NRC·CNRC
Institute for Research in Construction

Construction Technology Update No. 70

Options in the Selection of Materials for Basement Construction

By M.C. Swinton and T.J. Kesik

Selection of proper materials is essential to the construction of basements that will provide liveable and comfortable indoor space. This Update discusses some of the key materials issues in basement construction and reviews the options regarding available materials and methods, including recent developments that enhance performance and efficiency.

A multi-year research project carried out at NRC-IRC with the support of many industry partners produced a comprehensive publication, *Performance Guidelines for Basement Envelope Systems and Materials*.[1] The publication provides an extensive review of basement issues and guidelines for design and construction based on categories of intended basement quality (see "Classification of basements by intended use," Table 1.2 of the Guidelines). It also presents the wide spectrum of options that builders are faced with. This Update, drawing on the key features of the basement performance guidelines, focuses on material and system selection issues involved in specifying the basement system. Update No. 69 addresses site grading and basement drainage issues.

Basements in houses serve as the foundation for the superstructure of the building, and provide usable living space. When properly constructed, basements resist the imposed loads from the surrounding ground, control moisture and temperature fluctuations, and help maintain suitable indoor air quality and comfortable conditions for occupants. By selecting the most appropriate materials for construction, designers and builders can avoid many of the problems typically associated with basements.

In order to select suitable materials, one must first determine the intended use and expected quality of the basement. Basements intended to be used as living spaces usually require different materials than those used only for mechanical equipment and storage. As it is often difficult and costly to apply materials such as drainage layers to the outside of a basement after a house is constructed, it is important to identify the desired level of performance before beginning construction.

Key Considerations

The selection of appropriate materials for the basement envelope system requires careful consideration at the design stage of the various roles to be played by the materials, not only with respect to their individual properties but also as part of an interactive system. Proper design demands a good understanding of technical issues and the conditions under which construction will be undertaken. While there are often a number of solutions for dealing with particular conditions and circumstances, some may be more appropriate than others in achieving the desired performance objectives and occupant expectations cost effectively.[2]

The major considerations are as follows:

Performance related: strength to withstand soil stresses (including hydrostatic pressure, which may or may not be a factor), and the ability to control heat and moisture flow, air leakage, soil gas infiltration, noise transmission, and to minimize fire hazards.

Construction related: availability and cost of materials and labour.

Different elements of basement envelope system: above-ground portion, below-ground portion, floor slab, joints and intersections.

Roles of different materials used in basement construction: structure, drainage, dampproofing (see sidebar), waterproofing, framing/furring, insulation, air/vapour barrier, soil gas barrier, exterior and interior finishing materials.

Waterproofing: Treatment of the surface or structure to prevent the passage of water through the basement envelope under hydrostatic pressures.

Dampproofing: Treatment of a surface or installation of a technology to resist the passage of moisture caused by differences in moisture content, vapour pressure and temperature across basement envelope components.

Note: Most new Canadian house foundations feature footing drainage systems with complementary dampproofing elements in the wall. This approach normally precludes the need for waterproofing. The basement systems discussed in this Update are based on drained approaches that do not involve waterproofing.

Additional considerations essential to the selection of basement materials and systems:

- Will the materials fulfill their intended role with respect to critical control functions?
- Are the materials compatible with one another?
- What materials and systems are required to provide environmental control corresponding to the classification of the basement being constructed?[3]
- Are the selected materials and equipment permitted by the regulatory authority having jurisdiction?

Structural Materials and Systems

Preferences in structural systems are often related to geographical location and based on local economics and availability of materials, builder preferences and experience. In urban areas, the availability, speed of placement and low cost of transportation favour cast-in-place construction in tract-built developments. In rural communities, the economics of carting ready-mix preparations over longer distances and for longer periods of time favour concrete block, which is more transportable and storable. Similarly, the economics of a lighter-weight system such as permanent wood foundations (PWFs) have been favoured in some Western provinces, where builders have gained considerable experience with them.

