BLUEPRINTS* Services

Insulation for Geotechnical Applications

Styrofoam* Brand
Highload Insulation

*Trademark of The Dow Chemical Company

STYROFOAM High Load*

Throughout those regions where underlying soils are prone to frost action, highways, railways, building foundations, even buried utilities run the risk of damage from frost heaving and spring break-up.

Soil insulation is a means of protecting in-ground construction from the ravages of frost action. The concept itself is borne of the insulating principles common to the design of buildings above ground.

Above or below ground, the goal is to control the transfer of heat from one area to another with insulation. To this end, Dow Chemical Canada Inc. conceived and developed STYROFOAM High Load, a versatile CAN/CGSB 51.20-M87 TYPE 4 extruded polystyrene rigid board insulation.

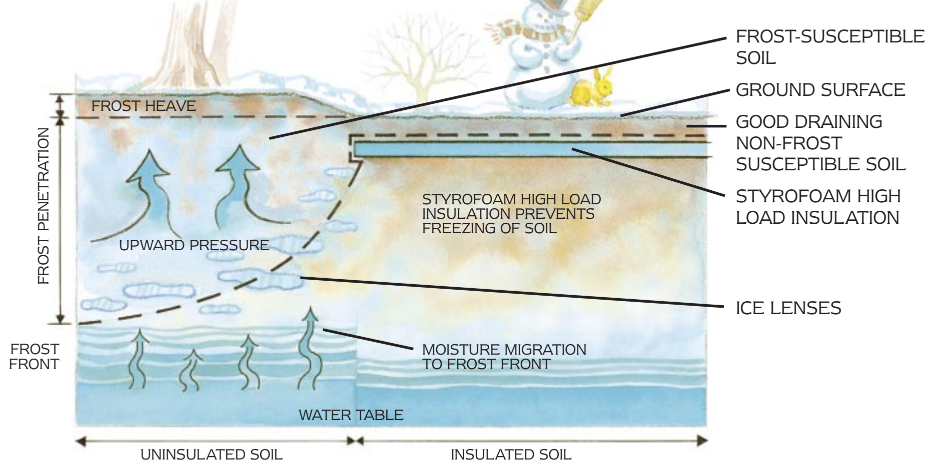
By placing a layer of STYROFOAM High Load insulation in the upper level of the soil, its unique combination of properties will effectively prevent harmful sub-soil frost action. Since 1962, STYROFOAM High Load has been used in engineering construction in Canada, the U.S.A., Japan and throughout Europe. On roadways, rail lines, airport pavements, culverts, building and transmission tower foundations, drainage works and in-ground utilities, STYROFOAM High Load has proven to be an economical, long term solution to ground frost problems.

STYROFOAM HIGH LOAD FOR SOIL INSULATION

In seasonal zones, STYROFOAM High Load insulation conserves the natural heat in the subgrade, retarding frost penetration during winter and, in turn, eliminating frost heave and spring break-up.

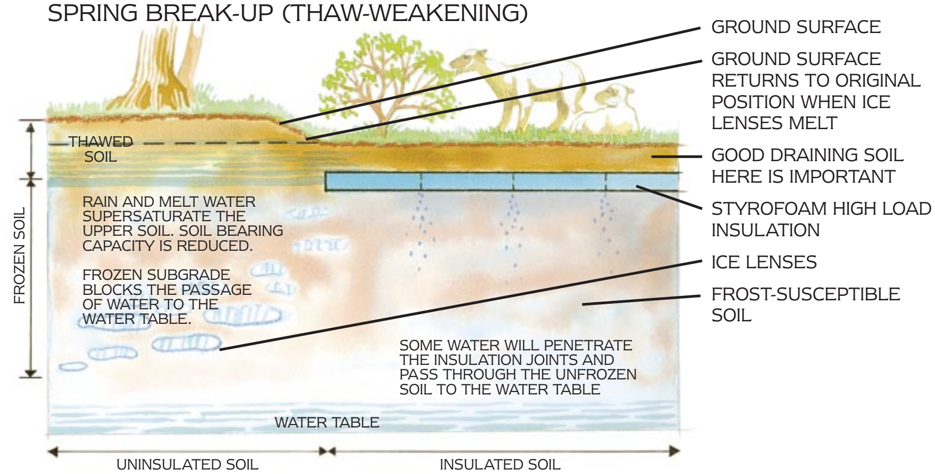
In permafrost zones, STYROFOAM High Load performs the inverse task of retaining the frozen state of the subgrade during summer months to prevent a warming influence in the subgrade which would result in thaw-weakening.

FROST HEAVE



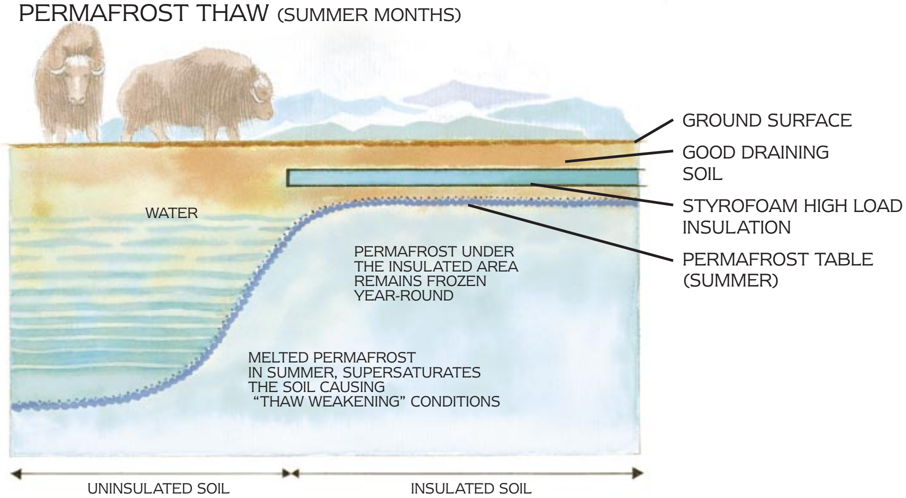
STYROFOAM High Load curtails heat loss from the subgrade. Frost penetration is reduced, preventing ice lenses from forming, which would normally result in frost heaving.

SPRING BREAK-UP (THAW-WEAKENING)



STYROFOAM High Load prevents the freezing of lower soil zones which would impede drainage and result in spring break-up. Where load-bearing capacity is important, an embankment with drainage ditches should be provided.

PERMAFROST THAW (SUMMER MONTHS)



STYROFOAM High Load prevents the thawing of permafrost during summer to retain the load-bearing capacity of the frozen subgrade.

