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EFFECTIVE METHODS TO REPAIR FROST DAMAGED ROADWAYS

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Introduction

Perhaps the most persistent pavement adversary in Minnesota is cold weather. It is virtually the only factor affecting pavement performance that we cannot modify or mitigate. Freezing temperatures in general, and temperature fluctuations above and below the freezing mark in particular, can have pronounced effects on subgrade and aggregate base stability and, in turn, pavement performance.

This report deals with methods to repair frost-damaged roadways. Specifically, it contains discussions concerning the mechanics of ground freezing and frost related roadway damage, the environments in which such damage occurs, and measures to evaluate the contributing factors along with recommendations to mitigate them and/or reduce the potential for additional roadway damage. A worksheet is also provided to allow prospective users of this manual to record the results of their work and help them both evaluate prospective repair methods and track their successes. As part of the research implementation process, a brief e-mail survey of local governments was conducted to gather information on Minnesota frost experience and repair procedures and is highlighted in this report.

Frost related pavement damage is caused primarily by:

1) The expansion and heaving of frost-susceptible subgrade materials as they freeze. This is commonly referred to as a **frost heave**.

2) The subsequent weakening of those materials as they thaw in the spring, which decreases their load-carrying capacity (as evident in the photo); commonly referred to as a **frost boil**.

For frost related roadway damage to occur, freezing temperatures, frost-susceptible materials and a source of water capable of saturating those materials must all be present.

Frost damage tends to occur at natural unconformities or constructed “transitions” in either the composition, consistency and/or drainage characteristics of subgrade materials. At such locations, variations in the expansion and/or strength loss potential of the materials are most pronounced, as are the differential movements.

Soils most commonly considered to be frost-susceptible include lean and fat clay, silty clay, non-plastic, fine sands with silt, and elastic silt. These fine-grained soils have poor drainage and have an affinity for attracting and holding water.

Differential frost heaving is a subgrade uniformity issue. Roads should be constructed and engineered to heave uniformly. Differential heaving is one problem that is addressed in this report. Frost boils are pockets/areas of weak subgrade materials that have been subjected to too much stress, causing the subgrade to "boil up" and mix with (contaminate) the base aggregate and cause the surface to fail.

Saturation of frost-susceptible soils can occur as surface drainage infiltrates through paved or unpaved surfaces, or as groundwater moves laterally or vertically through the soils (the latter generally occurring under capillary action). The presence of natural unconformities and constructed "transitions" (i.e., a sand subbase placed atop a clay subgrade, or a utility excavation in clay that is backfilled with sand) often creates a potential for saturation by producing reservoirs in which surface drainage and/or ground water can collect.

Common Conditions Where Frost Damage Occurs

The nature and extent of road damage varies according to the environment and traffic. Subgrade composition, groundwater conditions and drainage conditions all contribute. There are certain environments, however, in which one component or another is dominant — this strongly influences the selection of an appropriate solution. Generally, frost-damaged areas can be defined by three categories:

Non-Uniform Subgrades. Local geology, past alignment and utility construction can all have profound effects on the uniformity of subgrade materials. Different types of soils can have different drainage properties and frost-susceptibility. Affected areas may be extensive and cover a broad range of terrain. The magnitude of heaving and subsequent strength loss may be similarly broad, and may be worsened by groundwater.

Subgrades Near the Groundwater. Whether present continuously, seasonally or periodically (perched or otherwise), groundwater may play a critical role in frost related road damage. The extent to which frost-susceptible soils expand due to the formation of ice lenses when frozen is largely affected by the capillary potential (ability to attract water) of the soil. Silts have a particularly high capillary potential and ability to have ice lenses. Affected areas may be extensive and typically occur in the vicinity of local water features (lakes and swamps, for example), but they may also occur occasionally in broad, low plains. Additional, sometimes unexpected, sources of groundwater also include slopes that are host to springs and cuts that intercept or effectively bring the subgrade closer to groundwater.

