HIGH DENSITY EXTRUDED POLYSTYRENE INSULATION

AIRPORT RUNWAYS
COLD STORAGE INSTALLATIONS
UNDER CONCRETE FLOORS
RAIL BEDS
FOUNDATIONS
PLAZA AND PARKING DECKS
PERMAFROST PROTECTION
UNDER ROADWAYS

CELFORT® 300 & FOAMULAR® 400, 600, 1000 INSULATION BOARDS

MADE IN CANADA

OWENS CORNING®

INNOVATIONS FOR LIVING™

PRODUCT DESCRIPTION

Engineering applications requiring:

- High compressive strength
- Long-term thermal performance
- Hydrophobic insulation, closed cell structure
- No food value for rodents
- Ability to retain critical structural properties in severe freeze/thaw environments
- Environmentally certified, reusable and recyclable
- Excellent resistance to water
- Handles and installs easily

BASIC USE:

A series of high strength extruded polystyrene rigid insulation boards used for civil engineering and other commercial applications. Available in a range of compressive strengths to suit different construction needs. For use in cold storage installations; under concrete floors; foundations; plaza and parking decks; under roadways; rail beds; permafrost protection; airport runways; transmission line tower foundations; underground utility lines; walkways; fountain foundations; light weight fill and suited for diverse high load-bearing applications.

For use in Industrial, Commercial and Institutional (ICI) applications. In permafrost regions, the insulation is used to maintain the sub-grade in a frozen state during the summer period.

For use in both interior and exterior applications.

COMPOSITION AND MATERIALS:

Celfort® and **Foamular® PINK®** insulations' unique closed cell structure and continuous skin surface yield outstanding moisture resistance properties. A high R-value retained even after prolonged exposure in high moisture environments. Our patented process technology helps to ensure that **Celfort®** and **Foamular® Extruded Polystyrene Thermal Insulation Board** will not corrode or decay over time. **Celfort® 300, Foamular® 400, 600** and **1000** are Type 4 closed-cell thermal insulating foams (CAN/ULC-S701-01 supersedes CAN/CGSB512.0-M87).

Sizes and Thermal Properties: **Celfort®** and **Foamular®** high density insulation boards are available in a variety of thicknesses and standard sizes. Compressive strengths† from 30 psi to 100 psi (210 kPa to 690 kPa) meet the requirements of nearly every application.

Thermal Resistance: The long-term design thermal resistance of **Celfort®** and **Foamular®** insulation is 5.0 ft² hr°F/BTU for 1-inch thickness or RSI 0.87 (m² °C/W) for 25 mm thickness according to CAN/ULC-S770-00.[1]

Thermal Resistance,
Minimum R-value ASTM C-518-91, C-177-85

R-VALUE / inch		
5	75°F mean temp.	CAN/ULC-S701-01, ASTM C518
5.4	40°F mean temp.	CAN/ULC-S701-01, ASTM C518
5.6	25°F mean temp.	CAN/ULC-S701-01, ASTM C518

Thermal Resistance,
Minimum RSI ASTM C-518-91, C-177-85

RSI VALUE / 25mm		
0.87	24°C mean temp.	CAN/ULC-S701-01, ASTM C518
0.95	4°C mean temp.	CAN/ULC-S701-01, ASTM C518
0.99	– 4°C mean temp.	CAN/ULC-S701-01, ASTM C518

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† See Typical Physical Properties Table on page 3.

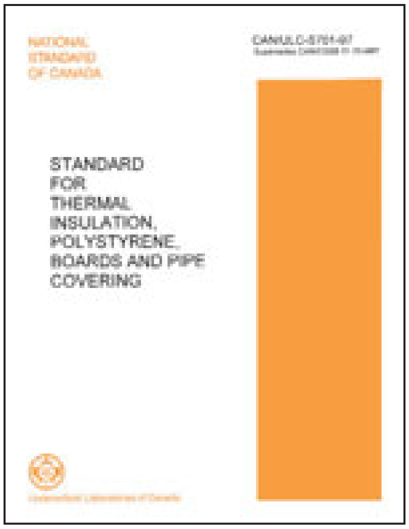
[1] CAN/ULC-S770-00 Standard Test Method for Determination of Long-Term Thermal Resistance of Closed-Cell Thermal Insulating Foams.

PRODUCT DESCRIPTION

STANDARD SIZES AVAILABLE ACROSS CANADA:

	Celfort® 300	Foamular® 400	Foamular® 600	Foamular® 1000
Standard sizes	24" x 96" (610 x 2438 mm)	24" x 96" (610 x 2438 mm)	24" x 96" (610 x 2438 mm)	24" x 96" (610 x 2438 mm)
*MTO widths	16" (610 mm), 400mm, 600 mm	400 mm		
Thickness	1", 1½", 2", 2½", 3", 3½", 4" (25, 38, 51, 64, 76, 89, 102 mm)	1", 1½", 2", 3", 4" (25, 38, 51, 76, 102 mm)	1", 1½", 2", 2½", 3" (25, 38, 51, 64, 76 mm)	1½", 2" (38, 51 mm)
Edges	Shiplap/butt edge	Shiplap/butt edge	Shiplap/butt edge	Shiplap/butt edge
**Drainage channels	Drainage channels upon request	Drainage channels upon request	Drainage channels upon request	Drainage channels upon request

*Available for only certain product thicknesses.
**Pre-engineered drainage channels can be used to increase moisture removal from the membrane surface.



NATIONAL
STANDARD
OF CANADA

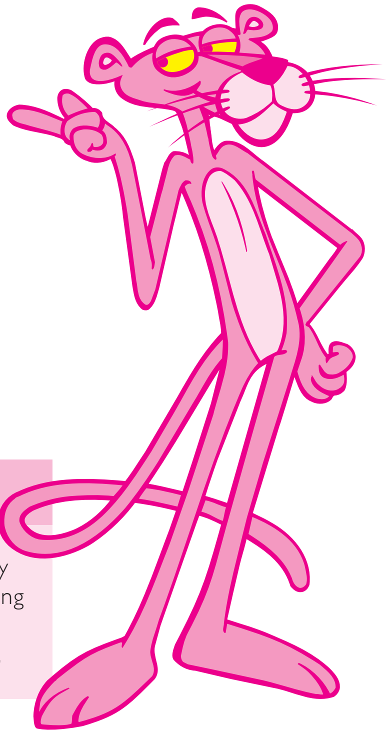
CAN/ULC-S701-97

STANDARD
FOR
THERMAL
INSULATION,
POLYSTYRENE,
BOARDS AND PIPE
COVERING

Tolerances: Conforms to CAN/ULC-S701-01 Types 4. See *Typical Physical Properties Table.*

LIMITATIONS:

Celfort® and **Foamular® Extruded Polystyrene Insulation Boards** are combustible. Local codes may require a protective or thermal barrier. Contact your local building inspector or the National Building Code of Canada **1995** for more information. For more information contact Owens Corning (1-800-GET-PINK). Not recommended where sustained temperatures exceed 74° C (165° F).



