

The Role of Extruded Expanded Polystyrene in Ontario's Provincial Transportation System

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Frost action is an aggravating and costly problem in regions where highways are exposed to sub-zero temperatures for prolonged periods. Pavement distortion can create hazards for the driving public and contributes to the deterioration of the overall pavement structure. Special highway design and construction features are often required to deal with this problem. Such treatments have included drainage improvements to the pavement structure and excavation of frost-susceptible material. Because of the excessive frost penetration in northern Ontario, however, such treatments are not always practical. In 1966, the Ontario Ministry of Transportation and Communications began using expanded polystyrene to insulate the subgrade at frost heave sites. Traced in this paper is the work carried out by the Ministry to evaluate the effectiveness of polystyrene. The establishment of specifications and standards currently in use to control frost heaving are also discussed. Reference is made to the Ministry's site-selection criteria on minimizing the potential for pavement icing over insulated sections. The Ministry also uses expanded polystyrene to insulate sewer and water mains and to prevent differential heaving at critical installations such as truck weigh scales. Standard drawings are included that illustrate the installation details. The paper concludes by describing several special projects on which relatively large quantities of polystyrene were used to control frost heaving.

In areas where highways are subjected to extended periods of sub-zero temperatures, differential frost heaving is an aggravating and often costly problem for roadway agencies. It can create serious safety hazards for motorists and cause permanent pavement deformation. Prolonged heaving will adversely affect the performance of a pavement and may eventually threaten the integrity of the pavement structure. Utility crossings such as sewer and water mains, which are located within frost zones, are vulnerable to freezing if left unprotected.

Special roadway design and construction features are often needed to minimize the effects of frost heaving.

It is accepted that all roadways heave during the winter season. This would not necessarily be a significant problem if the magnitude of this movement was the same at all points. Unfortunately, inconsistencies in the composition of roadbed materials and inadequate transitions between different

materials such as earth and rock can lead to differential heaving. During construction a conscious effort is made to ensure that materials within each layer of the pavement structure, and in the subgrade directly underneath, are uniform. Standards have been developed so that the compaction efforts applied during the placing of these processed and native materials are consistent.

The three principal factors responsible for frost heaving include freezing temperatures, frost-susceptible soil, and a moisture supply at or near the freezing front. Obviously the latter two are the factors over which there is the most control. Nevertheless, they may still contribute significantly to differential heaving despite efforts to construct homogenous subgrades and provide uniform compaction.

Pockets of subbase and subgrade materials often include high concentrations of silt and fine sand, materials that have an affinity for moisture. The magnitude of the voids in silts and fine sands are such that water travels quickly and is attracted from relatively great distances to form the ice lenses that grow with increasing accumulations of moisture.

TREATMENT OF FROST HEAVES

Excavation

Weeks and months of prolonged freezing temperatures are common to many states and provinces, hence efforts are made to deal with one or both of the controllable factors that contribute to frost heaving. The principal method of treatment used by the Ministry of Transportation and Communications (MTC) before 1966, and one that continues to be implemented in many cases, was the removal of the frost-susceptible material by excavation. Figure 1 represents the provincial design standard for this treatment.

All frost heave sites are monitored annually in late winter and early spring until a rehabilitation project is carried out on the highway. The sites are then drilled during the summer with power equipment to determine types and depths of the native materials along with current moisture conditions. The design value for the depth of excavation, t , varies with the depth of frost penetration and is selected so as to remove as much of the frost-susceptible materials as possible, bearing in mind the amount of excavation involved and the fact that it must be properly drained. The value for t varies from 1.2 m in southern Ontario to 1.5 m in northern and northwestern Ontario.

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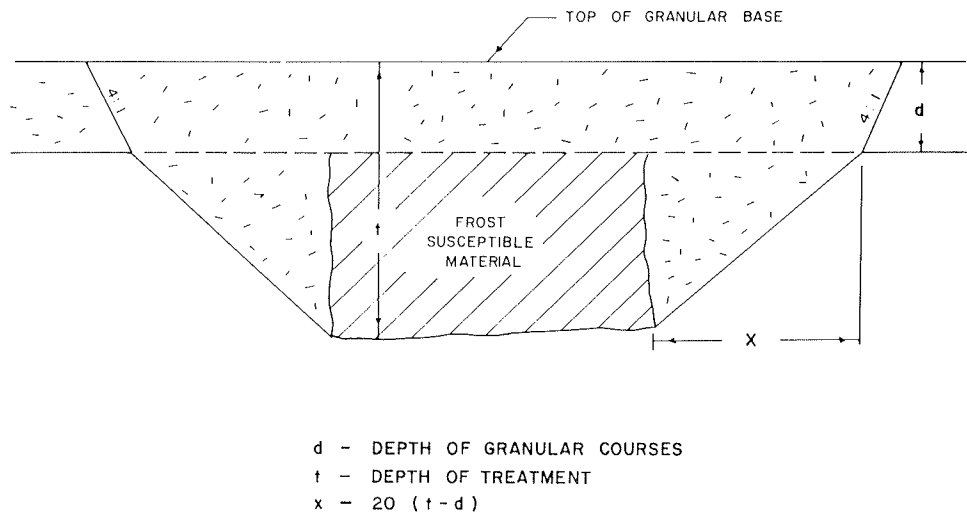


FIGURE 1 Excavation for treatment of frost heaves.

Drainage of the treated zone is influenced by the depth and efficiency of the highway ditch system. Side ditches are normally excavated to at least 0.5 m below subgrade level. The length of taper required for smooth transition into and out of treated areas is determined using the formula $x = 20 (t - d)$,

where

- x = length of taper,
- t = depth of treatment, and
- d = depth of granular courses.

Drainage

Frost heaves of low severity are often treated successfully by improving the drainage of the pavement structure. This can take the form of improved ditching or ditch cleanout, or the installation of perforated subdrains beneath the shoulder of the highway. The depth of the ditches or drains is, obviously, dependent on the availability of outlets to remove the collected water. Another factor that has a major bearing on the success of drainage is the presence of bedrock. Bedrock that is relatively close to the surface makes excavation, ditching, and the installation of drains difficult as well as expensive. Contract tender quantities for rock removal tend to be small and special equipment and expertise have to be brought to the site.

Insulation

Research into the use of expanded polystyrene began in the United States in the early 1960s (1). The first major research sites in Canada were established near Winnipeg, Manitoba, in 1962 and Sudbury, Ontario, in 1965 (2).