Manufactured systems such as precast concrete panels are beginning to emerge as innovative building materials. Potentially these can minimize on-site defects, thereby increasing the probability of meeting the basement's long-term functional requirements.

Each structural approach (see Figure 1), if properly designed, can be used to fulfill the various functions of the basement envelope, taking into account site conditions and intended use.

Cast-in-Place Concrete

From a designer or builder perspective, the two most important considerations regarding the use of cast-in-place concrete are the type of mix specified and the quality of the workmanship employed in its placement. Improper batching, mixing and placement practices can significantly affect the physical properties of the concrete and impair its performance.

Practically speaking, it is advisable to order concrete from a ready-mix supplier. The mix must be specified according to the desired performance, the intended use of the concrete and the expected conditions at the time of placement. All products and materials for the specification and production of the concrete should be the responsibility of the supplier and under his/her control. Unsupervised changes to the concrete mix on site often result in an inferior product.

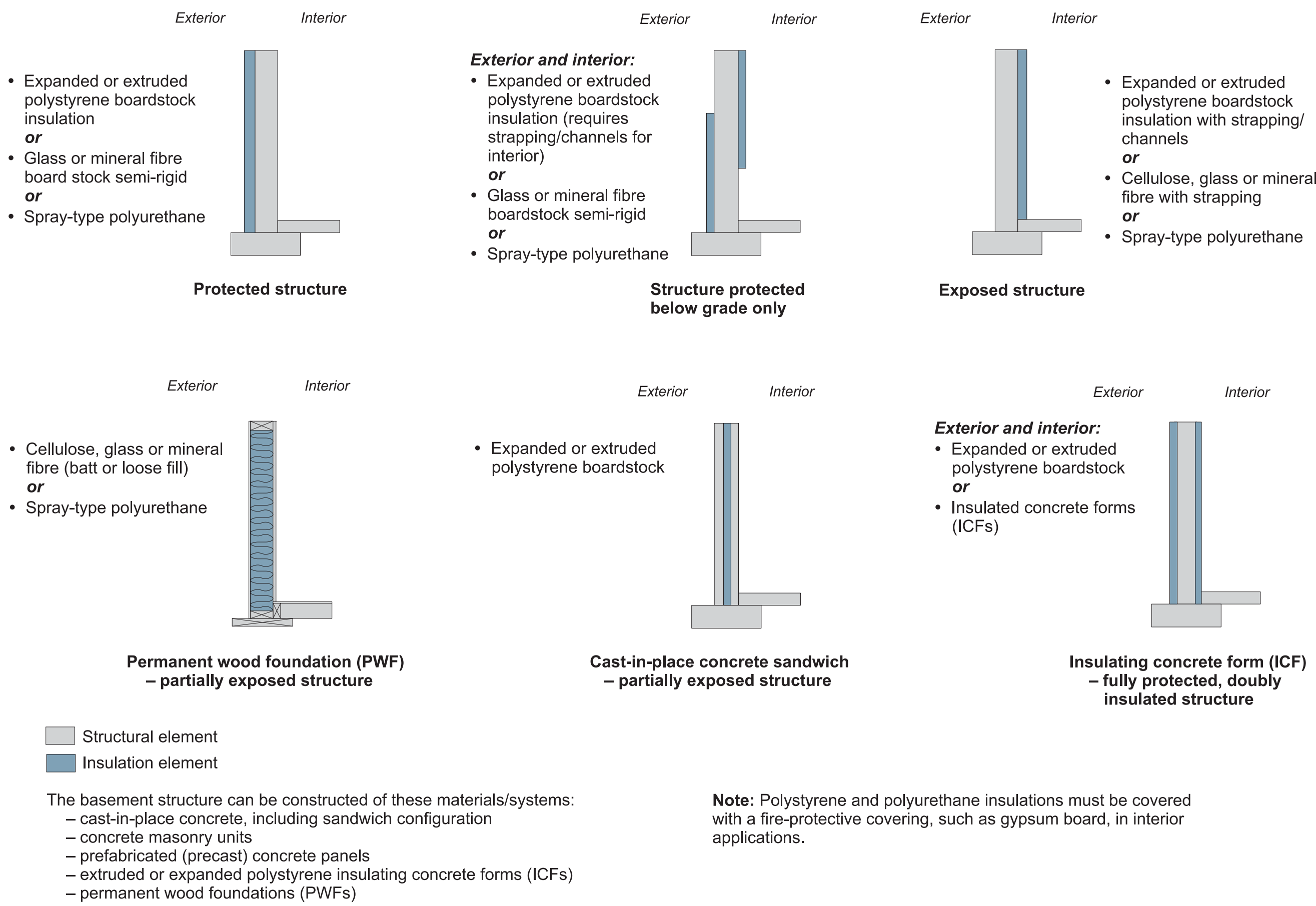

Figure 1. *Typical arrangements of structural and insulation elements*

Prefabricated Concrete Panels

Prefabricated or precast concrete panels are engineered products typically manufactured indoors under controlled conditions. The selection of these structural components for basement systems often necessitates the involvement of the supplier in the design and installation, as builders may not possess the necessary equipment and expertise.

Concrete Masonry Units (Concrete Block)

Unit masonry construction, concrete block and mortar materials used in concrete block construction must comply with code requirements and applicable standards cited therein. As with cast-in-place concrete, successful construction is highly dependent on workmanship.

Permanent Wood Foundations

The minimum acceptable service life of wood is dependent on the cost and convenience of its replacement and the consequences of failure. Because the exposure condition of wood in contact with the ground is severe, and the replacement of foundations is expensive and inconvenient, the preservative retention required for wood for such a use is high compared with the retention requirements for many other applications.

Permanent wood foundations (PWFs) must be designed in accordance with CAN/CSA-S406. All plywood and lumber used in PWFs must be pressure treated with preservatives in accordance with CAN/CSA 080.15-M. When the standards are followed, a reasonably long service life is possible.

Insulating Materials

