Evaluation of Frost Action Mitigation Procedures for Highly Frost-Susceptible Soils

Michael H. MacKay, David K. Hein, and John J. Emery

For areas of Ontario with significant frost penetration (more than 1.5 m) and frost-susceptible soils (silty sands to clayey silts) in the presence of moisture, significant pavement damage can result from both frost heaving and subsequent spring breakup. This frost-related flexible pavement damage is particularly acute in areas of variable soil and groundwater conditions. This is especially true with shallow, rapidly changing depths to bedrock that "trap" pockets of poor soils. The observation of pavement distresses in such circumstances, and experience with cost-effective frost action mitigation, is valuable in developing geotechnical evaluation techniques and practical pavement designs for such areas. The principal distress of severe wheelpath alligator cracking, its associated deformations, and residual frost heave are related to poor drainage (high groundwater or lack of drainage provisions) and poor loadcarrying characteristics and frost susceptibility of silty subgrades. Nonuniform pavement structure and subgrade support conditions because of utility installations also contribute to distress. Removing the frost-susceptible subsoils and replacing them with granular material and better drainage will eliminate most frost-related movements. But this is generally too costly. A less costly and fairly effective frost action mitigation approach, if properly constructed with approved materials, is the use of full or partial granular frost tapers in conjunction with deep drainage (typically in conjunction with utility installation in urban areas) or insulation using extruded expanded polystyrene. Overall examples of this approach from actual in-service pavements in the Muskokas area of north-central Ontario are presented.

Experience has indicated that the special design and construction features required to mitigate pavement damage due to frost action can result in significantly higher road construction and rehabilitation costs when compared to standard construction. If frost action is not controlled, permanent pavement deformation, damage to utilities and overall poor road performance will result in escalated and untimely pavement rehabilitation. A standard flexible pavement constructed in non-frost-susceptible conditions could anticipate a normal service life of 12 to 15 years. The same pavement structure could require major maintenance within 5 years when constructed in an area in which frost-susceptible subgrades are a problem.

The two principal damage effects of frost action in roadways are the reduction of subgrade support strength during the spring thawing period and differential frost heaving. The effect of reduced spring subgrade support can easily be minimized by ensuring that the pavement has adequate structural capacity to withstand the vehicle loadings, or by reducing the allowable load during this period (seasonal load restrictions).

John Emery Geotechnical Engineering Ltd., 52 Ashwarren Road, Downsview, Ontario, Canada M3J 1Z5.

The cost of providing adequate structural capacity may be prohibitive and must be weighed against the practicability of applying load restrictions (usually not enforceable in an urban environment). However, the structural capacity of a pavement can be readily improved through the selection of materials or by adopting standard construction techniques.

Differential frost heaving, caused by the formation of ice lenses and ice within the soil matrix immediately below the pavement structure, represents the most damaging effect of frost action on a pavement. For frost heaving to occur, the soil must be frost-susceptible, the temperature of the soil must be at or near freezing, and enough water must be present. Absence of any one of these features will prevent frost action from occurring.

Complete elimination of frost action requires removal of the frost-susceptible soils or water source. These are usually not practical options from a cost viewpoint, nor are they necessary, because the effects of frost action may be mitigated to tolerable limits by any or a combination of several treatment alternatives.

Frost action mitigation implies that the inevitable frost action is controlled to a satisfactory degree and that pavement serviceability is maintained by the most practical and cost-effective method.

The combined poor subsoil conditions (generally highly frost susceptible, variable subgrade soils with bedrock at or near surface to very deep over very short distances), high water table, and relatively long winters with a number of frost cycles result in extreme climatic and environmental impacts on the rural and urban pavements in many areas of Ontario and the rest of Canada. Standard pavement sections, designed and constructed in accordance with, for example, Ministry of Transportation of Ontario (MTO) guidelines, to eliminate the effects of frost action have performed unsatisfactorily in many cases or are too costly for many lower-tier municipal road agencies that must supplement funding received from the province on a one-for-one basis.

Over the past several years, several frost action mitigation procedures have been developed and implemented in the District Municipality of Muskoka to control, not eliminate, frost action. Subsequently, a demonstration project jointly sponsored by the Ontario Good Roads Association (OGRA) and MTO has been undertaken by the District Municipality of Muskoka to document the performance of these frost action mitigation measures and to construct trial sections using the most favorable methods for full performance monitoring and

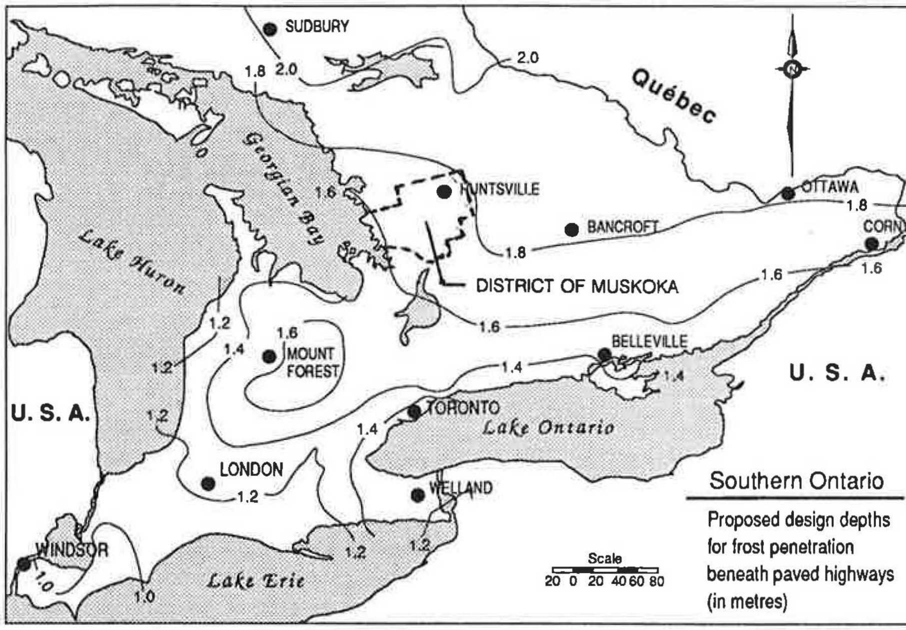


FIGURE 1 Key map showing frost penetration depths (*1*).