TECHNICAL DATA

APPLICABLE STANDARDS:

Required properties for **Celfort®** and **Foamular® Extruded Polystyrene Insulation Boards** are described in National Standard of Canada CAN/ULC-S701-01.

Celfort® and **Foamular® Extruded Polystyrene Insulation Boards** are suitable for all types of high strength construction applications. The boards are lightweight, durable and impact resistant which helps to reduce job site damage. Foam insulation can be scored and fabricated easily with common hand tools.

TYPICAL PHYSICAL PROPERTIES:

Property (units)	ASTM Method	Celfort® 300	Foamular® 400	Foamular® 600	Foamular® 1000
Thermal resistance[†]	C518 or C177	5.0 0.87	5.0 0.87	5.0 0.87	5.0 0.87
Compressive strength[††], min.: (psi) (kPa)	D 1621	30 210	40 275	60 415	100 690
Compressive modulus[††], min.: (psi) (kPa)	D 1621	1,086 7,490	1,400 9,650	2,200 15,170	3,700 25,510
Flexural strength[†††]: (psi) (kPa)	C 203	54 375	75 517	85 586	174 1200
Water absorption, max. (% by volume)	D 2842	0.70	0.60	0.55	0.50
Water affinity		Hydrophobic	Hydrophobic	Hydrophobic	Hydrophobic
Water capillarity		None	None	None	None
Dimensional stability, max. (% linear change)	D 2126	1.5	1.5	1.5	1.5
Linear coefficient of thermal expansion (in/in/°F) (min/m°C)	D 696	2.7 x 10^5 4.9 x 10^2	2.7 x 10^5 4.9 x 10^2	2.7 x 10^5 4.9 x 10^2	2.7 x 10^5 4.9 x 10^2
Maximum operating temperature (°F) (°C)		165 74	165 74	165 74	165 74
CAN/ULC-S701-01 supercedes CGSB 51.20-M-87	National standard of Canada	Type 4	Type 4	Type 4	Type 4
Ministry of Transportation MTQ Standard 14301, Type A & B			Complies	Complies	Complies

[†] Per inch (25 mm) thickness. [††] Value at 10% deformation or yield, whichever occurs first. [†††] Value at yield.

ALLOWABLE STRESS ON CELFORT® AND FOAMULAR® INSULATION:

Where compressive loads are applied to the insulation layer, such as under a concrete slab:

- Stress limits provide a factor of safety and a means to limit long-term compressive creep in the insulation layer.
- The allowable stress limits are defined based on a percentage of minimum insulation compressive resistance.

TECHNICAL DATA

RECOMMENDED STRESS LIMITS, kPa (psi):

	Celfort® 300	Foamular® 400	Foamular® 600	Foamular® 1000
Min. compressive strength	210.0 (30.0)	275.0 (40.0)	415.0 (60.0)	690.0 (100.0)
Live load, <20% OF MIN.	42.0 (6.0)	55.0 (8.0)	83.0 (12.0)	138.0 (20.0)
Dead load, <33% OF MIN.	70.0 (10.0)	90.0 (13.0)	137.0 (20.0)	228.0 (33.0)

RESISTANCE TO FREEZE/THAW CYCLING:

Celfort® and **Foamular® Extruded Polystyrene Insulation Board** has been tested for its ability to retain critical structural properties in a severe freeze/thaw environment. It has been demonstrated that it retains its load carrying ability (min. compressive resistance) after 1,000 freeze/thaw cycles carried out in accordance with ASTM C-666, procedure A (see chart below). Procedure A involves alternating freeze/thaw cycles with the test specimen totally submerged in water and exposed to freezing temperatures around the entire specimen.

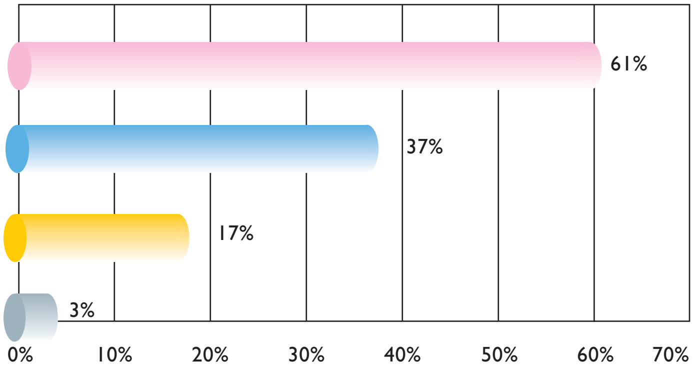
Freezing conditions are a factor in all parts of Canada. Freeze/thaw cycles testing helps to determine which insulations have the correct physical characteristics to withstand the severe site conditions of Canada.