Subgrades within Low Areas. "Low areas" occur wherever surface drainage and groundwater accumulate; they are typically associated with drainage features – swales, ravines, creeks, floodplains and wetlands – into or through which water flows. The distinguishing characteristic of a low area is not the mere presence of water in the area, but the tendency of water to flow toward and accumulate within the area. One visible example of a low area is the accumulation of surface drainage in ditches at low points along a roadway passing through rolling terrain. Perched groundwater over subsurface soil or bedrock is an example of a hidden low area.

Evaluating Prospective Repair Alternatives

A practicable solution for mitigating frost damage – one that addresses causes rather than symptoms - must consider whether or not it will be necessary to:

1) Improve subgrade, subbase and/or aggregate base quality/uniformity, and/or
2) Reduce or limit sources of water.

Determining the relative influence each action has on the problem will require considerations for available on-site and local equipment and materials, and an understanding of subsurface conditions in the affected area. Information obtained from the email survey of Minnesota local governments revealed that the most successful treatments address both subgrade quality and uniformity and surface/subgrade drainage.

The following paragraphs discuss some of the steps that should be taken to help evaluate repair alternatives. Details of various repair alternatives are discussed in the **Repair Methods** section of this report. Specific alternatives that have proven successful for some local governments have also been provided. A worksheet is also appended to this report to help record pertinent details concerning the affected area and to facilitate the selection of an appropriate treatment.

Construction/Maintenance History. Site history information will help put field observation and test results in perspective. Pertinent information may include grading and as-built plans, construction notes and maintenance records for the area(s) where frost damage has occurred.

Visual Observation. A reconnaissance will help define the limits of the repair, reveal the type of environment in which the frost damage occurred (i.e., low area), and possibly expose specific features (insufficient drainage ditches) that have contributed to the damage. Access to equipment capable of evaluating and improving subgrade conditions can also be determined at this time.

Subgrade Evaluation. Several methods are available to evaluate subgrade materials and determine how significant any inconsistencies in their composition, strength and moisture are to available repair alternatives. Some methods can also be used to evaluate the adequacy of existing pavement sections. Available methods include:

1. Pavement deflection testing [Falling Weight Deflectometer (FWD)] (to estimate in-place R-values or CBR values)
2. Penetration test borings or auger borings (to generate material samples for classification and laboratory testing, provide a means by which the relative density and stiffness of the subgrade materials can be estimated)
3. Dynamic cone penetrometer (DCP) testing (in combination with hand auger borings, provides information similar to that obtained from penetration test borings)

Soil samples can be further classified through laboratory testing. For more information please see the Mn/DOT Geotechnical and Pavement Manual (Section 4.2).

Construction Materials. Depending on the results of the visual observation and subgrade evaluation, it may be possible to make use of available on-site or local materials. However, some situations may require additional materials to solve the problem (such as sand to provide a free-draining subbase or fly ash to stabilize wet subgrade soils).

Repair Methods to Improve Subgrade Uniformity

No repair method is universal. As stated earlier, selecting an effective repair method requires an assessment of site-specific issues. Since each site is unique, each repair method should be unique. The following discussions highlight some of the common approaches to the repair of frost-damaged roadways.

Scarification, Blending and Recompaction. Some improvement in subgrade uniformity and pavement performance can often be made through simple scarification, blending and recompaction where differential frost heaves are the main problem and there is limited loss of support to the paved surface. This process is the least comprehensive of the subgrade improvement alternatives, and is best suited for situations where subgrade uniformity appears to be more critical than groundwater or surface drainage.

The process is completed as follows: After the areas of interest are stripped of pavement or surfacing aggregate, the exposed subgrade materials are:

- Scarified (6 to 12 inches) and blended,
- Moisture conditioned to within about 2 percent of their optimum moisture contents, and
- Recompacted to at least 100 percent of standard Proctor dry density (ASTM D 698).

