, and which remains sloped away after settlement of the backfill around the basement;
2. **Primary Water Management** - a continuous 'first line of defence' provided by the exterior insulation, which in the case of board products relies on proper installation details and fit between the joints;
3. **Secondary Water Management** - a properly constructed foundation wall, 'second line of defence' which resists moisture ingress in the event of a flaw or defect in the exterior insulation; and
4. **Effective Foundation Drainage** - a foundation drainage system which conveys water diverted by the primary and secondary water management measures to a storm sewer, sump, dry well or ditch, and which remains functional for the useful life of the building.

Acceptable moisture protection performance in class A basements depends on all of these control functions being provided irrespective of the type of basement insulation system.

Thermal Effectiveness

The thermal effectiveness investigations also revealed several interesting findings:

1. **Insulation Materials** - All of the insulation materials provided acceptable and sustained levels of thermal performance over the two full heating seasons. The results of the monitoring are presented in Figure 2. It was further observed that specimens sustained their performance even during major rain storms and winter thaws, when the effects of water movement were recorded at the outer face of the insulation specimens.
2. **Attachment of Protective Cover (Fibre-Cement Board)** - Thermal bridging due to the attachment of the protective cover to the concrete foundation wall can significantly reduce thermal effectiveness. The use of metal Z-bars attached vertically to the concrete wall, extending 270 mm below grade, reduced the effective thermal resistance of the insulation by 13% on average. The effect of these thermal bridges was detected as far as 740 mm below grade.

As a result of the in-situ testing of the thermal effectiveness of the insulation materials, energy simulations conducted subsequently under the Basement Guidelines Project could reasonably assume the nominal thermal resistance values of these materials, with the understanding that appropriate methods for attachment of the protective cover were applied.

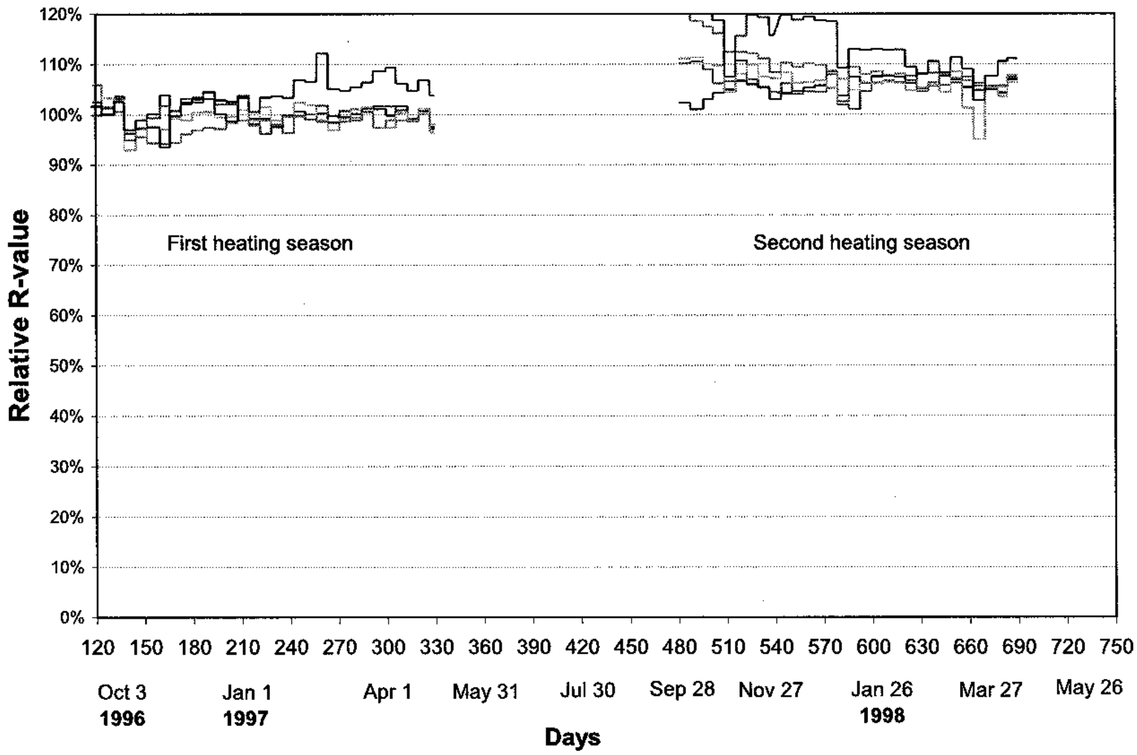


Figure 2 Range of Thermal Performance Result for Specimens on One Test Wall (EPS Type 1, EPS Type 2, Glass Fibre, Mineral Fibre and Sprayed-in-Place Polyurethane Foam)