cost-benefit analysis. The project will assist in the development of new standards for rural and urban roads in areas of severe frost action. These trial sections are currently in the design stage as part of a conventional road improvement project scheduled for construction in 1992.

BACKGROUND

The District Municipality of Muskoka is a typical north-central Ontario jurisdiction. Located only about 150 km north of Toronto and immediately east of Georgian Bay, the district encompasses a large geographic area of about 460,000 hectares that includes about 1200 lane-km of arterial, collector, and local collector roadways (almost all two-lane flexible pavements). A popular tourist area for its recreational activities, the permanent population of about 40,000 residents increases seasonally to at least 140,000 residents during summer (and is significantly greater than this when campers and nonresident visitors are included).

Climatological data for the area are readily obtained from published Environment Canada, MTO, and Ontario Ministry of the Environment reports. Figure 1 shows the mean frost penetration depths in southern Ontario, with Table 1 presenting the key climatological conditions in the Muskokas with the metropolitan Toronto area.

The Muskoka area has the highest mean annual precipitation in southern Ontario, which includes the highest mean snowfall. The freezing index is more than twice that experienced in metropolitan Toronto and southerly areas of the province. At 1.8 m, the frost penetration depth approaches that of areas of northern Ontario (2.0 m in the North Bay/Sudbury area) and is significantly higher than that in Toronto (1.2 m). These figures translate into 40 days a year of more frost, 27 percent more precipitation, 50 percent deeper frost penetration, and twice the freezing index of Toronto.

Another significant figure in terms of frost action is the number of frost-free days (interval between the last occurrence of frost in spring and first occurrence of frost in fall). At 120, the Muskokas experience substantially more frost cycles that can cause pavement damage than virtually all other areas of southern Ontario.

The geotechnical and hydrogeological conditions in the Muskokas are fairly typical of many areas in Ontario and Quebec. The top surface of the Precambrian Shield bedrock is quite rough. Such bedrock can be encountered as outcrop, near surface, and at significant depth, frequently over very short distances. The overburden soils are extremely variable (sand, silt, and clay with buried organic material), deposited as deltaic sediments from the former glacial lakes and in-filling the hollows in the Shield bedrock. Typical silt and very fine sand contents range from 40 to 70 percent, indicating mod-

TABLE 1 Comparison of Climatological Conditions, Muskokas and Toronto

Conditions	Muskokas	Toronto
Mean Annual Frost Free Days	120	160
Mean Annual Precipitation, mm	965	760
Frost Penetration, m	1.8	1.2
Freezing Index, °C-days	950	450

erately to highly frost susceptible soils. The widely variable bedrock depth creates natural transitions that can also introduce differential heaving problems where roads cross the transition between soil and bedrock.

The groundwater tends to be perched in the subsoil deposits over or within hollows in the bedrock. The district is known for the large number of lakes, streams, and other watercourses, and groundwater is generally found close to the surface or perched in more permeable pockets or lenses of soil.

STANDARD MTO FROST TREATMENT METHODS

The recent MTO *Pavement Design and Rehabilitation Manual* reports that differential frost heaving is not a serious problem in the performance of Ontario highway pavement structures, because soils of uniform frost susceptibility are used in the construction of the subgrade. The depth of frost penetration in Ontario is too great to practically provide pavement thicknesses that prohibit frost penetration into the subgrade. Therefore, the following actions are recommended to minimize (not eliminate) frost effects:

1. Give appropriate consideration to using uniform subgrade soils with respect to their susceptibility to frost heaving.
2. Design the pavement structure based on the reduced strength of the subgrade soils during the critical spring thaw period.
3. Intercept the water before it enters the frost-susceptible areas of the roadway through the provision of adequate side ditching and subdrains.
4. Prevent surface waters from entering the granular bases and subgrades with paved shoulders and edge drains.
5. Ensure proper treatment of transition points and boulders in the subgrade.
6. Use non-frost-susceptible granular backfill material to avoid differential heaving between the pavement approaches and structures.

In the event of differential frost action, MTO recommends three courses of action:

1. Subexcavation of as much of the frost-susceptible material as possible, considering the amount of excavation involved and considering that the excavation must then be drained from the bottom;
2. Drainage improvements (ditching or subdrains) with the depth entirely dependent on the availability of a suitable outlet to remove collected water; and
3. Installation of extruded expanded polystyrene insulation in accordance with Ontario Provincial Standard Drawings 514.01 and 514.02 (Figure 2).

FROST CONSIDERATIONS FOR MUNICIPAL ROADS

Whereas the MTO *Pavement Design and Rehabilitation Manual* reflects a design philosophy for highway pavements, it is used extensively by municipal engineers and MTO staff involved in the review and approval of provincially subsidized municipal roads projects. Some design considerations deemed important for municipal roads environment are not significant items for highway pavements. These include the presence of curb-and-gutter, underground services and intersections, and the limited right-of-way and road allowance that restricts the extent to which frost action mitigation measures and improvements can be incorporated.