At the Sudbury site on Highway 69, seven frost heaves were treated with expanded polystyrene. The depths installed were 50 mm and 75 mm. Results obtained from these trials between 1966 and 1968 showed that with an average of 1,200 degree-days C, the 50 mm of insulation permitted frost to penetrate from 0.3 m to 0.8 m, whereas the 75-mm layer prevented virtually all frost penetration below the boards.

As a result of the Sudbury trials, the MTC proceeded to treat numerous frost heave sites with the intention of preventing differential vertical movement. It was discovered, however, that although the main heave was eliminated, bumps often developed at either end of the insulated area. This was attributed to the fact that the surrounding roadway was heaving more than the treated section. Through experimentation and performance evaluation, the MTC eventually revised its policy to one of providing for controlled heaving. This meant that the differential heaving would be reduced to the extent that any hazard to the motorist would be eliminated and driving discomfort would be minimal.

EARLY CRITERIA FOR HIGHWAY INSULATION

The thicknesses of expanded polystyrene used by the MTC in the early days of highway insulation depended primarily on the number of degree-days of frost at each site (Figures 2 and 3). The rule of thumb used was 25 mm of insulation for each 555 degree-days C to prevent any penetration. Through trial and observation, other variables such as the minimum depth of granular material required above the insulation boards were determined. Development of the appropriate taper lengths and configurations necessary to minimize the previously mentioned bumps was also carried out. Preliminary transition standards introduced by the insulation manufacturer detailed a decrease in thickness from 80 mm to 25 mm in two steps of 2.4 m and 4.8 m respectively (Figure 4). The boards were placed so that the ends of adjacent rows were staggered by 1.2 m.

To establish the most effective use of expanded polystyrene as a highway insulating agent, the MTC constructed a full-scale insulation research site in northern Ontario in 1972. It was hoped that solutions to specific problems involving current construction techniques and design standards could be formulated.

VAL GAGNE TEST SITE

Objectives

The research installation was established in cooperation with Dow Chemical of Canada, Ltd. (3, 4). The location of the

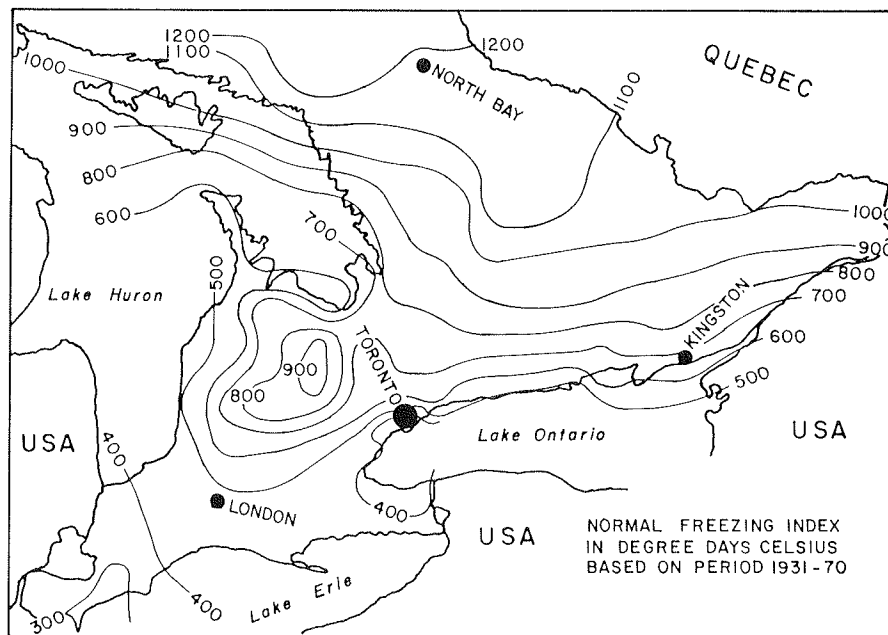


FIGURE 2 Freezing indices in southern Ontario.

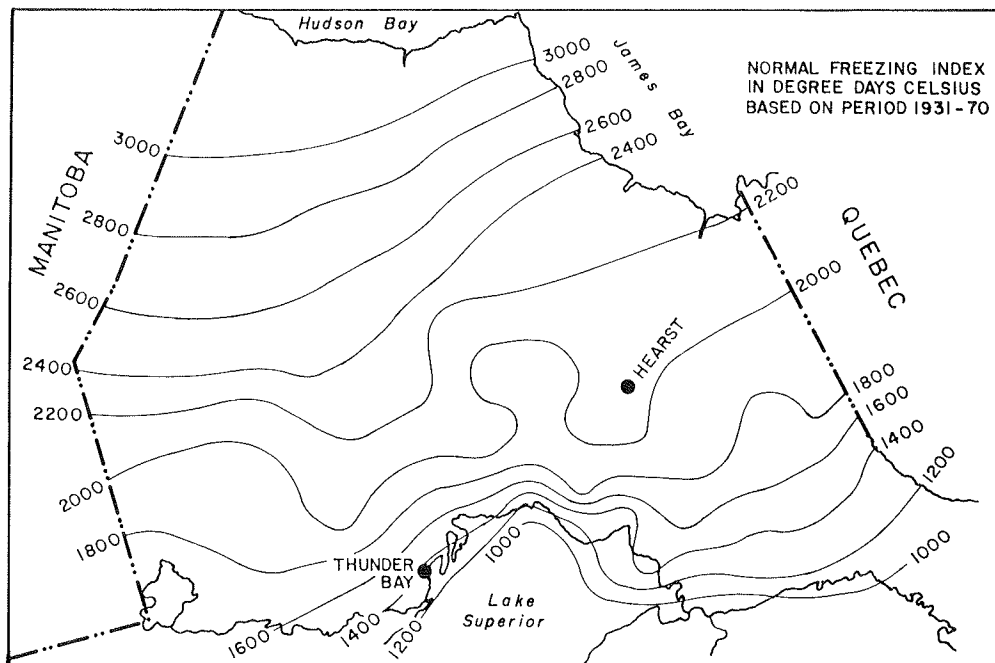


FIGURE 3 Freezing indices in northern Ontario.

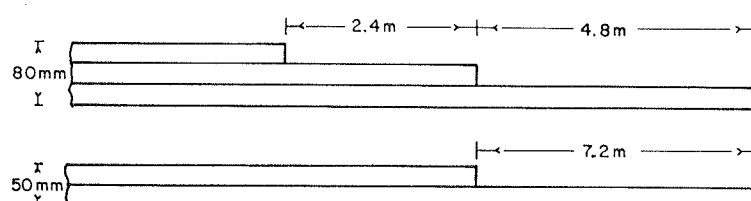


FIGURE 4 Early transition treatments for expanded polystyrene.

experimental site was at Val Gagne, 65 km south of Cochrane, Ontario.

