Introduction

This brochure describes the frost insulation of ground and civil engineering works using STYROFOAM* extruded polystyrene insulation from Dow. It covers the principles, design considerations and installation methods for frost and permafrost insulation.

The recommendations contained in this brochure should always be considered in conjunction with guidance from the relevant authorities and any local regulations.

*Trademark of The Dow Chemical Company
Sweden is a country with great climatic variations and temperature differences. The whole country is subject to ground frost, which in the North can reach depths of 2m. In some types of soil ground frost can produce frost heave - frost induced soil movement and expansion - which can damage roads, railways, service pipes and building foundations.

An effective method of protecting these structures is to insulate them with STYROFOAM, which reduces the risk of frost damage and cuts the associated repair and maintenance costs. This method of protection is often simpler and more cost effective than the alternative of forming deep gravel-filled foundations.

The use of STYROFOAM insulation can also reduce the effects of permafrost, producing substantial savings in maintenance and energy costs. The STYROFOAM preserves the heat built up in the ground during the summer, which prevents ground frost penetrating and increasing the permafrost layer.

The effectiveness of different methods of permafrost insulation has been tested in comparative trials. The results show that, for soils severely affected by ground frost, constructions using STYROFOAM insulation require only half the normal depth of sand or gravel foundations.

STYROFOAM boards are available in several types and sizes, enabling designers to match the properties of the insulation to the intended use and the environmental conditions.

**Frost index**

The severity of winter conditions is measured by the frost index, the total of daily average temperatures below freezing (number of days x temperature below zero, expressed in negative degree days). The map shows the climatic zones of Sweden based on the mean frost index.

Mean frost index 1961/62 – 88/89
**Insulating roads**

**Introduction**

STYROFOAM has been used to insulate roads against permafrost for over thirty years - one of the first projects, Edsvalla, was completed in 1966. It is now very common to use high performance insulation in such projects.

STYROFOAM greatly reduces frost damage in new and existing roads, bringing benefits for those using and maintaining roads:

- roads free of frost damage are safer;
- improved permafrost protection greatly reduces maintenance costs;
- more even roads give more comfortable driving;
- more even roads reduce fuel consumption, bringing environmental benefits.

Using STYROFOAM for insulating existing roads against permafrost requires some changes to the road structure, but ensures the road maintains its bearing capacity during the ground frost thaw.

**Requirements**

Insulation materials for roads must:

- have a high thermal capacity which will be maintained during the design life of the road (40 years);
- be strong enough to resist short and long term loading. The minimum permissible compressive strength is 0.25 MPa (at max. 5% deformation);
- have very low water absorption (see SS EN 12088);
- have high resistance to freeze/thaw cycles in damp ground (see SS EN 12091);
- resist degradation from environmental conditions;
- be safe and simple to install.

**STYROFOAM Solutions**

STYROFOAM is the blue extruded polystyrene insulation from Dow. The extrusion process gives STYROFOAM its characteristic closed cell structure and key physical properties:

- low thermal conductivity
- low water absorption
- high compressive strength

The STYROFOAM Solution for insulating roads is SOLIMATE*. Full product data for SOLIMATE is given in the STYROFOAM Product Data Brochure.

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*Trademark of The Dow Chemical Company*
Values for the tensile strength are quoted at the fifth percentile. These typical short term values (measured in accordance with SS EN 826) must be reduced for long term loading. Permissible long-term load stresses are calculated for 50 year periods.

The thermal resistance of insulation in roads is calculated according to the method given in the Highways Agency publication 1990:432. The Swedish Testing and Research Institute has drafted guidance on the use of the method. SOLIMATE has a value $\lambda_p \leq 0.045\text{W/mK}$ as required by VÅG 94.

Calculation of the thermal resistance of ground insulation must take account of the effect of moisture absorption. For SOLIMATE, which has a low moisture absorption, use a $\Delta\lambda$ (delta lambda) correction factor when calculating the overall thermal conductivity value.

**Design**

**General considerations**

When determining the amount of insulation required follow the guidance given in VÅG 94. The insulation thickness will depend upon:

- the climate zone;
- the soil's frost resistance;
- the frost index.

Designers should note that in areas with warm summers a greater heat store is built up in the ground than in areas with cooler summers, even if the daily mean temperature below 0°C per year is the same.

The design of the road structure will be affected by:

- road evenness class;
- underground risk of permafrost - assessed by the methods given in VÅG 94;
- traffic load;
- installation and maintenance costs.

Stretches of road with a high risk of ground frost or of surface ice may require special measures.

**Surface ice formation**

The unpredictable formation of ice on the road surface is dangerous, and particular care is required when designing insulated roads at locations with a high risk of ice formation, e.g. near water, or where the road is in permanent shadow. Transitions between insulated and un-insulated roads should not take place in such places, nor on curves.

Figure 02 shows the results of testing at VTI's skid pan in Linköping. The bars in the diagram represent the time, in hours, when the road surface temperature was below -2°C for three trial winters, and the percentage difference compared to a conventional un-insulated construction (furthest left in the figure).

Figure 02  Period of time when temperature of road surface is below -2°C for different superstructures, showing level of risk of slippery ice
**Insulating roads**

**Superstructure**
When designing the superstructure of the road, take account of:

- uniformity class;
- permafrost exposure class of the substructure;
- climate zone;
- insulation material;
- slipperiness of ice;
- transitions with un-insulated roads.

**New roads**
SOLIMATE boards must always be installed on a prepared substrate, selected in accordance with VÄG 94. The substrate must be at least 100mm thick, and of the same width and cross fall as the terrace surface. Before the insulation is installed the substrate should be levelled off and compacted with six transfers of a vibrating roller.

The insulation is installed on the substrate in one or two layers. Butt edged boards should be laid in two layers to prevent gaps in the insulation (figure 03). The boards are butted together and locked with a Foamlock fixing (figure 04) at about 1.5 per m².

As the insulation layer slows the flow of heat from the road’s subsoil, the road surface cools quicker than with un-insulated roads, resulting in a greater risk of ice. To counteract this the insulation should be at least 500mm below the finished surface.

**Permafrost insulation**

**New roads**
The need for permafrost insulation for new roads and traffic surfaces is determined by:

- risk of permafrost;
- standard of road;
- installation and maintenance costs;
- traffic load.

Figure 06 shows a typical build up of a new road incorporating SOLIMATE insulation as the permafrost protection.

**Existing roads**
When upgrading roads, the existing superstructure may be used as the substrate for the insulation, once it has been levelled off. To minimise traffic disruption it may be necessary to treat one lane at a time. Using a temporary barrier along the middle of the road makes it easier to join the two sets of insulation boards.
Existing roads

When planning the insulation of existing roads, take account of:

◆ ground conditions and drainage;
◆ bearing capacity, frost spread trend, and frost damage in existing superstructure;
◆ physical dimensions of the existing road;
◆ ice formation;
◆ transitions with un-insulated roads;
◆ wells, culverts and fixed structures;
◆ traffic technology conditions.

On existing roads the existing superstructure may be used as a substrate for the insulation (figure 08), or it may be removed to avoid problems with increasing carriageway heights or boundaries (figure 07). If the existing superstructure is removed the transitions between insulated and un-insulated sections of road will have to be modified.