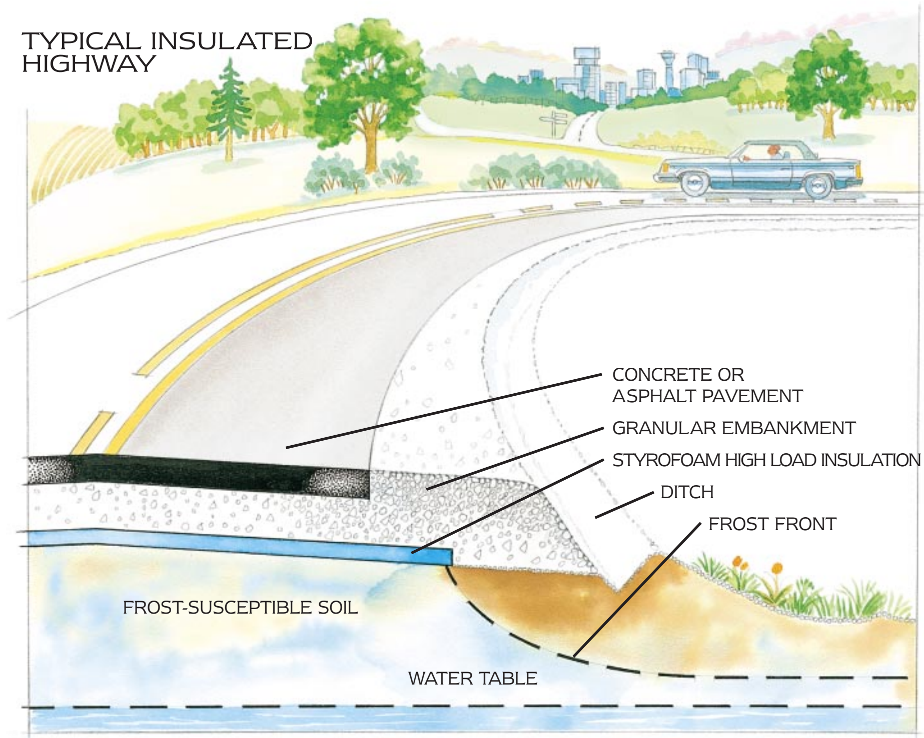
*Trademark of The Dow Chemical Company

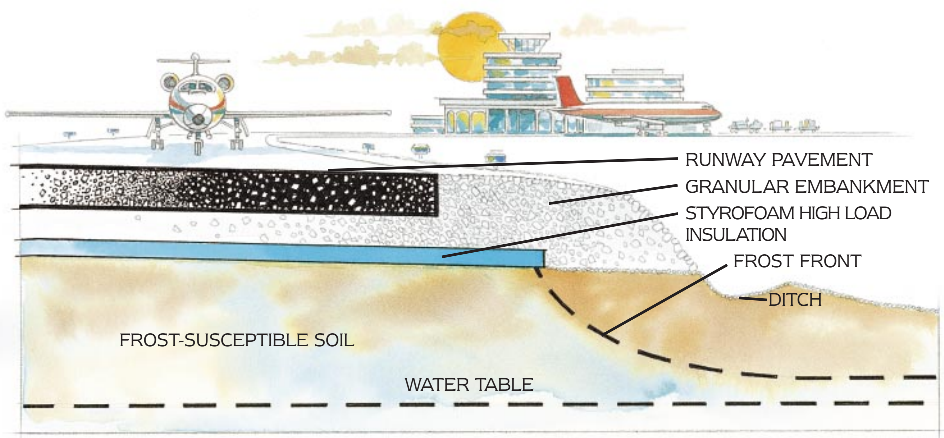
INSULATED PAVEMENTS AND RAIL LINES

For over 30 years, countless numbers of engineers have found that STYROFOAM High Load insulation is an ideal defence against the damage wrought by frost heave and spring break-up on projects including roadways, airport runways and rail lines.

Over the course of these many years, a number of test sites have been monitored to check the stability of STYROFOAM High Load. The assembled data shows no signs of frost heave or spring break- up. Samples of STYROFOAM High Load which have been recovered from various highway installations also show very little increase in water pick-up, little loss of thermal resistance, and in all cases the structural integrity of the insulation was retained.

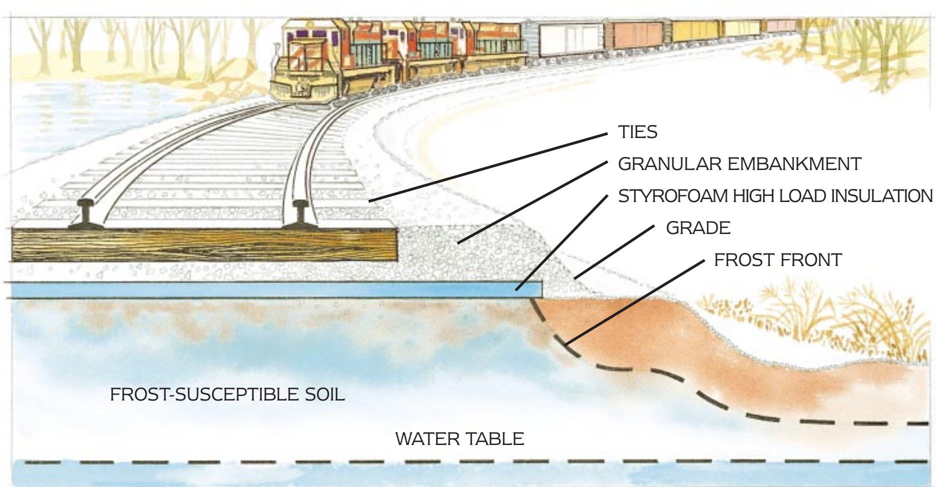
TYPICAL INSULATED HIGHWAY





TYPICAL INSULATED AIRPORT RUNWAY

In comparison to highways, airport runways are much wider and normally require a greater thickness of pavement. However, the same insulation principles apply as in insulated highways.



TYPICAL INSULATED RAIL LINE

The principle used in the design of railroad insulation is the same as the one used in highway and airport pavements. Consequently STYROFOAM High Load insulation should extend well into the embankment to provide adequate frost protection from the flanks.

INSTALLATION

STYROFOAM High Load insulation is laid over the prepared subgrade using conventional road building equipment and techniques. In areas where wind blow-off is a problem, the insulation can be pinned down with wooden skewers, weighed down with granular material, or if applied over old pavement, it can be stuck down with an asphalt emulsion adhesive tack coat. The first lift of granular material should be carefully placed and compacted to prevent damage or displacement of the insulation. Subsequent lifts and asphalt or concrete paving surfaces are then applied in the usual manner.

For more information, a "Highway Insulation" brochure can be obtained from any Dow Chemical Canada Inc. office.