RETENTION OF COMPRESSIVE STRENGTH AFTER FREEZE/THAW CYCLING:

	Foamular® 400
Retention of compressive strengths (%)	100
Minimum specification	40
Initial actual	52
After 1000 freeze/thaw cycles	52

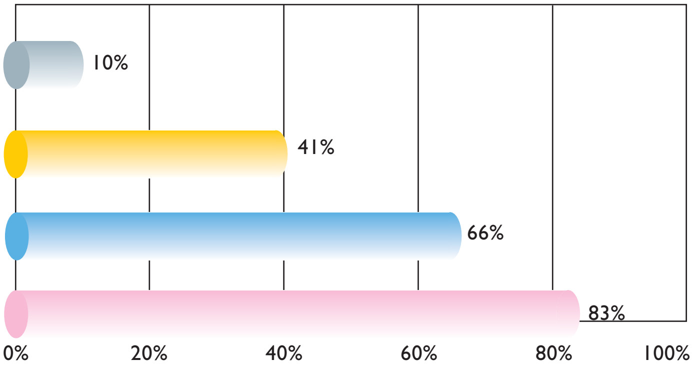
WATER ABSORPTION IN FREEZE/THAW CYCLING TEST:*

(ASTM C 666-73 Procedure A)
Moisture Effects Comparison



THERMAL RESISTANCE RATIO (TRR%):*

Retention of R-value after repeated exposure to moisture and freeze/thaw conditions
Moisture Effects Comparison



■ 2" PIR (aluminum) faced

■ 2" PIR (faced)

■ 1.5" Expanded PS Type 4

■ 2" Foamular XPS Type 4

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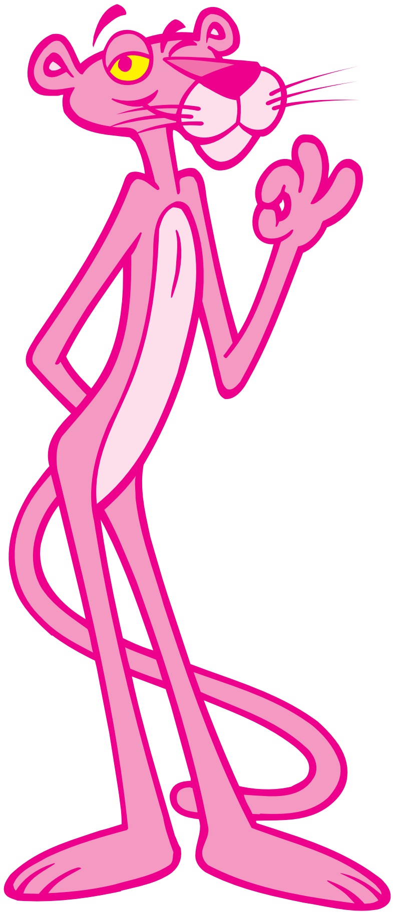
*Page 19 **Foamular®** Extruded Polystyrene PUB No-5-BL-17956-I, printed in U.S.A.

INSTALLATION



DELIVERY:

Celfort® and **Foamular**® insulation products are packaged in bundles of 2' wide x 2' high x 8' in length. Four bundles are arranged into units (pallets) of 4' wide x 4' high x 8' in length for ease of shipping and handling. Standard flatbed, min. 33,000 board feet.

PRODUCT IDENTIFICATION:

Each board is identified by product name and type. The physical properties, thermal properties, and applicable standards are also marked on each board. Owens Corning product is identifiable by its **PINK**® colour.

PACKAGING:

Units shipped in protective stretch-wrap bundles. Approximately 170 lb./1,000 ft² for each inch (25 mm) of thickness.

STORAGE:

If long-term exposure to the elements is expected, extruded polystyrene should be protected from excessive UV exposure to prevent discolouration.

INSTALLATION:

Product is to be installed in accordance with local building codes and architectural/engineering plans/specifications. Insulation for use in high strength applications (soils and civil engineering) to either prevent heat from leaving the ground or, in the case of permafrost applications, to prevent heat from entering the ground.

DESIGN EXAMPLES

DESIGN OF CONCRETE SLABS ON GRADE FOR COLD STORAGE APPLICATIONS

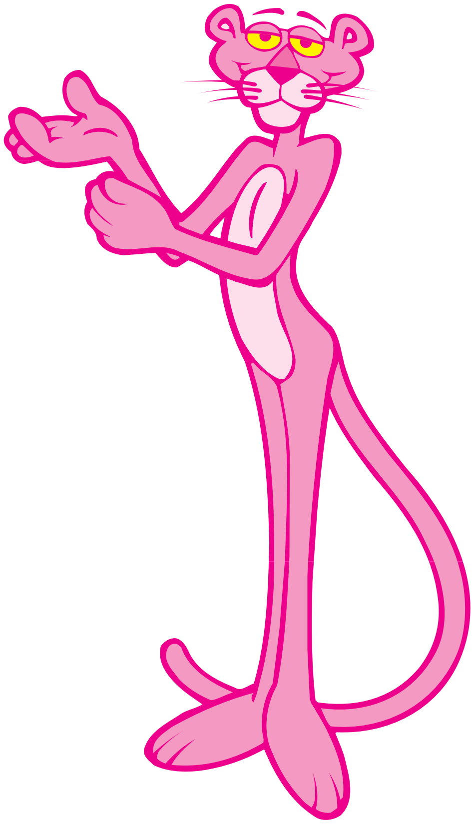
Note: Only Imperial values are used in design calculations in this section. Treat following design calculations as preliminary estimations. It is recommended that final concrete slab design be specified by a professional architect or engineer.

DESIGN OF CONCRETE SLABS ON GRADE SUPPORTED BY FOAMULAR® INSULATION

Insulated concrete slabs are common in cold storage facilities. These slabs and the layers below must be capable of supporting the live and dead loads imposed by vehicles, stationary and/or moving equipment, loaded storage racks and pedestrian traffic. **FOAMULAR® Extruded Polystyrene Insulation** provides support beneath insulated concrete floor slabs. The slab and supporting layers must be designed with consideration given to the rigidity of each layer. Proper design avoids excessive deflection which can result in cracking.

ALLOWABLE STRESS ON FOAMULAR® INSULATION LAYERS

A concrete slab must be capable of distributing loads over an area of sufficient size so that pressure on underlying layers does not exceed allowable limits. When **FOAMULAR® Extruded Polystyrene Insulation** is used below the slab, allowable stress limits are defined based upon a percentage of **Foamular®** insulation's minimum compressive strength. (Please refer to the Recommended Stress Limits table on Page 4.)



DETERMINING STRESS

Use the following charts and formulas to determine the stress present on the concrete slab and insulation layers. To determine the stress that **Foamular®** insulation will experience, you will need to know the deflection of the concrete slab (see Concrete Slab Design Formulas on page 7) as well as the foundation modulus.

