Evaluation of Spring Load Restriction Removal Protocols

tech transfer summary

An economical and easy-to-use protocol for timing removal of spring load restrictions was developed based on knowledge about a roadway's structure, base layers, and subgrade soils and the approximate depth to the groundwater table.

Objective

The main objective of this research was to develop an economical and easy-to-use protocol to help agencies time the removal of spring load restrictions (SLRs) on roadways.

Background

Many miles of roads in seasonal frost areas are highly susceptible to damage during the spring thaw period. To minimize the damage, many state and local transportation agencies apply SLRs, which limit the allowable load on the road during the critical time interval when the roadway structure is most vulnerable.

Over time, as the excess moisture dissipates, the roadway regains its strength and stiffness and the SLR can be removed. Deciding when to remove SLRs is complicated given the variable time window during and after thawing when excess moisture remains in the base and subgrade layers, causing the overall roadway structure to remain weak.

City of Concord, New Hampshire, http://www.concordnh.gov/1379/Spring-Operations

Image from an agency's website announcing lifting of spring load restrictions

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RESEARCH PROJECT TITLE
Evaluation of Spring Load Restriction Removal Protocols

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PRINCIPAL INVESTIGATOR
Heather J. Miller
Heather Miller & Associates

MORE INFORMATION
aurora-program.org

Aurora
Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103

The Aurora program is a partnership of highway agencies that collaborate on research, development, and deployment of road weather information to improve the efficiency, safety, and reliability of surface transportation. The program is administered by the Center for Weather Impacts on Mobility and Safety (CWIMS), which is housed under the Institute for Transportation at Iowa State University. The mission of Aurora and its members is to seek to implement advanced road weather information systems (RWIS) that fully integrate state-of-the-art roadway and weather forecasting technologies with coordinated, multi-agency weather monitoring infrastructures.

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Problem Statement

Historically, inspection/observation or time-based methods have been used to decide when to remove SLRs, but those methods are highly subjective. Directly measuring the load capacity of a road during the spring thaw recovery typically requires the use of a falling weight deflectometer (FWD), which is expensive and time consuming, requires road closures, and can only address a small segment of the road network. Alternative approaches using embedded moisture sensors also pose challenges in terms of installation and expense and only work for certain soil types.

A previously completed Aurora project (Miller et al. 2020) provided transportation agencies with a relatively reliable protocol for predicting when to apply SLRs based on atmospheric weather data. The application protocol was validated, but the volume of data available was insufficient to validate protocols regarding the timing of SLR removal.

A need remains for a more robust and cost-effective means of deciding when to remove SLRs.

Research Description

This project was funded primarily by the North Dakota Department of Transportation (NDDOT), which has a robust array of subsurface temperature depth probes (TDPs) throughout the state. Because TDPs enable accurate determination of frost out dates, it was decided that the protocol developed would define time windows after the end of thawing when the roadway has recovered a significant amount of stiffness and SLRs can be removed.

To develop the model, the research team utilized a wealth of FWD data from three test cells at the Minnesota Department of Transportation's (MnDOT's) MnROAD research facility. FWD data from nine other sites were used to validate the model, with three sites in North Dakota, three in New Hampshire, two in New York, and one in Maine.

The research team investigated several FWD deflection basin parameters to determine if those parameters could be used to detect seasonal changes in the response of the pavement, especially during thawing and strength recovery after the end of thawing. An initial analysis suggested that none of those parameters could effectively be used to determine the necessary time lag for strength recovery (after the end of thawing) for SLR removal.

Further analysis suggested that surface modulus values computed from Boussinesq equations would be more useful for this purpose. Numerous statistical analyses were performed on the FWD data sets, and model/protocol development considered factors such as base layer and subgrade type, effects of moisture, and depth to the groundwater table (GWT).

Key Findings

During model development, two factors were found to have the most significant influence on the recovery time necessary for SLR removal: subgrade type and depth of the water table.

In terms of subgrade type, roads with coarse-grained subgrades having less than about 5% to 7% fines were found to recover much more quickly than roads with subgrades having more than 15% fines. This was not surprising because clean, coarse-grained soils drain much more rapidly than soils with higher fines contents.

