Cost Effective Levels of Thermal Insulation for Basements in Canadian Housing

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ABSTRACT
This paper is based on recently completed research funded by Canada Mortgage and Housing Corporation to investigate cost effective levels of thermal insulation for basements in Canadian housing. The work is an update of a life cycle economic assessment appearing in *Performance Guidelines for Basement Systems and Materials Project* undertaken for the Institute for Research and Construction, National Research Council Canada in 1999. Since that time, the cost of space heating energy has escalated sharply and new methods and materials for insulating basements have emerged. The paper addresses the conference themes of new research and revised design understanding, and basement construction methods.

A methodology for energy modeling and life cycle cost analysis is presented in the first part of the paper followed by an assessment of the energy efficiency of current practices. These results are then contrasted with cost effective alternatives when several energy price escalation rate scenarios are examined using the Modified Uniform Present Worth method according to ASTM E 917, *Measuring Life-Cycle Costs of Buildings and Building Systems,* ASTM Standards on Building Economics, Fifth Edition, 2004.

The final part of the paper presents recommended basement envelope assemblies for achieving cost effective levels of energy efficiency while improving basement system performance with respect to moisture protection, thermal comfort and reduced susceptibility to mould. The paper is of interest to designers, builders and house occupants because basements are increasingly becoming viewed as liveable spaces that are expected to perform as well as above-grade areas of the building. For energy policy and building code agencies, the substantial energy savings cost effectively afforded by advanced basement envelope systems are compelling factors to update minimum thermal insulation requirements for basements.

INTRODUCTION
This paper is an update of previous work conducted under the terms of the *Performance Guidelines for Basement Envelope Systems and Materials* project on behalf of the Institute for Research in Construction, National Research Council Canada.[1] For a detailed description of the original study methodology, see:
http://irc.nrc-cnrc.gc.ca/pubs/rr/rr199/part6.pdf

Since the completion of the original 1999 *Economic Assessment of Basement Systems* study[2], fossil fuel energy prices in Canada have risen sharply and the escalation rate of energy prices has consistently outpaced interest rates. As an example, the Bank of Canada rate over the 7 year period since the original study was conducted has averaged 3.76% while the average annual increase in natural gas prices over the same time period was approximately 11%. During the 1999 study, an interest rate of 4% and an annual energy escalation rate of 1 % were assumed in the life cycle cost assessments. This tended to under value the benefits of energy conservation in basements and positioned full-height basement insulation as being only marginally more cost effective than partial height insulation, as well as favouring lower levels of thermal insulation. During this same period, the cost of residential basement construction also escalated by approximately 37%. For these reasons, CMHC commissioned this study to provide an updated economic assessment of basement system insulation options that more accurately reflects the rising costs of basement construction and space heating energy.

It is important to recognize that similar to the original study, a number of costs and benefits for various basement system options could not be monetized. For example, in flood-prone areas, external basement insulation options may minimize the time and costs associated with damage and cleanup following a basement flooding event. Factors such as thermal comfort and potential for mold growth could not be economically assessed within this study, however, it should be recognized that such factors may significantly influence the value and marketability of housing.

The primary objectives of this study were as follows:

1. To update the construction costs (material and labour) for various classes of basement systems currently available in the Canadian residential housing marketplace.
2. To update energy prices and energy price escalation rates to take into account expected trends in the energy marketplace.
3. To include a larger basement model to accompany the smaller basement model used in the original study so that the effect of basement size could be comparatively assessed.
4. To conduct a life cycle economic assessment taking into account the updated construction costs, energy prices and energy price escalation rates.
5. To prepare a report on the findings related to the preceding objectives.