Insulation materials vary in their physical characteristics, thermal effectiveness and cost. Some may be acceptable for a particular application but not well suited, or permitted, for others. One must select appropriate materials that possess properties corresponding to the environmental conditions to which they are exposed, and that lend themselves to proper performance and economical installation. While basement walls may be insulated on either the interior or exterior, not all available materials are suitable for both applications (Table 1). For exterior insulation applications, additional protection from impact damage is recommended above grade, and this should extend 300 mm below grade to assist with water management in this area of the basement wall.

Loose Fill

Loose fill insulations include glass fibre, mineral wool or cellulose products. Compressed bags of loose fill insulation material are generally broken up, mixed with air, and blown into place using special equipment. These products can be used only on the interior of basement walls to insulate framing cavities. They must be applied at the correct density for good performance, ideally by installers certified by the product or equipment manufacturer.

Boardstock

Various boardstock insulation products are used in building construction. Only the predominant types used in residential basement construction are discussed below.

Moulded/expanded polystyrene (EPS) is made by expanding polystyrene beads in a mould. To make boardstock, large blocks of expanded polystyrene are cut into sheets of various thicknesses using hot wires. Low-density expanded polystyrene is referred to as Type I, and higher-density material is referred to as Type II or III. All three materials are suitable for interior and exterior basement applications, with appropriate surface protection where exposed. Because these materials are combustible, they must be covered with a fire-protective covering, such as 12.7-mm (1/2 in.) gypsum board, if used to insulate living spaces.

Extruded/expanded polystyrene (XPS) is manufactured by extruding a hot mass of polystyrene through a slit. At atmospheric or reduced pressure it expands, creating a closed-cell foam material. This product is available as Type II, III and IV insulation, based on its density, and exhibits a higher thermal resistance per unit thickness than EPS. Extruded polystyrene is suitable for both interior and exterior basement applications, and must be fire-protected if used in living spaces.

Batts and Semi-Rigid Boardstock

Glass and mineral fibre insulations are available in batts for interior application or can be manufactured as a semi-rigid boardstock. Both are compressed to a higher density than when used in batt-type insulation (typically three to five times higher), and are generally held together with a binder. This type of boardstock can be used on the interior of basements, and is commonly used below grade on the exterior because its fibres efficiently promote the drainage of water reaching its outer surface.