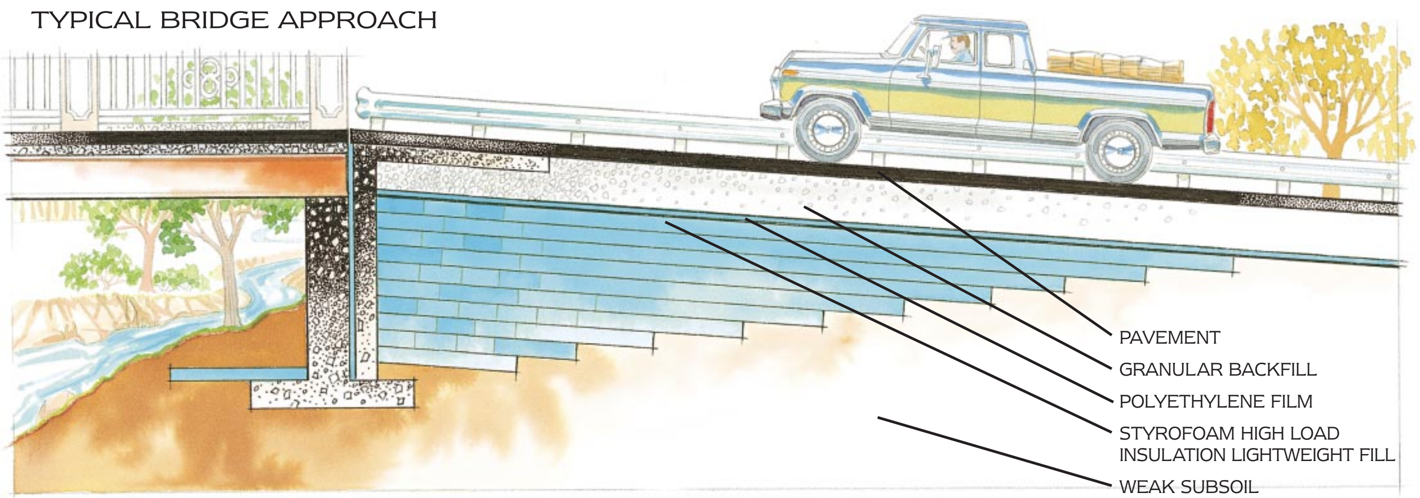
LIGHTWEIGHT FILL USING STYROFOAM HIGH LOAD INSULATION

In the design and construction of embankments or retaining walls requiring great depths of fill, unstable soils and settlement can pose grave problems. In these cases, special backfill materials and methods are necessary when dealing with problems over weak subgrades.

STYROFOAM High Load weighs less than 48 kg/m^3 (3 lbs./cu.ft.) compared with conventional backfill at 1800 to 2100 kg/m^3 (110-130 lbs./cu.ft.). That's a weight reduction of approximately 97%. Where no live loads are involved, the size and strength of retaining walls can be reduced greatly.

On a cautionary note, when using STYROFOAM High Load as a lightweight fill, it should have a cover of granular fill and polyethylene sheet to protect it from sunlight, physical damage, floatation and spills of incompatible chemicals.

TYPICAL BRIDGE APPROACH



SECTION THROUGH HIGHWAY BRIDGE APPROACH EMBANKMENT

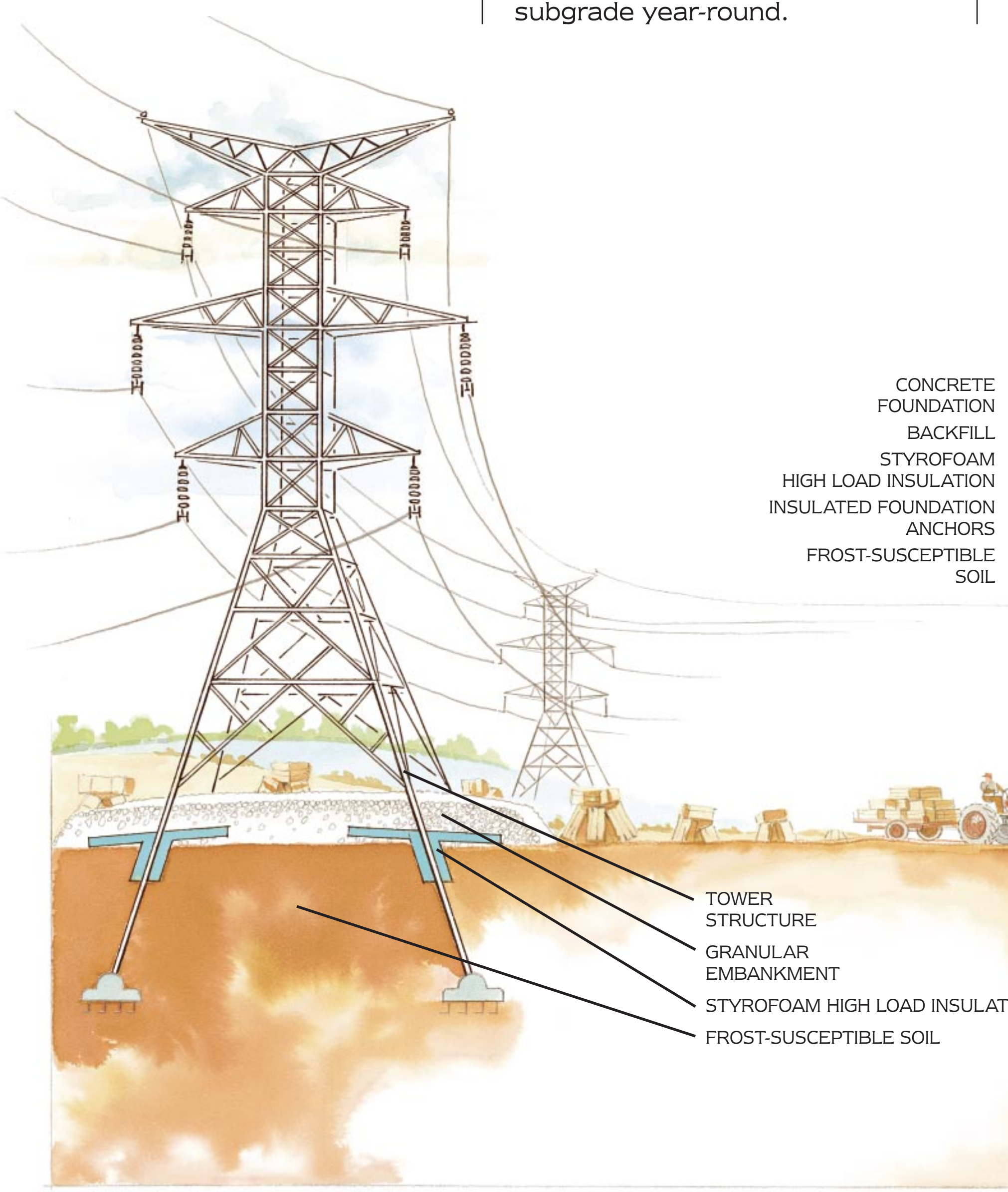
INSULATED TRANSMISSION TOWER FOUNDATIONS

The placement of STYROFOAM High Load in tower foundation areas can drastically reduce or eliminate heave and freezing forces which can result in bent and broken tower diagonal bracing. STYROFOAM High Load reduces the depth of frost penetration during the freezing season and therefore reduces the risk of damaging frost action. In permafrost zones, a pad of insulation over the tower base and around the foundation posts will prevent thawing during the summer and preserve a structurally sound subgrade year-round.

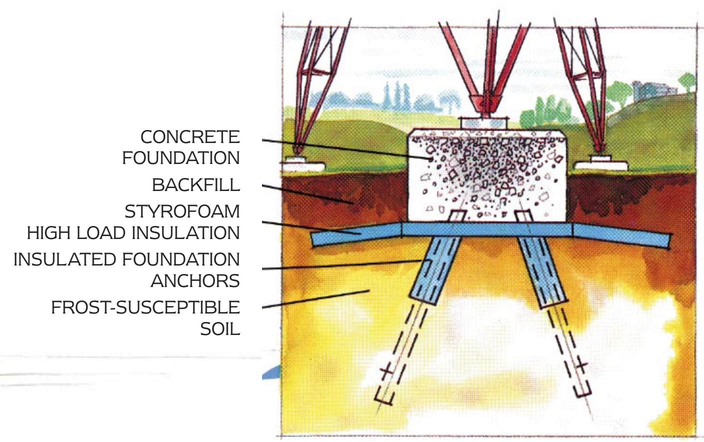
STYROFOAM HIGH LOAD AND BURIED UTILITIES

Conventional construction of buried water and sewer lines calls for placement below the frost line. This can sometimes mean deep excavation, rock cutting, even pumping stations. Where excavation is difficult and expensive, there is a cost-efficient alternative. Utility lines can be insulated with STYROFOAM High Load and placed closer to the surface. This technique can be used not only for new lines but also current ones where regrading would reduce the existing protective frost cover.