METHODOLOGY

This study employed a similar methodology to that associated with the 1999 *Economic Assessment of Basement Systems* study. The main difference is that the builder survey conducted in 1999 was not repeated due to a lack of resources. Instead, the 1999 prices were adjusted by employing 2006 material costs for thermal and moisture protection measures, and applying a construction price index to the 1999 builder unit costs. Recognizing this difference, the steps taken in this study are as follows:

1. Research was undertaken into the construction price index from 1999 to 2005 using Statistics Canada data, which was subsequently compared with R.S. Means Residential Cost Data (1999 versus 2005) to validate the former. The construction cost inflation rate for each of Toronto, Ottawa, Halifax, Edmonton and Victoria was later applied to the 1999 builder unit costs to arrive at 2006 costs. (Note: The costs up to December 2005 were applied in February 2006 assuming a negligible increase for this relatively short time difference).
2. Material costs were subsequently surveyed in February 2006 to derive unit costs for the various thermal and moisture protection measures considered in the study. These 2006 costs were later combined with the inflation adjusted 1999 builder costs to arrive at a total cost for each basement system insulation option.
3. A survey of energy prices and was conducted in February 2006 to determine consumer costs by fuel price across the 5 locations considered in this study. Energy price trends and forecasts were subsequently reviewed to develop reasonable energy price escalation scenarios.

4. A larger basement type was developed and modeled in BASECALC™ so that annual space heating energy demand for each insulation option was calculated across all 5 locations considered in the study.
5. A new life cycle cost assessment spreadsheet was assembled so that three different energy price escalation scenarios could be analyzed. The relationship of the discount or interest rate to the escalation rate for energy is critical when employing the modified present worth formula.
6. Following the life cycle assessment process, a detaled report was developed to present the results and provide an interpretation of their significance.

Due to the regional variations in basement construction practices across Canada, it was not possible to address every type of basement system in this study. However, the methodologies which have been developed may be applied by interested parties to yield specialized/localized answers to questions which commonly interest builders, consumers and society.

DESCRIPTION OF BASEMENT MODELS

The approach taken to basement modeling in this study is consistent with the original 1999 study. However, a larger basement type was developed so that the sensitivity of life cycle cost to basement size could be assessed.

The small basement model used for estimating costs and operating energy performance is depicted in Figure 1, while the large basement model appears in Figure 2. Critical features of the basement models are:

1. The average height of the small basement walls above grade is set at 1 foot (300 mm) in keeping with conventional practices for typical small new homes. For the large basement, the height above grade is set at 2 feet (600 mm), as larger basement window heights are common in larger custom houses. These variations enabled a more realistic modeling of the above-grade heat loss.
2. No windows are included in the basement models, recognizing that these are usually provided. The difficulty associated with the inclusion of windows is that the cost of the windows must be factored into the total basement system cost, and their orientation impacts solar gains. Window qualities and costs vary significantly, and the cost implications of window wells must also be considered. The windowless model enables more efficient economic and thermal analyses.
3. The heat loss modeling of basement systems with exterior insulation assumed no thermal bridging, where siding and stucco type cladding systems provided continuity of exterior insulation over above and below-grade walls. A separate limited analysis was conducted to determine the associated energy penalty for cases where exterior basement insulation was combined with above-grade masonry veneer wall cladding. The results of this analysis for Toronto, Ontario are discussed later in the paper.

PARAMETER	QUANTITY	UNITS
Length	28	ft
Width	24	ft
Height	8	ft
Perimeter	104	ft
Area	672	ft2
Volume	5376	ft3
Fdn. Wall Area	832	ft2
Above-Grade	104	ft2
Below-Grade	728	ft2

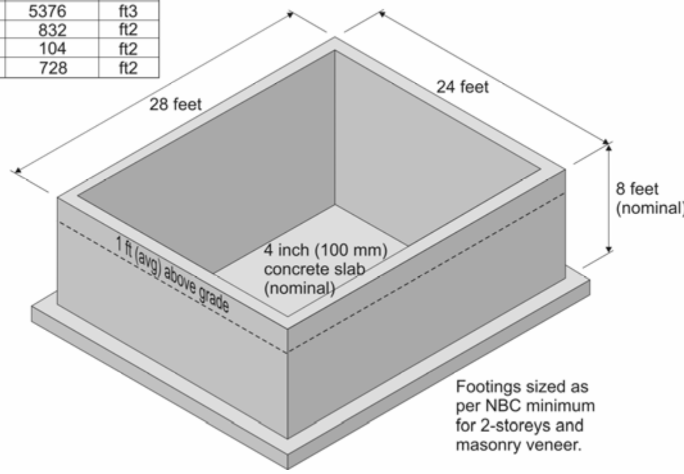

Figure 1. Physical characteristics of small benchmark basement model.