Foundation modulus is a measure of how much a substrate deflects under a given load, expressed as inches deflection per inch of thickness or "pci". The foundation modulus for various thicknesses of **Foamular®** insulation can be found in the table below:

FOAMULAR® INSULATION FOUNDATION MODULUS "K" (pci)

	Thickness					
Insulation	1"	1.5"	2"	2.5"	3"	4"
400	1100	1000	900	780	680	650
600	1520	1400	1275	1150	1040	790

Notes: For multiple-layer insulation systems, assuming layers are identical, the foundation modulus for the system (KT) equals the foundation modulus for one (1) of the layers (K1) divided by the total number of layers (L). KT=K1/L. For insulation systems which utilize a variety of thicknesses, the system foundation modulus (KT) is determined by adding the reciprocal of the foundation modulus for the individual layers (1/K1). The total is the reciprocal value for the foundation modulus of the entire insulation system.

DESIGN EXAMPLES

CONCRETE SLAB DESIGN FORMULAS

Stress Under Point Load in Field of Slab

$$fb = 0.316 \frac{P}{h^2} \left[\log h^3 - 4 \log \left(\sqrt{1.6a^2 + h^2} - 0.675h\right) - \log k + 6.48\right]$$

Deflection

$$D = \frac{P}{8 \sqrt{K \dfrac{Eh^3}{12\,(1 - \mu^2)}}}$$

Nomenclature

a	Radius of load contact area (in)
D	Deflection (in)
E	Modulus of Elasticity, concrete (psi) $E \approx 57{,}000 \sqrt{Fc}$
fb	Tensile stress, bottom of slab (psi)
Fc	Concrete compressive strength min (psi)
ft	Tensile stress, top of slab (psi)
Ft	Concrete tensile strength, allowed (psi) $Ft \approx 4.6 \sqrt{Fc}$
h	Slab thickness (in)
K	Insulation foundation modulus (pci)
L	Radius of relative stiffness (in) $L = \sqrt[4]{\dfrac{Eh^3}{12\,(1 - \mu^2)k}}$
P	Load (lb)
μ	Poisson's Ratio, .20 for concrete

ESTIMATING STRESS IN FOAMULAR® INSULATION LAYER

The stress that **FOAMULAR®** insulation will experience under a concrete slab can be estimated by multiplying the insulation's foundation modulus (K) by the deflection of the concrete slab (D).

F(Stress) = K x D

Deflection of the concrete slab can be determined by using the Concrete Slab Design Formulas (see above).

ANALYSIS OF UNREINFORCED CONCRETE SLAB AND FOAMULAR INSULATION FOUNDATION INTERACTION UNDER A STATIC POINT LOAD

The following design examples illustrate the interrelated performance of the floor slab and its underlying insulation layers. They show that changes in one component must be examined for their impact on other components. These examples also show that the tensile strength of concrete slab is more often a limiting factor than is the compressive strength of the insulation. The following explanations refer to the Design Examples Table on page 8.

DISCUSSION OF DESIGN EXAMPLES

Example 1 – The conditions listed result in a stress of 3.75 psi on the insulation layer. The stress is acceptable when related to the live or dead load recommendations for the chosen insulation. The actual stress in the concrete slab and also below that which is allowed, are indicated.

Example 2 – Changing the insulation layer from Example 1 results in reduced stress on the insulation layer. However, the increased insulation layers are prone to more defection and are less capable of supporting the load. Therefore, deflection in the concrete slab increases, which results in a concrete stress that is too high.

Example 3 – Increasing the thickness of the concrete slab in Example 2 reduces the concrete stress under the point load to an acceptable level. Other variable changes that reduce concrete slab tensile stress to acceptable levels include reducing load, increasing area of load contact, using a stronger concrete, adding steel reinforcement or increasing the insulation foundation modulus.

Example 4 – Changing to an insulation with a substantially greater foundation modulus and compressive strength results in a reduction in concrete tensile stress. Note that the foundation modulus in the example increased by 75% over that used in Example 2 to cause only a 7% reduction in concrete slab tensile stress. Variation of insulation foundation modulus within a small range has little impact on the final concrete slab design.

Example 5 – Excessive stress levels in the concrete slab can also be corrected by increasing the area of load contact. Note the decrease in concrete slab tensile stress from Example 2, which results from distributing the load over a larger area.

Example 6 – All of the previous examples focus on reducing the tensile stress in the concrete slab to an acceptable level. This example shows the effect of increasing the load to a level which places maximum allowable compressive strength on the insulation. Note the excessive tensile stress which results on the concrete slab.

DESIGN EXAMPLES TABLE

	Design Examples					
Variable Input	1	2	3	4	5	6
Point load (lb)	7200	7200	7200	7200	7200	21700
Radius of Contact area (in)	5	5	5	5	5.75	5
Concrete Properties						
Compressive Strength (min psi)	4000	4000	4000	4000	4000	4000
Tensile stress, allowable (psi)	291	291	291	291	291	291
Modulus of elasticity (psi)	3.6×10^6	3.6×10^6	3.6×10^6	3.6×10^6	3.6×10^6	3.6×10^6
Slab thickness (in)	5	5	5.5	5	5	5
Insulation Properties						
"K" Foundation Modulus (pci)	680	340	340	520	340	340
Number of layers	1	2	2	2	2	2
Thickness per layer (in)	3	3	3	3	3	3
FOAMULAR® - product	400	400	400	600	400	400
Calculations						
Concrete slab deflection (in)	0.0055	0.0078	0.0068	0.0063	0.0078	0.0235
Concrete tensile stress, actual (psi)	279	306	263	289	282	922
Insulation compressive stress, actual (psi)	3.75	2.65	2.30	3.28	2.65	8.00

Steel reinforced concrete slabs will distribute imposed loads differently than unreinforced slabs; therefore, the calculation techniques used to estimate stresses are different than those shown in this section. However, the concept of balancing stress levels between concrete and the insulation is the same.

Many types of concrete slab exist for different purposes and design techniques for each vary greatly. This section discusses one aspect, the **FOAMULAR®** insulation layers and their effects on slab thickness in the design of a simple, type "a", plain concrete slab. It is not the intent of this section to provide comprehensive design guidance. Rather, it is to demonstrate the importance of the relationship between a concrete slab and its supporting underlayers, and to identify **FOAMULAR®** insulation's physical properties which will be important to the slab designer regardless of the type of slab involved. In all cases, Owens Corning recommends that final concrete slab design be specified by a professional architect or engineer. The professional architect or engineer will assess the need for steel reinforcement due to structural shrinkage or temperature requirements, the need for expansion or contraction joints and other important concerns relating to slab durability.