RIGID TOWER FOUNDATION



GUYED TOWER FOUNDATION



DESIGN PROCEDURE

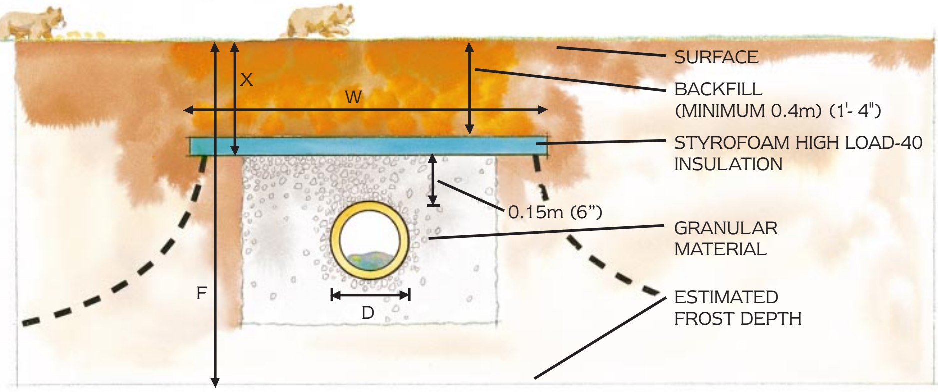
The Horizontal Insulated Utility Line method is widely used and gives satisfactory results if correct construction procedures are followed.

The inverted U Insulated Utility Line method can be used where the design width of horizontal layer is greater than allowed in the field. With the inverted U concept, the insulation width required is reduced by the introduction of two vertical legs. The dimensions of the two vertical legs and the top horizontal layer of insulation should be summed to give the total width of insulation (W) as shown below. The bottom of the vertical legs should be level with the bottom of the line. Table 1 can be used to determine the thickness of insulation needed to protect a utility line based on depth of cover and geography.

INSTALLATION

Using STYROFOAM High Load won't alter conventional line construction methods. However, in some cases a wider trench may be needed to accommodate the horizontal layer of insulation.

HORIZONTAL LAYER



WIDTH OF INSULATION: $W = 3D + 2[F - (X + D + 0.5)]$ For imperial calculation
$W = D + 2(F - X) - 0.3$ For metric calculation

WHERE W = WIDTH OF INSULATION (METERS) (FT)
D = PIPE DIAMETER (METERS) (FT)
X = INSULATION DEPTH (METERS) (FT)
F = ESTIMATED FROST DEPTH (METERS (FT)

INVERTED U

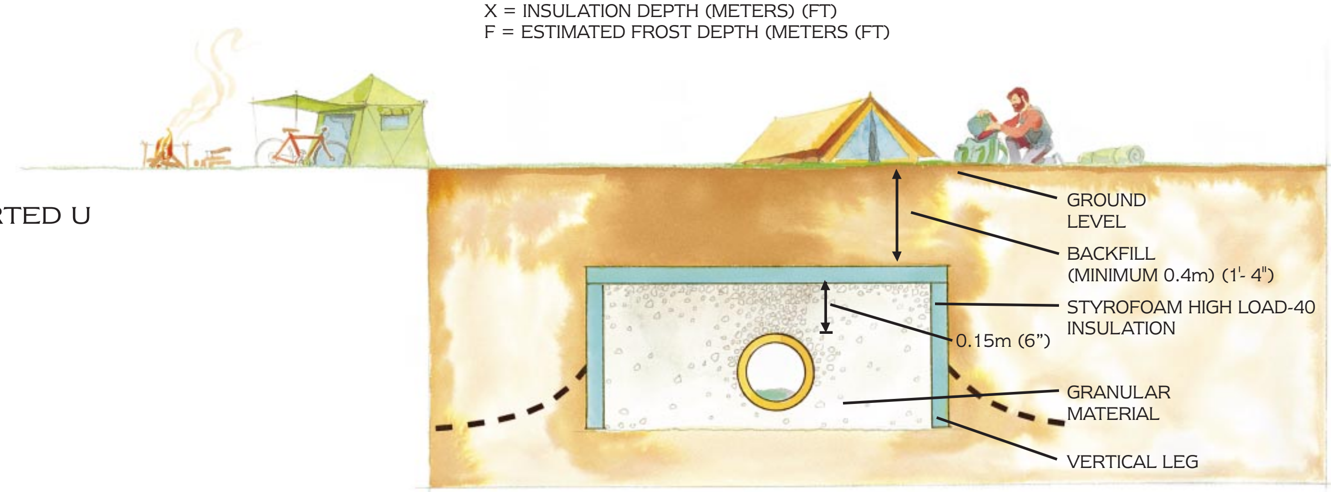


TABLE 1: THICKNESS OF STYROFOAM HIGH LOAD BRAND INSULATION
THICKNESS OF INSULATION IN MM AND INCHES

Design Freezing Index (°C-Days)

Amount of Backfill over the Insulation (m)	850	1125	1400	1675	1950	2225	2500
0.6	50.0	65.0	75.0	90.0	100.0	115.0	125.0
0.9	40.0	50.0	65.0	75.0	90.0	100.0	115.0
1.2	25.0	40.0	50.0	65.0	75.0	90.0	100.0
1.5	25.0	25.0	40.0	50.0	65.0	75.0	90.0
1.8	25.0	25.0	25.0	40.0	50.0	65.0	75.0
2.1			25.0	25.0	40.0	50.0	65.0
2.4				25.0	25.0	40.0	50.0
2.7					25.0	25.0	40.0
3.0						25.0	25.0

Design Freezing Index (°F-Days)

Amount of Backfill over the Insulation (feet)	1500	2000	2500	3000	3500	4000	4500
2'-0"	2.0"	2.5"	3.0"	3.5"	4.0"	4.5"	5.0"
3'-0"	1.5"	2.0"	2.5"	3.0"	3.5"	4.0"	4.5"
4'-0"	1.0"	1.5"	2.0"	2.5"	3.0"	3.5"	4.0"
5'-0"	1.0"	1.0"	1.5"	2.0"	2.5"	3.0"	3.5"
6'-0"	1.0"	1.0"	1.0"	1.5"	2.0"	2.5"	3.0"
7'-0"			1.0"	1.0"	1.5"	2.0"	2.5"
8'-0"				1.0"	1.0"	1.5"	2.0"
9'-0"					1.0"	1.0"	1.5"
10'-0"						1.0"	1.0"

EXISTING LINES

Centered over the length of the line, dig a trench 0.15 meters (6") above the top of the line. Remove large lumps of soil to ensure the trench bottom is smooth and place the insulation boards on this base, butted closely together. Where the inverted U method is used, the bottom of the vertical legs should be level with the bottom of the line. With bedding material holding the legs in place, place the horizontal layer of insulation on top of the legs after the line has been covered with 0.15 meters (6") of bedding.