Included in the basic objectives of the experiment were the following:

1. The development of a layout design to control the bump created at the transition from insulated to noninsulated sections,
2. The investigation of the depth of frost penetration below various thicknesses of insulation,
3. Investigation of the phenomenon of pavement icing over insulated sections,
4. Observation of thermal conditions at the edges of the insulation layer, and
5. Study of the durability of the polystyrene insulation boards.

Site Conditions

The Val Gagne area traditionally experiences severe winter weather with freezing indices of 1800 degree-days C or greater. Frost depth indicators have shown that penetration to a depth of 2.4 m to 3.0 m is common (4).

The section of highway chosen for the experiment was situated in a 1.2 m to 1.5 m cut. The native soil consisted principally of a silty clay, classified as CH under the Unified Soil Classification System or an A-7-6 by the AASHTO system.

Design and Construction

The experiment was designed to evaluate three different thicknesses of expanded polystyrene: 25 mm, 50 mm, and 75 mm. Trial areas were 29 m in length plus transitions. They were separated from each other by noninsulated control sections. The width of the insulation layers was extended 1.8 m beyond the edge of pavement.

The insulation boards were 2.4 m \times 0.6 m in size and tack-coated to the existing asphalt pavement with an emulsion. A 16.0 mm minus granular base material was end dumped and spread over the insulation to a depth of 450 mm with a small bulldozer. The entire site was then paved with 75 mm of asphaltic concrete.

Full site instrumentation was installed to measure ambient ground temperatures, frost penetration, and pavement heaving. Thermocouples and modified Swedish-designed frost depth indicators were used to monitor the first two variables and pavement movements were recorded by taking levels of nails embedded in the pavement. Details of the instrumentation schemes are described by Chisolm and Phang (4).

Results from Monitoring Data

During the winter months, temperatures above insulation are expected to be lower than those encountered below. The effect 50 mm of polystyrene had on the temperature regime within the roadbed for a typical Val Gagne winter is shown in Figure 5. Above the insulation, a maximum temperature of -40°C was recorded, whereas directly beneath the polystyrene the coldest temperature recorded was -3°C .

Frost penetration depths ranged from 1.0 m for 75 mm of polystyrene to 2.5 m for no insulation during the winter of 1975–1976. Frost penetration for all test sections over the 5-year monitoring period is summarized in Table 1.

The extent of frost heaving was significantly reduced with increasing thicknesses of insulation. The 50 mm and 75 mm thicknesses, illustrated in Figure 6, practically eliminated heaving at the site.

As stated in the objectives, it was intended to monitor the three test sections for icing. Because of the site location, however, only sporadic observations were possible and no further efforts were expended in this area. On a few occasions, a small amount of icing was noted.

Frost penetration measurements made transversely indicated that reducing the standard width of the insulation beyond the

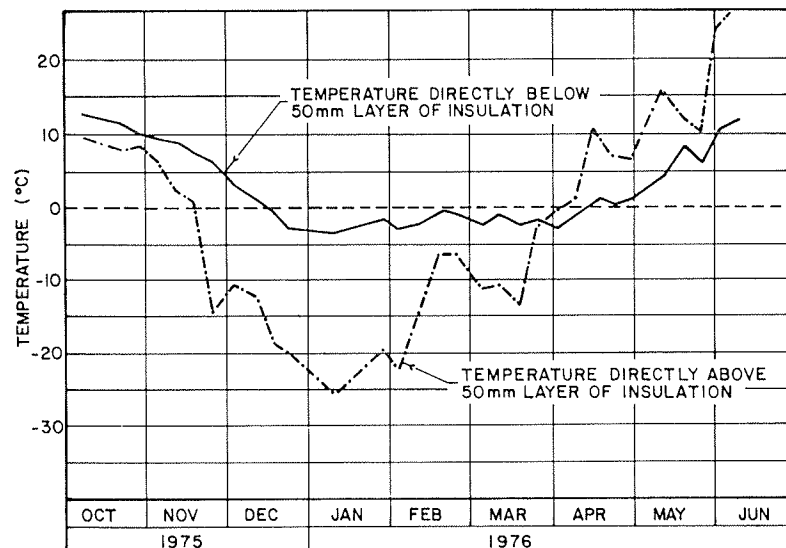


FIGURE 5 Temperature regime at test section containing 50-mm expanded polystyrene.

TABLE 1 AVERAGE FROST HEAVE AT CENTERLINE OF HIGHWAY

Section	1972-73	1973-74	1974-75	1975-76	1976-77
Control, no insulation	30	37	0	34	18
25 mm insulation	9	24	3	9	2
50 mm insulation	0	6	3	3	0
75 mm insulation	0	6	0	3	0

pavement edge from 1.8 m to 1.2 m would not substantially alter the lateral penetration profile.

Samples of the insulation board were recovered after 5 years and submitted to the laboratory for testing. The lab results are summarized in Table 2. Only the 25-mm thick sample exhibited a loss in thermal conductivity in the wet (field) state. The 50 mm and 75 mm samples showed negligible moisture pickup. Very little decrease in vertical compressive strength was observed in all samples.

Based on measurements made at the Val Gagne experimental site, a diagram of frost penetration versus thickness of insulation was created (Figure 7). This chart provides the designer with guidelines to determine the insulation thickness needed to control frost penetration and hence frost heaving.

MTC CRITERIA FOR HIGHWAY INSULATION

Selection of Insulation Sites

As mentioned at the outset, the excavation and backfill technique of treating moderate and severe frost heaves on Ontario highways is still in use. The decision to use this technique

is, however, based on several factors such as ease of drainage and potential for disruption to traffic flow. If the length of the area affected by the frost action is extensive, then polystyrene may be used to avoid excessive excavation of roadbed materials. Occasionally several frost heaves are encountered in close proximity. In this situation, the use of insulation often has a distinct economic advantage.

Frost heaving in highway cuts can be caused by high water tables. The obvious course of action would be to improve ditching; however this approach can be complicated because of impediments such as rock knobs within the ditch line, or the need to ditch through bedrock to obtain a suitable outlet.

Frost heaving is common at transitions between earth and rock fill, or at the limits of rock cuts. Expanded polystyrene becomes a viable option for treatment to avoid costly and difficult removal of roadbed materials. This option also minimizes disruption to motorists where traffic movement must be maintained.