Economic Assessment

The economic assessment methodology behind the findings presented in this paper is fully consistent with previous studies of a similar nature performed on behalf of IRC/NRCC.[10] A number of sources of information were accessed to arrive at the costs associated with each type of basement system considered in the Basement Guidelines Project.

First, a survey of a representative cross-section of Ontario builders was conducted in 1999 to determine costs and profits associated with various types of basement construction. At the same time, these data were augmented with a survey of building material prices. The builders' costs and the material costs were combined to estimate the system cost, including applicable taxes profit (12%), for a broad variety of basement constructions applied to a base case model, as depicted in Figure 3. These costs were adjusted to estimate costs in other housing markets across Canada using location factors developed by a recognized construction cost data provider.[11] This established the purchased basement system cost in each market location.

PARAMETER	QUANTITY	UNITS
Length	28	ft
Width	24	ft
Height	8	ft
Perimeter	104	ft
Area	672	ft^2
Volume	5376	ft^3
Fdn. Wall Area	832	ft^2
Above-Grade	104	ft^2
Below-Grade	728	ft^2

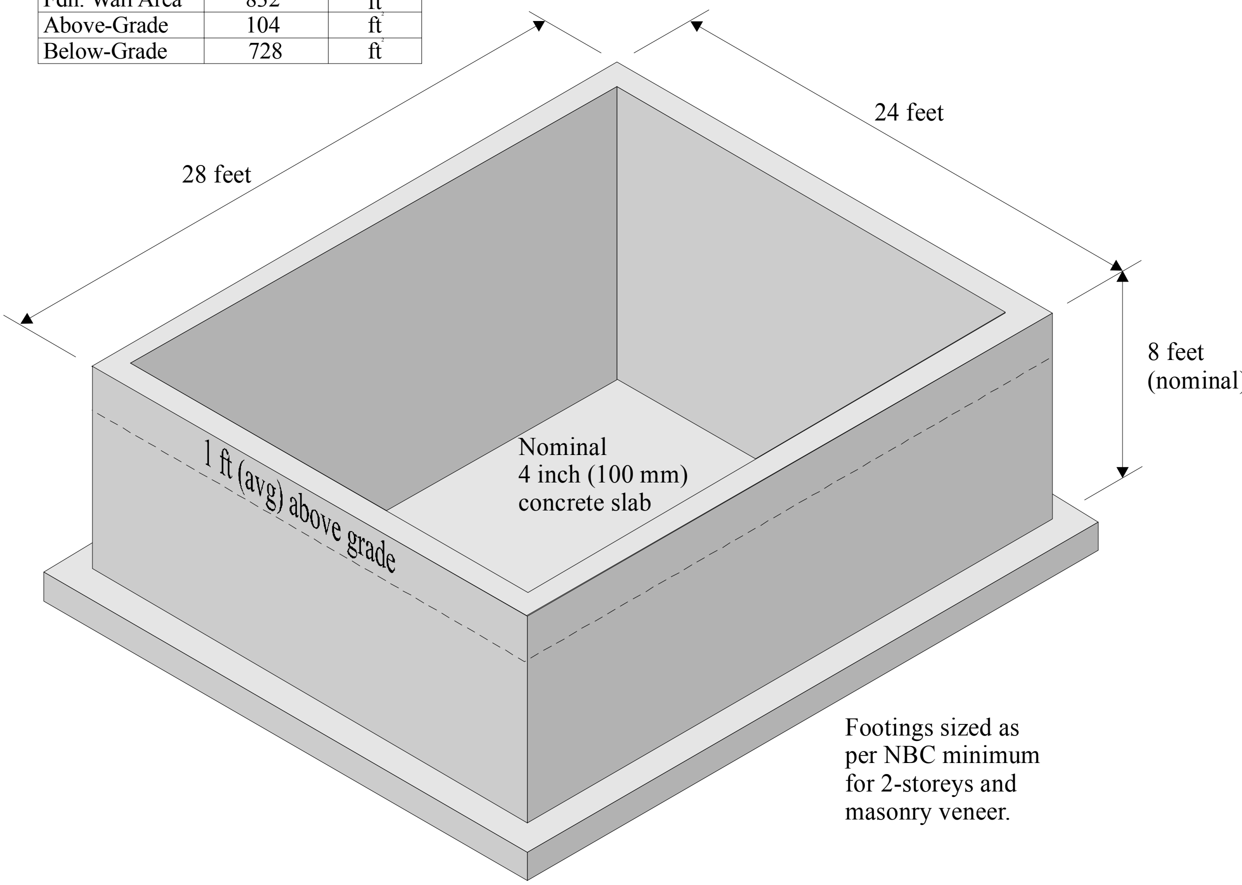


Figure 3 Base Case Basement Model Used in Economic Assessment Study

Second, the cost of heating the basement was estimated using the BASECALC™ computer simulation software.[12] Models of each basement system type were created and simulated for each of the selected market locations. The annual energy demand for each basement type in each location was converted to a purchased energy cost using energy cost data provided by Natural Resources Canada, Statistics Canada and various energy sector organizations. The costs of purchased energy used in the economic assessment are summarized in Table 3.

Space Heating Energy Source	Ottawa ($/GJ)	Toronto ($/GJ)	Edmonton ($/GJ)	Victoria ($/GJ)
Gas (80%)	8.73	8.73	5.80	8.73
Oil (80%)	12.20	12.20	9.96	13.20
Prop. (80%)	20.53	20.53	16.36	21.04
Elec. (100%)	20.44	25.64	20.86	17.00