> Compaction to 100% of standard Proctor density is generally adequate, and conforms to Mn/DOT Specification Section 2105.3F, Specified Density Method procedures. A cost-effective alternative for remote sites, or for projects with limited service requirements, is to simply compact the scarified, moisture-conditioned subgrade materials “until there is no evidence of further consolidation,” in general conformance with Mn/DOT Quality Compaction Method procedures.

A proof roll (using a loaded tandem truck) of the improved subgrade is also recommended to help evaluate the success of the process and to reveal “pockets” of loose or soft subgrade materials that require additional compactive effort or removal and replacement.

Removal, Surface Compaction and Recompaction. Removal, surface compaction and recompaction is one step better than the scarification, blending and recompaction process, in that the treatment extends farther into the subgrade. This method may also be better suited for frost heave rather than frost boil repair, where the loss of support to the paved surface is limited. By emphasizing recompaction over replacement, it is assumed that enhancing subgrade uniformity is more critical than mitigating the destabilizing effects that water has on subgrade strength.

The removal, surface compaction and recompaction process is similar to scarification and recompaction, but begins by extending excavations down <u>below</u> the top of the subgrade, and <u>then</u> scarifying, blending, moisture conditioning and recompacting the materials exposed in the excavation bottom. Typical excavation depths range from 12 to 24 inches, allowing new or reconstructed pavements to be supported on an 18- to 36-inch layer of compacted material (versus 12 to 24 inches through scarification, blending and recompaction alone). Again, the compaction can be measured by the Specified Density or Quality Compaction Method.

This method, even more so than simple scarification, can be difficult to apply where water, in addition to subgrade quality and/or uniformity, is an issue. Where excavations terminate near or in saturated soils, for example, it can be difficult to surface compact the excavation bottoms or recompact the excavation spoils due to high moisture contents. In such cases, it may be necessary to replace – as opposed to recompact – the excavation spoils, and also incorporate provisions to drain the area (see Reducing/Limiting Subgrade Moisture later in this text).

The process is completed as follows:

- The areas of interest are stripped of pavement or surfacing aggregate, <u>as well as part of the subgrade</u>. Typically 12-24 inches of material is removed.
- The remaining subgrade materials are scarified (6 to 12 inches) and blended.
- The subgrade materials are moisture conditioned to within about 2 percent of their optimum moisture contents.
- The remaining original materials are placed, blended, and compacted.
- If necessary, additional granular materials are placed and compacted.
- All compaction being completed as described above.

Removal and Replacement. Compacting or recompacting existing subgrade materials may enhance subgrade uniformity and improve subgrade quality, but was not regarded by many survey participants as an effective treatment where frost boils – caused primarily by subgrade strength loss during the spring thaw – were more prevalent than frost heaves, or where the observed damage and/or repair was impacted by water. Some soils – silts in particular – are difficult to compact even at moisture contents near optimum, and are considered highly susceptible to strength loss. Ice lensing and heaving may occur in both natural and compacted states. Recompaction is also largely ineffective where water is an issue, and the soils are more likely to be saturated to begin with.

Removal and replacement is the most comprehensive improvement method for non-uniform areas where both frost heaves and frost boils are present and, as already suggested, is the most appropriate improvement method for situations where the extent and/or magnitude of frost damage is strongly influenced by shallow groundwater trapped in layered soils and present in low areas. The degree to which subgrade and drainage conditions are improved will vary based on both the severity of the damage and the quality of suitable replacement materials.

On-site or imported materials classified under Mn/DOT Specification Section 2105.2B as Common Borrow or Granular Borrow, or even those that meet Table 3138-1 requirements for Class 5 aggregate base material, can enhance subgrade strength in non-uniform areas. Survey results cited a number of recycled materials, including bituminous, aggregate base and concrete, as having been used successfully to replace excavation soils. The ease of compaction and general resistance to expansion, heaving and strength loss, however, increases as the amount of silt- and clay-sized particles within the material decrease, and the overall range of particle sizes (including gravel) increases.