In northern Ontario, highways cross numerous deposits of swamp and muskeg that may be many meters deep. In order to minimize long-term settlements of the roadbed, the designer must keep the profile of the pavement as low as possible to

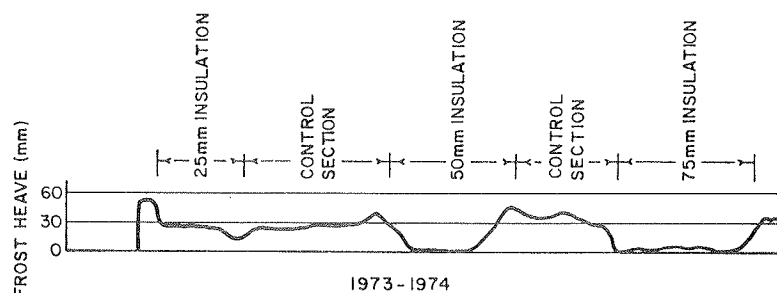


FIGURE 6 Frost heaving at Val Gagne test site.

TABLE 2 LABORATORY TEST RESULTS OF SALVAGED EXPANDED POLYSTYRENE

Test Section	'K' Factor (wet)	'K' Factor (dry)	Water Content % By Volume	Vertical Compressive Strength	
	ASTM C-518	ASTM C-518		@ 5% Defl.	@ 10% Defl.
	$\frac{W}{m^2 \cdot ^\circ C}$	$\frac{W}{m^2 \cdot ^\circ C}$		kPa	Kpa
25 mm Thickness	1.329	1.203	3.95	291.7	337.9
50 mm Thickness	1.260	1.203	1.29	519.2	577.8
75 mm Thickness	1.243	1.197	0.93	344.1	344.1

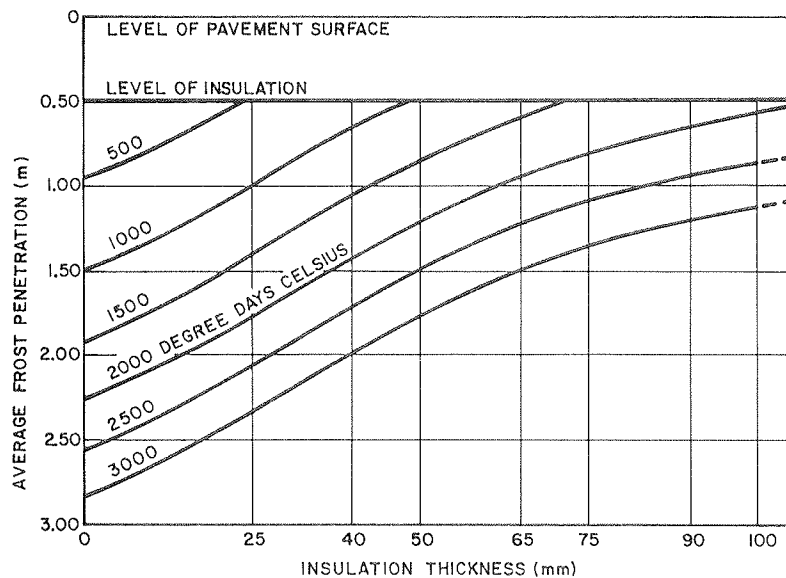


FIGURE 7 Design guidelines for selection of insulation thickness.

avoid overloading the sensitive subgrade. Drainage of the roadbed, however, can become a concern especially if the water table is at or near the surface of the swamp. The efficiency of standard highway ditches is substantially reduced as provision of outlets is difficult.

Because of the extensive penetration of frost in this part of the province, severe differential heaving of the roadbed can take place over swamps and muskeg. This differential heaving often results in cracks that develop roughly parallel to the centerline (Figure 8). They can occur at the centerline or anywhere within the pavement surface. Cracks up to 100 mm in width have even appeared within the granular shoulder.

The formation of these severe cracks is accentuated by the fact that the outer shoulder areas and side slopes are covered with snow during the winter. This deep cover of snow acts as



FIGURE 8 Cracking due to frost heaving in swamp.

insulation and prevents the frost from penetrating as deeply as it does beneath the cleared travelled portion of the highway. This is shown in Figure 9 (5). The resultant heaving thus creates a "broken back" type of movement in the roadbed and the stresses induced in the bituminous surface literally cause the pavement to split in a longitudinal direction.

This phenomenon had for years repeated itself in a section of Highway 17 that crosses an area known as the Raith Swamp, some 100 km west of Thunder Bay. The cracks along the centerline opened up each year to widths in excess of 200 mm, thus presenting a serious traffic hazard. Several remedial treatments were attempted over the years with little success. A trial area was established in which a 2.6-mm gauge wire mesh was embedded in the asphalt, but the extreme forces generated in the expanding pavement caused the mesh to rupture.

In 1977, a short reconstruction contract was carried out and experimental sections using polystyrene were included in the project to evaluate its effectiveness in controlling the serious heaving experienced in this area (5). Two 150-m test sections were established in which 50 mm and 80 mm thicknesses of expanded polystyrene were used to insulate the roadway. The insulation was placed within the subbase layer and covered with a total of 600 mm of granular base course and 50-mm hot mix.

After 2 years of detailed monitoring, the serious longitudinal cracking and stepped transverse cracking previously found at this site had not recurred, whereas extensive patching was required in the noninsulated section. It was also noted that the overall pavement performance was quite similar in both the 50 mm and 80 mm trials.

Since the experiment, a total of 740,900 board ft of expanded polystyrene have been placed in two contracts over the Raith Swamp, effectively eliminating the serious heaving problem.

Standard Treatment

From the results of the Val Gagne trials and observations of the performance of numerous subsequent installations, a set of

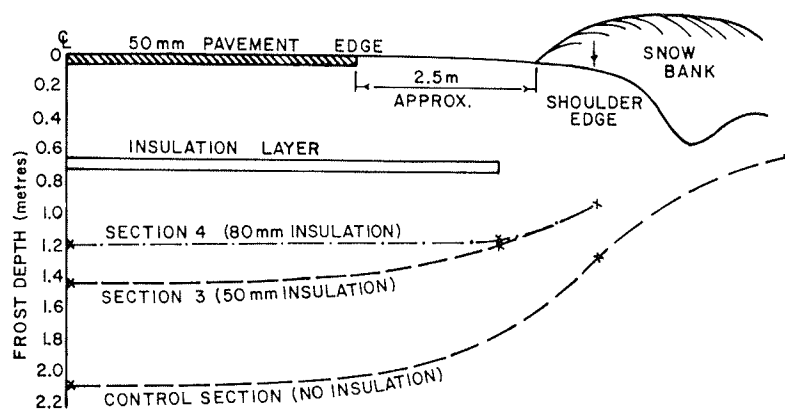


FIGURE 9 Effect of snow cover on frost penetration.