Table 01

<table>
<thead>
<tr>
<th>Road category</th>
<th>Evenness class</th>
<th>Permitted permafrost heave in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorways in climate zones 1 or 2</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>National roads or 110 km/h roads. ÅTD$_{p}&gt;$4000</td>
<td>4</td>
<td>50</td>
</tr>
<tr>
<td>Regional roads or 90 km/h roads</td>
<td>3</td>
<td>80</td>
</tr>
<tr>
<td>Local roads or 70 km/h roads</td>
<td>2</td>
<td>120</td>
</tr>
<tr>
<td>Footpaths and cycle paths</td>
<td>1</td>
<td>160</td>
</tr>
</tbody>
</table>

Table 02

<table>
<thead>
<tr>
<th>Permafrost risk class</th>
<th>Description</th>
<th>Examples of soil types</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soils with insignificant heave during frosting Frost heave during frosting process is as a rule insignificant. The class covers coarse grain types of soil and organic soil types with organic content &gt;20%.</td>
<td>Gravel, sand, sandy gravel, gravelly sand, gravelly moraine, sandy moraine, peat masses.</td>
</tr>
<tr>
<td>2</td>
<td>Soil with some degree of frost heave Small degree of frost heave during frosting process. The class covers mixed grain soil types with fine soil content ≥30% by weight.</td>
<td>Silty sand, silty gravel, silty sandy moraine, silty gravelly moraine.</td>
</tr>
<tr>
<td>3</td>
<td>Soil with moderate frost heave Moderate amount of frost heave during frosting process. The class covers fine grain soil types with clay content &gt;40% by weight, mixed grain soil types with fine soil content &gt;30% by weight.</td>
<td>Clay, clayey moraine, silty moraine, silty soil.</td>
</tr>
<tr>
<td>4</td>
<td>Soil with high frost heave High frost heave during frosting process. The class covers soil types with clay content ≤40% by weight.</td>
<td>Silt, clayey silt, silty clay, silty moraine.</td>
</tr>
</tbody>
</table>

Table 03

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evenness class 1 - 2</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>Evenness class 3 - 5</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>140</td>
</tr>
</tbody>
</table>

Insulation thickness as per VÄG 94 for SOLIMATE 300 BE-A-N and BS-A-N, or SOLIMATE 400 BS-A-N.
Determining insulation thickness

The required thickness of insulation is determined in the same way for new and existing roads.

1. Establish the evenness class of the road in accordance with VÄG 94 section 1.3.1.2. The lowest evenness class is 1 (see table 01);
2. Determine the ground frost risk class (the amount of frost heave occurring within the soil) using table 02 (see VÄG 94);
3. Identify the climate zone using the map on page 03;
4. Use table 03 to establish the insulation thickness for the climate zone and evenness class. For terrace insulation in frost risk classes 2 and 3 the stated values can be reduced by 10mm.

Transitions

To avoid abrupt transitions between insulated and un-insulated roadways the insulation should be gradually tapered towards the non-insulated road (figure 09). Where the insulation has been laid over rock, full thickness insulation should be laid until a 1m depth of homogeneous frost-heaving earth is reached, at which point tapering can begin.

New roads

For new roads the taper will be 16.0m, as specified in VÄG 94, Chapter 4, figure 4.6.4. The boards are laid at 600mm displacement and tapered as shown in figure 09. The boards are locked together with Foamlock.

Existing roads

If the construction and permafrost resistance of the existing road is worse than the new one the insulation should be tapered over 24m at the transition. The length of the taper must be adapted at junctions with side roads and driveways and must also take account of frost forces on the existing road.

Culverts and underpasses

Culverts and underpasses under roads, including footpaths and cycle ways, may need frost insulation to:

- protect the culvert against frost damage;
- protect against frost heave in the frost-insulated road above a culvert;
- protect against uneven frost heave in a non-frost-insulated above a culvert.

In culverts, the effect of frost varies according to whether they carry water or are dry. Water-carrying culverts have little or no frost effect upon the ground. Smaller culverts often freeze dry in the winter and should be insulated to prevent frost forces developing.

Small connecting culverts less than 600mm in diameter need frost protection only at the openings.

For large culverts the frost load increases proportionately with the diameter.

The insulation thickness, $h_k$, can be read from table 04. Adjust the result for particularly cold spots. In areas of severe exposure to cold it may be worthwhile combining SOLIMATE with a layer of frost-protected mass underneath. Figure 11 illustrates how to place SOLIMATE in the cutting and at openings.

For subways use $h_k$ without reduction. Use table 05 and the map on page 3 to determine the required width, $b$. 
## Insulating roads

### Table 04

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frost risk class 2 - 3 in roadbed</td>
<td>-</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
</tr>
<tr>
<td>Frost risk class 4 in roadbed</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>120</td>
</tr>
</tbody>
</table>

Required thickness \( h_k \) (mm) of SOLIMATE 300 BE-A-N, SOLIMATE 300 BS-A-N, or SOLIMATE 400 BS-A-N in outer zone.

### Table 05

<table>
<thead>
<tr>
<th>Climate zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frost risk class 2 - 3 in terrace</td>
<td>1</td>
<td>1.3</td>
<td>1.5</td>
<td>1.6</td>
<td>1.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Frost risk class 4 in terrace</td>
<td>1.1</td>
<td>1.5</td>
<td>1.8</td>
<td>2.0</td>
<td>2.1</td>
<td></td>
</tr>
</tbody>
</table>

Required width \( b \) (m) of SOLIMATE 300 BE-A-N, SOLIMATE 300 BS-A-N, or SOLIMATE 400 BS-A-N.

### Table 06 Dimensions of frost insulation in the inner zone of culverts/ conduits

<table>
<thead>
<tr>
<th>Type of subway</th>
<th>Largest internal measurement ( d ) (m)</th>
<th>Thickness ( h ) of frost insulation with SOLIMATE in inner zone</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert</td>
<td>d&lt;0.5</td>
<td>0</td>
<td>0.5 ( \leq d \leq 1.0 )</td>
</tr>
<tr>
<td></td>
<td>( d \geq 1.0 )</td>
<td>( (0.3 + 0.1 \times d) \times h_k )</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 10** Frost protection insulated drum bed. \( b = \) measurement as per table 05

**Figure 11** Frost insulation of culvert/ conduits
Insulating railways

Introduction
Railways are insulated to prevent frost heave causing track movement. Decisions on the need and extent for frost protection should be based on knowledge of climate zones (see map page 03) and the mean frost index 1975.

Requirements
The Railway Administration has adopted a policy that only HCFC - and CFC - free extruded cellular plastic insulation may be used to insulate railways. The policy satisfied the Environment Agency decree for the prevention of damage to the atmosphere by chemical products.

The specified insulation must have a \( \lambda \leq 0.036 \text{ W/mK} \), in accordance with BVF 585.53.

Insulation intended to withstand axle loads of 250 kN must have bulk density of at least 40kg/m\(^3\).

On dynamic load trials the deformation between the 10th and 2,000th load change must be not more than 5% of sample thickness. Material intended for 250 kN axle load must have a compressive strength of at least 450 kPa.

Insulation for use on railways must be type-approved by Railways Administration after testing at an approved testing institute. The test method and procedure is described in BVF 585:53.