Note: The costs of various types of space heating energy listed in the left hand column are based on 1999 data, and reflect the space heating system efficiency as noted in parentheses. In the last two quarters of 2000, significant and fluctuating increases for fossil fuels have occurred.				

Table 3 Purchased Energy Prices Used in the Economic Assessment

Third, the life cycle cost of each basement system type in each location was calculated according to a recognized American Society for Testing and Materials (ASTM) protocol.[13] A 30-year study period was selected in keeping with the approach established by the Model National Energy Code for Houses. For the analyses presented in this paper, the annual interest rate was set at 4%, and the annual energy escalation rate was set to 6%, indicating that energy prices are expected to rise faster than the general rate of inflation. These parameters were used within a modified uniform present worth equation to obtain the present value of the purchased basement system and heating energy over the study period. In this paper, the system and life cycle costs for exterior insulation basement systems and interior insulation basement systems were averaged, recognizing that variations between the costs of various system alternatives may be different within and between the selected market locations. The results are presented in Table 4 below, expressed in 1999 Canadian dollars.

	Ottawa (4,673 ^{O}C.Days)		**Toronto (4,082 ^{O}C.Days)**		**Edmonton (5,589 ^{O}C.Days)**		**Victoria (3,076 ^{O}C.Days)**	
Energy Demand	Exterior	Interior	Exterior	Interior	Exterior	Interior	Exterior	Interior
(GJ/year)	14.9	12.1	12.7	10.2	18.4	14.9	10.2	8.4
System Cost	$9,561	$9,480	$10,177	$10,090	$8,700	$8,626	$9,217	$9,138
Life Cycle Cost								
Gas (80%)	$14,863	$13,786	$14,695	$13,712	$13,054	$12,166	$12,844	$12,118
Oil (80%)	$16,975	$15,501	$16,494	$15,154	$16,179	$14,707	$14,704	$13,647
Propane (80%)	$22,034	$19,609	$20,805	$18,610	$20,983	$18,613	$17,962	$16,323
Elec. (100%)	$21,983	$19,567	$23,454	$20,733	$24,359	$21,358	$16,283	$14,945

Table 4 Comparison of Life Cycle Costs for Exterior Versus Interior Basement Insulation Strategies in Four Canadian Locations