NEW LINES

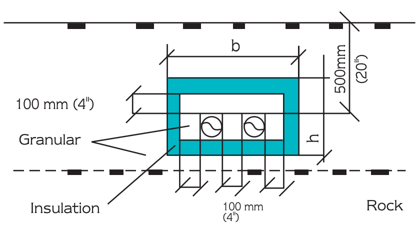
Granular material is compacted to provide 0.15 meters (6") protective cover for the line. Insulation is then laid to a pre-determined width and butted together. Normal backfill operations are then carried out. If the inverted U method is used, place the vertical legs along the walls of the trench, using bedding material to hold the legs in place. Compact the bedding material to provide 0.15 meters (6") cover for the line. Place the horizontal layer of insulation on this and backfill. Care should be taken to prevent vehicles and heavy equipment from bearing directly on the insulation. A minimum 0.20 to 0.25 meters (8" - 10") of compacted lift is required before any heavy traffic passes over the insulation.

INSULATION OF UTILITIES IN ROCK

In solid rock, frost penetrates easily due to the rock's high thermal conductivity and absence of any appreciable amount of water. Since there is little or no available heat from the ground and pipelines in rock must be insulated from freezing, these lines should be insulated from top to bottom and on all sides.

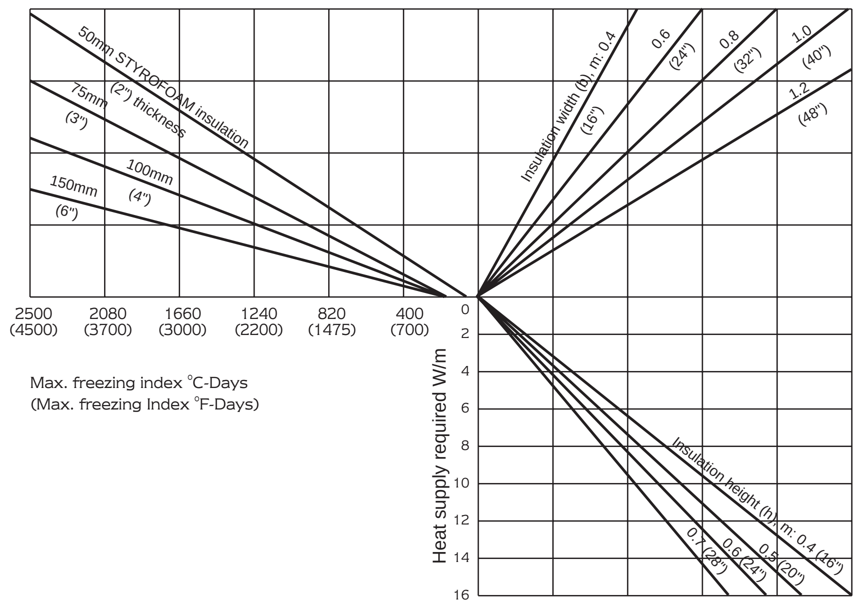
DESIGN PROCEDURE

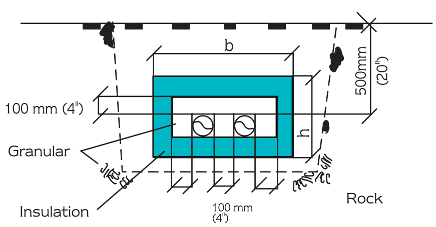
The insulation nomograms[1] below show the required insulation thickness for narrow and wide pipe trenches and the heat supply needed from the line itself or from an electric heating cable. A wide trench in rock means that the covering ground layer on the rock is so thin that the rock is within the expected frost depth, resulting in a freezing of the line from below. For a narrow pipe trench in rock, the laying depth doesn't have a major effect on the needed heat supply because of the proximity of the trench side slopes. When using the insulation nomograms, note that the required heat supply will be reduced for a given insulation thickness when the total width and height of the insulation is minimized.



Depth of pipeline Z = 0.5m

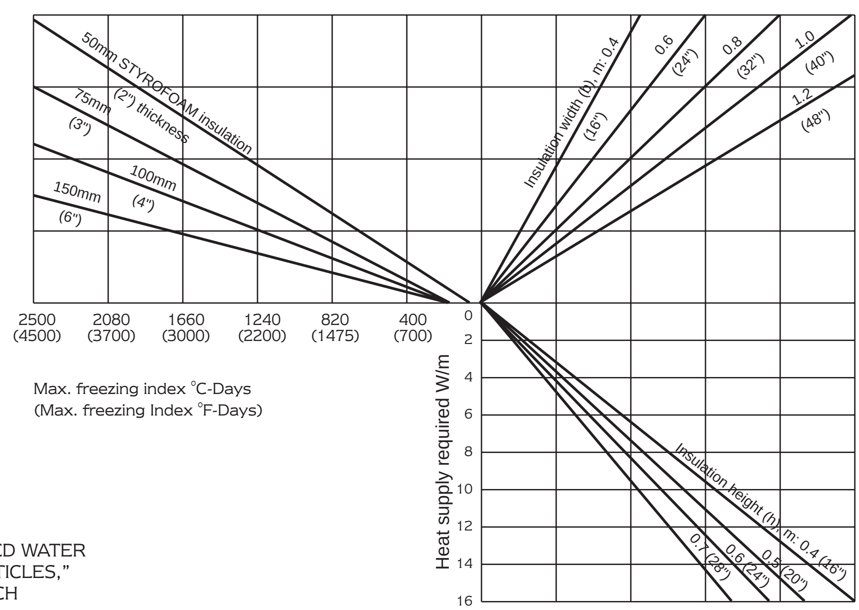
WIDE PIPE TRENCH IN ROCK





Depth of pipeline Z = 0.5m

NARROW PIPE TRENCH IN ROCK



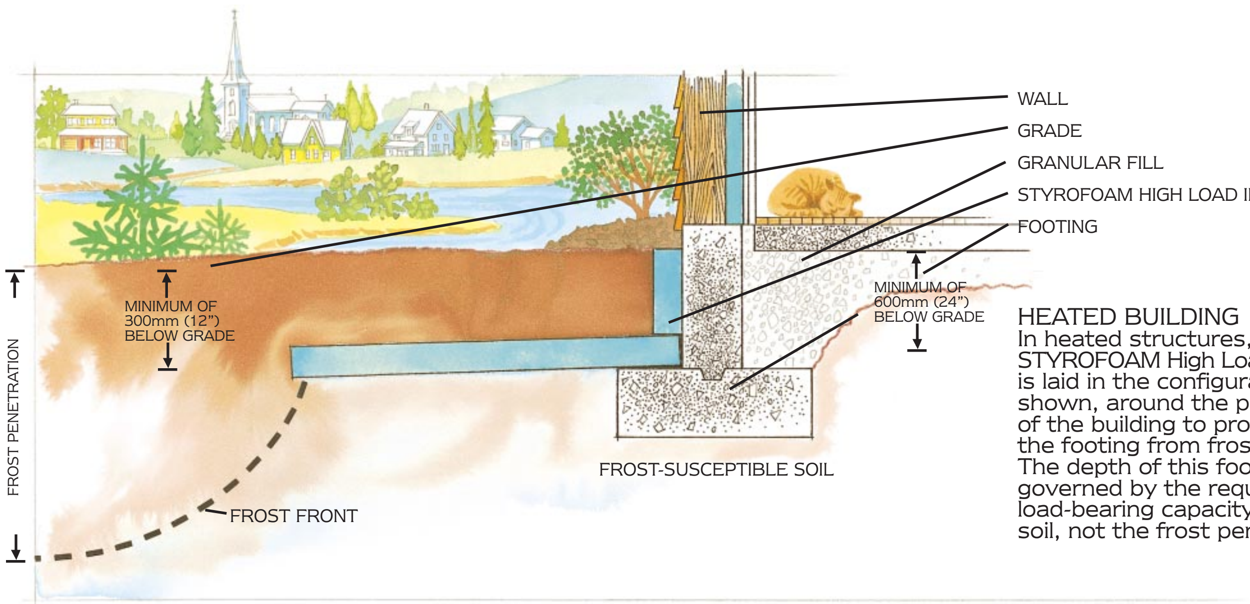
[1] GUNDERSON, P., "FROST PENETRATION OF BURIED WATER AND SEWAGE PIPES; THREE ARTICLES," NORWEGIAN BUILDING RESEARCH INSTITUTE, OSLO.