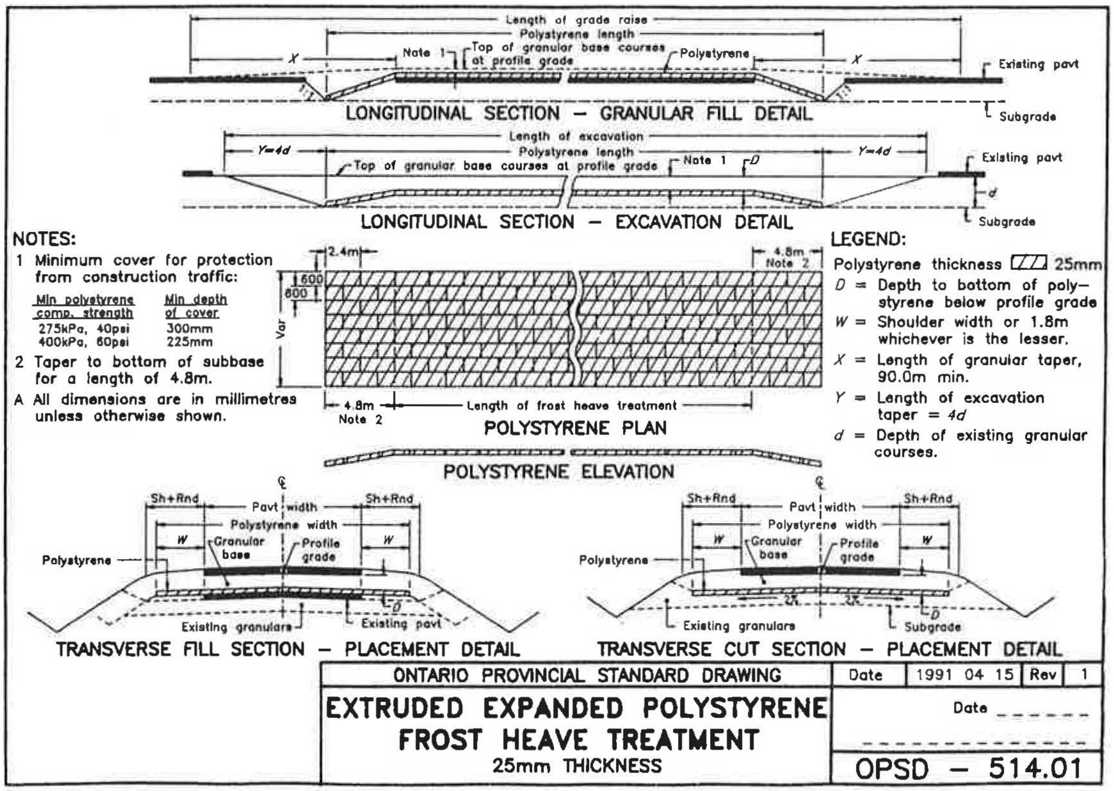
These common features of municipal roads can have a severe limiting impact on the type and extent of measures that can be practically incorporated to mitigate frost action. The presence of curb-and-gutter tends to restrict snow removal operations to the paved area between the curbs and the zone immediately behind the curb receives additional insulation from snow plowed on to the roadside. Consequently, differential frost action becomes a factor (Figures 3 and 4). Beneath the roadway, deeper frost penetration occurs. This area is subjected to more frost cycles and also thaws much earlier than the adjacent roadside, trapping moisture below the road surface. The presence of utilities and lateral connections to buildings suggests that frost tapers should be provided to control differential movements, but it also limits the extent to which frost tapers can practically be incorporated (especially costly if land acquisition is required). Intersections and driveways also create practical barriers to implementing some frost action mitigation measures because the work completed on a roadway directly affects adjacent pavements and requires that suitable transition treatments be provided wherever possible.

SPECIFIC MUSKOKA FROST ACTION MITIGATION MEASURES

The District Municipality of Muskoka, which represents an area of severe frost problems, recognized through practical experience that special considerations were required to lessen the effects of frost action on its municipal roads. The district and associated municipalities such as the town of Huntsville, with the assistance of their design and geotechnical and pavement engineering consultants, undertook in the mid 1980s to develop specific pavement design and construction procedures to deal practically with the severe frost problems and increase the service life of their road networks.

An interactive design approach was developed involving the geotechnical and construction materials engineering consultants, municipal design consultants, and the district municipality. A geotechnical and pavements investigation was initially conducted that consisted of an evaluation of the existing pavement (survey of observable distresses and performance history), representative boreholes to determine the subsoil (soil type, consistency, depth to bedrock) and groundwater conditions, and associated laboratory testing (grain size and hydrometer tests, moisture content determinations, etc.). The satisfactory performance of the relatively low volume pavements in this area is governed by frost-susceptibility characteristics of the subgrade soils and not strength. Hence, the emphasis during the investigation and associated laboratory testing is on determining drainage and frost-susceptibility characteristics of the subgrade and not strength parameters.