The examples in this section relate to interior slab loadings only, which are loadings placed on the surface of the slab in a position removed from free slab edges. Edge loading design becomes more complicated because it requires consideration of bending stresses in the top of the slab as well as the effects of slab edge curling. The interaction between the slab and the insulation below is similar regardless of load location, although rarely does interior loading govern design.

TYPICAL APPLICATIONS

PERIMETER OF FOUNDATION WALLS:

To reduce the heat flow through the floor slab and prevent frost penetration. Insulation that is installed on the inside of the foundation wall will increase the temperature of the floor slab. Insulation may be installed on the outside of the foundation as well but must be protected above the ground level.

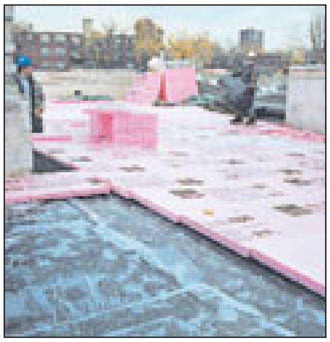
Insulating to prevent normal and tangential frost heave is easily accomplished with **Celfort**® 300. The thickness and location of insulation in a shallow foundation is dependent on whether the building is heated or unheated, the type of soil and building location.

PRODUCT:

Celfort® 300, 30 psi (210 kPa) Type 4

WATERPROOFING APPLICATIONS*:

To reduce heat flow and protect the waterproofing membranes. Insulation is typically installed above the waterproofing membrane. **Foamular**® insulation may also be supplied with grooves for additional drainage channels. Higher compressive strength insulation is used in areas of frequent pedestrian or vehicular traffic and ideal for plaza deck construction.



PRODUCT:

Foamular® 400, 40 psi (275 kPa) Type 4

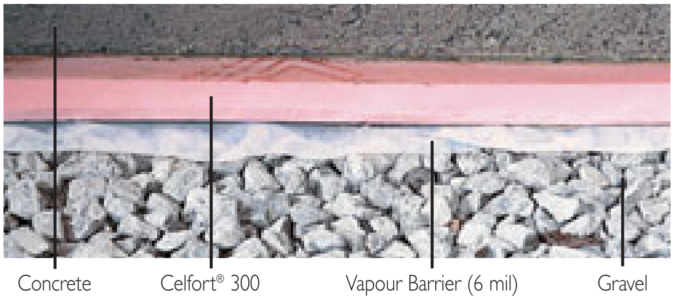
Foamular® 600, 60 psi (415 kPa) Type 4

UNDER CONCRETE SLAB APPLICATIONS*:

To reduce heat loss and possible heaving of slab. Define the performance requirements for the wearing surface (slab); frequency, design, climatic, and construction loads. For slab-on-grade applications review the subgrade material modulus.

Insulation may be placed vertically or horizontally out from the foundation. Insulation dramatically reduces heat loss and retains geothermal heat in ground.

The moisture-resistant and hydrophobic nature of **Celfort**® and **Foamular**® insulation provides excellent thermal performance even when placed directly in moist soil or covered in wet concrete.



PRODUCT:

Celfort® 300, 30 psi (210 kPa) Type 4

Foamular® 400, 40 psi (275 kPa) Type 4

Foamular® 600, 60 psi (415 kPa) Type 4

Foamular® 1000, 100 psi (690 kPa) Type 4

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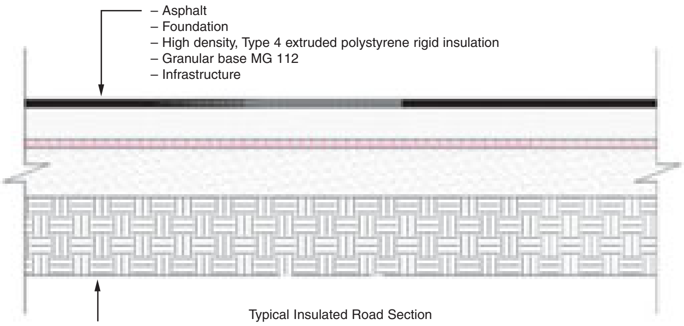
* Compressive strength requirements should be verified by a Structural Engineer.

TYPICAL APPLICATIONS

ROAD APPLICATIONS*:

To prevent frost action on highways, airport runways and railroad beds. Use granular base over insulation installed directly over an existing traffic surface or new compacted sub-grade soil.

In regions where soil normally thaws in spring and summer the layer of insulation works to conserve the natural heat in the subgrade, thereby slowing the penetration of frost during the winter. With proper design, frost heave and thaw weakening (spring break-up) can be eliminated. In permafrost regions, the insulation is used to maintain the subgrade in a frozen state during the summer period.



Typical Insulated Road Section

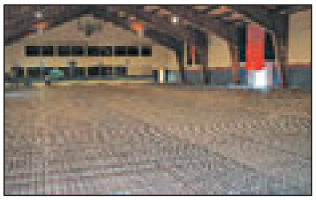
PRODUCT:
Foamular® 400, 40 psi (275 kPa) Type 4
Foamular® 600, 60 psi (415 kPa) Type 4

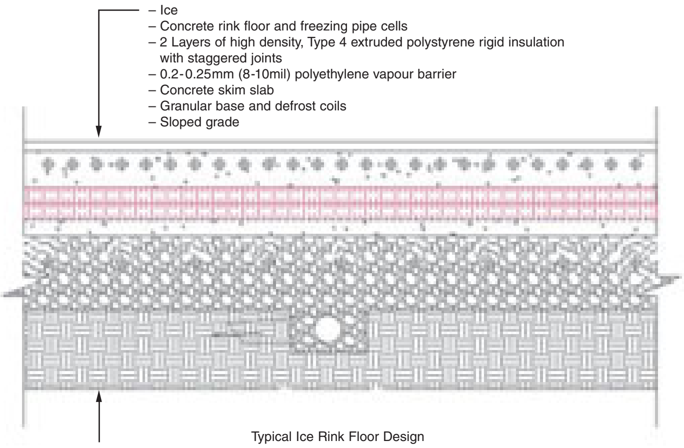
RECREATION CENTRE/ICE RINKS*:

To reduce frost penetration in subsoil and potential for heaving of slab. Insulation dramatically reduces energy costs and refrigeration requirements. Reduces ice making and de-icing time.