PARAMETER	QUANTITY	UNITS
Length	48	ft
Width	32	ft
Height	8	ft
Perimeter	160	ft
Area	1536	ft2
Volume	12288	ft3
Fdn. Wall Area	1280	ft2
Above-Grade	320	ft2
Below-Grade	960	ft2

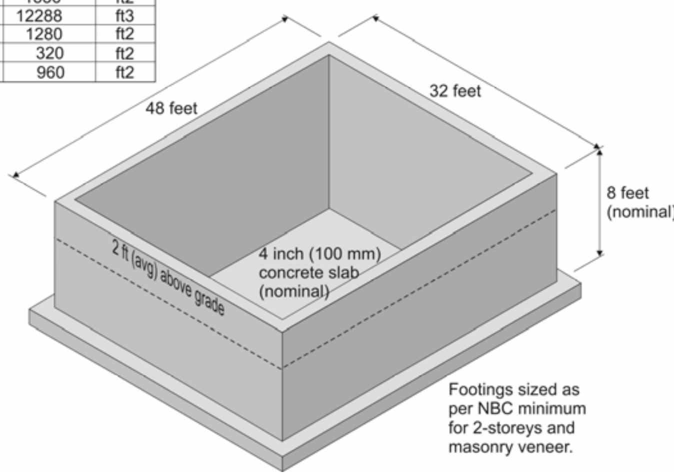

Figure 2. Physical characteristics of large benchmark basement model.

BASEMENT CLASSIFICATION SYSTEM

This study considers three classes of basements developed during the Basement Guidelines project and described in Table 1. The Basement Guidelines project recognized that while consensus had not been reached on minimum requirements for basements that satisfied the whole range of consumer expectations, there was an opportunity to develop an approach that was consistent with the newly emerging objective-based codes.

During the development of these guidelines 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 its intended use and the intensity, duration and frequency of environmental loads.

For the purposes of this study, the Class A-3 basement represents a full-height insulated basement that is not finished. The Class B basement is partially insulated and may be convertible to a Class A basement at some future point in time. The Class C basement is not practically convertible into a Class A basement because it lacks adequate moisture protection of the below-grade walls (i.e., no explicit drainage layer installed).

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 nor 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 as adopted in Basement Guidelines project.

ENERGY PRICES AND CONSTRUCTION PRICE INDICES
Energy and construction prices have risen sharply since 1999. Table 2 summarizes the data employed in the current update study. It should be noted, by comparing with the 1999 energy prices listed in Table 3, the cost of fossil fuels has increased more dramatically than construction costs during this period.

	Energy Price ($/GJ) February 2006				Location	1999-2005 Construction
	Gas	Oil	Propane	Electricity	Factor	Inflation
Toronto	15.01	21.57	29.25	26.67	1.14	135.2%
Ottawa	15.01	22.09	28.85	26.67	1.11	156.5%
Halifax	N/A	23.14	40.71	29.44	0.98	129.7%
Edmonton	7.21	20.29	20.95	27.50	1.01	148.6%
Victoria	15.40	23.53	28.46	19.36	1.07	117.0%
					Avg.	137.4%

Table 2. Energy prices, location factors and construction inflation for selected study locations.

	ENERGY PRICE ($/GJ) 1999			
	Gas	Oil	Propane	Electricity
Toronto	6.98	9.76	16.42	25.64
Ottawa	6.98	9.76	16.42	20.44
Halifax	N/A	9.47	18.34	26.11
Edmonton	4.64	7.97	13.09	20.86
Victoria*	6.98	10.56	16.83	17.00

Table 3. Energy prices used in original 1999 study.