INSULATED BUILDING FOUNDATIONS

The concept of insulated shallow foundations allows the placement of insulation in a configuration that will reduce frost penetration. This also allows for a corresponding reduction in foundation depth resulting in cost savings in excavating, backfilling, foundation materials and reduced perimeter heat losses. As shown in the diagrams below, the insulated foundation concept differs between heated and unheated buildings. In addition to reducing frost penetration, STYROFOAM High Load reduces high thermal gradients beneath the footings which minimizes moisture migration and reduces the effect of soil shrinkage.

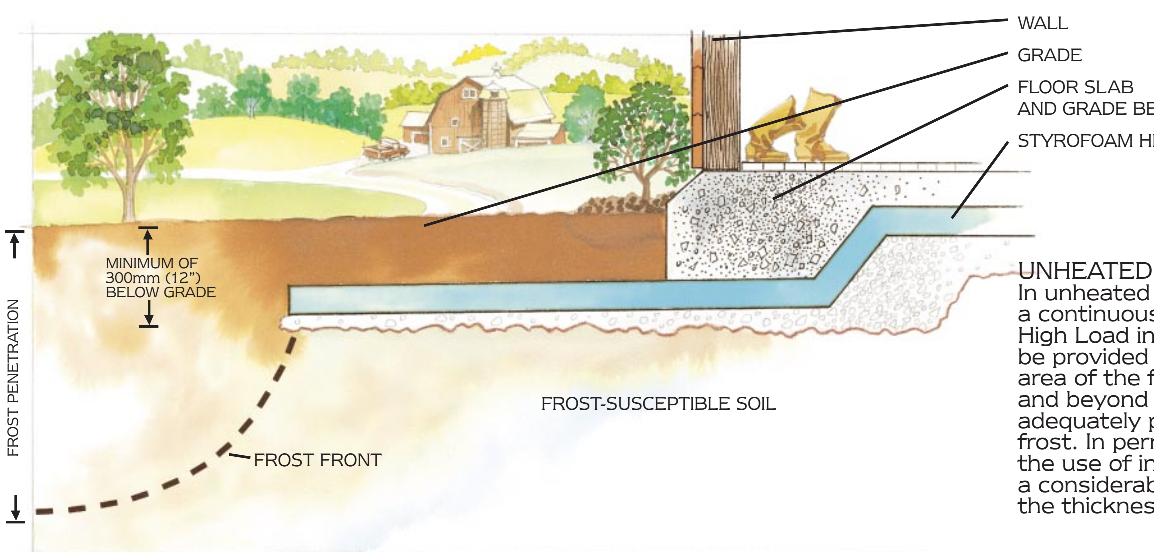
DESIGN DATA

Design criteria have been published by E.I. Robinsky and K.E. Bespflug, Journal of the Soil Mechanics and Foundations Division, Proceedings of the American Society of Civil Engineers, Volume 99 NOSM9, September 1973, Pages 649-667. Four of their nomograms are reproduced on the following pages.



HEATED BUILDING

In heated structures, the STYROFOAM High Load insulation is laid in the configuration as shown, around the perimeter of the building to protect the footing from frost damage. The depth of this footing is governed by the required load-bearing capacity of the soil, not the frost penetration.



UNHEATED BUILDING

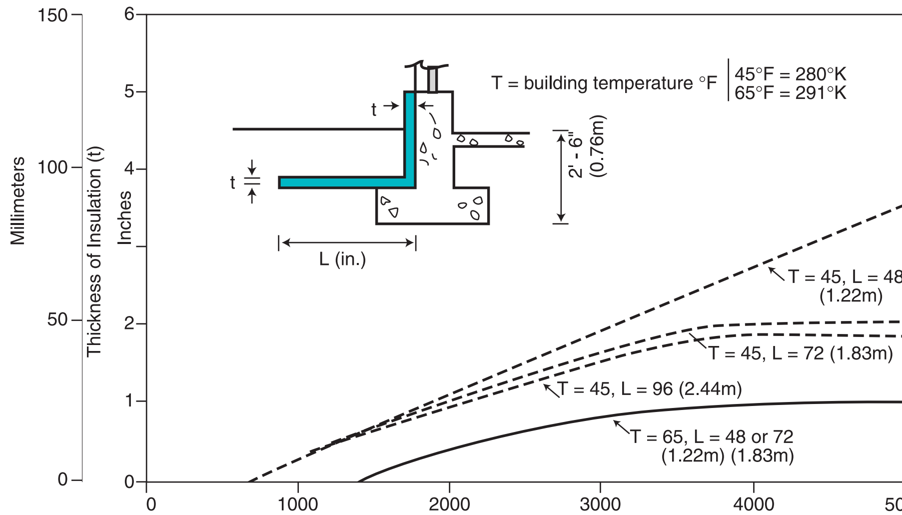
In unheated structures, a continuous STYROFOAM High Load insulation pad must be provided beneath the entire area of the floor, footings and beyond as required to adequately protect against frost. In permafrost regions, the use of insulation permits a considerable reduction in the thickness of granular fill.

SHALLOW FOUNDATION DESIGN NOMOGRAMS

When considering an insulated shallow foundation, it's important to take soil-bearing capacity into consideration as it may call for a deeper excavation. STYROFOAM High Load, with its high compressive strength, is an ideal choice for this application as it can sustain very high loading.