If it can be obtained, sand meeting Specification Section 3149.2B for Select Granular Borrow (modified to contain less than 50 percent of the particles passing a #40 sieve and less than 5 percent passing a #200 sieve where water is present), "breaker run" (typically a crushed rock with particle diameters on the order of 1 to 3 inches), or other crushed natural or recycled materials sieved to contain less than 5 percent fines will retain strength under saturated conditions and prove a more suitable medium for surface and subgrade drainage.

Whether sand, gravel, aggregate base material or another type of material is ultimately used will also be influenced by the quantity required (or desired); while 1 foot of crushed concrete or "breaker run" material may provide as much stability as 2 feet of Select Granular Borrow, for example, hauling it to the site may ultimately cost twice as much as hauling the sand. Therefore, it is a matter of economics.

The depth to excavate during removal and replacement situations depends partly on project economics and partly on the anticipated condition of the excavation bottoms. Excavations on the order of 12 inches may be adequate where the underlying, exposed materials are relatively stable, and the replacement backfill can be adequately compacted. Excavations on the order of 24 to 36 inches are more typical where the exposed materials are unstable, organic or debris-laden.

Placement of a woven or non-woven geosynthetic over the excavation bottom (the characteristics of which are discussed in more detail below) will help prevent the loss of backfill materials through "punching" failure, facilitate compaction of the backfill, and help maintain subgrade drainage and stability where frost boils (as opposed to frost heaves) are dominant, by limiting the migration of fine-grained subgrade particles into (and the eventual weakening of) the backfill.

The process is completed as follows:

- Strip the pavement or surfacing aggregate within the area of interest.
- Evaluate the area to determine the depth of excavation. Generally 12 inches is adequate where materials are stable, 24-36 inches in unstable areas (underlain with organics).
- Excavate and remove materials.
- Scarify, blend and compact subgrade (6 to 12 inches).
- Place geosynthetic.
- Place the new granular materials and compact.
- All compaction should be done as described above.

Northern Minnesota Practice

A cost-effective practice used in Northern Minnesota for township and low volume gravel roads, with lengthy frost damaged areas, involves the use of woven or non-woven geotextile. The geotextile is placed over the existing road and then covered with 8 to 12 inches of granular material.

The granular material provides adequate strength for a gravel road and the geotextile provides separation from the underlying fine-grained soils, thus protecting the granular material from contamination and subsequent strength loss. Generally 8 inches of granular material is sufficient, however, 10 inches may be more desirable to help prevent the geotextile from migrating to the surface due to routine blading of the road. Depending on the cost and availability of granular material, the first 6 inches of material may consists of select granular borrow; however, at a minimum the top 4 inches should be crushed Class 1 or Class 5 aggregate.

If it is desired to keep the original width and inslope, the subgrade needs to be widened to accommodate the additional granular material. For example, if the original road was 28-foot wide and had 1:3 inslopes, the subgrade will need to be 33 feet wide in order to have a 28-foot road surface after adding 10 inches of granular material. If the ditches are wide enough, a cost-effective method is to cut down the road and blade the material onto the road inslope to widen the road to the desired width. The depth of cutting the road down will depend on the ditch inslope and amount of granular material going back on the road.

Following is a summary of this treatment:

1) Obtain the necessary subgrade width by lowering the road and using the material on the inslopes to widen the subgrade.
2) Place a woven or non-woven geotextile over the existing material.
3) Place 4-8 inches of granular material (select granular borrow) and compact.
4) Place 4 inches of Class 1 or Class 5 aggregate and compact.

Reusing the excavation spoils eliminates the cost of removing and creates a wider subgrade yielding a finished surface with the same width as the original road. The geotextile enhances the effectiveness of the restored surface by helping to maintain separation between the surface and the underlying subgrade materials.