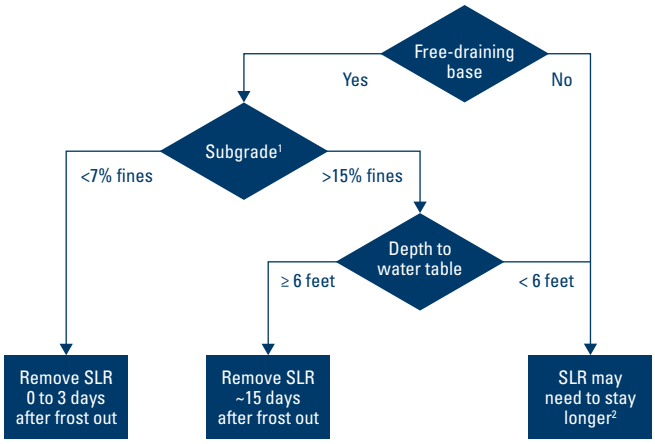
Based on data from MnROAD Cell 25, minimal (if any) recovery was observed beyond the frost out date for roads with very free-draining base and subgrade soils. Therefore, SLRs could be removed for such roads when the frost has gone out or a few days afterward.

Validation data from the Kancamagus Highway (NH 112) site in New Hampshire, however, suggested that even for roads with free-draining base and subgrade soils, it is important to place SLRs as soon as thaw begins penetrating the base layer(s) and to keep the SLR in place during the critical period when underlying frozen layers exist and prohibit drainage of excess moisture from the base layer(s).

Sensitivity studies conducted according to the 1993 American Association of State Highway and Transportation Officials (AASHTO) design guidelines suggest that maintaining SLRs from the start through the end of the thawing period can increase the design life of roads with free-draining base and subgrade soils by about 10%.

For roads with subgrades containing 15% or more fines, the statistical analysis suggested that SLRs could be removed around 15 days after frost out, as long as the roads have free-draining base layers and the GWT is deeper than about 6 ft below the top of the pavement. For road sections with shallower water tables and/or no free-draining base layers, worst-case conditions may exist, especially if cohesive subgrades are present. In such conditions, it may be prudent to leave SLRs in place for a longer period and/or reroute heavy traffic away from those sections.

Sensitivity studies conducted according to the AASHTO (1993) design guidelines suggest that maintaining SLRs from the start through the end of the thawing period can increase the life of roads with fine-grained subgrades by about 40% to 49%, depending on other factors such as the thickness of the asphalt layer and the thickness and quality of the base layer. Keeping SLRs in place for an additional 15 days after frost out results in an additional increase in service life of 12% to 16%, again depending on details of the asphalt and base layers.



[1] Subgrades with fines contents between 7% and 15% must be reviewed on an individual basis.
[2] The individual site must be reviewed for timing of SLR removal.

Decision tree for timing SLR removal

Implementation Recommendations

The decision tree shown here is suggested as a means of implementing the SLR removal guidelines developed in this study. To use this decision tree effectively, it is necessary to know the roadway structure, base layer(s), and subgrade soils and the approximate depth to the groundwater table.

The first consideration is whether the road has a free-draining base layer (i.e., a sandy or gravelly material with no more than about 5% to 7% fines). If the road has no free-draining base layer (and/or if other conditions prevent drainage of the base layer), then the site needs to be reviewed, and extra precautions may need to be taken regarding the SLR.

For example, an agency may need to further reduce allowable loads and/or leave the SLR in place for a longer period. Alternatively, the agency may limit the SLR duration and accept that the road may face additional maintenance costs and a shorter life.

If the road has a free-draining base layer, then the subgrade type becomes the primary consideration. For subgrades with relatively clean gravels and sands (less than 7% fines), the SLR could be removed within 0 to 3 days after frost out.

For subgrades with clays, silts, and silty (or clayey) sands (soils with more than about 15% fines), the depth to the GWT becomes important. If the GWT is relatively deep (6 ft or more), the SLR should remain in place for 15 days beyond the frost out date, but little is gained by leaving it in place much longer.

For subgrades with more than 15% fines and shallow water tables (less than about 6 ft deep), the site needs to be reviewed, and extra precautions may need to be taken regarding the SLR. (Examples are noted above.) This is especially true for road with clay subgrades and shallow water tables, where worst-case conditions may exist.

No sites were available for this study with subgrades containing between 7% and 15% fines. For such cases, the research team recommends being prudent, erring on the side of caution, and leaving the SLR in place for about 15 days after frost out.

Implementation Benefits and Readiness

Lifting SLRs too soon can lead to increased maintenance costs and shorter design lives for roadways, while leaving SLRs in place for too long can result in undue delays in the movement of goods and the provision of services.

The decision tree and protocol developed through this work can be used to implement the SLR removal guidelines from this study. Using this methodology may help transportation agencies lift their SLRs more quickly than they have in the past.

References

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

Miller, H. J, R. L. Berg, and M. A. Kestler. 2020. *Demonstration and Inter-Comparison of Seasonal Weight Restriction Models – Phase II*. Aurora Program, Institute for Transportation, Iowa State University, Ames, IA. **https://publications.iowa.gov/35060/1/seasonal_weight_restriction_models_phase_II_w_cvr.pdf**.