For heated buildings, it is recommended to increase the thickness of the STYROFOAM High Load at the corners of the building to 1-$^1/_2$ times the chosen

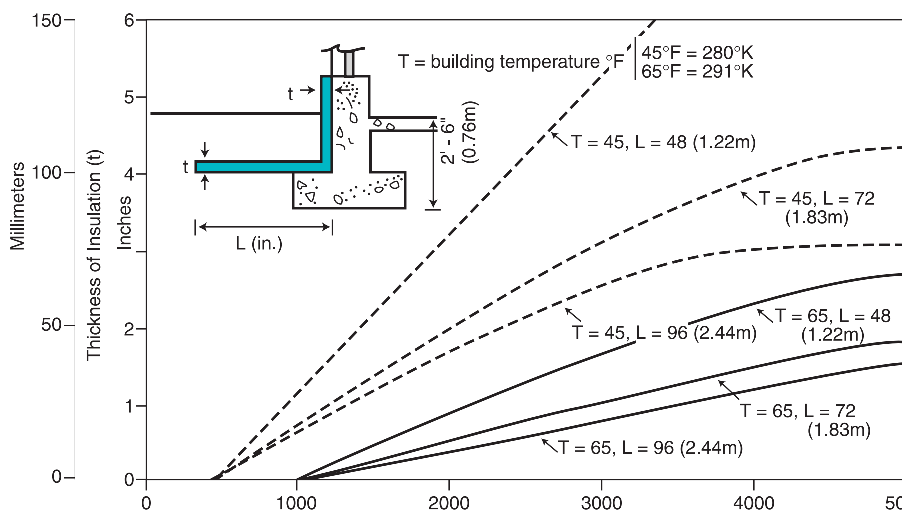
Generalized Design Curves for Minimum Insulation Requirements for Heated Structures on Clayey or Silty Soil with Insulation Extending to 1 ft. (300 mm) Above Grade



Freezing Index, (F. Degree-Days)

Soil Conditions: dry density = 85 pcf (1362 kg/m³), water content = 30%
all soil water freezes at 32°F (273°K)

Generalized Design Curves of Minimum Insulation Requirements for Heated Structures on Sandy Soil with Insulation Extending to 1 ft. (300 mm) Above Grade

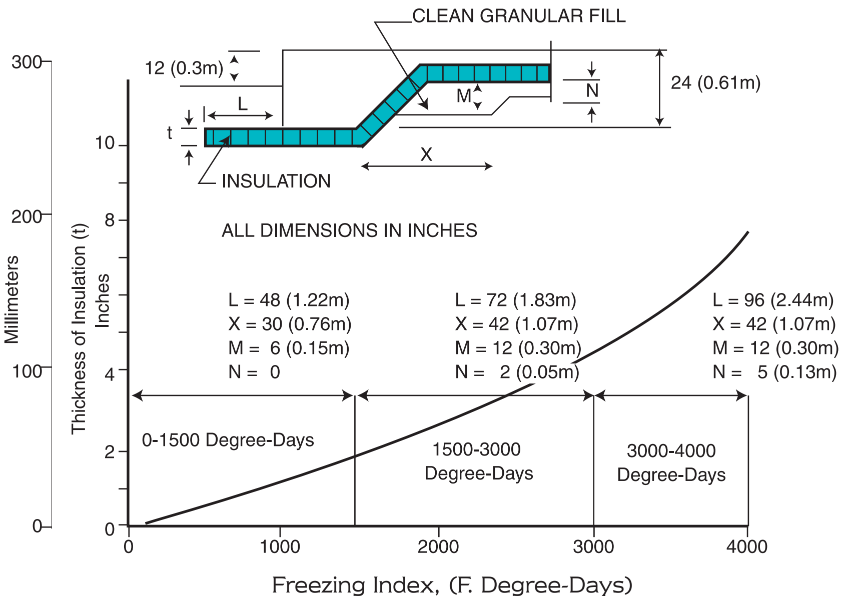


Freezing Index, (F. Degree-Days)

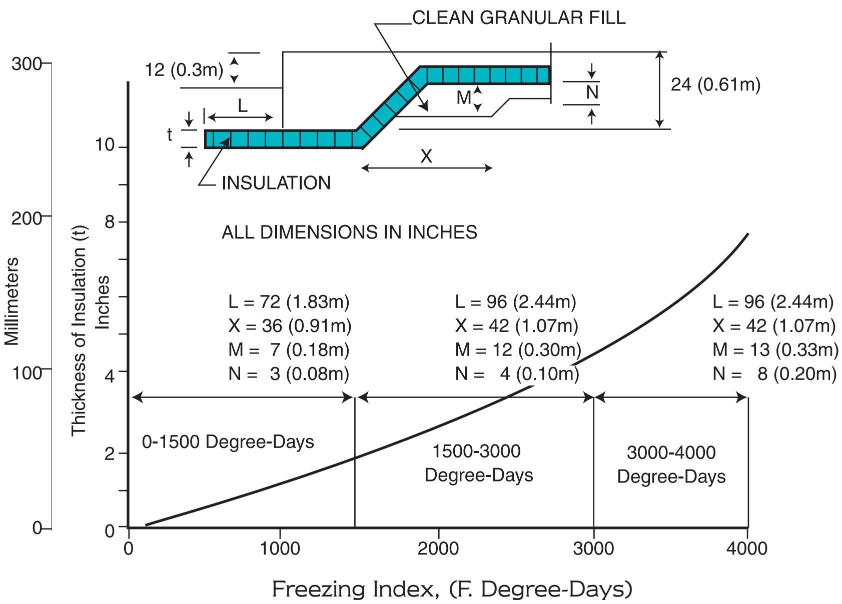
Soil Conditions: dry density = 105 pcf (1681 kg/m³), water content = 10%
all soil water freezes at 32°F (273°K)

thickness, t. The thicker insulation should extend back from the corners along the walls and grade beam a distance equal to the chosen width of the perimeter insulation slab, L.

It is recommended that the perimeter insulation strip be placed on a slight slope, grading away from the structure to encourage drainage.



Design Curve for Foundation Insulation of Unheated Structures on Clayey or Silty Soil; Assumptions: Dry Density 85 PCF (1,361 kg/m³), Water Content 30%; All Soil Water Freezes at 32°F (273°K)



Design Curve for Foundation Insulation of Unheated Structures on Sandy Soil; Assumptions: Dry Density 105 PCF (1,681 kg/m³), Water Content 10%; All Soil Water Freezes at 32°F (273°K)

STYROFOAM HIGH LOAD FOR ICE RINKS

Due to its high compressive strength, high resistance to water absorption and tolerance to soil conditions, STYROFOAM High Load is ideal for installation below rink floors. Insulating with STYROFOAM High Load is recommended for these reasons:

1. to raise the frost line above the level of soils susceptible to frost heaving in rinks which operate seasonally.
2. to reduce the initial and long-term operating costs of soil heating equipment in rinks which operate continuously.
3. to reduce ice-making time.
4. to reduce the required capacity of refrigeration equipment.

SOIL CONDITION

If practical, the ice rink should be located on a site where the soil is not susceptible to frost heaving. If this isn't possible, the site should be prepared in the following manner. Remove the upper layer of frost-susceptible soil to a minimum depth of 300 mm (1 ft.). Replace this with a compacted, free draining, non-frost-susceptible material which will provide proper drainage and eliminate frost heaving. If the insulation is to be placed directly on this base material, the base material should be compacted and leveled as specified by an engineer, and any large stones which might damage the insulation removed.

SEASONAL VS. CONTINUOUS USE

If the rink has a seasonal operation requirement, the design relies on a warm summer cycle to melt any frost that may have accumulated below grade. If the rink has been designed for continuous operation, the insulation will NOT prevent the freezing of the subgrade. A soil heating device can resolve this. In this case, the insulation acts as a separator between the heating and refrigeration equipment.

APPLICATION

The insulation is placed below the refrigerated slab or sand layer and should extend 900 mm to 1200 mm (3 ft-4 ft) beyond the edges of the refrigerated layer. The insulation is usually applied over the compacted base material or a concrete sub-slab.

