OWENS CORNING® FOAMULAR®
Energy-Saving, Moisture-Resistant XPS Insulation

BURIED UTILITIES
SI UNITS

GEOTECHNICAL DESIGN AND INSTALL GUIDE

BURIED UTILITIES

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INTRODUCTION

In areas where groundwater, soil conditions, surface improvements, obstructions or other constraints result in insufficient cover to protect utility lines from freezing, insulation may be used to prevent the lines from freezing. Placing a layer of rigid board insulation above a pipe is often effective when the soils underlying the pipe are frost-susceptible. The width and thickness of the insulation depend on the depth of the buried pipe and the frost penetration depth. The method below provides a guideline for determining the minimum insulation thickness.

DESIGN PROCEDURE

1. Determine the freezing index, mean annual surface temperature (using the n-factor), and the soil's applicable thermal and frost susceptibility properties as described in the Frost and Thaw Protection section of the "Roadways and Airfields" Design and Install Guide.
2. Calculate the frost depth using the Modified Berggren equation (as provided in the Frost and Thaw Protection section of the "Roadways and Airfields" Design and Install Guide).
3. Calculate the required insulation width to prevent frost from reaching the utility line from the sides. A schematic of the horizontal and inverted U configurations is shown in Figure 1.

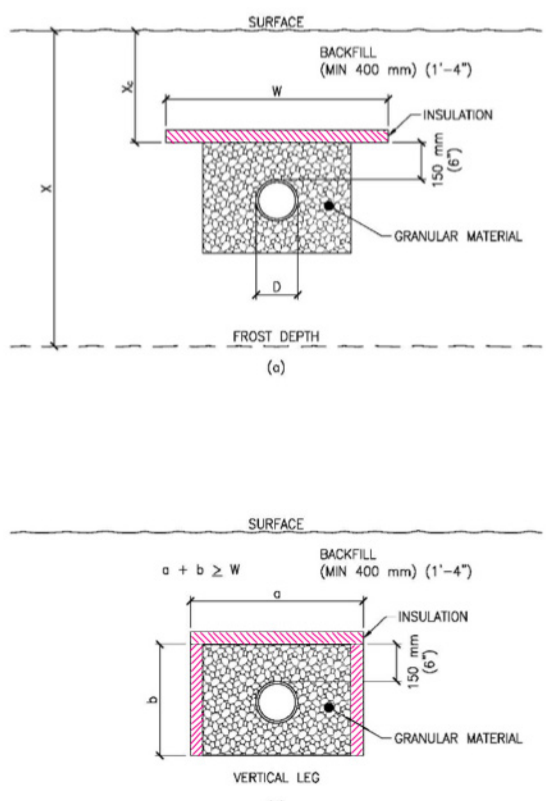

Figure 1: Insulation of Water and Sewer Lines: (a) horizontal layer; (b) inverted U (from Andersland and Ladanyi)

Horizontal Layer: Insulation Required Width

Assuming the distance between the pipe and insulation is 150-mm: $W = D + 2(x - x_c) - 0.3$

Where

W = width of insulation (m)

x = Frost depth (m, from the Modified Berggren equation, as calculated in the Frost and Thaw Protection section in the "Roadways and Airfields" Design and Install Guide)

D = Pipe outside diameter (m)

x_c = Depth of insulation cover (m)

Inverted-U: Insulation Required Width

The Inverted-U orientation can be used to reduce the trench width and reduce heat flow through the sides of the trench. Where the distance between the pipe and insulation is assumed to be 6 inches: $W \leq a + b$

Where

a = Top width (m)

b = Length of vertical legs (m)

Detailed thermal analysis of this problem has shown that the bottom of the vertical legs of insulation must extend to at least the bottom of the pipe. The sum of the length of vertical legs and horizontal component must be greater than or equal to the width required for the horizontal configuration (per Cold Regions Utilities Monograph).

Insulation Box

Another, less common, method of insulating buried utilities is to put them inside a box made of rigid board insulation filled with granular soil (sand or bedding material). Often, pipes are insulated with pre-formed insulation or spray-on insulation rather than placed in a box for constructability reasons. Box-shaped insulation should not be used on ground susceptible to frost heave, as this can damage the insulation.

4. Determine the thickness of insulation required. Typical insulation thicknesses for various freezing indexes and cover thicknesses are provided in Table 1. The insulation thicknesses provided in the table account for heat flux from the pipe to the soil, resulting in lower insulation thicknesses than might be required in road embankments under the same climate conditions. The typical values account for various soil types and nonflowing vs. flowing water in the utility line. The insulation thickness may vary from the provided values, depending on the temperature of the fluid inside the pipe, insulation around the pipe, and soil properties. Additional thermal analysis should be performed to evaluate the heat loss from the pipe and determine the insulation thickness required at that site.

Table 1. Typical Insulation Thickness for Buried Utility Lines in Seasonal Frost Areas with 150-mm Clearance

COVER (M)	DESIGN FREEZING INDEX (ºC•DAY)										
	275	555	850	1125	1400	1675	1950	2225	2500	2780	3050
	INSULATION THICKNESS (MM)										
0.3	38	51	64	76	89	102	114	127	140	152	165
0.6	25	38	51	64	76	89	102	114	127	140	152
0.9		25	38	51	64	76	89	102	114	127	140
1.2			25	38	51	64	76	89	102	114	127
1.5				25	38	51	64	76	89	102	114
1.8					25	38	51	64	76	89	102
2.1						25	38	51	64	76	89
2.4							25	38	51	64	76
2.7								25	38	51	64
3.0									25	38	51

5. Verify that the stress acting on the insulation does not exceed the XPS insulation's compressive strength using a 2H to 1V stress projection.