The life cycle cost parameters employed in the analyses are summarized in Table 4. As noted previously, the low future energy cost scenario is more of an historical datum, unlikely to be seen in a world energy market of depleting resources. The high scenario reflects the situation where current energy prices in Canada begin to approach prices in other developed countries. The 30 year study period corresponds to that used in the analyses supporting the Model National Energy Code for Houses.

	Future Scenarios		
Parameter	***Low***	***Current***	***High***
Interest or Discount Rate	2.0%	3.0%	5.0%
Energy Escalation Rate	4.0%	7.0%	12.0%
Study Period (years)	30	30	30

Table 4. Life cycle cost parameters used in 2006 study.

These cost data were input to a life cycle cost model along with the BASECALC™ space heating energy simulation results for each basement insulation option.[3] The life cycle cost analyses were conducted according to an acknowledged method using the modified uniform present worth method.[4]

FINDINGS

The update study considered 5 locations (Toronto, Ottawa, Halifax, Edmonton and Victoria) and 17 different basement insulation options for 2 sizes of basement, requiring 170 energy simulations. These results were used to estimate basement heating costs for natural gas, oil, propane and electricity. The complete study findings appear in 32 tables, hence it is not possible to present all of the findings within this paper. Instead, two tables are presented for comparison purposes, one for a small basement and the other for a large basement, located in Ottawa and heated by 80% efficiency natural gas.

Ottawa - Natural Gas 80% Efficiency, Small Basement

Class A-3 Basement (Full Height Insulation, Unfinished)										
Basement		**Annual**	**Capital**	**Annual**		**LCC of Energy**			**LCC of Basement System**	
Option	**R-Value**	**GJ**	**Cost**	**Energy**	***Low***	***Current***	***High***	***Low***	***Current***	***High***
Ext XPS	12	12.3	$14,617	$231	**$9,487**	**$13,187**	**$21,904**	**$24,105**	**$27,805**	**$36,521**
Ext Fibre	9.9	13.1	$14,206	$246	**$10,104**	**$14,045**	**$23,328**	**$24,310**	**$28,251**	**$37,534**
Ext EPS	11.25	12.4	$14,032	$233	**$9,565**	**$13,294**	**$22,082**	**$23,597**	**$27,327**	**$36,114**
Ext SPF	12	12.3	$15,354	$231	**$9,487**	**$13,187**	**$21,904**	**$24,841**	**$28,541**	**$37,258**
Int. Fibre	12	11.7	$13,550	$220	**$9,025**	**$12,544**	**$20,835**	**$22,574**	**$26,094**	**$34,385**
Int. Cell.	12	11.7	$13,605	$220	**$9,025**	**$12,544**	**$20,835**	**$22,630**	**$26,149**	**$34,440**
Int. Batt	20	9.8	$13,798	$184	**$7,559**	**$10,507**	**$17,452**	**$21,357**	**$24,304**	**$31,249**
Int. XPS	10	12.5	$14,926	$235	**$9,642**	**$13,402**	**$22,260**	**$24,568**	**$28,328**	**$37,186**
Int. EPS	9	12.8	$14,447	$240	**$9,873**	**$13,723**	**$22,794**	**$24,320**	**$28,170**	**$37,241**
Int. SPF	12	11.7	$16,202	$220	**$9,025**	**$12,544**	**$20,835**	**$25,226**	**$28,746**	**$37,037**
ICFs	22	9.3	$18,945	$174	**$7,173**	**$9,971**	**$16,561**	**$26,118**	**$28,916**	**$35,506**
Class B Basement										
Basement		**Annual**	**Capital**	**Annual**		**LCC of Energy**			**LCC of Basement System**	
Option	**R-Value**	**GJ**	**Cost**	**Energy**	***Low***	***Current***	***High***	***Low***	***Current***	***High***
Int. Fibre	12	16.0	$11,627	$300	**$12,341**	**$17,154**	**$28,493**	**$23,968**	**$28,781**	**$40,120**
Int. Cell.	12	16.0	$11,652	$300	**$12,341**	**$17,154**	**$28,493**	**$23,994**	**$28,807**	**$40,145**
Int. Batt	20	14.8	$11,741	$278	**$11,416**	**$15,867**	**$26,356**	**$23,157**	**$27,608**	**$38,097**
Int. XPS	10	16.5	$12,258	$310	**$12,727**	**$17,690**	**$29,383**	**$24,985**	**$29,948**	**$41,641**
Int. EPS	9	16.7	$12,038	$313	**$12,881**	**$17,905**	**$29,739**	**$24,920**	**$29,943**	**$41,778**
Class C Basement										
Basement		**Annual**	**Capital**	**Annual**		**LCC of Energy**			**LCC of Basement System**	
Option	**R-Value**	**GJ**	**Cost**	**Energy**	***Low***	***Current***	***High***	***Low***	***Current***	***High***
Gas 80%	N/A	33.3	$10,829	$625	**$25,685**	**$35,702**	**$59,301**	**$36,515**	**$46,531**	**$70,130**

