ERDC/CRREL TR-00-6

Cold Regions Research and Engineering Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Thaw Weakening and Load Restriction Practices on Low Volume Roads

Maureen A. Kestler, Thomas Knight, and Audrey S. Krat

June 2000

Approved for public release; distribution unlimited.

20000802 166

DTIC QUALITY INSPECTED 4

Abstract: Low volume roads subjected to seasonal freezing are highly susceptible to damage from traffic during midwinter and spring thaws. Such traffic-induced damage can be minimized by a variety of design methods; however, most are not economically feasible. As a result, loads are often restricted or prohibited during thaw-weakened periods. While this practice reduces road maintenance costs, the economic impact on industries that rely on continued heavy trucking can be significant. This report reviews the process of ice segregation and thaw weakening, and then discusses both quantitative and qualitative results from a survey on load restriction practices that was distributed to state departments of transportation (DOTs). Survey topics include state DOT load restriction practices, types and mileage of roads posted, methods for determining dates for imposing and removing load restrictions, enforcement of restrictions, and feedback from road users.

How to get copies of CRREL technical publications:

Department of Defense personnel and contractors may order reports through the Defense Technical Information Center:
DTIC-BR SUITE 0944
8725 JOHN J KINGMAN RD
FT BELVOIR VA 22060-6218
Telephone 1 800 225 3842
E-mail help@dtic.mil
msorders@dtic.mil
WWW http://www.dtic.dla.mil/

All others may order reports through the National Technical Information Service:
NTIS
5285 PORT ROYAL RD
SPRINGFIELD VA 22161
Telephone 1 800 553 6847 or 1 703 605 6000
1 703 487 4639 (TDD for the hearing-impaired)
E-mail orders@ntis.fedworld.gov
WWW http://www.ntis.gov

A complete list of all CRREL technical publications is available from:
USACRREL (CEERD-IM-HL)
72 LYME RD
HANOVER NH 03755-1290
Telephone 1 603 646 4338
E-mail techpubs@crrel.usace.army.mil

For information on all aspects of the Cold Regions Research and Engineering Laboratory, visit our World Wide Web site:
http://www.crrel.usace.army.mil

Technical Report
ERDC/CRREL TR-00-6

US Army Corps
of Engineers®
Cold Regions Research &
Engineering Laboratory

Thaw Weakening and Load Restriction Practices on Low Volume Roads

Maureen A. Kestler, Thomas Knight, and Audrey S. Krat

June 2000

Approved for public release; distribution is unlimited.

PREFACE

This report was prepared by Maureen A. Kestler, Research Civil Engineer, Civil Engineering Research Division, U.S. Army Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, and Thomas Knight and Audrey S. Krat, formerly of CRREL. Funding of this research was provided by CRREL.

The authors thank David van Deusen of Mn/ROAD and Thomas Moore of the USDA Forest Service for technically reviewing this report.

The authors thank Thomas Moore and Peter Bolander (USDA Forest Service), David Van Deusen (Mn/DOT), state DOTs, and USDA Forest Service regional offices for their assistance with information provided in this report. They also thank CRREL's editing and illustrating departments.

The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of the use of such commercial products.

CONTENTS

ILLUSTRATIONS

TABLES

Thaw Weakening and Load Restriction Practices on Low Volume Roads

MAUREEN A. KESTLER, THOMAS KNIGHT, AND AUDREY S. KRAT

INTRODUCTION

Three conditions are necessary for the occurrence of ice segregation:

1. The soil must be *frost susceptible.*
2. A *water source* must be available to the freezing zone.
3. *Freezing temperatures* must penetrate into the soil.

Ice segregation itself is a complex interaction of heat and moisture flow (U.S. Army and the Air Force 1985). Negative pore pressures are generated at the freezing front, causing moisture to migrate toward the front. This results in ice lensing near the freezing front and frost heaving at the pavement surface. During midwinter and spring thaws, ice lenses melt both downward from the surface and upward from lower depths. Melting ice lenses leave the soil unconsolidated. Additionally, downward melting releases excess water that cannot drain through the underlying frozen layers. Consequently, support capacity is reduced, and the pavement system becomes susceptible to damage during trafficking. Figure 1 shows a typical low volume road exhibiting signs of pavement distress from trafficking during spring thaw.