Spray Type

Spray-type insulations are a relatively recent innovation in residential basement construction. There are three types predominantly used for basements.

Spray cellulose insulation is available in a variety of formulations to suit specific applications. It is applied using special applicators that mix water with the insulation material (which has been blended with adhesive(s) by the manufacturer), allowing it to hold together and adhere to the surface to which it is applied. Wet-spray materials are gaining broader market acceptance because they offer thorough cavity coverage and increase envelope airtightness slightly. Several of the spray-applied materials require the installation of a mesh over the face of the wall to contain the insulation prior to the installation of the gypsum board.

Spray mineral fibre insulation is similar to spray cellulose insulation in terms of its variety of formulations and applications. Both cellulose and mineral fibre spray-type insulations can only be used on the interior of the building envelope.

Table 1. Permissible placement of thermal insulation for basements

	Permitted Placement	
Insulation Type	**Interior**	**Exterior, Below-grade**
Glass or mineral fibre batt	YES	NO
Glass or mineral fibre loose fill	YES	NO
Cellulose loose fill	YES	NO
Glass or mineral fibre boardstock (semi-rigid)	YES	YES
Expanded polystyrene boardstock (Types I, II and III)	YES*	YES
Extruded polystyrene boardstock (Types II**, III and IV)	YES*	YES
Glass or mineral fibre spray type	YES	NO
Cellulose spray type	YES	NO
Polyurethane spray type	YES*	YES
Insulated concrete forms	YES*	YES

* Because these materials are combustible, they must be covered with a fire-protective covering, such as gypsum board, if used to insulate living spaces.

** Manufacturer may still restrict use to interior and exterior above-grade applications.

Spray polyurethane foam (SPF) formulations are available in a variety of spray applications. For large applications, the material is mixed on site using special foaming equipment. For smaller applications, single-component polyurethane foam is available in cans with "gun"-type dispensers or in 4.5-kg (10-lb.) canisters for sealing spaces around windows, doors and other penetrations. The quality of workmanship must be assured by a third-party organization that is recognized for its training program for those involved in the installation and follow-up inspection of this type of insulation.

SPF can be successfully used on both the interior and exterior below-grade areas of the building envelope, but it must be covered with a fire-protective covering, such as 12.7-mm (1/2 in.) gypsum board, on the interior of living spaces.

Insulated Concrete Forms

Basement foundation construction using insulated concrete form (ICF) technology represents a relatively recent innovation where thermal insulation, either EPS or XPS, is moulded to create formwork for cast-in-place concrete. After placement and curing of the concrete, the formwork remains in place to provide interior and exterior insulation of the (typically) reinforced concrete foundation structure. ICF systems are permitted for use in Canada under new provisions of Part 9 of the National Building Code (NBC) 2005.[4] More complex ICF configurations may require Canadian Construction Materials Centre evaluations that include usage and limitations criteria, or may be based on Part 4 engineering specifications. The NBC requirements for ICF systems apply to each of the constituent materials—plastic foam insulation and concrete.

Drainage Materials

The structural system for basements will not normally provide adequate control of moisture from exterior sources. Proper site grading and basement drainage must be provided explicitly (see Update 69 for detailed information).

Typically, drainage and dampproofing are used in situations where the foundation drainage system is effectively drained by gravity and where the local groundwater does not rise above the footings. In areas with periodically ineffective foundation drainage, waterproofing should be applied to resist hydrostatic pressures. As well, it is important to consider and address the ability of the basement wall and slab to support the additional loads due to the build-up of hydrostatic pressure. Foundation drainage should also be provided even when waterproofing is used to decrease the possibility of groundwater accumulating and finding its way through a weak link in the system.

Granular Drainage Layer and Drainage Pipe
Granular drainage layers represent an alternative to drainage pipes for the purpose of foundation drainage. Typically, granular drainage layers are used when active foundation drainage (sump and sump pump) is required. When gravity drainage to a storm sewer, ditch or dry well is possible, drainage pipes are typically installed. In Canada, the most commonly used foundation drainage pipe is comprised of corrugated plastic tubing and fittings made from thermoplastic materials designed for the drainage of land, foundations and under floors.