Table 5. Life cycle cost assessment of small basement in Ottawa – 80% efficiency natural gas.

Table 5 is divided into data for the 3 basement classes, indicating each insulation option with its corresponding R-value, annual energy consumption, capital cost and life cycle costs. For Class A-3 basements, the highest life cycle energy cost is associated with exterior fibre insulation (glass or mineral wool), while the lowest life cycle energy cost is achieved using insulated concrete forms (ICFs). After the capital cost has been added to the life cycle energy cost to obtain the life cycle cost of the basement system, the R-12 exterior sprayed polyurethane foam has the highest life cycle cost, and the lowest life cycle cost is achieved using interior R-20 batt (glass or mineral wool). These relationships hold true across all of the energy price escalation scenarios for the Class A-3 analyses in Table 5. Class B basements employ fewer insulation options, all of which are interior applications. Again the R-20 interior batt is the most cost effective option with interior foam board insulation having the highest life cycle costs. The Class C basement, which is uninsulated, has the highest life cycle costs among all basement classes.

It is interesting to note that full-height insulation is the most cost effective option over the 30 year study period when the same insulation strategy is being considered, however, some lower cost partial-height insulation strategies can be more economical than higher cost full-height insulation strategies. But as noted earlier in this paper, there are benefits associated with insulation strategies that have not been monetized and for certain situations, these may take a higher priority than life cycle energy and/or basement system costs.[5]