STYROFOAM Solutions
STYROFOAM is the blue extruded polystyrene insulation from Dow. The extrusion process gives STYROFOAM its characteristic closed cell structure and key physical properties:
- low thermal conductivity;
- low water absorption;
- high compressive strength.

STYROFOAM thermal insulation has been used as frost protection on railways since 1975.


SOLIMATE is available in a range of thicknesses enabling engineers to match the insulation to the requirements of individual projects. Full product data for SOLIMATE is given in the STYROFOAM Product Data Brochure.

Installation
All installation should take place in accordance with the guidance in BVF 585:53.

Where there is a risk of permafrost formation SOLIMATE should be laid on a gravel bed.

SOLIMATE insulation up to 100mm thick may be laid using one layer of boards, with shiplapped edges fitted tightly together to avoid frost bridges. Insulation thicker than 100mm should be laid as two layers with square-edge boards butted together and joints staggered between layers.
**Insulating railways**

Lay the insulation high on the track base with at least 30mm of ballast between the boards and the underside of the sleepers.

On existing tracks the insulation boards are best laid with ballasting. When laying 4.0 or 5.0m long boards the ballast machine shaft width must be at least 500mm longer than the length of the boards (figures 12 - 14).

**Laying in curves**

Wedge-shaped boards are available for use in curves with a radius less than 1500m. Boards 4.0 to 5.0m taper from 600mm at one end to 400mm at the other. The wedge-shaped boards are laid to match the radius of the curve.

Wedge-shaped boards are available for laying in single and double layers. For single layer laying there are jointed boards suitable for either left hand or right hand bends. For double layer laying there are square-edged boards which suit all curves.

Wedge-shaped boards are manufactured to order. When ordering specify the direction of the curve (left or right hand) with reference to the direction of laying. High load boards may also be ordered.

**Transitions**

Transitions between insulated track and un-insulated track are formed by tapering the insulation. The length of the taper depends upon the thickness of the insulation. Board thicknesses are increased or decreased in 30mm steps.

No tapering is required when the insulated track joins a fixed structure, such as a bridge or rock installation, which is not susceptible to frost heave.

![Figure 15](image1.png)

**Figure 15**

![Table 07](image2.png)

**Table 07** Only extruded cellular plastic approved by Railways Admin as per BVF 585.53 to be used on tracks; $\lambda \leq 0.036$ W/mK.

<table>
<thead>
<tr>
<th>Vertical compression strength</th>
<th>SOLIMATE 400-A-N</th>
<th>SOLIMATE 500-A-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axle load, kN</td>
<td>$\leq 225$</td>
<td>$\leq 250$</td>
</tr>
<tr>
<td>Density, kg/m³</td>
<td>$35 - 40$</td>
<td>$40 - 50$</td>
</tr>
<tr>
<td>Compressive strength, kPa</td>
<td>$\geq 350$</td>
<td>$\geq 450$</td>
</tr>
<tr>
<td>Deformation, % of thickness</td>
<td>$\leq 5$</td>
<td>$\leq 5$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dynamic compression requirements</th>
<th>SOLIMATE 400-A-N</th>
<th>SOLIMATE 500-A-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axle load, kN</td>
<td>$\leq 225$</td>
<td>$\leq 250$</td>
</tr>
<tr>
<td>Load, max kPa</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>Load, min kPa</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Load form, trapezoid-shaped square wave with rise time at 90% of amp, Milliseconds</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>Deformation, % of thickness</td>
<td>$\leq 5$</td>
<td>$\leq 5$</td>
</tr>
<tr>
<td>Load shifts, number</td>
<td>$2 \times 10^6$</td>
<td>$2 \times 10^6$</td>
</tr>
<tr>
<td>Load shifts, Hz</td>
<td>$1.0 - 4.0$</td>
<td>$1.0 - 4.0$</td>
</tr>
</tbody>
</table>
**Insulating airfields**

**Introduction**
High levels of frost insulation are vital for airfields, to prevent frost heave and maintain the evenness of runways and other surfaces. The insulation must withstand the high loads exerted by aircraft, which makes STYROFOAM, with its high compressive strength, ideal for insulating civil and military airfields.

**Requirements**
Aircraft exert extremely high static loads when stationary, for example during boarding and alighting, as well as high dynamic loads during landing, braking and turning.

These place heavy demands on the runway surface and the underlying insulation.

The insulation specification must match the conditions at each airfield, taking account of local ground and weather conditions. The thickness of insulation required is determined from the climate zone and the required standard of surface evenness. Airfields will usually have thicker insulation than roads, because of the importance of preserving evenness and reducing maintenance time.

**STYROFOAM Solutions**
STYROFOAM is the blue extruded polystyrene insulation from Dow. The extrusion process gives STYROFOAM its characteristic closed cell structure and key physical properties:

- low thermal conductivity;
- low water absorption;
- high compressive strength.

The STYROFOAM Solution for frost insulation of airfields is SOLIMATE 400 BS-A-N.

SOLIMATE 400 BS-A-N is also used on airfields in very cold climates, to prevent permafrost melting in summer and affecting the evenness of the runway.

Full product data can be found in the STYROFOAM Product Data brochure.

**Design**
The insulation must be covered by a protective layer of gravel, with a capillary-breaking material forming the lower part. The thickness of the protective layer is determined by the loadbearing and load-spreading characteristics of the surface and the protective layer. The runway surface should consist of asphalt concrete or cement concrete.

The runway should be insulated across its whole width. Where insulated and un-insulated surfaces meet the insulation should be tapered for a distance of at least 24m.

![Figure 17 Section through runway with concrete surface and asphalt surface](image-url)
Lightweight fill in roads and railways

Introduction
The stability of ground with a poor bearing capacity can be improved by the replacement of some of the soil with a lightweight fill of STYROFOAM, making it possible to build roads and other structures (figure 18). Replacing a 300mm layer of soil with STYROFOAM extruded polystyrene foam will give a weight reduction of 500kg/m².

Lightweight fill can be used to reduce mass in a bridge approach, which will reduce the load on, and movement of, the bridge abutment (figure 19).

Using lightweight fill to replace some of the covering earth layer can reduced structural loads in underground car parks. The method is simple and cost effective compared to the alternative of steel or concrete reinforcement.

STYROFOAM Solutions
STYROFOAM is the blue extruded polystyrene insulation from Dow. The extrusion process gives STYROFOAM its characteristic closed cell structure and key physical properties:
- low thermal conductivity;
- low water absorption;
- high compressive strength.

Figure 18 Lightweight fill on road and rail embankments

Figure 19 Lightweight fill in a bridge approach
The STYROFOAM Solution for lightweight fill of roads and railways is SOLIMATE LW-A-N, which has been developed for use in road and railway applications which require high loadbearing and moisture resistance.

SOLIMATE LW-A-N combines excellent long-term moisture resistance with high compressive strength. It resists deformation and shrinkage, eliminating the risk of subsidence or shrinkage.

SOLIMATE LW-A-N is delivered in shrink-wrapped packages 3.0m long and 0.6m wide with a nominal thickness of 400mm. Other lengths are available on request. Full product data can be found in the STYROFOAM Product Data brochure.

**Design**

**General considerations**

Replacing some of the heavy soil where ground has poor bearing capacity with SOLIMATE LW-A-N significantly improves the ultimate bearing resistance. The material can also be used for improving bearing resistance on roads and railway banks.