PAVEMENT DESIGN IN SEASONAL FROST AREAS

The pavement thickness design procedure for high-traffic-volume highway and runway pavements subjected to seasonal freezing should include trial designs that account for the effects of frost action (Yoder and Witczak 1975). The U.S. Army Corps of Engineers pavement design procedure includes designing for normal conditions, full or limited subgrade frost penetration (LSFP), and reduced subgrade strength (RSS). The frost action trial design is typically selected based on cost. In the case of many low volume roads, such rigorous trial design procedures are not used. Instead, roads evolve over the years as additional gravel or asphalt concrete (AC) surfacing is added to fill in ruts or overlay cracks. Consequently, these low volume roads (that are often built upon frost-susceptible subgrades) are highly susceptible to damage from trafficking during thaw-weakened periods.

Techniques other than LSFP and RSS (to reduce frost penetration and thaw weakening) are either costly or require additional research. Incorporating insulating layers, capillary cutoffs, or drainage layers can be costly for low volume design traffic. Using reduced tire pressures (alone or in combination with load reductions and load restrictions) may provide another alternative method for reducing springtime damage to low volume roads (Bradley 1997, Davies et al. 1998, Kestler et al. 1998, Mahoney et al. 1994, Moore 1997). However, even if research confirms the promising preliminary results, regulatory and policy-making departments must determine methods for enforcement. This will take time. Furthermore, using lower tire pressures may reduce, but will probably not eliminate, the negative impact of traffic on thaw-weakened roads. Most states in the northern United States impose load restrictions on low volume roads during thaw-weakened periods. This practice, when properly imposed and enforced, successfully minimizes springtime road

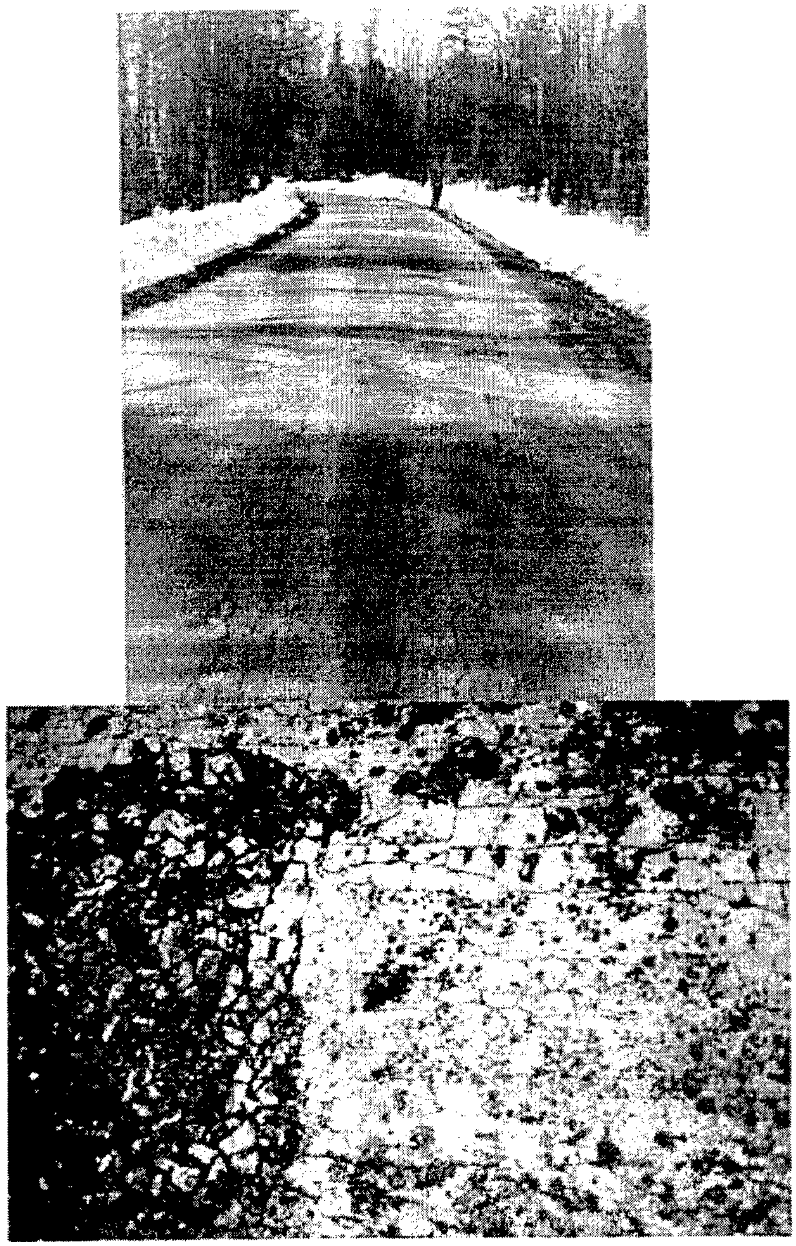


Figure 1. Low volume road with traffic-induced pavement distress during spring thaw.

damage. While the economic impact on selected industries that rely on continuous trucking is significant, two or three trucks on one spring day might cause the equivalent damage of design traffic during the entire year, if load restrictions are not imposed. This appreciably increases road maintenance and pavement reconstruction costs.