Ottawa - Natural Gas 80% Efficiency, Large Basement										
Class A-3 Basement (Full Height Insulation, Unfinished)										
Basement		**Annual**	**Capital**	**Annual**	**LCC of Energy**			**LCC of Basement System**		
Option	**R-Value**	**GJ**	**Cost**	**Energy**	***Low***	***Current***	***High***	***Low***	***Current***	***High***
Ext XPS	12	20.8	$25,106	$390	**$16,044**	**$22,300**	**$37,041**	**$41,150**	**$47,406**	**$62,147**
Ext Fibre	9.9	22.3	$24,473	$418	**$17,201**	**$23,908**	**$39,712**	**$41,673**	**$48,381**	**$64,185**
Ext EPS	11.25	21.3	$24,206	$400	**$16,429**	**$22,836**	**$37,931**	**$40,635**	**$47,042**	**$62,137**
Ext SPF	12	20.8	$26,239	$390	**$16,044**	**$22,300**	**$37,041**	**$42,283**	**$48,539**	**$63,280**
Int. Fibre	12	20.4	$22,338	$383	**$15,735**	**$21,871**	**$36,328**	**$38,073**	**$44,209**	**$58,666**
Int. Cell.	12	20.4	$22,423	$383	**$15,735**	**$21,871**	**$36,328**	**$38,158**	**$44,295**	**$58,752**
Int. Batt	20	17.1	$22,720	$321	**$13,190**	**$18,333**	**$30,452**	**$35,909**	**$41,053**	**$53,171**
Int. XPS	10	21.8	$24,456	$409	**$16,815**	**$23,372**	**$38,821**	**$41,271**	**$47,828**	**$63,277**
Int. EPS	9	22.4	$23,718	$420	**$17,278**	**$24,016**	**$39,890**	**$40,996**	**$47,734**	**$63,608**
Int. SPF	12	20.4	$26,418	$383	**$15,735**	**$21,871**	**$36,328**	**$42,153**	**$48,289**	**$62,746**
ICFs	22	15.6	$31,929	$293	**$12,033**	**$16,725**	**$27,781**	**$43,962**	**$48,655**	**$59,710**
Class B Basement										
Basement		**Annual**	**Capital**	**Annual**	**LCC of Energy**			**LCC of Basement System**		
Option	**R-Value**	**GJ**	**Cost**	**Energy**	***Low***	***Current***	***High***	***Low***	***Current***	***High***
Int. Fibre	12	28.8	$19,256	$540	**$22,214**	**$30,877**	**$51,287**	**$41,471**	**$50,134**	**$70,543**
Int. Cell.	12	27.8	$19,295	$522	**$21,443**	**$29,805**	**$49,506**	**$40,739**	**$49,101**	**$68,802**
Int. Batt	20	25.7	$19,431	$482	**$19,823**	**$27,554**	**$45,767**	**$39,255**	**$46,985**	**$65,198**
Int. XPS	10	28.8	$20,227	$540	**$22,214**	**$30,877**	**$51,287**	**$42,442**	**$51,105**	**$71,514**
Int. EPS	9	29.1	$19,889	$546	**$22,446**	**$31,199**	**$51,821**	**$42,335**	**$51,088**	**$71,711**
Class C Basement										
Basement		**Annual**	**Capital**	**Annual**	**LCC of Energy**			**LCC of Basement System**		
Option	**R-Value**	**GJ**	**Cost**	**Energy**	***Low***	***Current***	***High***	***Low***	***Current***	***High***
Gas 80%	N/A	62.1	$18,029	$1,165	**$47,900**	**$66,579**	**$110,588**	**$65,929**	**$84,608**	**$128,617**

Table 6. Life cycle cost assessment of large basement in Ottawa – 80% efficiency natural gas.

Table 6 presents the results for the large basement model and it indicates that the life cycle cost relationships are identical to Table 5, supporting the view that insulation strategies that are cost effective for small basements are at least as cost effective for large basements. The large basement model is indicative of the typical size of basement for new, single-detached houses. Assuming the high energy price escalation scenario is imminent, the life cycle energy savings associated with Class A-3 basements (full-height insulation) is significant when compared with Class B and C basements. It approximately corresponds to the premium associated with upgrading the above-grade dwelling to R-2000 standards.[6]

ENERGY IMPACT OF THERMAL BRIDGING FOR EXTERIOR INSULATED BASEMENTS SUPPORTING MASONRY VENEER

Based on the BASECALC™ simulations, thermal bridging depicted in Figure 3 reduced the thermal effectiveness of the insulation by approximately 20%, averaged for small and large basements, compared to exterior insulation systems where thermal bridging was controlled.