Once the geotechnical conditions have been established for a particular project, the municipal designs for the roadway



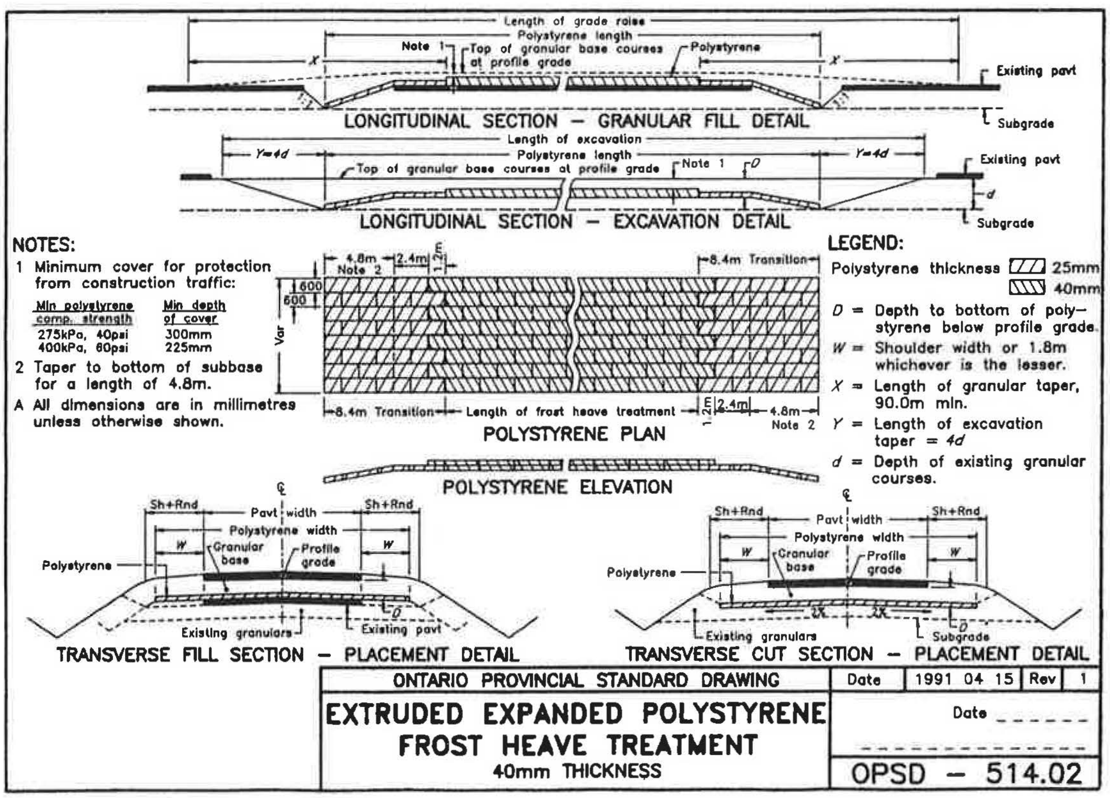


FIGURE 2 Extruded expanded polystyrene frost treatments.

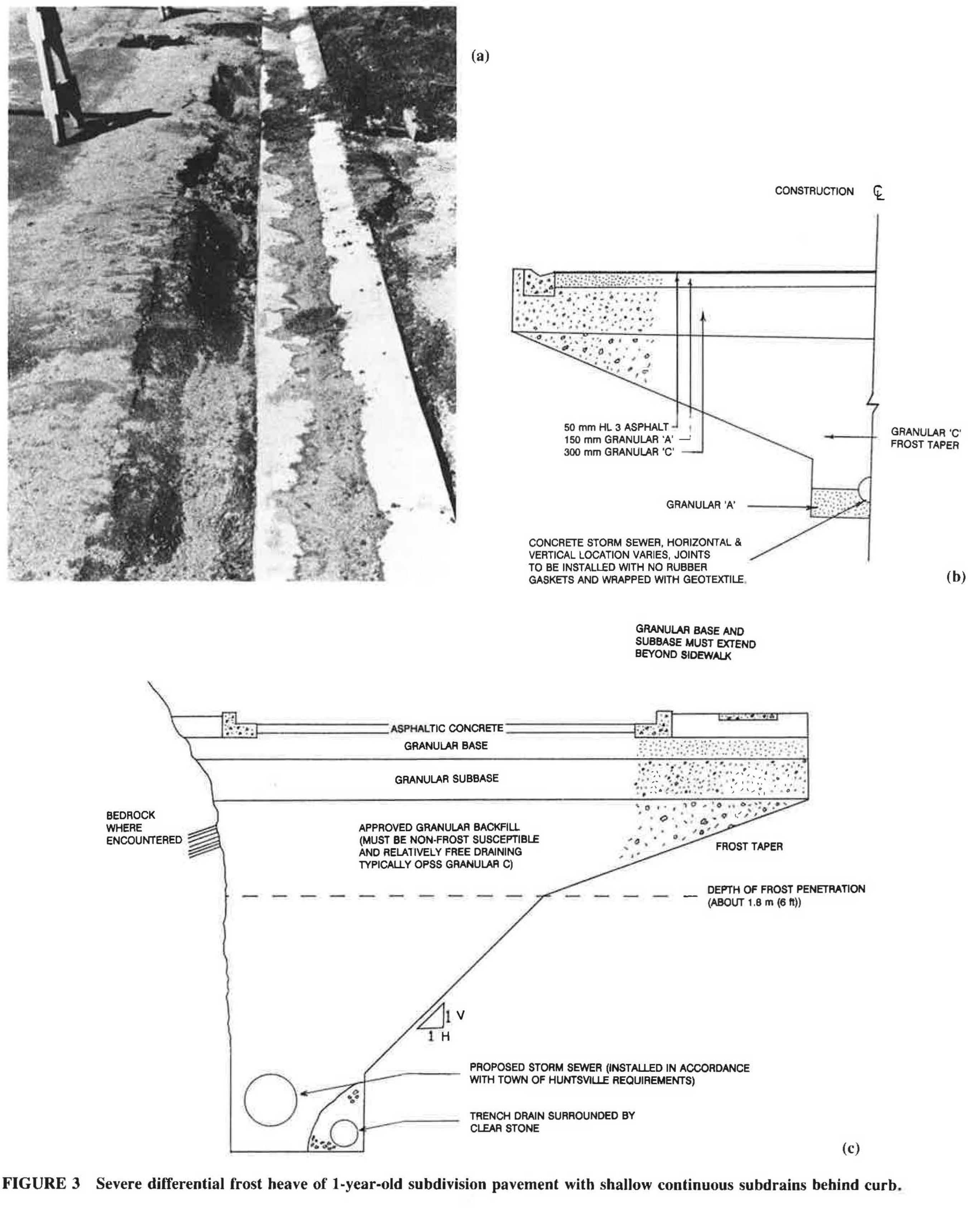


FIGURE 3 Severe differential frost heave of 1-year-old subdivision pavement with shallow continuous subdrains behind curb.