The thickness of insulation is based on ice temperature and whether facility is run as a seasonal or continuous operation.[2]

Significant energy cost can be avoided through the use of insulation below the ice slab in continuous operations.





Typical Ice Rink Floor Design

PRODUCT:
Celfort® 300, 30 psi (210 kPa) Type 4
Foamular® 400, 40 psi (275 kPa) Type 4
Foamular® 600, 60 psi (415 kPa) Type 4

UTILITY APPLICATIONS*:

To offer thermal protection, reduce compressive loads on underlying soils. Protect systems such as sewer and water.

See Owens Corning's Utility Line Design Information.

- Utility lines
- Walkways
- Fountain foundations
- Light-weight fill
- Bridge approaches
- Retaining walls
- Landscaping applications

PRODUCT:
Celfort® 300, 30 psi (210 kPa) Type 4
Foamular® 400, 40 psi (275 kPa) Type 4
Foamular® 600, 60 psi (415 kPa) Type 4

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[2] Design guidelines are available through organizations such as the Ontario Recreation Facilities Association Inc.

* Compressive strength requirements should be verified by a Structural Engineer.

DESIGN FREEZING INDEX MAP OF CANADA

PREPARATORY WORK:

Determine the insulation thickness required to prevent freezing temperatures from occurring underneath the layer of insulation for the application.

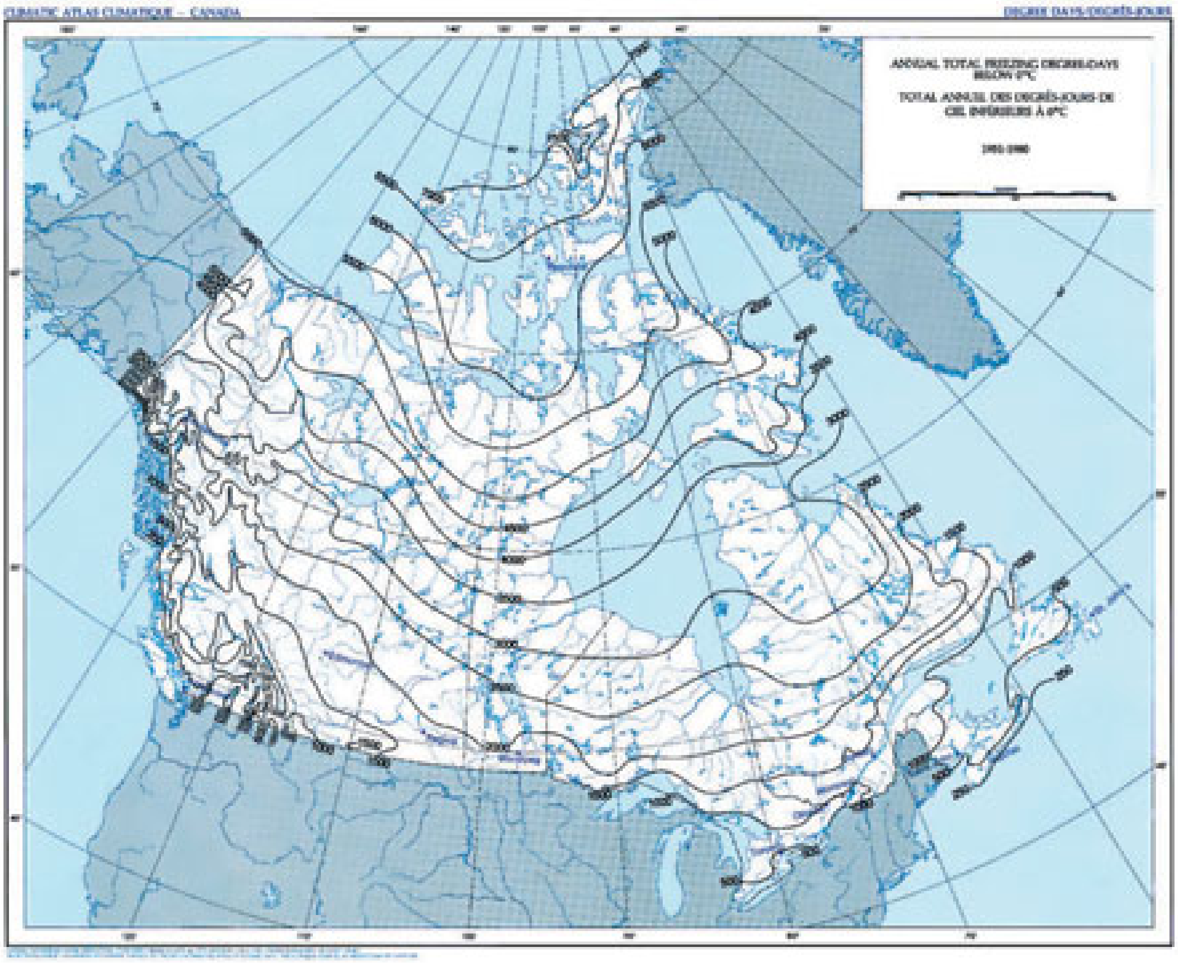
Reference climatic data for the selected region:

- Air Freezing Index
- Average Frost Penetration
- Soil Type/Profiles

The compressive strength requirements of insulation should always be verified by a Structural Engineer.

- Loading frequencies
- Strength of sub-base material
- Expected loads
- Wearing surface material

Air temperature records can be used to gauge the severity of ground freezing by using the degree-day concept. (If the daily mean air temperature is -1°C this will be one degree-day.) The "Freezing Index" is simply the accumulated total of degree-days of freezing for a given winter.



1 degree-day F=1 degree.day C x 1.8

Freezing Index Map of Canada available from Enviroment Canada.