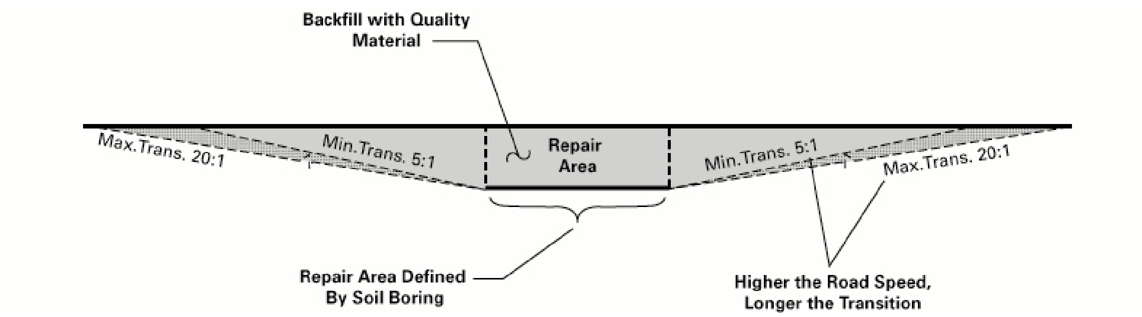
Placement and compaction of replacement backfill should follow the same guidelines as described above for the simple scarification and removal/recompaction alternatives (i.e., Specified Density or Quality Compaction Method).

Embankment Modification. In shallow groundwater situations or in low areas, raising the existing alignment can provide sufficient clearance above groundwater to reduce the impact that groundwater and infiltrating subsurface drainage has on subgrade stability and pavement performance. Raising the existing alignment can also reduce the extent to which excavations need to be advanced into wet, saturated or potentially unstable materials. Finally, raising the existing alignment will provide an opportunity to support pavement materials on a uniform cushion of higher quality material than may have existed. This treatment method can be expensive, depending on the quantities of material required.

Pavements can be somewhat isolated from the effects of water by raising existing alignments at least 2 to 4 feet above the groundwater or saturated subgrade materials. The composition and drainage characteristics of the embankment fill will depend on the height to which the alignment can be raised (embankment geometry is often limited by right-of-way, minimum road width requirements, and surface drainage issues). Common Borrow, Granular Borrow or Class 5 aggregate base material may be adequate in the event a generous (3 to 4 foot) raise in grade can be achieved. Coarser, more free-draining material, however, such as Select Granular Borrow, may be more appropriate where only a limited raise in grade (less than 3 foot) is necessary.

Transitions. The process of replacing weak or poorly draining subgrade materials with higher strength or more free-draining subgrade materials itself creates material transitions that, if abrupt, can cause unfavorable amounts of differential frost heave. Transitions were cited in the survey results as contributing to frost damage at the boundaries of previous repairs. Tapering the edges of corrective excavations is therefore necessary to reduce potential differential movements.

Excavations need to be tapered both perpendicular and parallel to the alignment. A 4:1 (horizontal:vertical) taper is generally adequate perpendicular to the alignment. Parallel to the alignment, however, the taper will vary depending on design speeds; while a minimum 5:1 taper may be adequate for a low-volume city street, a 20:1 taper is more typical for a highway repairs. The graphic below shows how such tapers are applied.



Longitudinal Transitioning

Constructability – Stabilization, Separation and Reinforcement. Obtaining adequate compaction can be difficult on wet, submerged or weak excavation bottoms. Backfill materials that are particularly coarse-grained (i.e., "breaker run") can "punch" and be lost into organic soils or soft clays. Drainage within coarse-grained materials can also be constricted or blocked by fine-grained particles that migrate into them.

General subgrade or excavation bottom stabilization can be achieved with the aid of chemical additives such as lime or fly ash. (Note: Mn/DOT requires fly ash to be carefully evaluated before use by the MnDOT Environmental Services office.) Lime and fly ash are typically used to absorb excess moisture and facilitate compaction. Because their stability effects are generally considered to be temporary, perhaps their greatest benefit is providing a more stable platform on which existing subgrade materials, or replacement backfill materials, can be compacted.