Foundation Wall Drainage Materials
Additional means of providing foundation wall drainage are currently available in Canada. These typically rely on either a plastic membrane or thermal insulation system to effectively convey water adjacent to the basement walls downwards to the drainage pipe or granular drainage layer.

Plastic Membranes
Currently evaluated plastic membrane products available in Canada are typically made of carbon-compounded high-density polyethylene sheet, manufactured in such a way that the material has a dimpled surface on one side to provide an air gap between the concrete wall and the adjacent soil. When properly installed, such products provide a level of dampproofing performance equivalent to that required by the NBC. However, they are not intended to resist flood conditions. Where there is a risk of flooding or drainage backup, appropriate waterproofing measures should also be considered.

High-Density Mineral Fibre Insulation (in dual role)
Semi-rigid glass or mineral wool insulation products may play a dual role—as thermal insulation and as foundation wall drainage. These products are designed to be used as a protective layer or a capillary breaking layer against the foundation wall to protect it against transient or intermittent water that may come in contact with it.

Foam Plastic Insulations (in dual role)
Foam plastic insulations, both boardstock and spray type, have been demonstrated by NRC-IRC's research to successfully manage excess water in the soil next to the basement wall. Spray polyurethane foam on the exterior of basement walls has also been shown to be an effective option to manage water in the soil next to the basement wall.

For further information on exterior insulation basement systems (EIBS), readers can refer to Update No. 36.

Materials for Interior Moisture and Air Control

Materials used for control of moisture and air movement may be selected to deal with each control function separately or, as is often the case, to deal with both simultaneously. This section examines the use of such materials normally applied on the interior of the basement envelope and insulated from the inside. (For basement systems with exterior insulation on concrete walls and slabs, interior moisture build-up is rarely an issue because interior surfaces are kept warmer and tend to dry toward the inside without explicit moisture control.)

Interior Dampproofing
Interior dampproofing is required when a separate interior finish is applied directly to a concrete or unit masonry wall, or to a concrete slab that is in contact with the soil. It is also required where wood members are applied in direct contact with below-grade concrete or unit masonry for the installation of insulation and/or finish.

In the case of walls, the dampproofing must extend from the basement floor up to ground level. Permissible dampproofing materials include polyethylene film that is 0.05 mm, or thicker; type S roll roofing; or any membrane or coating with similar properties. This implies that a variety of plastic foam and specially faced insulation materials also satisfy requirements for interior dampproofing. However, in general such materials with a permeability of less than 170 ng/(Pa.s.m^2) should meet the requirements for low-permeability materials in Section 9.25 of the NBC 2005, if they are applied to the interior surface of the above-grade portions of the foundation wall.

For floors-on-ground, the dampproofing must be installed beneath the floor, except when a separate floor is provided over a slab, in which case the dampproofing may be applied on top of the slab. Dampproofing membranes installed below the slab must consist of either 0.15-mm, or thicker, polyethylene film, or type S roll roofing lapped not less than 100 mm (4 in.). Where dampproofing is applied above the floor slab, it must consist of two mopped-on coats of bitumen, polyethylene film (0.05 mm thick), or any other material providing equivalent performance.

Vapour Diffusion Control

The control of vapour diffusion is essential for all insulated assembles inboard of the foundation wall and floor slab. There are several materials options available:

- polyethylene sheets or film;
- a membrane-type vapour barrier material other than polyethylene;
- a coating over the interior finish; or
- a material satisfying the permeability requirements for vapour barriers (e.g., plastic foam insulation; plastic or rubber finishes).