FREEZING INDICES FOR CANADA*

Location	°F Days	°C Days
NWT		
Fort McPherson	7,747	4,304
Yellowknife (A)	6,506	3,614
British Columbia		
Abbotsford (A)	45	25
Cranbrook (A)	1,314	730
Kamloops (A)	603	335
Vancouver (A)	31	17
Victoria (A)	28	16
Alberta		
Banff	1,963	1,091
Calgary (A)	1,791	995
Edmonton (A)	2,593	1,441
Fort McMurray (A)	4,024	2,236
Lethbridge (A)	1,326	737
Manitoba		
Brandon (A)	3,388	1,882
Portage La Prairie (A)	2,855	1,586
Winnipeg (A)	3,251	1,806
Saskatchewan		
Moose Jaw (A)	2,555	1,419
Prince Alberta (A)	3,739	2,077
Saskatoon (A)	3,284	1,824
Ontario		
Belleville	1,143	635
Sudbury (A)	2,435	1,353
Thunder Bay (A)	2,696	1,498
Ottawa (A)	1,829	1,016
Toronto (A)	897	498

Location	°F Days	°C Days
Quebec		
Chicoutimi	2,536	1,409
Montreal (A)	1,583	879
Quebec (A)	2,059	1,144
Sept-Iles (A)	2,746	1,526
Three Rivers	2,139	1,188
New Brunswick		
Bathurst	1,915	1,064
Charlo	2,246	1,248
Fredericton (A)	1,561	867
Moncton (A)	1,397	776
Saint John (A)	1,137	632
Nova Scotia		
Halifax (A)	856	476
Sydney (A)	811	451
Truro	1,025	569
Prince Edward Island		
Charlottetown (A)	1,201	667
Newfoundland		
Cornerbrook (A)	4,584	2,547
St. John's (A)	648	360
Goose Bay (A)	3,646	2,025
Nunavut		
Resolute Bay	11,166	6,203
Iqaluit (A)	7,555	4,197
Yukon		
Whitehorse	3,596	1,998

To obtain Freezing Indices for locations across Canada go to Environment Canada's website: www.msc-smc.ec.gc.ca/climate/climate.normals/index.e.cfm.

USE OF FREEZING INDICES

Winter air temperatures vary substantially from year to year at all locations in Canada. Therefore, it is generally inappropriate to use the long-term mean air freezing index for design purposes. Common engineering practice is to choose some recurrance interval and to estimate the most severe winter likely to occur within that period. For example, W.T. Horne[3], in 1987, developed a simple relationship between design freezing index, taken as the coldest winter over the last 10 year period, and mean freezing index by curve fitting data for 20 cities across Canada. Horne's relationship is:

$$I_d = 100 + 1.29\ I_m$$

Where I_d = Design Freezing Index (°C-days)
I_m = Mean Freezing Index (°C-days)

DETERMINATION OF MAXIMUM FROST PENETRATION

Designers using the good practices of Chapter 15 of the Canadian Foundation Engineering Manual 3rd Edition may use a simplified solution to the frost penetration relationship by using a modified Berggren equation:

$$X = \lambda\ (2k\ I_s/L)^{0.5}$$

Where X = depth of frost penetration
I_s = surface freezing index which can be estimated from air freezing index times a ground surface interface factor "n"
k = thermal conductivity of the frozen soil (W/m.K)
L = volumetric latent heat, and
λ = a dimensionless coefficient

See Table 15.1 of Canadian Foundation Engineering Manual 3rd Edition for n-factors for surface types. Volumetric latent heat can be estimated from relationship:

$$L = Y_d\ w\ L_s$$

Where Y_d = dry unit weight of the soil (t/m^3)
w = water content of the soil expressed as a fraction and
L_s = latent heat of fusion of water to ice which can be taken as 334 kJ/kg

See Figure 15.4 (Frozen Coarse-Grained Soil) or Figure 15.5 (Frozen Fine-Grained Soil) for frozen soil thermal conductivity and Figure 15.6 for estimation of the Lamda (λ) Coefficient in the Canadian Foundation Engineering Manual 3rd Edition.

[3] Horne, W.T. "Prediction of Frost Heave Using the segregation Potential Theory"; University of Alberta, Department of Civil Engineering, Unpublished M.Sc. Thesis, 194 pages, 1987.

USE OF FREEZING INDICES

INSULATION OF SLABS ON-GRADE AND SHALLOW FOUNDATIONS

The conventional approach for protection of building foundations against frost heave action is to locate shallow foundations at a depth greater than the design depth of frost penetration. An example is the modified Berggren equation above which can be used to establish the minimum depth of soil cover over an external footing. The depth of perimeter foundation walls for heated structures may be reduced somewhat due to the heat loss from the building using local building codes or local experience. However, a designer should exercise caution where a significant depth of the footing cover is comprised of dry, coarse-grained soil as frost depths can exceed local experience.

Conditions such as high groundwater table or particularly deep predicted frost penetration may make it impractical to excavate for footings below the design depth of frost penetration. For these and other cases where shallow foundations are desired, thin soil cover and extruded polystyrene insulation may be used in designs. The design methodology for insulated foundations was developed by Robinsky and Bespflug in 1973. Summaries of their design charts for heated and unheated structures have been adapted and are shown in Figures 15.8 and 15.9 respectively, used by permission from Canadian Foundation Engineering Manual 3rd Edition.[4]

Figure 15.8: Design curves for minimum insulation requirements for heated structures (adapted from Robinsky and Bespflug, 1973)