Subgrade stability and/or material separation can also be achieved with a variety of non-woven and woven geotextiles, or geogrids, placed over excavation bottoms. Though geotextiles often provide a sufficient amount of tensile strength to support construction equipment and facilitate material placement and compaction operations, their primary role is to limit the migration of fine-grained subgrade particles into coarse-grained backfill materials.

Mn/DOT Specification Section 3733.1 recommends the use of a "Type V" geotextile for separation and stabilization, the properties of which are identified (Table 3733-1). Because they are highly extensible (capable of stretching), geotextile seams are typically sewn when placed over soft, compressible and/or unstable materials (e.g., peat or organic clay). However, when placed over materials where deformation is not an issue, overlapping of individual geotextile strips is generally performed.

Geogrids are typically used for reinforcement applications and areas of potential differential settling. Geogrids are a less extensible, higher strength alternative to woven and non-woven geotextiles. Geogrids have large apertures particularly suited for coarser-grained, gravelly backfill materials, or material with angular rock such as "breaker run" (which can puncture geotextiles). Geogrids can provide both temporary support to construction equipment and permanent support to pavement sections. Geogrids can also be overlapped or clipped together (as opposed to being sewn).

Factors influencing the decision to use a woven or non-woven geotextile versus a geogrid include availability, cost and ease of installation, and the composition of the overlying material (e.g., "breaker run" material versus sand). Strength is more typically a design consideration when, prior to construction, it becomes evident that an embankment, for example, requires reinforcement to help prevent failure or differential settling. Woven or non-woven geotextiles are better for applications were separation is the primary goal.

More information concerning the properties and appropriate selection of both geotextiles and geogrids can be found in the Federal Highway Administration (FHWA) *Geosynthetic Design and Construction Guidelines* report, or at www.fhwa.dot.gov.

Considerations for Alternative Subgrade Materials. Other synthetic and structural products commonly considered in the design stage are available to help solve frost damage problems. Such products include lightweight fills (e.g., Geofoam®, shredded or chipped tires and wood chips) and cellular confinement systems (geocells).

Lightweight fills are used primarily to reduce settlements of embankments constructed over compressible subgrade materials, and may therefore not be practical for small, isolated repairs. The use of lightweight fills, however, does enhance subgrade uniformity and reduces frost susceptibility, and can enhance subgrade drainage as well. Products that insulate like Geofoam®, on the other hand, can contribute to differential roadway surface icing under some circumstances.

Cellular confinement systems are used primarily to increase the strength and load-carrying capacity of pavements constructed over weak and compressible subgrade materials. By creating a reinforced, three-dimensional structure below pavements, these systems also enhance subgrade uniformity and provide significant resistance to differential subgrade movement.

Strategies to Reduce/Limit Subgrade Moisture

Surface Drainage. Limiting the amount of surface drainage to which pavement subgrade materials are exposed can significantly reduce the magnitude of subgrade heaving upon freezing and strength loss upon thawing. This is generally accomplished in urban areas through the installation of curb and gutter, and storm drainage systems. In rural areas, pavements are sloped to drain into ditches that ultimately carry water into streams, lakes, swamps or other low areas.

Ideally, ditches should extend at least 2 to 4 feet below pavement subgrade elevations to effectively reduce the effects of subgrade moisture on pavement structure performance. Periodic ditch maintenance is required to prevent sediment, debris and vegetation from obstructing the flow of water in ditch bottoms.

Subsurface Drainage. Surface drainage percolating into, and groundwater moving through pavement subgrades need outlets to limit their ability to saturate and weaken subgrade materials. This is generally accomplished by installing drainpipes below free-draining subbase layers, or below the aggregate base layer where a subbase is not provided.