SOLIMATE LW-A-N can also be used to limit, eliminate or level out subsidence. Other applications include levelling out subsidence at transitions between ground reinforced with piles and non-reinforced ground.

The use of SOLIMATE LW-A-N lightweight fill also reduces horizontal soil pressure on support constructions.

Lightweight fill is not normally used at abutments to railway bridges as problems can arise if the material absorbs braking and acceleration forces. The Railway Administration’s bridge constructor must approve any design where it is proposed to use lightweight fill against a railway bridge.

The guidance given here is based on the Railway Administration’s manual ‘Light filling in railway banks’ (BVH 585.11). Although intended for railways, the instructions may be used as the basis for design of other applications such as roads and bridges.

**Design density**

For a design life of 80 years the design density of SOLIMATE LW-A-N is assumed to be the nominal density plus an allowance for water absorption equivalent to 0.4kN/m³. Otherwise the design density is taken to be 0 kN/m³, where the least favourable value is applied.

For a partial coefficient of 1.3 and a design life of 80 years a density of 1.0kN/m³ may be used. Where there is a risk of heave the design weight is set at -10.0kN/m³.

**Compression and deformation**

To avoid subsidence, boards for lightweight fill must be flat: the thickness tolerance is set at ±0.5%.

The boards must resist deformation by static and dynamic loads, this is particularly important for railway embankments. Tests for short term loading are carried out in accordance with SSN 826 (ISO 844): boards must withstand loads up to 0.25Mpa, without breakage, or a relative deformation greater than 5%.

Dynamic load tests are carried out in accordance with the Railway Administration’s special testing method: the deformation between load shifts 10 and 2,000,000 must not exceed 5%.

**Installation**

1. **Preparation**

   - Prepare a levelling bed of approximately 100mm thick natural or crushed material 0 – 20mm diameter, packed with at least four passes of a 75kg vibrator plate. The levelling bed must be finished to an accuracy of +/-10mm per 3m with a maximum deviation of +/-20mm from the finished level.
2. Laying lightweight fill -

- Lay packs of lightweight fill in brick bond with at least a 300mm overlap. In some circumstances a 150mm overlap is permissible;
- Lay successive layers at right angles to each other (see figure 20);
- Prevent wind movement by pushing 1m long trussing irons through the packs at 1,0 to 2,0m centres;
- Inspect each layer to ensure it is flat. The greater the number of layers, the more important this becomes (figure 20).

The maximum gradient of the lightweight fill depends upon the ground conditions, but must never exceed 2:1. The edges of the lightweight fill must be stepped out if the height exceeds one metre, otherwise vertical sides may be constructed.

3. Supporting slopes

- The sides of embankments should be constructed with underballast which meets BVH 581.15 D1.42. Do not use rubble;
- Place ballast with care, using a bucket shovel or mechanical shovel;
- Pack the ballast carefully with a shovel or vibrator plate. There should be at least 500mm ballast surrounding the lightweight fill;
- The angle of the fill should not exceed 2:1.

4. Superstructure

- The superstructure should be constructed with underballast which meets BVH 581.15 D1.42. Do not use rubble;
- Tip the first layer of underballast crossways and spread out to form a layer 400mm thick over the lightweight fill. Do not tip the underballast directly onto the lightweight fill;
- Pack the first layer with four passes of vibrating rollers with a static line load between 15 and 20kN/m², or with equipment with a similar packing effect;
- Lay the rest of the underballast and ballast and pack in accordance with guidance in Mark AMA;
- Do not allow wheeled traffic on the surface until a 400mm thickness of superstructure has been laid.

Table 08  SOLIMATE LW-A-N is approved by the Railways Administration and meets the requirements in BVH 585.11.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Method</th>
<th>Unit</th>
<th>SOLIMATE LW-A-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength</td>
<td>SSEN 826</td>
<td>kPa</td>
<td>250</td>
</tr>
<tr>
<td>(max. 5% def.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic deformation</td>
<td>The Railway Administration</td>
<td>%</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Water absorption</td>
<td>DIN 53434</td>
<td>vol %</td>
<td>&lt; 0,2</td>
</tr>
<tr>
<td>Length</td>
<td></td>
<td>mm</td>
<td>3 000</td>
</tr>
<tr>
<td>Width</td>
<td></td>
<td>mm</td>
<td>600</td>
</tr>
<tr>
<td>Thickness / package</td>
<td></td>
<td>mm</td>
<td>400</td>
</tr>
<tr>
<td>Thickness tolerance</td>
<td></td>
<td>%</td>
<td>± 0,5</td>
</tr>
<tr>
<td>Cell gas</td>
<td></td>
<td>Air</td>
<td></td>
</tr>
<tr>
<td>On diffusion</td>
<td>EN 12088</td>
<td>vol%</td>
<td>&lt; 3</td>
</tr>
</tbody>
</table>

Figure 20
Insulating tunnels

Introduction
In tunnels water often seeps out of the bedrock, from the roof and the base. As the water nears the tunnel entrance there is a risk of it freezing and producing ice build ups. High water pressure can produce significant quantities of water and ice, causing safety problems.

Securing tunnels against frost can protect:
- tunnel vaults from water and frost;
- the roadway from permafrost;
- the drainage system from frost formation.

Protecting tunnels against frost makes heavy demands on the insulation material, which must maintain its key properties for a design life of the tunnel (usually 50 years).

The insulation must have:
- high compressive strength maintained over a long design life to prevent damage or deterioration during installation and operation (see SSEN 1606);
- high resistance to freeze/thaw cycles in damp environments (SSEN 12091);
- very low water absorption by diffusion (SSEN 12088);
- 50 year value for thermal conductivity.

STYROFOAM Solutions
STYROFOAM is the blue extruded polystyrene insulation from Dow. The extrusion process gives STYROFOAM its characteristic closed cell structure and key physical properties:
- low thermal conductivity - documented 50 year values;
- low water absorption by diffusion;
- high compressive strength;
- resistance to repeated freeze thaw cycles.

STYROFOAM meets the requirements for tunnel insulation in accordance with test methods set out in SSEN 1606, SSEN 12080, SSEN 12088, and SSEN 12091. The STYROFOAM Solution for insulating tunnel vaults is FLOORMATE SL-A-N, which can be used in pre-fabricated concrete units. The STYROFOAM Solutions for insulating tunnel carriageways are FLOORMATE 600-SL-A-N and SOLIMATE 500-RS-A-N.

Table 09  Guideline thickness. Exact calculations to be done as per F10.

<table>
<thead>
<tr>
<th>F10T (h˚C)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;10 000</td>
<td>50</td>
</tr>
<tr>
<td>&gt;20 000</td>
<td>70</td>
</tr>
<tr>
<td>&gt;30 000</td>
<td>80-100</td>
</tr>
</tbody>
</table>

Figure 21  Insulated carriageway in tunnel

*Trademark of The Dow Chemical Company

STYROFOAM Solutions: Insulation of Ground and installation works
Insulating tunnels

The STYROFOAM Solution for insulating tunnel drainage is SOLIMATE.

Full product data can be found in the STYROFOAM Product Data brochure.

Design

Frost load

Frost penetrates tunnels by means of wind, the funnel effect, cold fall, and the suction effect from traffic and ventilation. Precautions against frost are required from F10 years winter (h°C) and is called F10T. The amount of frost in the outside air can be taken from the local authority table and adjusted for the height above sea level. Local values for F10T are calculated after that.