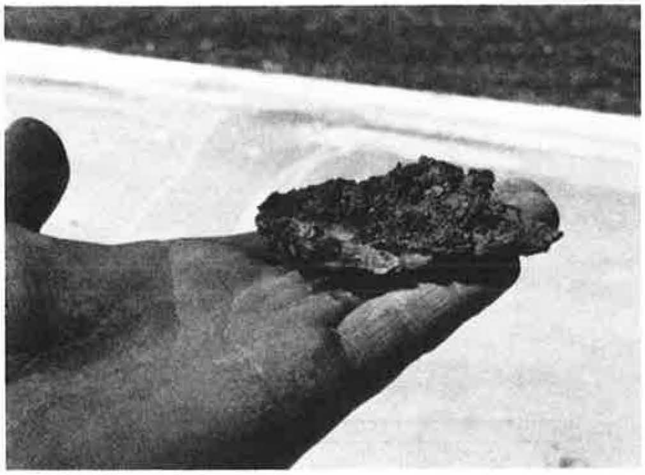


FIGURE 4 Ice lens removed from frost-susceptible silty subgrade at about 1.5 m. This excavation work was completed in late July after normal summer weather in the District Municipality of Muskoka.

(service requirements, road allowance, road alignment) are reviewed to determine the most practical method of incorporating suitable frost action mitigation measures that limit the effects of frost to tolerable levels.

The frost-susceptible native subsoils, access to free water, poor site grading, and steeply sloping bedrock make it difficult and costly to completely eliminate frost movements. Therefore, the use of partial or modified frost tapers augmented by positive drainage improvements and somewhat thicker asphalt concrete surfacings have been adopted as standard treatments since about 1986 and have proven over the past 6 years on a number of sites to effectively address the previously severe frost problems.

Typical frost taper details are shown in Figure 5, and are generally in accordance with OPSD 205.06, with some modifications to taper sideslope gradients to accommodate road allowance limitations. The slope of the frost taper should be as gradual as possible to the curb line. Outside the curb line, the slope of the taper may be increased, noting that differential frost heave may be accentuated wherever the frost taper changes slope. In addition, frost tapers should be extended in transverse directions at all intersections and at the end of tapered roadway sections. When bedrock is encountered within the frost penetration depth of 1.8 m, the bedrock must be stripped of all frost-susceptible soil and backfilled with approved granular material.

Wherever possible, positive drainage is incorporated at the base of any tapers or granular material to ensure that the subgrade does not have access to free water. If frost tapers are installed in conjunction with storm sewers, then the storm sewer itself may be adapted to function as the necessary drainage outlet (open joints or perforations in the storm sewerpipe must be wrapped with a suitable geotextile to prevent influx of the backfill material). When it is not practical to provide drainage within the frost taper, deep (about 1.8-m) geotextile-wrapped perforated plastic subdrains must be installed beneath the pavement edges on both sides of the road.

Observations of in-service low traffic volume pavements designed in accordance with the standard MTO structural design matrix (Table 2) confirmed that the MTO-specified asphalt concrete surface thickness of 50 mm was not adequate, with cracking and deformation apparent after a relatively short time. Consequently, the recommended minimum asphalt concrete surfacing thickness was increased by the district to 90 mm, even for light-duty roads. This has performed significantly better than the former 50-mm thickness but has been cut back to 50 or 75 mm on several projects, resulting in poor performance as discussed in the following case histories. A recent 1991 revision to the MTO design procedure now approves the use of thicker asphalt concrete surfacings (90 to 130 mm) for higher traffic volume rural roads [annual average daily traffic (AADT) > 2,000].

CASE HISTORIES AND OGRA-MTO DEMONSTRATION PROJECT

As previously noted, the development of frost action mitigation measures for municipal road construction in frost-susceptible soils has been ongoing for some time. The recently approved OGRA-MTO Demonstration Project finally provided the opportunity to confirm technically the design rationale and quantify the advantages of this approach from performance and cost-benefit viewpoints, for an actual project to assist in development of new standards for municipal pavement construction in seasonally severe frost areas.

Several case histories are presented to demonstrate the development of the frost action mitigation design approach:

- District Road 2 (Brunel Road)—Standard MTO design (poor performance);
- Echo Bay Road—Recommended frost action mitigation measures not implemented because of cost considerations (poor performance);
- King Crescent, West Street, and North Street—Constructed as recommended with exception of one section on which subdrainage not included and subsequently heaved (good performance); and
- Susan Street—Constructed as recommended (good performance).