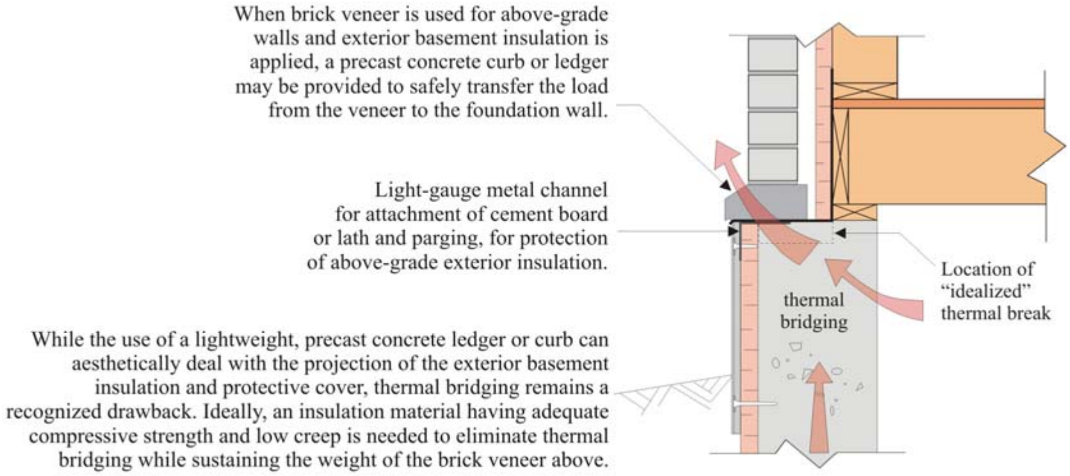

Figure 3. Thermal bridging issues for exterior insulated basements supporting masonry veneer.

For a small basement in Toronto, the average energy demand penalty associated with thermal bridging is 2.3 GJ, a 22.7% increase over the exterior basement insulation options where thermal bridging is controlled. The small basement, when heated by 80% efficiency natural gas equipment, carries an average annual cost premium of $44.25. Life cycle cost premiums range from $1,793 to $4,140 depending on the economic scenario. In the case of 100% efficiency electric heating, the average annual cost premium is $81.25, and the life cycle cost premiums range from $2,549 to $5,885.

For a large basement in Toronto, the average energy demand penalty associated with thermal bridging is 3.4 GJ, an 18.8% increase over the exterior basement insulation options where thermal bridging is controlled. The large basement, when heated by 80% efficiency natural gas equipment, carries an average annual cost premium of $63.50. Life cycle cost premiums range from $2,603 to $6,010. In the case of 100% efficiency electric heating, the average annual cost premium is $90.25, and the life cycle cost premiums range from $3,700 to $8,543.

A set of selective analyses indicated that a similar relationship is observed in the other 4 locations examined in this study, with slightly increased penalties for thermal bridging corresponding to colder climates and higher energy prices, and conversely slightly decreased penalties corresponding to warmer climates and lower energy prices, relative to Toronto.

In general, the energy penalty associated with thermal bridging in exterior insulated basements supporting masonry veneer is significant and carries a relatively high life cycle cost premium. However, it is also important to recognize that with such a high proportion of basements eventually being finished to provide additional livable space, there is a future opportunity to install interior insulation and manage the thermal bridging. Properly arranged and installed, this additional insulation can significantly improve the thermal performance and energy efficiency of the basement system.

CONCLUSIONS

Based on the findings of this update study, the following conclusions were drawn from the findings:

1. The assumption made in the original study that measures which were cost effective in a small basement would be even more cost effective in a larger basement has been proven correct. The life cycle cost per unit floor area for large basement systems is lower than for small basements because for simple basement geometries, the basement envelope area does not increase linearly with floor area. Put simply, cost effective insulation strategies in small basements are even more cost effective in larger basements.
2. In all five locations, irrespective of the thermal/moisture protection option selected, Class A-3 basements (full-height insulation with proper moisture protection) delivered the lowest energy and total life cycle costs. Class B basements (partial-height insulation) and Class C basements (uninsulated cellars) are not cost effective to consumers of housing under any energy pricing scenario.
3. For all types and sizes of basements assessed in this study, the lowest life cycle energy cost was associated with basements constructed using insulating concrete forms (ICFs).
4. For all types and sizes of basements assessed in this study, the lowest total life cycle cost was associated with basements insulated internally, full-height to a nominal level of R-20 (RSI 3.52).
5. The annual energy costs and life cycle system costs for externally versus internally insulated basements remain marginally higher. According to the BaseCalc™ software developers, external insulation is slightly less efficient per unit of thermal resistance than internal insulation due to the larger available contact surface areas contributing to thermal bridging influences. This study did not examine a complete floor slab and wall system insulation wrap strategy, but for basements heated with in-floor hydronic systems, this may prove to be a critical practice for life cycle cost effectiveness.
6. There is considerable justification for reviewing the cost effective levels of thermal insulation for basement systems in regulatory codes and standards governing residential energy efficiency in Canada due to the sharp escalation in energy prices recently experienced and forecasts of the continuation of this trend well into the foreseeable future.