Insulating tunnel vaults

Table 09 gives the approximate thickness of FLOORMATE 200 SL-A-N required for values of F10T.

Insulating the carriageway

The carriageway is constructed by lowering the bottom of the tunnel to make sufficient room for the road construction. However, the ground beneath the roadway can be affected by permafrost which, in conjunction with water penetration, can cause frost heave, potholes and poor bearing capacity. To prevent this the carriageway must be insulated.

The carriageway should be insulated in accordance with the guidance on page 07. The depth of insulation material is determined using table 03. Precise calculations can be made using the mean annual temperature and the value for F10: seek professional advice for individual projects.

Insulation boards should have shiplapped edges, to prevent the formation of cold bridges, and should be jointed with Foamlock, so they cannot slide apart when the base course is applied.

Because of the heat being given off there is no risk of ice sheet forming within tunnels.

Frost prevention of tunnel drainage

Water leaking into the tunnel must have a frostproof run-off from the inlet point to the frost protected overflow ditch. The insulation requirement is determined according to table 10. A 600mm board width is sufficient. The insulation should be laid as deep as possible in the ditch. See also the section ‘Insulating water supply and waste pipes’.

<table>
<thead>
<tr>
<th>F10T(h°C)</th>
<th>Insulation of overflow ditch</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 4000</td>
<td>Not necessary</td>
</tr>
<tr>
<td>4000 - 6000</td>
<td>Necessary if the water quantity in the ditch is less than 1 l/s</td>
</tr>
<tr>
<td>&gt;6 000</td>
<td>Necessary if the water quantity in the ditch exceeds 1 l/s</td>
</tr>
</tbody>
</table>
Introduction

Pipework systems must be protected against frost to maintain trouble-free performance. The water in pipes must not freeze and the pipelines must not be damaged or fractured by frost action.

Heavy demands are placed on insulation material for water supply and sewage installations: it must maintain its insulating capability for the service life of the pipe - between 50 and 100 years - and must withstand loads from works traffic.

STYROFOAM Solutions

STYROFOAM is the blue extruded polystyrene insulation from Dow. The extrusion process gives STYROFOAM its characteristic closed cell structure and key physical properties:

◆ low thermal conductivity - documented 50 year values;
◆ low water absorption by diffusion;
◆ high compressive strength;
◆ resistance to repeated freeze thaw cycles.

The STYROFOAM Solution for insulating water and waste pipes is SOLIMATE. Full product data for SOLIMATE can be found in the STYROFOAM Product Data brochure.

The use of SOLIMATE will achieve considerable savings for the insulation of water supply and sewage systems:

◆ the laying depth need not be so deep - requiring less excavation;
◆ the reduced trench depth causes less subsidence, resulting in fewer repairs;
◆ the environmental effects of trench excavation is minimised as is the risk of any effect on ground water;
◆ operating and maintenance costs can be kept down by making the pipelines more accessible;
◆ co-ordination with piping systems like cables and district heating is made easier.

Design

General considerations

The depth of frost penetration is affected by climate and soil factors such as:

◆ ground water level;
◆ water saturation;
◆ soil composition;
◆ type of surface;
◆ drainage conditions;
◆ the heat stored in the soil;
◆ the heat provided by the running water.

Water supply and sewage pipes should be placed on a bed of 8 - 12mm filling material and covered with the same material to a depth of at least 100mm. There should be at least 650mm of fill above the insulation board, giving a total depth of 800mm above the pipes. Joints, valves and inspection chambers must be insulated as effectively as the rest of the pipe network.

Figure 24 Maximum frost index $F_{max}$ as per SMHI in Sweden during winters 1901/02 - 1975/76 h °C.
4. select the form of insulation
3. determine heat release from pipes;
2. determine frost depth;
1. determine climatic and soil factors;
2. Determine frost depth

The frost depth varies widely between different soil types, depending mainly on water content and thermal conductivity. Soils have therefore been divided into groups, with defined relationships. The frost depth is calculated on the basis of sand and gravel and the value for the actual soil type determined using the correction factor. The soil types and their correction factors are given in table 12. In shaft pits the frost depth is determined by the composition and quantity of the surrounding fill. In cases of uncertainty use the ‘stone’ soil type.

To determine the frost depth and design frost index:

◆ determine the necessary climatic factors. Consider frost hollows and the effect of radiation from the soil (table 11 and figure 24);
◆ determine the appropriate correction factor for the soil type;
◆ correct the frost index for pipes in snow-covered ground (figure 25);
◆ determine the frost depth for ‘sand and gravel’ soil, using figure 26. Then correct the frost depth with reference to the soil type;
◆ determine the frost index on the basis on the corrected frost depth;
◆ finally, consider any special geological conditions which may affect the result.

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Correction factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone - crushed stone and stony gravel</td>
<td>1.4</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>1.0</td>
</tr>
<tr>
<td>Silt (Clay, mixed soil, soil with high frost risk)</td>
<td>0.85 (0.7)</td>
</tr>
<tr>
<td>Soil very liable to freezing</td>
<td>0.5</td>
</tr>
<tr>
<td>Turf/ peat, bark</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Table 12 Correction factor to determine frost depth in different soil materials. Note that for clay there is a special dimensioning diagram, so that no correction need be made.
Determine the heat release from the pipes

The heat given off from the pipe network is extremely important for pipe protection. Although frost protection is intended primarily for water supply pipes it is beneficial to utilise the heat from water supply pipes and waste water pipes.

Electrical cables placed in a pipe trench also give off significant quantities of heat. Larger supply cables often cannot be placed under the insulation as the quantity of heat given off is too great, but even small cables provide useful additional heat.

Water pipes: the heat a smaller pipe gives off can be calculated using the formula:

\[
q = \frac{4190 \times Q \times V}{L}
\]

- \(q\) = heat given off in W/m
- \(Q\) = mean flow of water of pipe, averaged over 24 hours in l/s
- \(V\) = allowed temperature fall in °C
- \(L\) = length of pipe in metres

Waste water pipes: a waste water pipe is often the main heat source for protecting water supply and waste pipes from frost: it should therefore be placed near the water supply pipe. The average temperature of waste water is 15 - 25°C on in-take; there is normally no risk of it freezing. Just a small fraction of the surplus heat can be utilised as the waste water is in the pipes for a short time. If about 20 flats are connected and the flow of waste water fairly consistent a 3 - 5°C cooling should be expected.

The heat output can be calculated using the same formula as water supply pipes. For smaller waste water pipe, with fewer than 20 flats connected, the heat release can be determined in accordance with figure 27. A waste water service which has no flow still gives off heat, as a result of air being ventilated through the pipe; this assumes ventilation occurs over roofs and ceilings.

Figure 27 Heat release from smaller wastewater pipe de-aerated over roofs and with insulated well cover
Insulating water supply and waste pipes

Figure 28 Heat given off from a main cable as a function of the electrical load

Figure 29 Heat given off from a service cable as a function of the electrical load

Figure 30 Determination of insulation width and thickness for varying overburden, heat given off and frost quantity. Based on sand and gravel
Insulating water supply and waste pipes

electric cables: electric cables to electrically heated houses release a considerable amount of heat at maximum load, which is particularly useful in cold climate regions.