MTC standard drawings has been developed for expanded polystyrene installations on Ontario highways. Shown in Figure 10 is the layout for a single 25 or 40 mm layer of insulation (6). Experience has shown that the "saw tooth" configuration at the ends of the treatment has been most effective in preventing the formation of bumps in the transition zones.

The insulation is extended beyond the edge of pavement a distance of 1.8 m, or that equivalent to the shoulder width, whichever is less. The polystyrene can be placed in the roadbed using excavation and backfill construction. This design suits conditions where raising the profile grade of the roadway is undesirable (Figures 11 and 12). The boards are placed at the bottom of the excavation and held in place with wooden skewers. Alternatively, several shovels of granular material can be placed on each board to prevent it from shifting or being

blown about. If more than one layer of insulation is applied, succeeding layers are placed so that they cover the joints in the layer immediately underneath (7).

Where it is more economical, the insulation boards can be placed directly on the existing pavement and covered with a granular lift. In order to provide maximum protection for the insulation, the compacted granular cover should be no less than 300 mm in depth.

Selection of Insulation Thickness

When the MTC began using expanded polystyrene to treat frost heaves, the intent was to eliminate any frost penetration, hence relatively thick layers of insulation were used. It was common to place anywhere from 75 mm to 100 mm polystyrene on

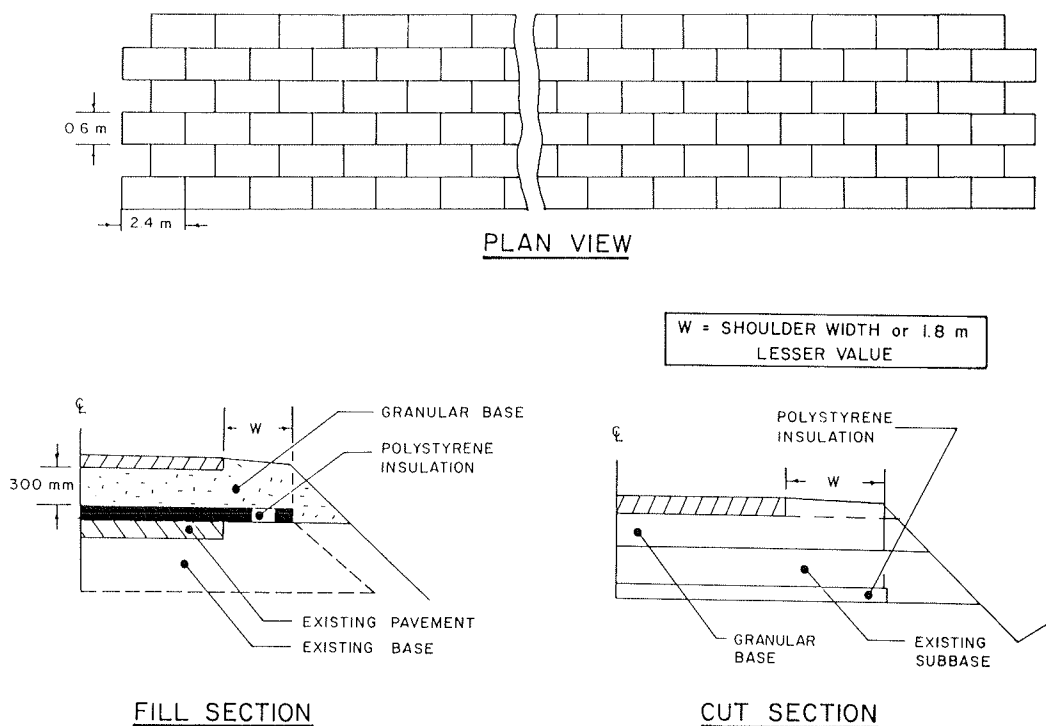


FIGURE 10 Use of expanded polystyrene for frost heave treatment.

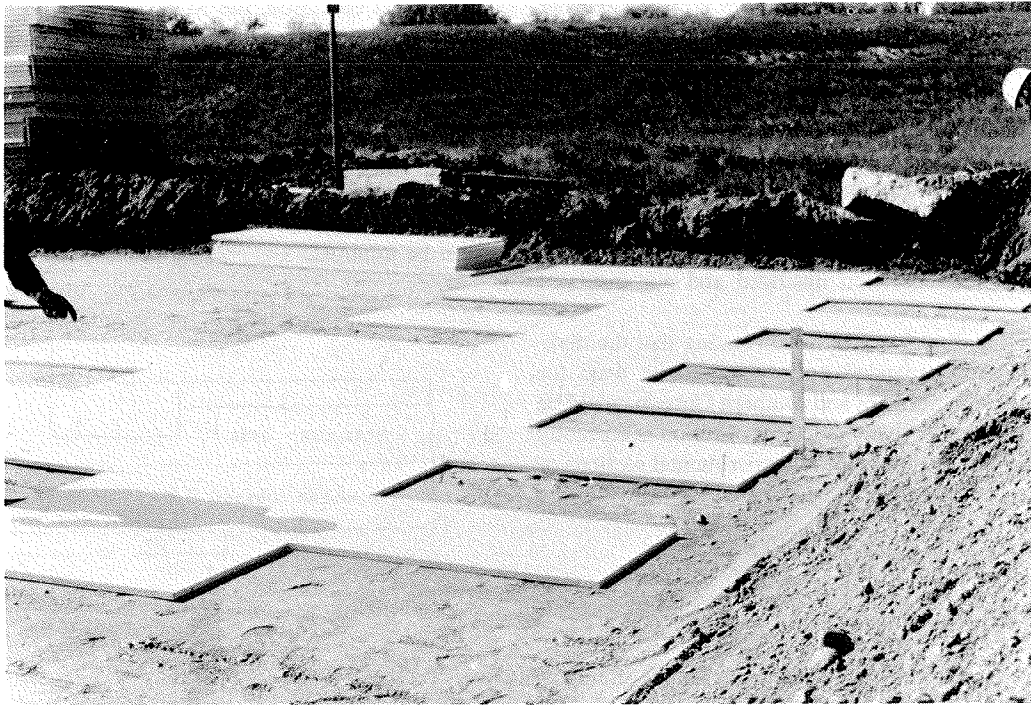


FIGURE 11 Placement of insulation boards at end of treated area.



FIGURE 12 Frost heave treatment using expanded polystyrene.

highways located in northern Ontario in an effort to prevent heaving (8).