The common view that exterior systems are significantly more expensive than interior systems was not confirmed in the study. In general, exterior insulation basement systems cost marginally more than interior systems across all selected locations. This can be explained by a consistent set of performance requirements being imposed on each type of system in accordance with class A-3 basement criteria and applicable Code requirements. For example, when masonry veneer construction is considered, the cost of a masonry curb or ledger to align the bottom of the veneer with the projected exterior insulation represents a significant premium. But when plastic insulation materials on the interior are considered, a non-combustible protective cover such as gypsum board must be applied, consequently requiring expenditures on services concealed within the interior insulation system. Not all exterior basement insulation systems are integrated with above-grade masonry veneer walls, and similarly, not all interior insulation systems use plastic insulation materials. Hence, the averages provide a reasonable generic cost comparison over the whole of new housing starts.

In terms of life cycle costs, interior basement systems marginally outperform exterior systems when less expensive energy sources are used to provide space heating, and significantly outperform exterior systems when the cost of heating energy is high. This may be attributed to the difference in annual heating energy demand between exterior and interior systems. In this study, the BASECALC™ simulations assumed a masonry veneer resulting in a significant thermal bridge at the top of the concrete foundation wall. When the basement is modeled assuming siding, stucco or some other cladding which readily facilitates continuity of exterior insulation over the entire wall envelope, the differences in thermal performance between the two approaches significantly diminish.

Apparent anomalies occur when regional energy prices differ significantly from national averages. For example, in Edmonton where the climate is much colder than Victoria, the life cycle costs for fossil fuels are almost identical due to the marked difference in energy prices. In view of the recent trend in escalating energy prices, particularly for fossil fuels, it may be prudent for designers and energy efficiency regulatory authorities to re-examine optimum levels of thermal insulation. It may also prove compelling to investigate the life cycle cost of significant thermal bridging associated with currently acceptable building practices.

Comparative Performance Considerations

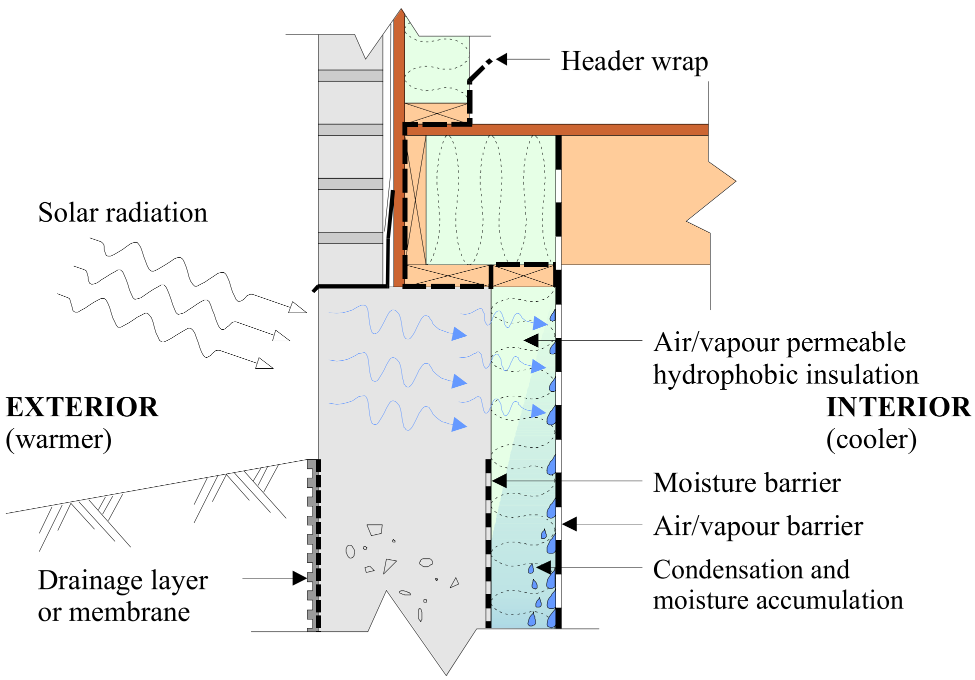
If basements are intended to provide livable space of comparable environmental quality to the above-grade floors of a dwelling, how should they be constructed, and how are they constructed?