Important Note: In practice, considerable care must be exercised when selecting insulation strategies for existing basement without proper moisture protection measures.[7]

RECOMMENDATIONS

The selection of a suitable basement insulation option is largely governed by the intended use of the basement. Within the spectrum of site conditions encountered by builders across the country, there can be large lot sizes and natural slopes that allow surface drainage away from the house in all directions, local soils can be free draining and stable, the water table can be well below the footings, and the local climate can be relatively dry most of the time. In such conditions, a very basic basement configuration meeting minimum code requirements can perform adequately using any of the basement insulation options assessed in this study. Nevertheless, it is improbable that all of those favourable conditions exist at every construction site. As a result, when the builder (and subsequently the homeowner) is dealing with one, some or many challenging conditions in a given location, consideration has to be given to additional measures that may be needed beyond the code minimum to compensate for those challenging site conditions. In most cases, exceeding minimum code requirements will be necessary to achieve acceptable levels of performance corresponding to modern consumer expectations, especially for fully finished, liveable basements.

In view of the life cycle cost assessments, and the related published work on basement performance problems, Table 7 presents the recommended basement insulation options for new and existing homes. Note that in all cases, full-height basement insulation is recommended over all other configurations.

Soil/Sewer Condition	New	Existing
Well drained soil, no sewer back-up problems	Any option*	Any interior option 5 - 10
Poorly drained soil, poor site drainage	Exterior options 1 – 4 and 11 preferred	Non-vapour permeable interior insulation options 8 or 10 recommended
Rising water table, some sewer backup problems	Exterior options 1 – 4 and 11 recommended	Exterior options 1 – 4 recommended
Flooding and/or chronic sewer back-up problems	Exterior options 1 – 4 and 11 only	Exterior options 1 – 4 only

* Refer to Table 8 for description of basement insulation options.

In existing basements, water leaks and sewer backup problems should be corrected prior to insulating. Refer to *Practical Measures for the Prevention of Basement Flooding Due to Municipal Sewer Surcharge: Final Report*, by T. Kesik and Kathryn Seymour, Canada Mortgage and Housing Corporation, 2003. *(External Research Program Research Report) 95 pages*.

For related information, refer to:
Molds in Finished Basements, 1996. Prepared by Scanada Consultants for CMHC.
Performance Guidelines for Basement Envelope Systems and Materials: Final Research Report. NRC-IRC, 2005.

Table 7. Recommended basement insulation options for new and existing homes.

It is important to emphasize that through the Basement Guidelines project field studies, it was confirmed that all of the exterior insulation materials noted in Table 8 maintained their thermal effectiveness under very wet soil conditions.[8]

Insulation Option	Abbreviation	Thermal Resistance
1 - Exterior extruded polystyrene - 2-1/2"	Ext XPS	R-12 (RSI 2.11)
2 - Exterior glass/mineral fibre - 3"	Ext Fibre	R-9.9 (RSI 1.74)
3 - Exterior expanded polystyrene - 3"	Ext EPS	R-11.25 (RSI 1.98)
4 - Exterior sprayed polyurethane foam - 2"	Ext SPF	R-12 (RSI 2.11)
5 - Interior glass/mineral fibre - 3-1/2"	Int. Fibre	R-12 (RSI 2.11)
6 - Interior cellulose - 3-1/2"	Int. Cell.	R-12 (RSI 2.11)
7 - Interior glass/mineral fibre - 5-1/2"	Int.Batt.	R-20 (RSI 3.52)
8 - Interior extruded polystyrene - 2"	Int. XPS	R-10 (RSI 1.76)
9 - Interior expanded polystyrene - 2-1/2"	Int EPS	R-9.4 (RSI 1.66)
10 - Interior sprayed polyurethane foam - 2"	Int. SPF	R-12 (RSI 2.11)
11 - Insulated concrete forms (generic)	ICFs	R-22 (RSI 3.87)

Table 8. Description of basement insulation options assessed in this study.

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