LOAD RESTRICTION SURVEY

During the spring of 1997, a 19-question survey on load restriction practices was distributed to 45 state DOTs. Surveys were not sent to Hawaii, Florida, Alabama, Mississippi, and Louisiana because of their warm climates. Several surveys were also sent to several U.S. Department of Agriculture Forest Service (USFS) offices (as the USFS maintains approximately 360,000 miles of low volume roads), and to selected report companies. The remainder of this report discusses survey results.

Thirty-six state DOTs and three USFS Regional Offices responded to the survey. Figure 2 shows the states in which DOTs post springtime load restrictions. Regions north of the white line are categorized as areas of seasonal freezing based on either 0.3 m (1 ft) of frost penetration in 10 years or an average temperature of 0°C (32°F) during one month in 10 years. Although some states north of the white line in Figure 2 appear to have no load restrictions, roads may be posted by agencies other than state DOTs, such as counties, cities, towns, the USFS, and private organizations. All but two of the states that post load restrictions indicated that restrictions are enforced, and they are most commonly enforced (with the penalty of a fine) by the state police/highway patrol. Interestingly enough, the only state that indicated restrictions did not significantly reduce road maintenance also indicated that it might be correlated to a lack of strict enforcement. One case was cited in which, even when restrictions are posted, trucks are occasionally allowed to haul through the night from approximately midnight until 5:00 a.m., during which time the roads stiffen because of nighttime freezing. This practice was allowed for logging operations so as to minimize the adverse economic impact (to the timber company) of a complete prohibition on hauling. Researchers in another state are developing a quantitative technique for indicating when frozen roads will not be damaged. This could partially counteract the negative effect of spring haul restrictions on local economies.

Sixteen state DOTs indicate that they post load restrictions annually, and four states post their roads at least occasionally or when conditions warrant. All of the states posting restrictions do so on asphalt-surfaced roads, 12 on chip-sealed roads, and only five on gravel-surfaced (or unsurfaced) roads. Unsurfaced and gravel-

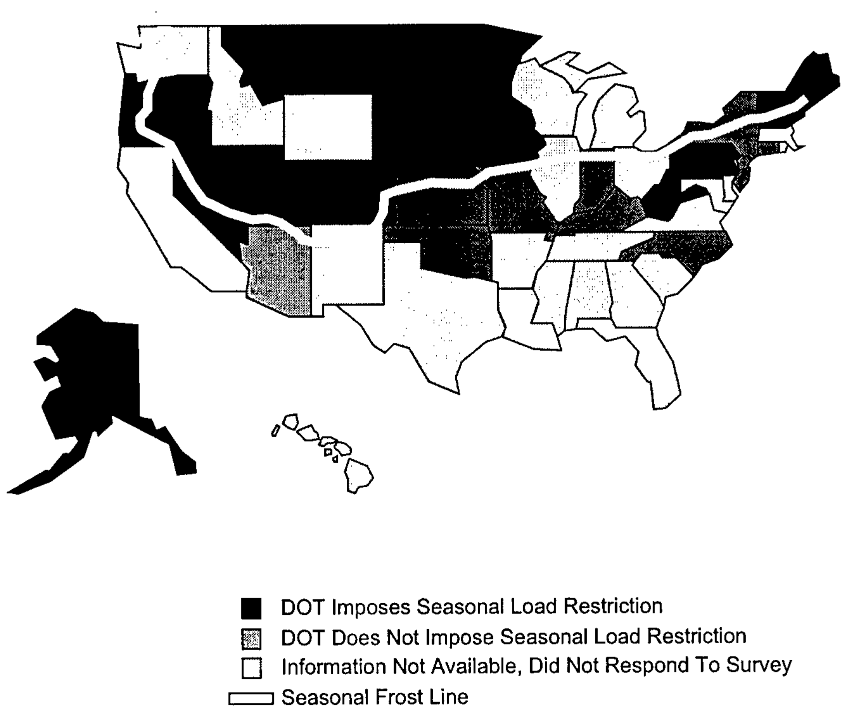


Figure 2. States in which DOTs post seasonal load restrictions. Seasonal frost line is based on 0.3 m (1 ft) frost penetration in 10 years or an average of 0°C (32°F) during one month in 10 years.