When builders in Ontario were surveyed regarding their criteria for the selection of basement insulation systems, moisture protection was given the highest priority. This was followed by cost and marketability considerations. Most builders viewed exterior insulation basement systems to be significantly more expensive than interior systems because they only considered the thermal control functions they provided. More correctly, the use of a drainage layer or membrane were not viewed as an additional cost because in Ontario, when class A basements are constructed, these control measures are mandated by the provincial building code. However, the whole basement system comparison indicated that the differences in first and life cycle costs are not significantly different. This underlines the importance of the proposed basement classification system which provides an objective set of minimum requirements corresponding to an expected level of performance.

Builders also noted that interior basement insulation systems were generally more marketable because they offered homebuyers a basement which they could use and later make habitable by finishing it, often themselves. Exterior insulation systems potentially caused homebuyers to perceive the basement as less desirable because it appeared uninsulated. Several of the builders reported that when they constructed their own homes, an exterior basement insulation system was selected due to building science considerations conveyed through prior R-2000 Program training they had received. These views suggested that when provided with expert knowledge about basement system performance, a significant proportion of homebuyers, in this case about one-third of the builders who built their own homes, preferred EIBS. However, due to common misconceptions among homebuyers, all of the builders constructed class A basements using interior systems.

Among their minor considerations, builders noted that from a cash flow perspective, EIBS required a greater expenditure during the early stages of house construction, while interior systems were typically executed several weeks before the closing dates on their homes. None of the builders considered the potential benefits of EIBS for winter construction in soils which are susceptible to adfreezing.

A common performance problem reported by builders using interior systems related to the above-grade portion of the foundation walls constructed from wet materials (i.e., cast-in-place concrete). When interior insulation systems employing strapping and air/vapour permeable, hydrophobic cavity insulation materials (e.g., glass and mineral fibre) were installed, moisture problems were commonly observed during the first summer following construction. This phenomenon is depicted in Figure 4 below.

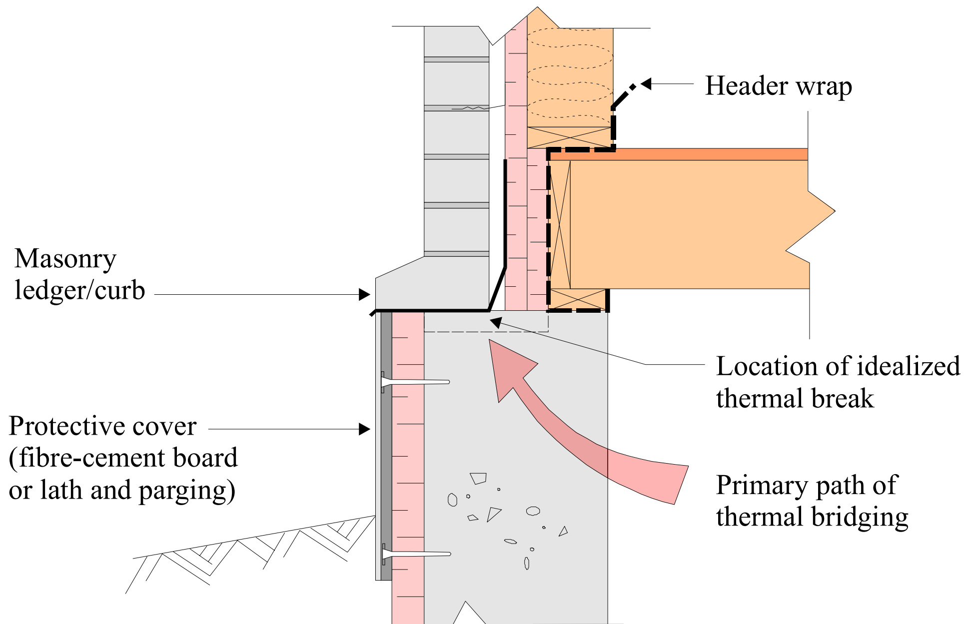


The dominant temperature gradient during summer months drives moisture entrained in the foundation wall inward, where it condenses on the outboard face of the air/vapour barrier. Much of the insulation and strapping normally reach saturation, and in some cases, bulk water runs out the bottom of the interior finished wall assembly (often mistaken for leakage).