District Road 2 (Brunel Road)

Brunel Road is a moderately heavy traffic district road (AADT = 1,500 to 2,000) entering the town of Huntsville. The section outside the town limits is constructed to a rural cross section; the section within the town limits is upgraded to an urban standard. The rehabilitation work was designed and constructed in 1981, with the following construction details provided by staff of the District Municipality of Muskoka. The utility trenches were backfilled with native material to the finished subgrade elevation. In the urban section, the pavement structure consisted of 75 mm of asphalt concrete over 150 mm of granular base and at least 600 mm of granular subbase. The subgrade was crowned with a center-to-edge slope of about 3 percent, but the pavement was crowned with an edge to edge slope of 2 percent. Continuous subdrains were to have been provided immediately below the finished subgrade and behind the curbs with a drainage swale on the

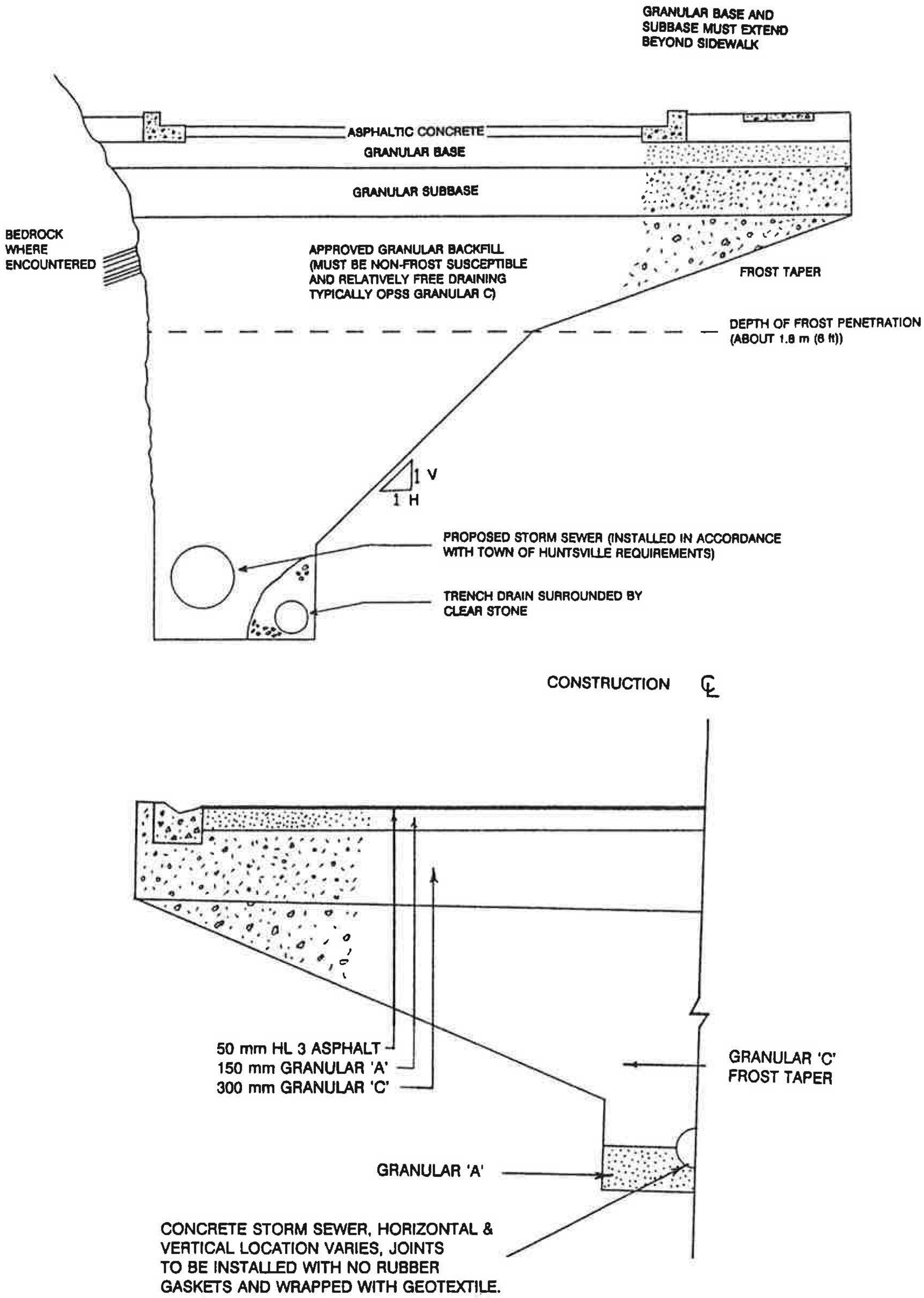


FIGURE 5 Typical frost taper details.

TABLE 2 Structural Design Guidelines for Flexible Pavements—Secondary Highways (1)

AADT	Pavement Structure Elements	Subgrade Material: Gravels and Sands Suitable as Gran-Borrow	SANDS AND SILTS: 5-75 µm <40%	SANDS AND SILTS: 5-75 µm 40-55%	SANDS AND SILTS: 5-75 µm >55%	Lacustrine Clays	Varved & Leda Clays
2000-3000 AADT	HM	90	90	90	90	90	90
	B	150	150	150	150	150	150
	SB**	-	300	450	600	450	800
	GBE	330	530	630	730	630	865
1500-2000 AADT	HM	50	50	50	50	50	50
	B	150	150	150	150	150	150
	SB**	-	250	300	450	300	450(300-600)
	GBE	250	415	450	550	450	550(450-650)
1000-1500 AADT	CL	50	50	50	50	50	50
	B	150	150	150	150	150	150
	SB**	-	250	300	450	300	450(300-600)
	GBE	240	405	440	540	450	540(450-640)
500-1000 AADT	ST*	-	-	-	-	-	-
	B	150	150	150	150	150	150
	SB*	-	150	250	300	250	350(250-450)
	GBE	150	250	315	350	315	385(315-450)
200-500 AADT	ST*	-	-	-	-	-	-
	B	150	150	150	150	150	150
	SB**	-	150	250	300	250	300
	GBE	150	200	315	350	315	350
Less than 200 AADT	Gravel	-	-	-	-	-	-
	B	100	100	100	100	100	100
	SB**	-	150	250	300	250	300
	GBE	100	200	265	300	265	300

