FROST ACTION CONSIDERATIONS IN ROADWAY CONSTRUCTION

Edward J. Hoppe
Virginia Transportation Research Council

INTRODUCTION

The effects of climate and water on roadway design, construction, and performance have always been of the highest importance. Frost action beneath the roadway surface is a major concern at locations experiencing freeze-thaw cycles. Cold-region climate contributes to accelerated pavement damage resulting from freezing and thawing process combined with heavy truck traffic.

Typically, there are three conditions necessary to cause a frost heave:

1. Freezing temperatures
2. Frost susceptible soils
3. Availability of water

In the absence of any of these conditions frost heave does not take place. Thus, efforts are being made to mitigate at least one of them in roadway constructions in cold regions.

FROST PENETRATION

In cold regions it is sometimes advantageous to limit the depth of frost penetration by providing thermally insulating material at some depth below the road surface. Field experiments conducted in northern Quebec (Konrad et al., 1996) involved evaluation of sawdust, tire chips and sand mixture, and extruded polystyrene (styrofoam). These materials were placed in instrumented roadway sections and their insulating properties were measured. The instrumentation consisted of heave gages, thermistors, TDR probes, and piezometers. Falling Weight Deflectometer (FWD) tests were also performed to determine mechanical characteristics of each test section. The results indicate that the test section insulated with saw dust performed well and had the best cost-performance ratio. This section consisted of 200 mm of sand placed on natural soil, 370 mm of sawdust, 450 mm of crushed stone, and 150 mm of asphalt pavement. The test section insulated with styrofoam material also provided good thermal protection to the underlying subgrade. By contrast, it was discovered that sand/tire chip layer was not effective in preventing frost penetration into the frost-susceptible subgrade.

The lack of adequate thermal insulation of tire chip/sand mix was also observed at an experimental embankment test section constructed in Virginia (Hoppe, 1994). This embankment was built of shredded tires and sandy soil mixture to a height of approximately 7.5 m. The instrumentation included settlement probes, soil pressure gages and temperature sensors. The embankment performed very well from the standpoint of reducing vertical soil pressures on the foundation soil, by approximately 60%. However, the temperature data collected at the base of embankment shows no appreciable difference from a comparable embankment constructed with conventional materials.

FROST SUSCEPTIBILITY

There are various definitions of frost-susceptible soils. In the US, the Corps of Engineers criterion stipulates that there should be no more than 3% of particles smaller than 0.02 mm (Janoo et al., 1997). To make it more practical to implement, the Corps also recommended a criterion of no more than 2% of particles passing the #200 sieve (0.075 mm), since it is usually the smallest sieve used in the grain size analysis. It has been discovered than this criterion can be overly conservative in some cases. The use of the 0.075 mm grain size alone as an indicator of frost susceptibility was not found to be justified by others (Vinson et al., 1986).

In Norway, the grain size criteria for frost susceptibility involve 0.002 mm, 0.02 mm, and 0.2 mm sizes (Knutson, 1993). Soils are categorized into four groups, ranging from T1 (no frost susceptibility) to T4 (high frost susceptibility), as shown in Figure 1. Highly frost-susceptible soils are typically coarse silts with less than 40% of particles smaller than 0.002 mm, more than 12% of particles smaller than 0.02 mm and more than 50% of particles smaller than 0.2 mm.

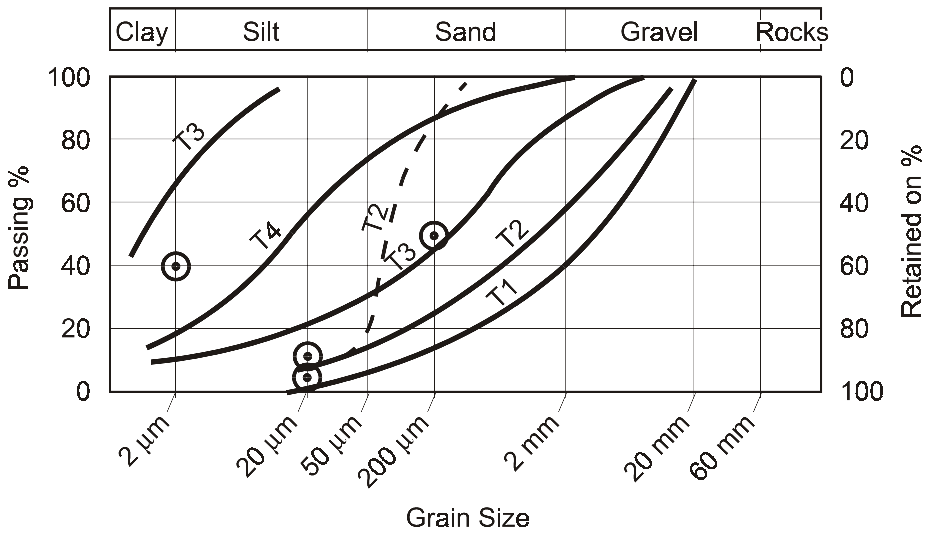

Figure 1. Norwegian frost susceptibility criteria.

In roadway aggregates, frost-susceptibility criteria based on the grain size need to be evaluated with respect to the stability of compacted material and associated raveling and dusting potential. Current state of the practice for maintaining and upgrading unpaved aggregate roads in Australia and New Zealand stipulates 10–20% of particles passing the 0.075 mm sieve (Jahren, 2001) in order to reduce raveling. In addition, 4% cross fall is typically applied to aggregate roads, to improve water runoff and reduce potholes. In Minnesota, where freeze-thaw problems are very acute, the latest unpaved aggregate road specifications require 8-15% of particles passing the 0.075 mm sieve, reflecting a change from previous 0-15% requirements (Johnson, 2000). A maximum of 10% is specified for aggregates under asphalt pavements.