As MTC's experience with frost action and insulation increased and it became apparent that all roads heaved to a certain degree during the winter months, the philosophy of preventing frost heaving gradually changed to one of controlling frost heaving by permitting some frost penetration. This would provide for a tolerable ride over the frost heave area and greatly reduce the severity of any bumps that might develop in the zones of transition between insulated and non-insulated roadbed.

In 1978, a policy directive was issued stating that the maximum thicknesses of expanded polystyrene to be used for treating frost heaves in northern and southern Ontario would be 40 mm and 25 mm respectively (9). This criterion is currently being adhered to in Ontario except for experimental sections or applications such as weigh-scale sites where very little heaving can be tolerated.

Insulation of Utilities

Protection of sewer and water mains from freezing is an important consideration in the design of such systems. Ideally, the lines are located below the maximum frost penetration limit; however, this may not always be possible. Locating the mains below the frost line could involve excavations up to 3.0 m in depth in northern Ontario. Excavating trenches through rock is very expensive and difficult and high water tables may necessitate locating the lines close to the ground surface. The protective covering over mains may be reduced if road profile grades require lowering during reconstruction of streets.

A cost-saving alternative is to insulate the main with expanded polystyrene. Illustrated in Figure 13 is a typical design used by the MTC in the town of Geraldton where the water table was unusually high. The freezing index for this area is approximately 2,000 degree-days C. Native soil is used for backfill between the insulation covering and the pavement structure to maintain uniformity within the subgrade. The width and height of the polystyrene installation is dependent on the diameter of the main. Sufficient clearance must be allowed between the pipe and the insulation for proper placement and compaction of the backfill.

Pipeline crossings present a slightly different problem with respect to frost heaving. Because the contents in the pipeline are usually warm, the material surrounding the pipe does not experience the same degree of freezing as that at a greater distance. A situation is thus created where a dip in the road surface occurs caused by heaving away from the pipe.

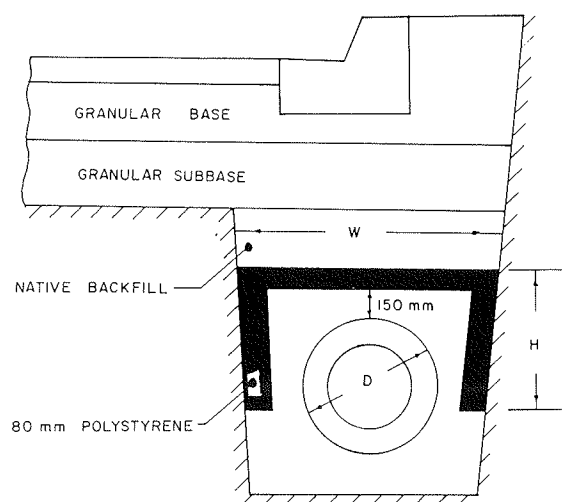
On several occasions pipelines have been boxed in with polystyrene boards, thus preventing heat loss into the surrounding backfill material, and modifying the differential vertical movement.

Weigh Scale Sites

The MTC is responsible for regulation of the trucking industry in the province of Ontario. In order to monitor excessive loading and to ensure that commercial vehicles are in sound

mechanical condition, the MTC operates 48 truck inspection stations throughout the province.

These sites are located adjacent to the highways and consist basically of an underground scale, scale house, and paved parking area. It is crucial that these scales operate accurately at all times. The differential in vertical movement between the concrete approach slabs and the scale platform should be kept to a minimum. The overall heaving of all these components must be minimal.



D (mm)	W (m)	H (m)
600 AND LESS	1.2	0.6
675 / 750	1.5	0.6
840	1.5	0.9
900 & GREATER	1.8	0.9

FIGURE 13 Expanded polystyrene insulation for sewers and water mains.

Expanded polystyrene is placed at all truck inspection stations, as shown in Figure 14, to control heaving because of frost action. The standard thickness employed in Ontario is 75 mm. The insulation is placed below the approach slabs and the scale pit and is extended outward to protect the asphalt driving lane and parking area.

Pavement Icing

A phenomenon associated with highway insulation is the occasional occurrence of pavement icing above treated areas (5). The principal cause of pavement icing is the trapping of ground heat beneath the insulation. The pavement is hence somewhat cooler than that in noninsulated sections, where it tends to be warmer due to the latent ground heat.

Under certain conditions of high humidity, or if rain or snow is present, ice may form on the cold surface and present a

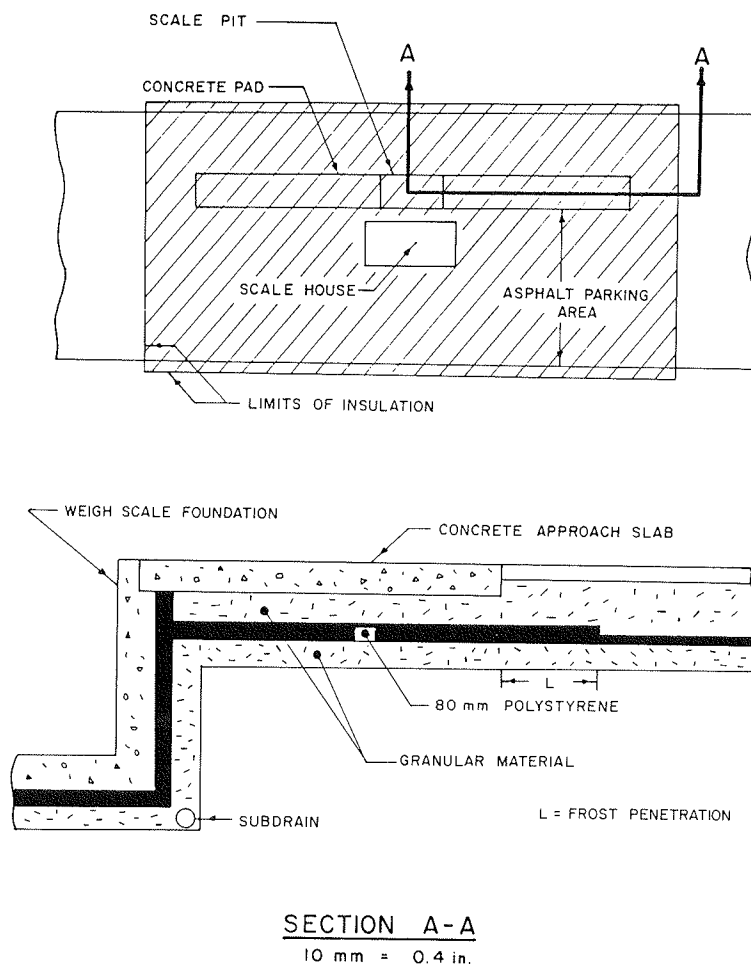


FIGURE 14 Expanded polystyrene insulation at weigh scale.

potential hazard to the motorist. The possibility of ice formation increases with the thickness of the insulation layer. It has also been noted that the closer the polystyrene is to the roadway surface, the greater the possibility of icing.