Table 1. Types of restrictions specified by state DOTs.

- Total shutdown.
- Speed limit restriction (speed unspecified).
- Load limit (load unspecified).
- 6 and 7 tons (5.4 and 6.3 metric tons) per axle.
- 6 tons per single axle and 7 tons per tandem axle.
- 11 tons (10 metric tons).
- Half the legal load limit.
- High enough to accommodate school buses.
- Over 15 tons (13.6 metric tons): total shutdown.
- 6–15 tons: load limited to the product of 300 × the sum of inches of the width of all tires.

surfaced roads are not typically under state jurisdiction; therefore they are posted by towns, counties, or another responsible agency. Types of restrictions varied considerably. A list is provided in Table 1.

A total of 3420 miles of gravel-surfaced road were reported as posted, and a total of 34,800 miles of asphalt-surfaced road were reported as posted. Although 10 states indicated that they post chip-seal surfaced roads, no states provided estimates of miles posted. Figure 3 shows a histogram indicating the breakdown of lengths posted.

Only a few states estimated road maintenance costs/mile and road maintenance savings/mile by imposing load restrictions. Estimates of savings were as high as a few hundred thousand dollars per mile. This adds up to millions of dollars per year per state. From the point of view of road maintenance agencies, load restrictions are unquestionably cost effective. However, local economy is adversely affected.

Figure 4 shows a breakdown of methods used for determining when to impose and when to remove load restrictions. More than half of the responding states that post load restrictions use subjective techniques, such as observation, to both place and remove load restrictions. Many of these states indicated that they post restrictions only after the first signs of springtime pavement distress are observed. By doing this, some damage is being allowed. Many also indicated that their preference would be to switch from current reactive methods to more quantitative methods (such as using a falling weight deflectometer [FWD]) if adequate resources were available. Twenty-four percent of responding DOTs currently use quantitative methods (e.g., FWD, frost tubes, or thaw