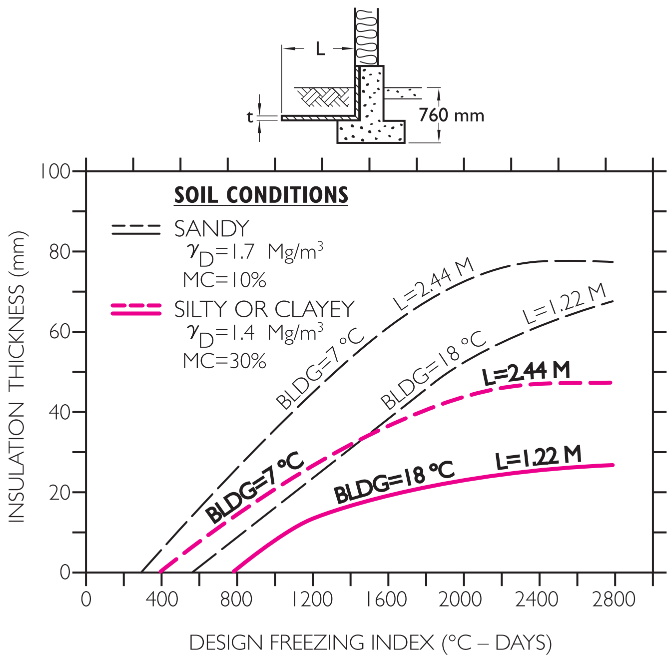
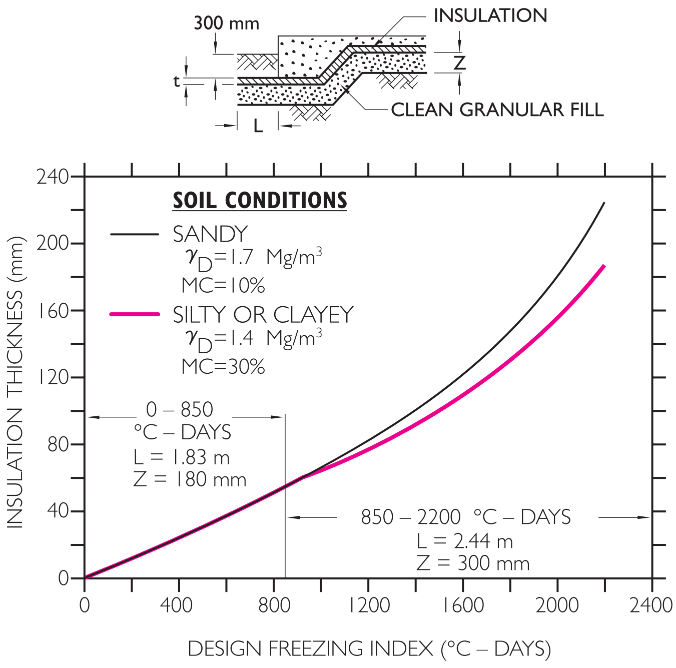


Figure 15.9: Design curves for minimum insulation requirements for unheated structures (adapted from Robinsky and Bespflug, 1973)



Note, the design curves for minimum insulation requirements for heated structures are used to just prevent frost heave damage, higher insulation levels are desireable for energy efficiency and occupant comfort reasons.

The Canadian Foundation Engineering Manual 3rd Edition has specific recommendations where structures have a greater risk of frost heave and in certain cases these structures must be separated from the primary structure. Buildings without basements are often supported on cast-in-place concrete piles with perimeter grade beams. Perimeter concrete grade beams formed and cast on the ground are particularly susceptible to damage by frost action. Since foam insulation has a high compressive strength it cannot be used as a void former to absorb heave movement. A proper minimum thickness of well drained and well compacted clean granular fill as well as foam insulation is required under grade beams and it is a common practice to make reinforcing in grade beams symetrical top and bottom such that some uplift load can be tolerated without risk of cracking. Tension reinforcement must also be provided in cast-in-place concrete piles with adequate tie-in reinforcement at the connections.

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[4] Canadian Foundation Engineering Manual, 3rd edition, 1992, publ. Canadian Geotechnical Society. www.cgs.ca.

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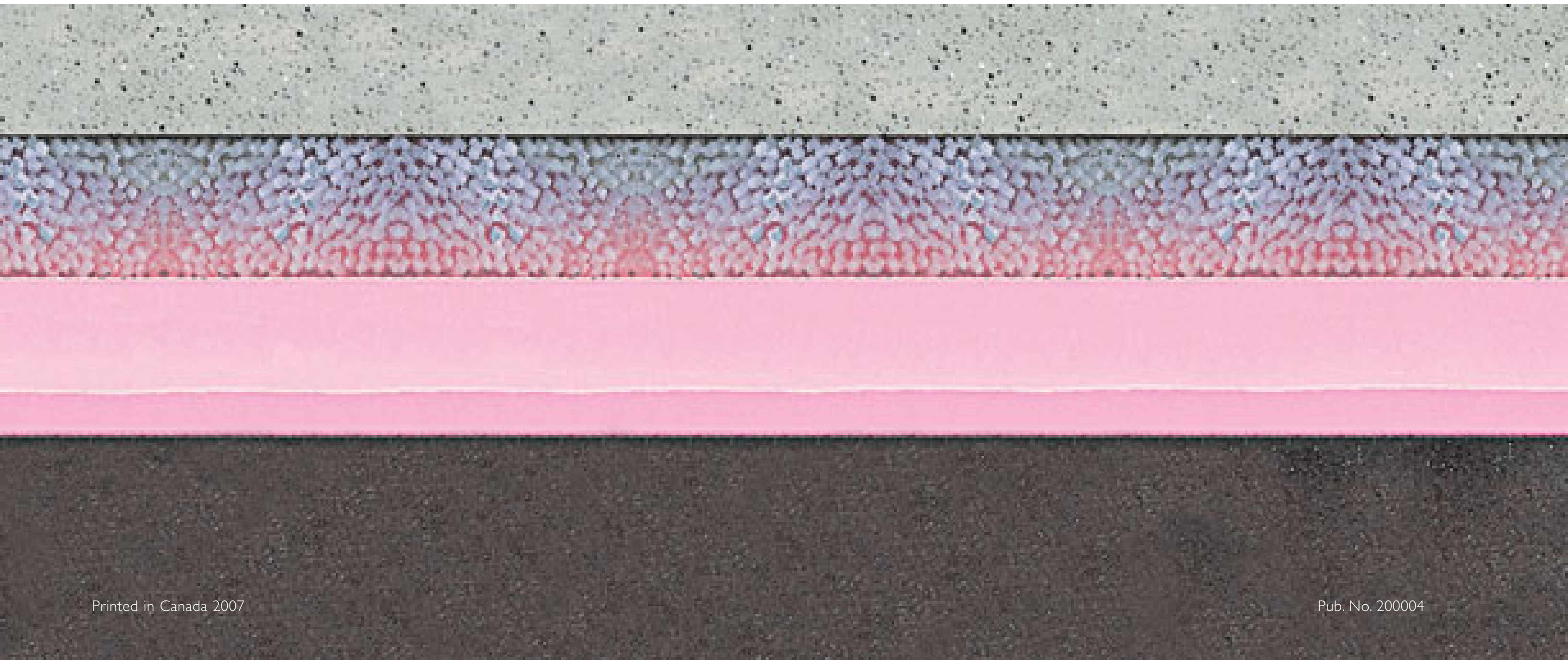

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