Additional measures include disking and re-compacting the foundation soil for homogeneity, in order to reduce differential heave (Van Dusen, personal communication, 2002).

DRAINAGE

Water can enter a pavement section from the surface through precipitation, laterally through a groundwater flow, and upwards through capillary action. Proper drainage is essential for optimum operation of a roadway in any climate. In Maine, tests were conducted to evaluate the use of special geocomposite drainage net, serving as a drainage layer and a capillary barrier on frost-susceptible subgrade soils (Christopher et al., 2000), as shown in Figure 2. This drainage system proved to be very effective, classifying as good to excellent based on AASHTO requirements (AASHTO, 1993).

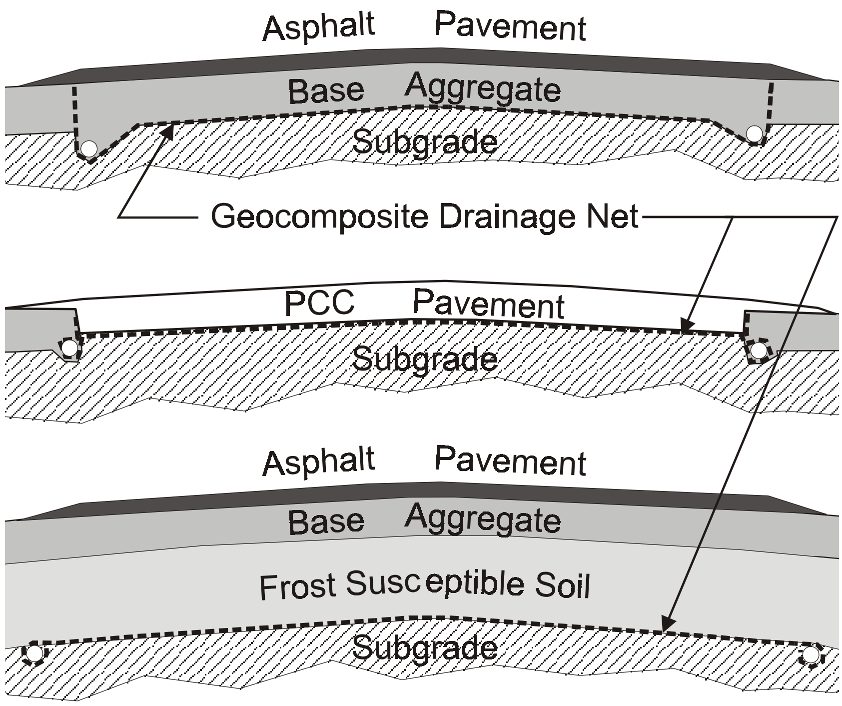

Figure 2. Potential applications of geocomposite drainage net.

In Virginia, laboratory tests were conducted to examine the influence of particles passing the 0.075 mm sieve on permeability of the aggregate material (Hoppe, 1996). The results indicate no direct correlation between these variables. However, an inversely proportional relationship was observed between the permeability and the coefficient of uniformity, indicating that the grain size distribution, as opposed to grain size by itself, is significantly influencing aggregate permeability.

CONCLUSIONS

Detrimental impact of frost action on roads can be mitigated by controlling depth of frost penetration, replacing or modifying frost-susceptible soils and providing effective drainage. Grain size-based frost-susceptibility criteria for roadway materials need to be reconciled with the requirements for stability.

There is a substantial amount of on-going research aimed at improving pavement design in general and the resistance to freeze-thaw effects in particular. In the US, the Strategic Highway Research Program (SHRP) analyzes data from various parts of the country. The Minnesota Road Research Project (Mn/ROAD) is a facility for conducting detailed studies at one particular location. Both approaches are aimed at defining and resolving problems concerning pavement design, construction, and performance.

REFERENCES

AASHTO, (1993). *AASHTO Guide for Design of Pavement Structures*. American Association of State Highway and Transportation Officials, Washington, D.C.

Christopher, B. R., Hayden, S. A., and Zhao, A. (2000). *Roadway Base and Subgrade Geocomposite Drainage Layers*. Testing and Performance of Geosynthetics in Subsurface Drainage, ASTM STP 1390. American Society for Testing and Materials, West Conshohocken, PA.

Hoppe, E. J. (1994). *Field Study of a Shredded-Tire Embankment*. Virginia Transportation Research Council, Charlottesville, VA, 46 pp.

Hoppe, E. J. (1996). *The Influence of Fines on Strength and Drainage Characteristics of Aggregate Bases*. Virginia Transportation Research Council, Charlottesville, VA, 33 pp.

Jahren, C. T. (2001). *Best Practices For Maintaining And Upgrading Aggregate Roads in Australia And New Zealand*. Minnesota Department of Transportation, St. Paul, MN, 75 pp.

Janoo, V. C., Eaton, R., and Barna, L. (1997). *Evaluation of Airport Subsurface Materials*. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH, 32 pp.

Johnson, G. (2000). *Aggregate Roads Research Bulletin 04*, Minnesota Department of Transportation, St. Paul, MN.

Knutson, A. (1993). *Frost action in soils*. Norwegian Road Research Laboratory, Oslo, 40 pp.

Konrad, J.-M., Dore, G., and Roy, M. (1996). *Field Observations of Instrumented Highway Sections with Different Frost Protections*. Proceedings of the Eighth International Conference on Cold Regions Engineering, Fairbanks, Alaska, p. 652-663.

Vinson, T. S., Ahmad, F., and Rieke, R. (1986). *Factors Important to the Development of Frost Heave Susceptibility Criteria for Coarse-Grained Soils*. Transportation Research Record 1089. Transportation Research Board, Washington, D.C.