DESIGN EXAMPLE

List of Variables:

- C_d – Duration Factor
- F'_a – Allowable design stress (kPa)
- F_a – Design stress (kPa)
- q – Applied surface pressure (kPa)
- n_f – Surface freezing n-factor
- n_t – Surface thawing n-factor
- D – Pipe outside diameter (m)
- P – Load (dead load plus live load)
- R – Thermal resistivity (RSI)
- x – Depth of freeze (Modified Berggren equation)
- x_c – Depth of insulation cover
- z – Depth below surface (m)
- t – Insulation thickness (mm)
- W – Width of insulation (m)
- a – Top width of insulation (m)
- b – Length of vertical legs (m)

Example Calculation:
A 300-mm OD underground utility pipe is being installed in an embankment at a site with a freezing index of 2225°C • day and thawing index of 3050°C • day. The unit weight of the gravel fill is 2000 kg/m^3 with a water content of 6%. The site will be subjected to oversized vehicles. A layer of FOAMULAR® GEO 60 will be installed 150-mm above the pipe. The pipe will be installed 1.5-meters below ground surface. The design tire pressure of traffic is 965 kPa with a contact area of 0.25 m^2.

From the Frost and Thaw Protection section in the"Roadways and Airfields" Design and Install Guide and assuming a n_f=0.9 and n_t=2.0, the depth of freeze (excluding insulation) is determined to be 3-m.

The required insulation width is determined.

Given:
D = 0.3 – m
x = 3 – m
x_c = 1.5 – m

$W = D+2(x-x_c) - 0.3 = 0.3m + 2(3m - 1.5m) - 0.3 = 3m$

Use 3 meters of horizontal insulation 150-mm above the top of the pipe.

Disregard heat transfer from the pipe into the soil. Determine the required insulation thickness to prevent the pipe from freezing by using the Modified Berggren equation and setting the active layer thickness to 1.7 – m. Use Lv = 41,841 kJ/m^3, kf = 2.73 W/m K. This can be done by trial-and-error with different insulation thicknesses, or by calculating the average thermal conductivity required to achieve the desired frost depth and determining the insulation thickness from there. In this case, 102-mm of insulation results in a frost depth of 1.84 meters. 76-mm of insulation results in a frost depth of 1.91-meters. 152-mm of insulation results in a frost depth of 1.80-meters. In this case, adding additional insulation beyond 102-mm has minimal benefits and is unnecessary. A frost depth of 1.84-meters with 102-mm of insulation reaches the mid-point of the pipe. If the pipe has flowing fluid or external insulation around the pipe itself, this is an acceptable frost depth.

Use 102–mm of insulation.

Note that the insulation thickness calculated is larger than the insulation thickness from Table 1. This is because the heat transfer from the pipe into the soil is not accounted for in the modified Berggren calculation.

Now check that the stress acting on the insulation does not exceed the insulation's compressive strength using a 2V to 1H stress projection.

B = 0.5 m

q_0 = 965 kPa
z = 1.5 m
A = 0.25 m^2
$A_z = (0.5m + 1.5m)^2 = 4\ m^2$

$$q_z = \frac{A}{A_z} * q_o = \frac{0.25\ m^2}{4\ m^2} * 965\ kPa = 60.3\ kPa\ (2{:}1\ method)$$

$$q_{z,total} = 60.3\ kPa + 1.5\ m * 2000 \frac{kg}{m^3} \left(\frac{kPa}{101.97\ \frac{kg}{m^2}} \right) = 89.7\ kPa$$

The allowable stress on the insulation is determined using an impact duration factor C_d defined in the Bearing Applications section in the "Roadways and Airfields" Design and Install Guide. The minimum compressive strength of the FOAMULAR® GEO 60 is 414 kPa.

F_a= 0.5 • 414 kPa = 207 kPa

$F_a^1 = C_d F_a$ = 3 • 207 kPa = 621 kPa

The allowable compressive strength is larger than the stress acting on the insulation.

INSTALLATION

Utilities should be installed in a trench or berm with sufficient cover to protect the pipe and insulation. Consult local and state design standards to determine the minimum cover depth requirements. Insulation should be placed a minimum of 150-mm above the top of the pipe over a smooth surface to prevent dimpling or damaging the insulation. A sand layer is generally acceptable as a leveling/smoothing material. Boards should be butted together and may be secured with a fastener.

New Lines

A minimum of 150-mm of granular cover should be placed and compacted above the utility pipe prior to insulation installation. FOAMULAR® GEO should be laid with edges butted together. If layers are used, the layers should be laid with overlapping, and offset vertical joints. The trench should be backfilled over the insulation in lifts, taking care to avoid equipment and vehicles bearing directly on the insulation. Cover requirements vary depending on loading conditions and the foam's allowable compressive stress.

Existing Lines

Due to the difficulty in installing vertical insulation adjacent to existing lines, a horizontal layer of insulation is recommended for this application. A trench should be excavated to 150-mm above the top of the existing pipe. The soil should be graded and compacted prior to placing the insulation board. FOAMULAR® GEO should be laid with edges butted together. If layers are used, the layers should be laid with overlapping, and offset vertical joints. Backfilling should be performed using the methods described for New Lines.

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Owens Corning Foam Insulation, LLC
One Owens Corning Parkway
Toledo, OH 43659
www.owenscorning.com

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