Larger supply cables normally give off so much heat they cannot be placed under the insulation, but by placing them alongside the insulation the heat given off is still utilised and reduces the frost load on the pipes. The heat given off by a cable under the insulation must not exceed 10 - 15 W/h, depending on the design of the insulation. Figures 28 and 29 show the heat given off as a function of load from main and service cables respectively.

surface/ storm water: surface water pipes are cold pipes and therefore at risk of freezing. Cold air passing through the surface water system can often contribute to frost formation within the pipe. The use of air locks can stop cold air being drawn into drains and so prevent cooling. A surface water drain should not be sited next to a water pipe without precautions such as box insulation.

heat cables: if the calculated pipe heat is insufficient or uncertain, e.g. in sparsely populated areas, it may be supplemented by a heating cable. The thermostatic control should be very sensitive with a minimum tolerance of +/- 0.5º.

Example: The frost quantity is 25000hºC, mean annual temperature 6ºC and minimum laying depth 0.8m. The heat output of the pipe is 5 W/m. Using the methods in this section the pipe requires a 1.2m width of 50mm thick insulation. If the calculation ignores the heat from the pipe the insulation must be 2m wide and 100mm thick. This illustrates the significance of the pipe heat for frost protection.

4. Select the form of insulation

Horseshoe shaped insulation makes effective use of the heat given off from the pipes and allows the width of the pipe trench to be reduced (figure 32). Higher vertical boards increase the effect of the insulation: 300 or 600mm high side insulation is recommended for ease of construction. Use figure 34 to establish insulation dimensions. If the pipes give off no heat the insulation effect per surface unit is the same as for horizontal insulation.

Box shaped insulation (figure 33) obtains the maximum benefit from pipe heat. It should not be used on ground liable to frost heave, as heave under the box can cause damage. The method is used most often for pipe trenches through rock.

Use figure 35 to establish insulation dimensions and bear in mind the following points:

- a small narrow insulation box gives the best insulation effect;
- place pipes with a cooling effect outside the box, e.g. surface water pipes;
- compensate for uneven pipe heat by having a larger insulation box - the sand filling will store the heat better.
Insulating water supply and waste pipes

Insulation thickness
- 50 mm
- 80 mm
- 120 mm
- or 2 x 50 mm

Z = distance from ground surface to culvert

Figure 34 Horseshoe shaped insulation, sand and gravel

Figure 35 Wide pipe trench in rock
**Insulating sports surfaces**

**Introduction**
Sports surfaces must be protected against frost to maintain the quality of the playing surface and to prevent the risk of unevenness and reduced bearing capacity during the thaw. The most effective way to do this is to use thermal insulation beneath the surface, rather than excavate and replace large quantities of substrate. Insulated tracks enable the season to be significantly extended. The spring sun will quickly thaw and dry out the surface layer so the season can start early. In the autumn a carefully built and well drained, insulated sports surface will be able to offer good conditions long after the frost has come. The long season is beneficial for users and maximises the return on investment.

The playing surface is the most important for users, and for artificial grass and synthetic materials it is also the most expensive item, it should therefore be protected from frost damage by effective insulation.

**The STYROFOAM Solution for insulating sports surfaces is SOLIMATE. SOLIMATE will meet the demanding requirements for sports surfaces. Full product data for SOLIMATE can be found in the STYROFOAM Product Data brochure.**

**Design**

**Drainage**
A high standard of drainage is one of the most important prerequisites for any sports arena, as the effectiveness of the drainage system influences both the length of season and the usefulness of the structure. The drainage system should be designed to match the amount of precipitation and the drainage coefficient of the track. Dense surface layers should be laid with a slope or surface channels and there should always be a dense system of drainage pipes in the ground (figures 36 and 37).

Drains should be formed at 4.0 - 6.0m centres and based on 300mm deep trenches with a 10% slope. The trench should be lined with a geotextile and the 75mm diameter plastic drainage pipes laid on a minimum 1:100 slope. The trench should be backfilled with compressed permeable material such as coarse dry sand (0 - 8mm diameter) with good filtering properties (figures 36 and 37). At the perimeter of the track the drainage pipes should be connected to a 100 - 150mm diameter primary, which in turn discharges into the main surface water drain.

**STYROFOAM Solutions**
STYROFOAM is the blue extruded polystyrene insulation from Dow. The extrusion process gives STYROFOAM its characteristic closed cell structure and key physical properties:

- low thermal conductivity - documented 50 year values;
- low water absorption by diffusion;
- high compressive strength;
- resistance to repeated freeze thaw cycles;
- resists mechanical and chemical damage during installation and use.

**Figure 36 Drainage and surface water system for football or sports fields**

**Figure 37 Principles of track drainage**
**Insulating sports surfaces**

**Superstructure**

The design of sports and football arenas should be similar to that of class III roads (figure 38). SOLIMATE 300 or SOLIMATE 400 should be laid in a single layer over the whole track, extending 0.5 - 1.0m beyond the edges. Use butt edged boards laid with a 5mm gap between them for drainage. At transitions to non-insulated areas extend a layer of thinner insulation for 2.0 - 3.0m. Form the superstructure with 250 - 350mm of well graded gravel or crushed stone.

**Installations with snow-melting equipment**

Electrical heating systems can be used to create facilities which can be used all year round. Insulation with SOLIMATE will ensure running costs are kept to a minimum.

**Artificial grass surfaces**

Artificial grass surfaces are popular as they offer good conditions for training and competition all year round (figure 39). Although installation costs are high, the operating cost per hour is low, as an artificial grass surface can replace up to 15 natural grass surfaces. The surfaces can work well with mechanical snow clearance, without the need for heating.

Artificial grass surfaces should be frost insulated with SOLIMATE topped with sand and two layers of asphalt (50 + 30mm). For further guidance consult the Local Authority Association.

**Athletics tracks**

Athletics tracks require greater standards of evenness and stability than football fields. They must therefore be frost insulated, level and well packed (figure 40).

The surface layers can be dense or porous, to allow water to drain through. The asphalt bed should be laid in two layers either dense or open to match the surface. Use 90 and 60 kg/m² asphalt to AB 12/8, laid in accordance with the supplier’s recommendations.

**Tennis courts and other ball games**

Surfaces for ball games may be built with gravel or artificial fibre surface: all good courts will require frost protection.

Artificial fibre surfaces are usually built to the same specification as athletics tracks, although the specifications for the surface and sub-surface are usually determined by the supplier or system constructor.

Gravel can give durable playing surfaces if materials are selected and laid carefully and properly maintained.

---

**Figure 38** Sketch for building up frost-secure football or sports areas with SOLIMATE

1. Playing surface
2. Sub surface
3. Bearing and reinforcement layer of well-graded gravel or crushed stone (minimum thickness 250mm)
4. Geotextile filter
5. SOLIMATE
6. Levelling drainage layer
7. Geotextile filter

**Figure 39** Sport areas for ball games

1. Artificial grass
2. Shock absorbent layer
3. Asphalt
4. Base course - sand
5. SOLIMATE
6. Levelling/ drainage layer
7. Ground
Artificial ice rinks

Artificial ice rinks are insulated to avoid frost heave, which can cause unevenness in the base, and to save energy. Planning and building an artificial ice rink is a complex task which it is not possible to describe fully here: consult the Local Authorities Association for further information.