Notes: All AADT Volumes refer to Present Traffic.
HM - Hot Mix Asphalt & Thickness, mm
B - Base Thickness, mm
SB - Subbase Thickness, mm
GBE - Granular Base Equivalency Thickness, mm (1 mm HM = 2 mm B = 3 mm SB = 1.11)
CL - Cold Mixed, Cold Laid or Road Mixed Mulch
ST - Double Surface Treatment or Single Surface Treatment with Prime
* - Apply surface treatments 0.25 m wider than lane width.
** - Proposed subbase thicknesses may be decreased or increased respectively, for harder or softer subgrade conditions in each category, except for varved and leda clay subgrade where exceptionally large ranges are shown.

upslope side of the road to intercept surface runoff. It is understood that the subdrains were cut back significantly during design to only 6.0-m subdrains provided at catchbasin locations on the downslope side of the road. The subdrainage requirements were reduced even further during the actual construction, and the drainage swale is not continuous.

In the rural section, subdrains were to be provided immediately below the subgrade along both road edges. Shallow drainage swales were also specified along both edges with the swale invert at the same elevation as the top of the subgrade. The pavement structure consisted of 75 mm of asphalt concrete over 150 mm of granular base and 600 mm of granular subbase. Both the pavement and subgrade were crowned with a center-to-edge slope of 2 percent.

After 10 winters, District Road 2 is considered to be in poor condition (Figure 6). Severe frost-related distress is observed in both urban and rural sections. The urban section distress is more obvious because of the presence of curbs. Severe differential movement of the upslope edge of the pavement and curb has taken place to such an extent that full width padding of the roadway has been necessary to maintain surface drainage. Longitudinal and transverse cracking related to frost heaving and distortions of the pavement confirm that the frost treatments used are not adequate for this roadway and are the principal reason for the low serviceability of this road after only 10 years.

Echo Bay Road

The original frost mitigation recommendations for Echo Bay Road, in Huntsville, included 90 mm of asphaltic concrete over 150 mm of Granular A base and 300 mm of Granular B subbase, with granular frost tapers to be provided in an area where storm sewer installation was proposed. Relatively deep subdrains were also recommended along the pavement edges in frost-susceptible soil areas. Significant revisions to the original design recommendations were completed to reduce costs, and the as-built pavement structure was reduced to 50 mm of asphalt concrete over 150 mm of Granular A base and 300 mm of Granular C subbase. Frost tapers were provided (Granular C backfill) in the storm sewer area and continuous but shallow subdrains were provided beneath the pavement edges in other urban sections.

The reconstruction work was completed in late 1987, and after one winter, substantial localized frost-related problems were observed. Some of the frost-related distresses were attributable to poor construction and improperly installed sub-

FIGURE 6 Severe differential frost heave of approximately 10-year-old District Road 2 pavement. The extensive padding has been replaced nearly annually to restore surface drainage and ride through the intersection.

drains. Sections of the subdrain were found to be collapsed, and the subdrain outlet at one catchbasin was lower than the catchbasin outlet (i.e., water actually flowing into the pavement structure from the subdrain). In addition, because of late season construction, the subdrains were not given enough time to drain the subgrade properly.

Remedial recommendations included repairing the failed subdrains and reinstating the damaged pavement. Deep subdrains (1.8 m depth) were recommended through a section of the roadway at which severely frost susceptible soils were encountered, but they have not been installed to date. Some other relatively minor, localized frost movements have taken place since 1988, but the repaired areas do not appear to represent a problem beyond aesthetic difference from reconstructed pavement (i.e., patch areas are quite visible). The concrete gutter is also slightly higher than the pavement, and ponding occurs. An overlay will ultimately be required to rectify these problems, and deep subdrains will be necessary in the area that is highly susceptible to frost.

King Crescent, West Street, and North Street

The King Crescent, West Street, and North Street improvements in Huntsville were to initially include installation of storm sewers. These were not completed, and the rehabilitation consisted of pavements reconstruction, including the provision of concrete gutters. Continuous subdrains were recommended, and the pavement structure was to consist of 90 mm of asphalt concrete over 150 mm of Granular A base and 300 mm of Granular B subbase.

The pavement was constructed as recommended, except that subdrains were not provided on North Street. This was because designers anticipated that the steep longitudinal grades would provide adequate subsurface drainage. After three winters, the only significant frost-related distress is observed at the top, flatter portion of North Street on which localized frost heaves have occurred next to the curbs.

Susan Street

The recommended frost treatment for Susan Street consisted of tapering of the subgrade from the frostline in the service trenches to behind the curb and walkways. The storm sewer was situated along the south side of the road and, as such, the taper from the north side to the service trench was relatively gradual. The storm sewer was constructed with geotextile-wrapped open joints, and the lower portion of the storm sewer trench itself was constructed within geotextile-wrapped 19-mm clear stone bedding. The pavement structure consisted of 90 mm of HL 4 over 150 mm of Granular A base and at least 150 mm of Granular B subbase, tapering to 1.8 m thick at the storm sewer.

After four winters, the Susan Street pavement is in good condition. A moderately severe longitudinal construction joint crack appeared after the first winter, but it is not considered to indicate differential frost effects.