STYROFOAM High Load brand insulation Thickness Required for Seasonally Operated Rinks

Ice Temperature	Months of Operation		
	5-6	7-8	9-10
-6°C (22°F)	50 mm (2")	60 mm (2½")	75 mm (3")
-9°C (16°F)	60 mm (2½")	75 mm (3")	Design for continuous operation

Note: Use 300 mm (1 ft.) of non-frost-susceptible fill under the insulation.

STYROFOAM High Load brand insulation Thickness Required for Continuously Operated Rinks.

ELECTRIC HEATING SYSTEMS	
– high cost power areas	75 mm (3")
– low cost power areas	50 mm (2")
FUEL FIRED HEATING SYSTEMS (unless fuel costs are unusually high)	50 mm (2")

Note: In view of the possibility of high energy costs in the future, consideration should be given to increasing the thickness of the insulation.

FEATURES

STYROFOAM High Load insulation has a range of properties which makes it suitable for soil applications.

1 EXCELLENT INSULATING CHARACTERISTICS: possesses one of the highest thermal resistance (RSI) (R) values when compared with other insulations.

2 VERY LOW WATER ABSORPTION: applications where the insulation is used below ground (e.g., under highways) present severe conditions which include high soil humidities, long-term exposure to water and freeze-thaw cycles. Under these conditions most insulating materials are subject to water absorption, physical break-down and loss of insulating properties. Due to its low water absorption and high strength, STYROFOAM High Load insulation is virtually unaffected and retains its insulating value as evidenced by samples of STYROFOAM High Load removed from highway installations after as long as 14 years in the ground.

3 HIGH COMPRESSIVE STRENGTH: good durability and resistance to damage. Three compressive strengths to choose from: High Load-40, High Load-60 and High Load-100. Refer to properties table for information.

4 UNIFORM CONSISTENCY: the extrusion and foam manufacturing process produces boards of consistent thickness, density, strength, thermal and moisture resistance, etc.

5 UNIQUELY SUITED FOR IN-GROUND APPLICATION: withstands repeated freeze/thaw cycling without physical degradation such as crumbling or waterlogging. Will not sustain mould or decay.

6 PROVEN PERFORMANCE: monitoring of installations since 1962 verifies that STYROFOAM High Load insulation has the properties necessary for long-term performance in soil insulation applications.

7 CUTS EASILY: and is non-irritating and non-toxic.

8 STANDARDS AND ACCEPTANCES: STYROFOAM High Load insulation meets or exceeds the requirements of CGSB Specification CAN/CGSB-51.20-M87 (Type 4).

PRECAUTIONS

1 STYROFOAM High Load insulation must be protected against exposure to sunlight, physical damage, and incompatible chemicals (solvents, petroleum products, etc.) that might seep into the ground from accidental spills. Where flooding or high water table may submerge the insulation, the overlying backfill must provide sufficient ballast to prevent floatation. These protective measures usually are attained with a cover of granular fill and a layer of polyethylene sheet.

2 To avoid surface degradation, do not leave STYROFOAM High Load insulation exposed to direct sunlight for long periods of time. Cover insulation temporarily stored on the jobsite with a light-colored tarpaulin.

3 BURNING CHARACTERISTICS: although STYROFOAM High Load brand insulation contains a flame retardant agent to inhibit accidental ignition from a small fire source, it will burn and once ignited may burn rapidly releasing dense smoke. STYROFOAM High Load insulation must not be exposed to an open flame or other ignition source.

4 DIFFERENTIAL ICING: when STYROFOAM High Load insulation is placed in the ground, under a highway or paved area, it acts to prevent or diminish freezing of the subgrade in seasonal areas, or thawing in regions of permafrost. Since the insulated section has a different thermal regime than the adjacent non-insulated section, different surface temperatures can result between the two. Under certain conditions, the difference in temperature between sections can be sufficient to allow one surface to support the formation of ice while the adjacent surface does not. This discontinuous or "differential" icing phenomenon also occurs over conventional non-insulated pavement sections in practically all areas subject to freezing and thawing conditions. Frequency of occurrence is dependent primarily on meteorological conditions and the thermal properties of the highway section.

Precautions should be taken by the design authority to minimize the consequences of differential icing. Studies have found that differential icing can be minimized by either lowering the insulation in the pavement section, or by putting in thinner sections of insulation. We strongly recommend that insulated sections should not be started: i) in the middle of a curved portion of road; ii) at the top of a hill; iii) near a major intersection; or iv) near a railway crossing. See Dow publication "Highway Insulation".

5 LONG-TERM CREEP AND FATIGUE: Like all building materials, designers must use adequate safety factors to limit long-term deformations when loading STYROFOAM High Load insulation. See Dow publication "Highway Insulation".

SPECIFICATIONS

Property	High Load-40	High Load-60	High Load-100
Compressive Strength[1] (min) ASTM D1621-73	275kPa (40 psi)	415kPa (60 psi)	690kPa (100 psi)
Tensile Strength (Typical) ASTM D1623-78 (Method A)	480kPa (70 psi)	590kPa (85 psi)	860kPa (125 psi)
Shear Strength (Typical) ASTM C273-61	275kPa (40 psi)	310kPa (45 psi)	350kPa (50 psi)
CGSB Classification	Can/CGSB – 51.20 – M87 (Type 4)		
Flexural Strength[2] (Typical) ASTM C203-91	480kPa (70 psi)	585kPa (85 psi)	585kPa (85 psi)
Compressive Modulus (Typical) ASTM D1621-73	9650kPa (1400 psi)	15170kPa (2200 psi)	25510kPa (3700 psi)

NOTE:
① At 5% deformation or **yield**, whichever comes first. Suitable safety factors must be employed to limit long-term creep and fatigue deformations.
② For 25 mm or 1 inch thickness.

PROPERTY	METRIC	IMPERIAL
†Thermal resistance. Typical 5 year aged R-value or RSI[1] ASTM C-518-91, C-177-85	0.87 $(m^{2\circ}C)/W$	5.0 $ft^2 hr^\circ F/BTU$
Linear thermal coefficient of expansion ASTM D696-79	6.3×10^{-2} mm/m/°C	3.5×10^{-5} in/in/°F
Capillarity	NONE	NONE
Water vapor permeance[1] (max) ASTM E96-90	35 ng/Pa s m^2	0.6 perms
Water absorption (% by volume) (max) ASTM D2842-90	less than 0.7	less than 0.7
Maximum operating temperature	74°C	165°F

NOTE:
① For 25 mm or 1 inch thickness.
† Based on a sample 1½" thick, the typical R-value (28 days at 70°C) = 5.2 (ft^2 hr°F/BTU-inch) [RSI = 0.92 ($m^{2\circ}C$/W-25.4 mm)]

PRECAUTIONS:
This product is combustible and should be properly installed.
For specific instructions see Dow literature available from your supplier or from Dow.

DOW Styrofoam® Brand Highload Insulation

Styrofoam
Brand
Highload
Insulation

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Warning: STYROFOAM brand insulation products are combustible and may constitute a fire hazard if improperly used or installed. Consult Dow for further information. The material contains a flame retardant additive to inhibit accidental ignition from small fire sources. During shipping, storage, installation and use, these products should not be exposed to open flame or other ignition sources.

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