In northern Ontario where the bulk of expanded polystyrene has been placed, temperatures tend to be consistently cold all winter, so pavement icing has not been a serious problem. District maintenance staff, nevertheless, give the same attention to sections of insulated highways as they do to all other areas to ensure that adequate sanding is carried out should icing occur.

In the interests of safety, MTC policy (9) dictates that expanded polystyrene will not be used for treatment of frost heaves where a demand for increased traction or braking is foreseen. Such sites include horizontal curves, crests of hills, intersections, and railway crossings.

USE OF EXPANDED POLYSTYRENE IN ONTARIO

Since the introduction of expanded polystyrene to Ontario in 1966, the technique of controlling frost heaving in the highway system has been implemented on a continuing basis.

The bulk of the polystyrene used has been placed in the northern and northwestern regions of the province, although the number of rehabilitation projects containing expanded polystyrene on an annual basis has declined somewhat since the late 1970s. In recent years, insulation has been applied on fewer jobs, albeit in larger quantities per project. Some of these specific uses are described later in this report.

In the late 1960s, the MTC was using up to 1.5 million board ft each year. By 1972, there were approximately 300 frost heave sites containing insulation (8). Quantities used in the northwestern region alone are summarized in Table 3. Since 1981, the application of expanded polystyrene in Ontario highways has been as follows:

Year	Expanded Polystyrene (board ft)
1981	1,650,000
1982	2,400,000
1983	1,575,000
1984	1,380,000
1985	2,244,700
1986	362,500

Since 1983, the number of installations has dropped significantly. The total amount of polystyrene used in 1984 and 1985

TABLE 3 ANNUAL USE OF EXPANDED POLYSTYRENE INSULATION IN NORTHWESTERN REGION

YEAR	BOARD-FEET OF INSULATION USED	YEAR	BOARD-FEET OF INSULATION USED
1966	31,500	1976	19,200
1967	19,000	1977	198,020
1969	620,700	1980	19,700
1970	193,900	1981	87,600
1971	400,000	1982	5,500
1972	282,000	1983	4,600
1973	133,500	1984	673,000
1974	276,300	1985	7,400
1975	30,300	1986	18,300

was high mainly because of certain projects on which large quantities were usually placed.

By the end of the 1986 construction season, the MTC will have installed in excess of 15,000,000 board ft of expanded polystyrene on Ontario highways.

SPECIAL APPLICATIONS

Highway 417: Ottawa

In 1976, an MTC contract was awarded for construction of a section of a four-lane rural highway approximately 10 km west of the city of Ottawa. Because of potential noise problems for a new subdivision development adjacent to the right-of-way, it was required that the grade be depressed some 3.0 to 4.0 m below the original ground line. The depressed grade crossed 600 m of a poorly drained area where the native soil consisted of a wet, sensitive Leda clay. Because of complications in transporting and disposing of approximately 153,000 m³ of this wet material, it was decided to treat the clay with hydrated lime and use it to construct adjacent embankments (10). Construction was completed in 1977.

During the winter of 1978, the Ottawa area experienced a brief period of unusually mild weather with rain. When temperatures returned to normal, the pavement over the embankments distorted dramatically, so much so that the outside driving lanes had to be closed to traffic. Subsequent investigations revealed that the addition of 2 percent lime had apparently changed the clay to a more friable silt type of material, which heaved when inundated with moisture.

Initial attempts to control the severe heaving included placing subdrains below the shoulder, cold-planing the most severely distorted areas, and waterproofing the shoulders.

Although the situation improved somewhat, further treatment was warranted. In 1984, it was decided to blanket the main lanes and paved shoulders with insulation. A total of 219,600 board ft of 25-mm expanded polystyrene was placed directly on the existing pavement and covered with 300 mm of

granular base plus 110-mm asphalt concrete. A high-density insulation board having a compressive strength of 410 kPa was used in this case. The 1985 annual average daily traffic (AADT) for this section of highway was 18,000, with 19 percent made up of commercial vehicles.

Since the installation of the polystyrene, pavement performance during the spring has been satisfactory. Plans are underway to extend the treatment into other affected areas.

GO-ALRT TRANSIT LINE

In 1985, the MTC began construction of the rail bed for a light rail transit line intended to transport commuters between the city of Toronto and neighboring towns to the east.

The type of transit car under design was relatively new to the MTC, hence a plan was developed to provide a zero-maintenance design for the facility.

Construction of the subgrade involved excavation of several cuts, which consisted of soils containing a relatively high percentage of silt. It was decided to place expanded polystyrene insulation within the ballast layer to minimize heaving of the guideway during winter and to avoid unnecessary shutdowns of the system for maintenance purposes.

A total of 1,125,000 board ft of polystyrene was installed over the section between Pickering and Oshawa in 1985 (Figure 15). The 40-mm layer of insulation was located at approximately the midpoint of the 420-mm thick subballast layer.

Within the above section, a test area was established to evaluate the effectiveness of various thicknesses of expanded polystyrene used for this purpose. To date, initial monitoring data has not been processed; however, general observations have revealed very little difference in performance among the trials.

Lightweight Backfill to Structure

Settlement of embankments over unstable soils or at structure approaches is a serious concern to the highway engineer.

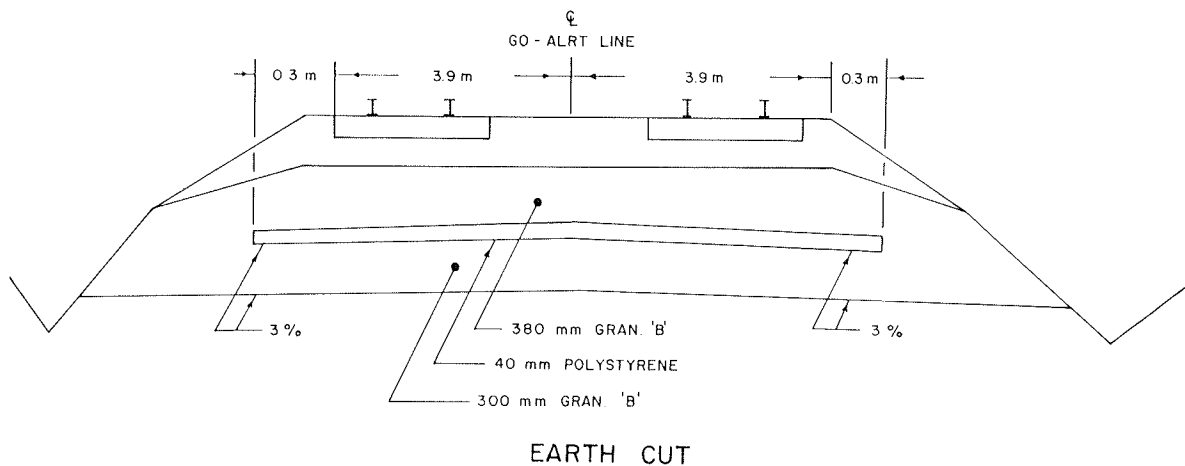


FIGURE 15 Insulation of rapid transit rail line.