Figure 4 Common Moisture Problem Associated with Interior Insulation Strategies

Measures to avoid this problem include: 1) the use of a hydroscopic cavity insulation, such as cellulose, to absorb the moisture and then to slowly release it over time; 2) the use of a hydrophobic, air impermeable cavity insulation, such as sprayed-in-place polyurethane foam; 3) the use of a low air/vapour permeable board insulation between the interior strapping and foundation wall; 4) the use of dry foundation wall construction (e.g., concrete masonry units); and 5) the termination of full-height insulated assembly above the floor to permit the escape of accumulated water.

Exterior basement insulation systems also pose detailing problems with respect to thermal bridging at the top of the foundation wall when masonry veneer is selected as an exterior wall finish. Figure 5 depicts the challenge associated with addressing this concern.



Unlike siding and stucco type cladding systems, the integration of masonry veneer with exterior insulation basement systems poses several challenges. Builders have demonstrated success with the use of a lightweight, precast concrete ledger or curb to aesthetically deal with the projection of the exterior basement insulation and protective cover. However, thermal bridging has not been easily addressed. Ideally, an insulation material having adequate compressive strength and low creep is needed to eliminate thermal bridging while sustaining the weight of the ledger and brick veneer above.

Figure 5 Challenges Associated with Integrating EIBS and Masonry Veneer Walls

Based on the BASECALC™ simulations, thermal bridging depicted in Figure 4 reduced the thermal effectiveness of the insulation by approximately 20% on average, compared to interior systems with the same nominal R-value of insulation installed. If combined with thermal bridging associated with the inappropriate attachment of the protective cover, potentially one-third of the thermal effectiveness of EIBS may be compromised when masonry veneer walls are constructed. On the other hand, EIBS are ideally suited to siding and stucco type cladding systems, resulting in continuity of exterior insulation over below and above-grade walls.

Conclusions

Based on the findings of the in-situ testing and economic assessment study conducted within the Basement Guidelines Project, it was reasonable to conclude:

1. External insulation basement systems provide acceptable moisture protection performance comparable to drainage membranes or granular layers.
2. In-situ thermal performance of the five insulation materials tested indicated that the nominal thermal resistance values were maintained in the below-grade environment.
3. The costs for exterior and interior insulation basement systems which comply with the requirements of class A basement systems are practically equivalent.
4. Construction moisture problems associated with vapour permeable interior insulation systems at the above-grade areas of the foundation wall may be avoided through the use of an exterior system.
5. Thermal bridging in exterior systems coupled to above-grade masonry veneer wall systems remain to be practically addressed at the time of construction, however, future finishing of the basement can address thermal bridging through the addition of interior thermal insulation, and result in a super energy efficient basement.
6. Defects such as water leakage, though significantly reduced, may be repaired easily and cost effectively when exterior systems are employed.
7. In flood prone areas, or areas where municipal sewer surcharge (back-up) are prevalent, exterior systems reduce the costs associated with water damage, and the risks of harmful contaminants (bacteria, molds, etc.) residing in interstitial spaces of interior systems.[7]
8. In swelling soils, or soils susceptible to adfreezing, exterior insulation basement systems potentially reduce problems related to surrounding soil movement.

This paper has presented information derived from the Basement Guidelines Project which represents a comprehensive program of in-situ testing, energy modelling and economic assessment in order to provide manufacturers, designers, builders, regulatory officials and consumers with a broader perspective on basement system performance, and not just the materials employed therein. The approach taken here points to the future of building system performance assessment whereby all interested stakeholders are enabled to participate, review and comment on the process and the results, so that Canadian construction technology can better respond to meet tomorrow's challenges.

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[7] A recent CMHC study (Forest, Tom W. and Mark Y. Ackerman, *Basement Walls That Dry: Final Project Report*. Canada Mortgage and Housing Corporation, Ottawa, March 1999.)indicates that most conventional interior insulation assemblies exhibit poor drying characteristics after wetting. This suggests that health risks associated with bacteria and mold growth within the insulated assemblies are higher when wetting incidents are chronic.

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