The simplest artificial ice rink consists of a gravel layer with cooling pipes dug in and the associated cooling plant. To achieve improved performance and greater economic viability the following features are also desirable:

- frost insulation of the ground to avoid heavy frost heave and long-term unevenness;
- insulation to limit energy consumption, improve temperature control and speed ice laying/thawing;
- a track system suitable for other activities when the surface is not covered with ice.

STYROFOAM Solutions

STYROFOAM is the blue extruded polystyrene insulation from Dow. The extrusion process gives STYROFOAM its characteristic closed cell structure and key physical properties. The STYROFOAM Solutions for insulating ice rinks are SOLIMATE and FLOORMATE. SOLIMATE and FLOORMATE have:

- high long-term compressive strength (see SSEN 1606). This ensures the insulation is not damaged and does not deteriorate during installation or operation. High compressive strength allows the hall to be used for different functions;
- high resistance to repeated freeze/thaw cycles in damp environments (SSEN 12091);
- low water absorption by diffusion (SSEN 12088);
- 50 year values for thermal conductivity.

Full product data for SOLIMATE can be found in the STYROFOAM Product Data brochure.

Design

General

There are two main types of artificial ice rink:

A) permanent ice rinks operating all the year round. These systems are designed and run on the following principles:

- constant underheating;
- relatively small requirement for temperature control of the ice;
- temporary floors or other objects are placed over the ice, or the ice is removed.

B) multi-purpose rinks where the ice is laid for a limited period only, so the hall can be used for other purposes. These rinks should have slow thermal response. The superstructure above the cooling pipes should be kept to a minimum while the insulation should be as thick as practicable to reduce the freezing and thawing time. Asphalt may be used for the bearing surface, but the mechanical stresses in such multi-purpose halls are so great that concrete is usually a better solution. These rinks do not usually need underheating, but it may be built-in to improve long-term flexibility of use.
**Insulating sports surfaces**

**Insulation and heating coils**

Modern indoor rinks often have two pipe systems - cooling pipes and heating coils. Cooling pipes are needed to form and maintain the ice. However, these will also cool the ground beneath the rink, making the plant run less economically. There is also a risk of permafrost forming if the ground does not thaw while the rink is not in use.

Where the operating season exceeds six months heating coils must be installed beneath the slab to prevent the formation of permafrost. For rinks which operate for less than six months a layer of SOLIMATE or FLOORMATE will ensure the reduce the heat loss from the ground and prevent the formation of permafrost. A well insulated slab can also be thawed more quickly, enabling the rink to be used for other purposes. The use of SOLIMATE insulation will reduce the amount of earth which has to be removed.

---

Figure 41  Rink with asphalt surface for sport and variable use

- Ice
- 30 mm open asphalt
- Cooling pipes
- 50 mm open asphalt
- Base course
- FLOORMATE
- Any underheating
- Levelling and drainage layer
- Any fibre cloth
- Ground

Figure 42  Rinks for ball games/ athletics

- Ice
- Track with stone waste covering
- Cooling pipes in sand or drained asphalt
- Base course
- SOLIMATE
- Heating
- Levelling and drainage layer
- Geotextile filter
- Ground

Figure 43  Concrete rink on ground susceptible to frost, with underheating

- Ice
- Reinforced concrete slab
- Cooling pipes
- Sliding layer
- FLOORMATE
- Underheating pipes
- Levelling and drainage layer
- Any fibre cloth
- Ground

Figure 44  Concrete rink on insulated concrete slab

- Ice
- Reinforced concrete slab
- Cooling pipes
- 30 mm levelling concrete
- Slip plane
- FLOORMATE
- Membrane
- Heating pipes
- Re-inforced concrete slab
Introduction
The foundations, substructure and floors of unheated structures can be at risk of frost heave if the base layer is not kept frost free. The most effective way of reducing the risk of damage from frost heave is to insulate the ground beneath the structure and adjacent to it.

STYROFOAM Solutions
STYROFOAM is the blue extruded polystyrene insulation from Dow. The extrusion process gives STYROFOAM its characteristic closed cell structure and key physical properties:-
◆ low thermal conductivity - documented 50 year values;
◆ low water absorption by diffusion;
◆ high compressive strength;
◆ resistance to repeated freeze thaw cycles.

The STYROFOAM Solution for insulating unheated structures is SOLIMATE.
Full product data for SOLIMATE can be found in the STYROFOAM Product Data brochure.

Design
General
The advice and guidance in this section is based on more than 30 years’ experience of frost insulation with STYROFOAM. The guidance follows that in the New Building Regulations (NR) and ‘Frost in Soil and Building’ (research report R132:1983). However, the design and specification of individual projects remains the responsibility of the owner and his agent (e.g. architect, consultant or contractor).

Insulation thickness
The insulation must be thick enough to prevent the temperature in the sub-soil liable to freezing dropping below 0°C (figure 46). It must also prevent the layer between the insulation and the subsoil freezing.

The following information is required to calculate the insulation thickness:
◆ local frost index $F_{\text{max}}$ (figure 24, page 18);
◆ local mean annual temperature $t_m$ (table 11, page 19);
◆ the thickness of the drainage layer between the insulation and the subsoil;
◆ the thickness of the soil layer above the insulation.

![Figure 46](image-url)
**Insulating unheated structures**

**Frost index**: the frost index is a measure of the severity of winter conditions. The maximum frost index $F_{\text{max}}$ during the years 1901 to 1975/6 can be read from figure 24 on page 18. For constructions where a certain amount of frost heave is permissible the design may be based on the mean frost index, which is derived using the formula:

$$F_{\text{med}} = 0.75 \times (F_{\text{max}} - 11200) \, h^\circ \text{C}$$

The frost index should never be reduced to take account of any short periods of heating in normally unheated buildings as the heat transferred to the soil has only a marginal effect.

When evaluating the results be aware of local conditions which can create so-called frost hollows.

**Drainage layer**: the drainage layer beneath the insulation should be at least 0.1m thick. The drainage layer will always contain a certain amount of moisture, which has to freeze before the temperature of the layer can drop below 0°C. A thicker drainage layer therefore reduces the amount of insulation required.

**Soil layer above the insulation**: in freezing conditions the thermal resistance of the soil above the insulation depends mainly upon its moisture content: high moisture content reduces the thermal resistance.

Table 13 shows the thermal conductivity for common soil types when frozen; bracketed figures show values for high or low moisture content. The relatively poor thermal resistance of all soil types means there has to be at least 300mm of soil to have an effect on the required insulation thickness. The soil layer above the insulation should be of material not liable to frost attack.

**Calculating insulation thickness**: for projects with sand and gravel above the insulation read the insulation thickness $d_{\text{dim}}$ from the figure 47, using:

$$F = \text{design frost index;}$$
see figure 24 or the formula on page 31

$$t = \text{annual mean temperature;}$$
see table 11, page 19

For soil types other than sand and gravel, the value $d_1$ must be corrected using the formula:

$$d_1 = d_0 \times \frac{1.3}{\lambda_{\text{soil}}}$$

where

$$d_0 = \text{thickness of soil layer above insulation,}$$

and

$$\lambda_{\text{soil}} = \text{thermal conductivity given in table 13}$$

**Edge protection**

To prevent frost forming beneath the structure the insulation must be extended beyond its perimeter.