Although attempts are made to maintain low profiles over swampy terrain, long-term settlements are often unavoidable, especially where organic deposits are many meters deep and cannot be economically excavated and replaced with suitable materials.

In recent years the use of various types of lightweight fill materials has become quite common. Expanded polystyrene has been promoted and used successfully for this purpose, primarily as an integral part of bridge approaches. Its light weight makes it easy to handle and engineering properties such as high strength and low moisture absorption are conducive to its use in this way.

Recently it was noted that the abutments at an MTC bridge on the Buskegau River in northern Ontario were slowly moving inwards. It was concluded that this movement was caused by pressure from the backfill to the structure. In 1984, a decision was made to remove a portion of the existing backfill at each approach and replace it with expanded polystyrene.

The insulation boards were tied together to form $2.4 \text{ m} \times 0.6 \text{ m}$ bundles and placed behind the abutments, as shown in Figure 16. In each layer the bundles were laid at right angles to those below. The polystyrene was then covered with two layers of 6-mm polyethylene sheeting, followed by granular material compacted in 225-mm lifts.

The structure will be closely monitored to see if the treatment described has been successful in stabilizing the abutments.

CONCLUSIONS

The heaving of pavements is an expected phenomenon in geographical regions that experience prolonged periods of freezing temperatures. It is therefore important during the design and construction of highway pavement structures to attempt to provide uniformity of materials in the roadbed.

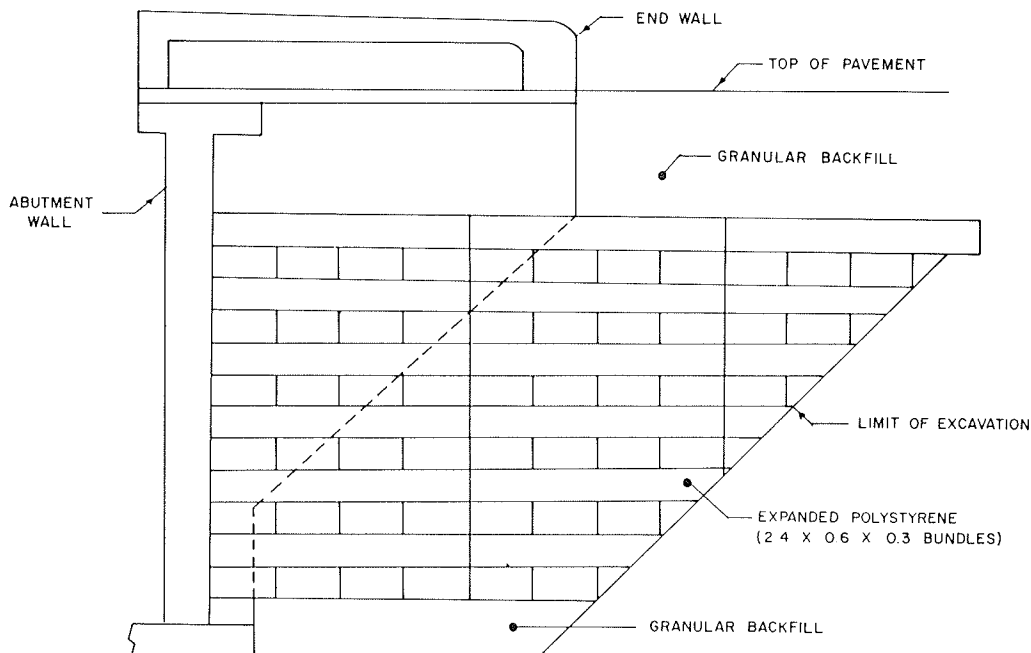


FIGURE 16 Use of expanded polystyrene as lightweight fill at structure.

Because of varying textures of subgrade soils and non-uniform moisture contents in these soils, differential frost heaving does occur. If this differential movement is severe enough, potential hazards can be created for the motorist and long-term performance of the pavement itself will be adversely affected.

The MTC has always depended on conventional treatments such as excavation and backfill, and subsurface drainage to abate the effects of frost heaving. These efforts have generally been successful; however, they are not always feasible in regions where frost can penetrate up to 3.0 m in depth.

Experiments carried out by the MTC have shown that expanded polystyrene insulation can be an effective tool in alleviating the problems created by differential heaving. Test results have indicated that 80 mm of polystyrene will effectively prevent frost penetration into the subgrade in areas where the freezing index can reach 1,800 degree-days C.

At the transitions between insulated and non-insulated pavements, staggering the ends of the polystyrene boards by 1.2 m has been shown to be effective in minimizing the formation of bumps caused by abrupt changes in the amount of heaving.

On reviewing its early experience with expanded polystyrene as an insulating agent, the MTC adopted a design philosophy of controlled frost heaving as opposed to the elimination of frost penetration. This approach provides a tolerable ride for the travelling public and at the same time minimizes the potential for pavement icing. To achieve this aim, MTC policy has been established to restrict the maximum thicknesses of polystyrene in installations designed to control frost heaves to 40 mm and 25 mm for northern and southern Ontario respectively.

Recognizing that icing of pavements placed over highway insulation is possible, the MTC has prohibited the use of expanded polystyrene in locations where traction and braking requirements are critical. These sites include horizontal curves, crests of hills, intersections, and railway crossings.

To date, extensive use of insulation boards has been the only major effort to prove successful in preventing damage due to heaving in pavements that are constructed over swamps having high water tables.

The provision of a comfortable and safe driving surface is the principal goal of any roadway agency. The Ontario MTC has adopted the use of expanded polystyrene as a significant tool in its efforts to achieve this goal over the past 20 years. It

will continue to be an important feature of the province's construction and maintenance programs.

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