Air Leakage Control

Materials for air leakage control must satisfy requirements for resistance to air pressures, and more importantly, should be selected keeping in mind the continuity of the air barrier system. In basements, air leakage control is required at key interfaces between building assemblies. It is critical where the superstructure attaches to the foundation walls, typically at the floor header assembly. Penetrations around windows, doors, ducts, piping and wiring must also be properly sealed. Finally, adequate control of soil gas at the perimeter and penetrations of the basement floor slab must be provided, including airtight covers for sumps and traps in floor drains. The materials for air leakage control should be considered in the context of the air barrier system provided.

Polyethylene with Sealants

Where polyethylene sheet or film serves as an air barrier material, it must conform with CAN/CGSB-51.34-M. Typically, joints in the polyethylene are lapped and clamped. Penetrations of the polyethylene and junctions with other materials are typically sealed using sealants or special tapes that should be selected on the basis of compatibility with the adjoining materials and durability.

Sheet/Panel and Gaskets/Sealants

When sheet or panel materials are selected for the air barrier system, penetrations and joints are typically sealed with gaskets and/or sealants. Specific materials are not prescribed in the NBC, but any material must provide an effective barrier to air movement under differential pressure due to stack effect, mechanical systems or wind.

Sprayed-in-Place Air Barrier

Extensive evidence now supports the use of spray polyurethane foam as an element that can effectively form part of the air barrier system. All SPF formulations must comply with the requirements of CAN/ULC-S705.1-01, and the installation must comply with CAN/ULC-S705.2-1998.

Soil Gas Control

Floors-on-ground, other than garages, must be constructed to reduce the potential for entry of radon or other soil gases. In most cases, this can be accomplished by placing 0.15-mm polyethylene under the floor, and sealing the perimeter and penetrations with a flexible sealant. Where polyethylene is used beneath the slab, it must comply with CAN/CGSB-51.34-M. Section 2.10 of the *National Housing Code of Canada 1998 and Illustrated Guide*[5] contains further information on soil gas control measures.

Conclusions

The selection of materials and systems for basements is largely governed by the intended use and occupancy of the basement. Site conditions are also a major determinant and, in fact, it is very likely that in most cases, these conditions will be less than ideal. This means that consideration will have to be given to additional measures beyond the minimum requirements of the NBC to achieve acceptable levels of performance corresponding to modern consumer expectations, especially for fully finished, liveable basements. (A full description of these additional measures is available in the references cited below.)

References

1. Swinton, M.C. and T.J. Kesik, Performance Guidelines for Basement Envelope Systems and Materials, *Research Report 199, Institute for Research in Construction, National Research Council Canada*, 193p., October 2005. http://irc.nrc-cnrc.gc.ca/pubs/rr/rr199/index_e.html
2. Economic Assessment of Residential Basement System Insulation Options. CMHC Research Highlight Technical Series 07-103. Canada Mortgage and Housing Corporation.
3. Occupancy-based Classification System for Design and Construction of Residential Basements. CMHC Research Highlight Technical Series 06-109. Canada Mortgage and Housing Corporation.
4. National Building Code of Canada. Canadian Commission on Building and Fire Codes, National Research Council. Ottawa, 2005.
5. National Housing Code of Canada 1998 and Illustrated Guide, National Research Council of Canada, 1998.

***Mr. M.C. Swinton** is a Principal Research Officer in the Building Envelope and Structure program at the National Research Council Institute for Research in Construction.*

***Dr. T.J. Kesik** is a professor of building science in the Faculty of Architecture, Landscape and Design at the University of Toronto.*

Performance Guidelines for Basement Envelope Systems and Materials

The Guidelines were developed under the guidance of the project steering committee, which was comprised of industry association and government agency representatives. This committee ensured that the Guidelines reflect the best collective knowledge of Canadian industry and related public and private agencies.

The complete report is now available at http://irc.nrc-cnrc.gc.ca/pubs/rr/rr199/index_e.html

June 2008
ISSN 1206-1220

"Construction Technology Updates" is a series of technical articles containing practical information distilled from recent construction research.

Canada

For more information, contact Institute for Research in Construction, National Research Council of Canada, Ottawa K1A 0R6
Telephone: (613) 993-2607; Facsimile: (613) 952-7673; Internet: http://irc.nrc-cnrc.gc.ca