For foundations greater than 4m across, the edge protection should follow the pattern shown in figure 48, with the width, $b_1$ taken from table 14. Structural columns and walls within the building should be insulated in accordance with figure 49: they do not require edge protection if the floor is insulated.

For foundations less than 4m wide, as well as wall and column foundations, the edge protection should follow the patterns shown in figure 50 or 51, with the widths $b_2$ and $b_3$ taken from table 14.

The width of the edge protection may be reduced, to allow for the relevant frost depth (see figure 55), the thickness of the soil layer and the type of soil above the insulation. Where there is a risk of major frost heave in the surrounding soil there should be no reduction in the width of edge protection.

Table 13

<table>
<thead>
<tr>
<th>Soil type</th>
<th>$\lambda_{\text{soil}}$ W/mK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone - crushed stone (road metal)</td>
<td>1.0 (0.6 - 1.3)</td>
</tr>
<tr>
<td>Stony gravel</td>
<td>1.3 (0.7 - 1.8)</td>
</tr>
<tr>
<td>Sand and gravel</td>
<td>1.3 (1.7 - 1.8)</td>
</tr>
<tr>
<td>Silt</td>
<td>2.3 (1.7 - 2.8)</td>
</tr>
<tr>
<td>Clay and mixed soil</td>
<td>2.0 (1.6 - 2.4)</td>
</tr>
</tbody>
</table>

The thermal conductivity for frozen material.

The values in brackets for high or low moisture content in the material.
First, correct the frost depth, $h$, for the soil type;

$$h = h_0 \times k$$

where

$h_0$ = frost depth shown in figure 55

$k$ = soil type correction factor taken from table 15

Then, calculate the revised width of edge protection, $b_{red}$:

$$b_{red} = b \times (1 - (d_1/h))$$

where

$b$ = width of edge protection from table 14

d$_1$ = thickness of soil layer above the insulation

**Calculation example:**
a column foundation with a base depth $d_1 = 0.5$m is to be frost insulated to prevent frost heave in clayey moraine soil:

backfill material: moderately damp crushed stone

location: Sundsvall

thickness of drained layer, $d_2$: 0.1m

1) **Calculate the insulation thickness:**
from fig 24, (page 18) take the maximum frost index, $F_{max} = 38400h^\circ C$
from table 11 (page 19) take the mean annual temperature, $t_m = 3.9^\circ C$
the adjusted soil thickness, $d_{i1} = 0.5 \times (1.3/1.0) = 0.65$
from figure 47, read off the insulation thickness as 80mm.

2) **Calculate the width of edge protection:**
the required edge protection beyond the foundations, $b_3$, is taken from table 14. Straight-line interpolation gives:

$$b_3 = 1.5 + (2.25 - 1.5) \times 0.84$$

$$= 2.13m$$

3) **Reduce the width of edge protection for the base depth:**
from figure 55, frost depth, $h_0 = 1.9$m correction factor for clayey moraine from table 15 = 0.6

calculated frost depth, $h = 1.9 \times 0.6 = 1.14m$

reduced width, $b_{red} = 2.13 \times (1 - (0.5/1.14)) = 1.2m$

So the column foundation is insulated with 80mm of FLOORMATE, extending 1.2 from the structure, in accordance with figure 50 or 51.
Design details must provide unbroken insulation. Even quite small cold bridges allow heat losses from the soil, which may then freeze and heave. Follow the examples in Figures 48 to 54.
**Insulating unheated structures**

**Retaining walls, cellar walls, re-entrants**

Unheated structures which have differences of level must be protected against frost forming beneath the foundations and behind vertical surfaces. Such structures include:

- walls in unheated spaces bearing on ground vulnerable to frost;
- support walls;
- ramps.

**Protecting small structures**

There are many small structures that will benefit from frost protection, including:

- car ports;
- external stairways;
- large flower boxes;
- smaller water basins (empty);
- small sheds and playhouses;
- benches and toys.

Without frost protection they can be warped by frost, making them ugly and difficult to use. They must be protected from frost if they are joined to a building or other fixed structure.

The simplest method of frost protection is to place them on FLOORMATE immediately below ground level. The insulation thickness should be determined using the method on page 31.

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**Figure 52**  Frost protection of a retaining wall using FLOORMATE. Drainage provided by water permeable fill

**Figure 53**  Frost protection of a retaining wall using FLOORMATE. PERIMATE DI provides frost protection and drainage. $b_2$ shows the extent of ground insulation required to prevent frost heave on the upper edge

**Figure 54**  Frost protection of external staircase
Insulating unheated structures

Table 15

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Multiplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAVEL</td>
<td>1.7</td>
</tr>
<tr>
<td>dry stony block-like gravel; stone filling; packed stone filling; crushed stone.</td>
<td></td>
</tr>
<tr>
<td>SAND</td>
<td>1.2</td>
</tr>
<tr>
<td>stony block moraine; sandy gravelly moraine; sandy gravel; gravelly sand.</td>
<td></td>
</tr>
<tr>
<td>FINE SAND</td>
<td>1.0</td>
</tr>
<tr>
<td>Fine sandy ground moraine; moraine clay; sandy fine sand; fine sand-like sand.</td>
<td></td>
</tr>
<tr>
<td>CLAY</td>
<td>0.6</td>
</tr>
<tr>
<td>clayey moraine; fine sand-like sprinkler; fine sand; flour-like clay.</td>
<td></td>
</tr>
<tr>
<td>Soil highly liable to frost attack</td>
<td>0.5</td>
</tr>
<tr>
<td>Peat masses</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Frost depth $h_0$ in frost active soil

Frost depths apply to frost active friction soil or moraine for winters with high frost penetration. The values are based on the following assumptions:

- the ground surface is free of snow
- there is no vegetation cover
- no heat comes from buildings and pipes
- frost penetration is not hindered e.g. by ground water lying near the surface, or insulation
Handling and storage

STYROFOAM boards should be stored on a clean, flat surface in an area free from flammable or volatile materials. When large quantities of the boards are stored indoors, the building should be ventilated to allow a minimum of two air changes per hour.

When stored for long periods in the open, the boards should be protected from direct sunlight to avoid degradation. Light coloured plastic sheeting is a suitable protective cover.

Avoid dark materials as excessively high temperatures may develop beneath them. Solvent attack may occur if STYROFOAM boards are in direct contact with materials that contain volatile organic components e.g. solvents.

Care must be taken to protect the boards from flames and other sources of ignition during storage and installation.

Note

Recommendations about the methods, use of materials and construction details are given as a service to designers and contractors.

These are based on the experience of Dow with the use of STYROFOAM boards. Any drawings are meant only to illustrate various possible applications and should not be taken as a basis for design. Since Dow is a materials supplier and exercises no control over the installation of STYROFOAM boards, no responsibility is accepted for such drawings and recommendations.

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The site includes:
- on-line U-value calculator.
- downloadable design details.
- the latest case studies featuring STYROFOAM Solutions.

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The STYROFOAM Solutions CD is a complete guide to generating STYROFOAM Solutions.
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- all STYROFOAM Solutions information in an accessible screen format.
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Technical support
The Dow Technical Centre offers extensive technical support and consultancy advice for specifiers, including:
- guidance on insulation practice.
- detailed product application information.
- project specific U-value calculations and condensation risk analyses.

To consult the Technical Centre:
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