Ideally, drainpipes should be embedded in free-draining gravel, which, in turn, is wrapped in a filter fabric. It is more common, however, to install drainpipes that are wrapped in a filter "sock." For the drainpipes to be most effective, they should be embedded below the lower boundary of the subbase or aggregate base layer (which should be sloped to drain toward the drainpipes). Drainpipes in urban settings can be tied into area catch basins; drainpipes in rural settings need to be "daylighted" into adjacent ditches at regular intervals, or at low points, along the alignment.

Depending on the volume of subsurface moisture to which the pavement subgrade is exposed, a single drainpipe, installed perpendicular to the alignment at a low point, perhaps with "finger" drains extending parallel to the alignment in each direction, may be adequate. It may also be necessary to install a series of drainpipes parallel to the alignment, down the centerline and/or along opposite drive lanes or shoulders.

Conclusions

As stated earlier, no repair method is universal; the evaluation of appropriate treatments requires:

- An understanding of site conditions,
- An assessment of the impact that *subgrade quality, uniformity, surface and subsurface drainage*, have had on the development and propagation of frost damage,
- And the best available materials, equipment, and funding.

The following pages are provided as a guide to help select the appropriate treatment. In general, the most successful treatments address both subgrade quality/uniformity, and surface/subgrade drainage.

Worksheet
Effective Methods to Repair Frost Damaged Roadways

DATE: ____________________

ROAD NAME: ____________________

TO/FROM: ____________________

EVALUATOR: ____________________

Construction/Maintenance History

	Available	Not Available	Pertinent details
Plans	☐	☐	____________________
Specifications	☐	☐	____________________
Construction notes	☐	☐	____________________
Maintenance records	☐	☐	____________________

Visual Observation Results

Nature/extent of damage (describe): ____________________

____

Area topography (describe): ____________________

____

Area drainage (describe): ____________________

____

Equipment access (describe): ____________________

____

Recommended Subgrade Evaluation

	Yes	No	Scope
Deflection testing	☐	☐	____________________
Penetration test borings	☐	☐	____________________
Auger borings	☐	☐	____________________
Dynamic cone penetrometer testing	☐	☐	____________________
Laboratory testing	☐	☐	____________________
Engineering consultation	☐	☐	____________________

Preliminary Construction Materials Checklist

	Yes	No	Describe
Are soils/aggregates available on-site or locally?	☐	☐	____________________
Do existing drainage structures need repair/replacement? (ditches, culverts, tile)	☐	☐	____________________
Might additional drainage structures be required? (tile, catch basins)	☐	☐	____________________
Should structural "enhancements" be anticipated? (woven or non-woven geotextile, geogrid)	☐	☐	____________________

Effective Methods to Repair Frost Damaged Roadways

Situation

Frost Heave

Damage appears to be due primarily to expansion and heaving upon freezing

&

There appears to be limited loss of subgrade strength and pavement support upon thawing

Both may be present in damaged areas to varying extents

Frost Boil

Damage appears to be due primarily to loss of subgrade strength and pavement support upon thawing

&

There appears to be limited amount of expansion and heaving upon freezing

Evaluation

Step 1 — SUBGRADE CONSISTENCY

A

Where there is differential heaving due to non-uniform subgrade soils

proceed to:

- Scarify and recompact
- or
- Remove and recompact
- or
- Remove and replace

B

Where there is differential heaving due to presence of buried structure

proceed to:

- Remove and recompact
- or
- Remove and replace
- and
- Taper existing trench sidewall*

C

Where there is subgrade weakening and loss of pavement support

proceed to:

- Remove and recompact
- or
- Remove and replace
- and
- Include a geotextile or geogrid underlayment

* All improvements that involve replacement with dissimilar materials should include provisions for tapering excavation sidewalls.

Step 2 — SUBGRADE DRAINAGE

A

Where there is evidence of shallow or perched groundwater

B

Where there is a topographically low area present

in addition to, or independently of subgrade improvement provisions:

- Include drain tile
- and
- Raise the existing embankment
- and
- Provide or improve ditches