



RESEARCH SERVICES SECTION

TECHNICAL SUMMARY

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PROJECT COST:

\$79,493



Two-inch lengths of steel reinforcement bar were used as frost pins to measure how far frost heave elevates pavement surfaces.



Effects of Seasonal Changes on Ride Quality at MnROAD

What Was the Need?

During the winter, soil under a roadway that has been saturated with water freezes and expands, causing the road to rise. When this occurs unevenly, the result is rougher roads during the winter and spring, and in some cases, cracked pavement surface layers. This problem of “frost heave” is very common in Minnesota, especially on lower volume roads, and can cause serious damage to concrete, asphalt and gravel pavements. It presents one of the greatest challenges to engineers to keep Minnesota’s 130,000 miles of roads well maintained throughout the year. Cracked and heaved pavements lead to a bumpy or otherwise poor driving experience for motorists.

Engineers typically respond to these problems with “rough road” signs in the spring, but in extreme cases, roads may require spot grinding, localized overlays or replacement of pavement and underlying materials. These maintenance responses can be costly. While engineers have reduced the occurrence of frost heave over the last 30 years with more blending of lower-lying materials, little is known about the mechanisms involved.

What Was Our Goal?

The objective of this study was to identify how different pavement designs are affected by frost heave and how this relates to ride quality during different seasons. This information will help engineers design pavements to better withstand seasonal variations.

What Did We Do?

Researchers investigated frost heave by gathering and analyzing related data and correlating it to pavement characteristics and ride quality. Much of this data was from MnROAD test cells constructed in the early 1990s, collected as part of normal operating procedures at the time.

First, they selected 20 pavement sections at the MnROAD research facility—eight constructed with portland cement concrete and 12 with hot-mix asphalt. They then installed frost pins—2-inch-long pieces of rebar—into the pavement sections flush with the surface and surveyed periodically through the seasons to determine the heights of the pins over a four-year period. Mn/DOT’s pavement management vans were driven over MnROAD test cells at different times of the year to measure ride quality.

Researchers then evaluated this heave and ride data to determine:

- How different mix designs (HMA, PCC, base types and thicknesses, subgrade type) affect the total (maximum), duration and consistency of frost heave throughout the year
- How the frost measured for the MnROAD test cell designs correlates to the measured ride roughness

What Did We Learn?

Design Features. Investigators found that:

- For concrete, a longer design life has no significant impact on frost heave performance, but design life correlates with better resistance to frost heave in asphalt.
- Clay subgrades experience more frost heave than sand subgrades under both concrete and asphalt.
- Better drainage results in less frost heave for both concrete and asphalt.
- For both concrete and asphalt, thick pavements bear heavier loads and often extend the pavement structure down to the level that frost penetrates the soil, reducing frost heave. A thicker pavement even mitigates the impact of nonuniform frost heave.

continued

“We found essentially that pavements over a sand subgrade, thicker pavement structures and pavements with drainable bases exhibit less frost heave than other pavements.”

—Lev Khazanovich,
Principal, Associate
Professor, University of
Minnesota Department
of Civil Engineering

“This study confirmed our current practices in responding to frost heave, but didn’t provide enough input to change our design specifications. Improving data collection and ride analysis methods may offer more insight.”

—Benjamin Worel,
MnROAD Operations
Engineer, Mn/DOT Office
of Materials

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Damp subgrade and pavement may shift during expansion in freezing temperatures, causing frost heave that can severely damage surface conditions and ride quality.

- Asphalt binder types do not affect frost heave performance.
- In asphalt designs, coarser base materials hold less water and so suffer less frost damage.
- In concrete, joint spacing does not affect overall frost heave magnitude, but frost heave damage is more concentrated in short-spaced slabs, which have smaller areas for the distribution of heave stress.

Ride Quality. While investigators could not confirm a correlation between frost heave and ride quality deterioration on flexible pavements, they did not reject the hypothesis that frost heave degrades ride on rigid pavements insofar as thicker concrete pavements experience less frost heave damage.

Seasonal Variations. Frost pin elevations begin to increase at the end of September and reach their highest points in early March, then decrease until mid-April. From May to September, frost pin elevations change very little. Though ride quality improves in summer months, no seasonal statistical connection was established between pin heights and ride quality.

What’s Next?

Investigators suggest that a refined approach to ride quality data collection and assessment methods might offer better data on any correlation between ride quality and frost heave magnitude.

Since thicker MnROAD test cells exhibited less frost heave, which was correlated with ride quality in concrete pavements, there is also a need for further investigation of the benefits of using thicker bases under concrete pavements.

Investigators recommended other improvements in design and construction practices to improve ride quality, including research into the mix design for HMA pavements to reduce thermal cracking—the main cause of roughness—and steps to improve the initial roughness of concrete pavements.