OGRA-MTO Demonstration Project

The OGRA-MTO Demonstration Project program consists of a number of projects involving innovative or new road maintenance and construction methods completed by OGRA member agencies with MTO support to provide performance and cost data and to assist in the development of new design and construction standards. A demonstration project entitled *Frost Action Mitigation Study* was submitted by the District Municipality of Muskoka and accepted in two phases. The first phase consisted of a review of the international technical literature and project experience, including the inspection of selected pavement sections within the district since about 1981 to assess the relative effectiveness of alternative treatments for incorporation in Phase II. This phase was completed and reported in February 1991. Phase II is to consist of an actual road reconstruction project incorporating selected frost action mitigation measures so that specific performance comparisons can be completed and costed to assist in the development of new or revised standards for municipal roads construction in frost-susceptible soils. This work has been approved for completion in 1991 (designed) and 1992 (constructed), with monitoring to continue into 1995.

The literature review included the following:

1. Dialog search of the TRB Transportation Research Information Services data-base;
2. MTO technical manuals and research reports on frost action, mitigation and pavement design procedures; and
3. Corporate technical library and project files that include a number of pavement investigations and rehabilitation projects completed in Muskoka.

The literature survey and review of selected papers indicates that the international research since about the early 1950s has focused primarily on the adequacy of pavement structure designs during the moisture-weakened spring thaw subgrade conditions. The consensus of opinion appears to be that the necessary pavement structure to resist frost movements is usually adequate to address structural concerns during the seasonally weakest condition.

Although most of the technical literature is in general agreement with the Canadian (and in particular, Ontario) pavement design approach, several papers provide additional insight into frost action mitigation alternatives that could be considered viable for severe frost areas in Ontario (*2,3,4*).

Kubo (*5*), reporting on the Japanese procedures for frost action mitigation at a recent Paving in Cold Areas Japan-Canada Technical Exchange (noting that the Japanese island of Hokkaido has similar snowfall and freezing index to both the Muskokas and Buffalo, N.Y.), indicated three basic approaches:

- Replacement: the frost-susceptible subsoil is excavated to 70 percent of the frost penetration depth and replaced with non-frost-susceptible granular soils (partial frost tapers).
- Heat insulation: extruded expanded polystyrene insulation is used in conjunction with replacement. Differs from Canadian practice in that the insulation is installed only beneath the road shoulders to control differential movement at the edges.
- Chemical treatment: the frost-susceptible subsoil is sub-excavated and mixed with additives such as cement or lime to reduce the permeability of the frost-susceptible soil (used primarily where suitable granular materials are scarce or not available).

Rutherford has determined that thin pavements (50 mm or less of asphalt concrete) on secondary roads in frost areas reach critical asphalt tensile strains within the short time required for the granular base to thaw (*6*). However, for 100-mm asphalt concrete surfacings, the pavement did not experience deflections or strains in excess of those occurring during the summer until some subgrade thawing occurred, with subgrade vertical strain the critical parameter; that is, secondary roads in frost areas require thicker asphalt surfacings to resist critical tensile strains along the asphalt-granular interface.

For the proposed 1991–1992 Phase II work, six trial sections will be incorporated in a typical urban road reconstruction project (two-lane urban section, AADT < 2,000, 1.3 km long, with storm and sanitary service improvements and widening) in Huntsville:

1. Control section consisting of the standard MTO design and construction approach using conventional subdrains and ditches, backfill, subbase, base, and resurfacing with 50 mm asphalt concrete;
2. Same as Section 1, but with 90-mm asphalt concrete surfacing.
3. Provision of full frost tapers extending up from the frost line at the service trench (~ 1.8 m depth) to the top of the

TABLE 3 Proposed Trial Section Monitoring

Monitoring Activity	Test Method To Be Used	Frequency
A. Initial Survey (Pre-Construction)		
a) Surface Condition	Visual survey of existing distress including type and level of severity.	NA
b) Surface Profile Determination	Dynatest Surface Roughness Profiler (longitudinal and transverse profiles).	NA
c) Geotechnical/ Pavement Investigation	Representative test holes and laboratory analysis of samples.	NA
B. Cost Data	Obtain 'as built' unit costs for trials for comparison with 'standard' construction.	Once during construction
C. Post-Construction		
a) Surface Condition	Visual	Immediately after construction then semi-annually until Spring 1995 (6 sets of observations supported by photos).
b) Surface Profile	Dynatest SRP (longitudinal and transverse profiles).	Immediately after construction then semi-annually until Spring 1995 (6 sets of measurements - 3 winters).

subgrade just behind the curb (or sidewalk where present), resurfacing with 50 mm of asphalt concrete.

4. Provision of partial frost tapers extending from about 70 percent of the frostline, at the service trench (~ 1.25 m) to the top of the subgrade just behind the curb (or sidewalk if present), and resurfacing with 50 mm of asphalt concrete.

5. Same as Section 4 but with 90-mm asphalt concrete surfacing.

6. Provision of deep subdrains or edge drains ("fin drains") 1.8 m below the top of subgrade and resurfacing with 50 mm of asphalt concrete.

Each section will be at least 150 m long. The work is to be tendered with the specific unit costs obtained for meaningful comparative cost analyses. The pavement monitoring program is presented in Table 3. In addition, the MTO Automated Road Analyzer (ARAN) equipment will be used to provide additional profile information to supplement the Dynatest SRP monitoring.

With the nature of the frost problems in this area and the selection of trial section components, meaningful performance information is anticipated after one to two winters. The performance results, cost comparisons, and recommended new standards for frost action mitigation for municipal roads in seasonally severe frost areas will be the subject of a future paper upon completion of this OGRA-MTO Demonstration Project in the District Municipality of Muskoka.

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