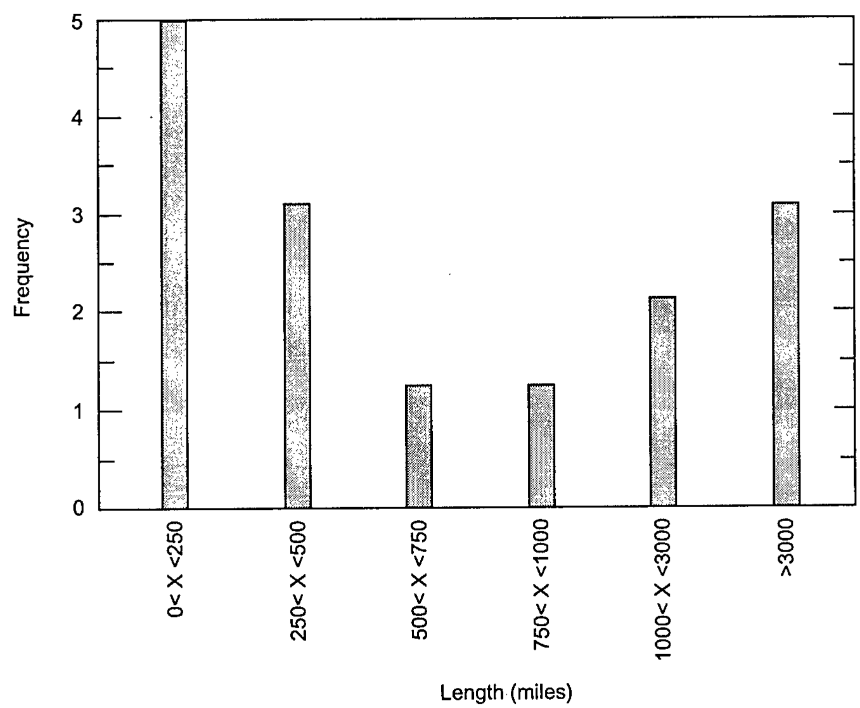
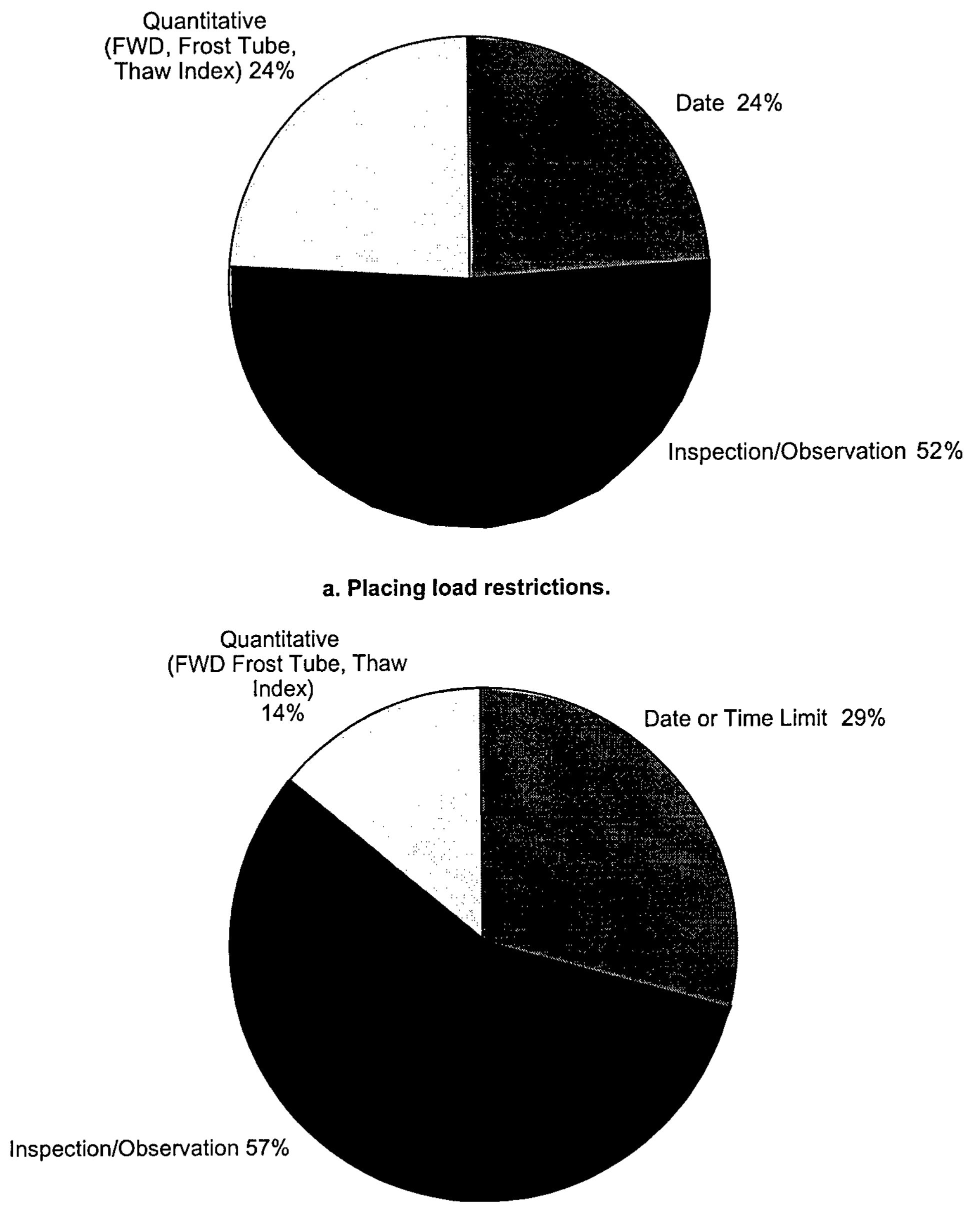


Figure 3. Breakdown of lengths of asphalt roads posted by state DOTs.



a. Placing load restrictions.

b. Removing load restrictions.

Figure 4. Methods for determining when to place and remove road load restrictions.

index) to place load restrictions (Fig. 4a); only 14% use quantitative methods to remove load restrictions (Fig. 4b). The remaining 10% who use such methods simply keep restrictions in place for a specific length of time or remove restrictions subjectively. Approximately one-quarter of the responding states use dates to impose restrictions.

Several states, particularly those using quantitative techniques, stated that they were comfortable about the start of the load-restricted period (the start of thaw is well defined: temperatures over 0°C [32°F], loss/reduction of frozen layer, sudden decrease in pavement deflection or stiffness as measured using an FWD, etc.). However, as observed in pavement engineering studies, recovery is not well defined. This is reflected by

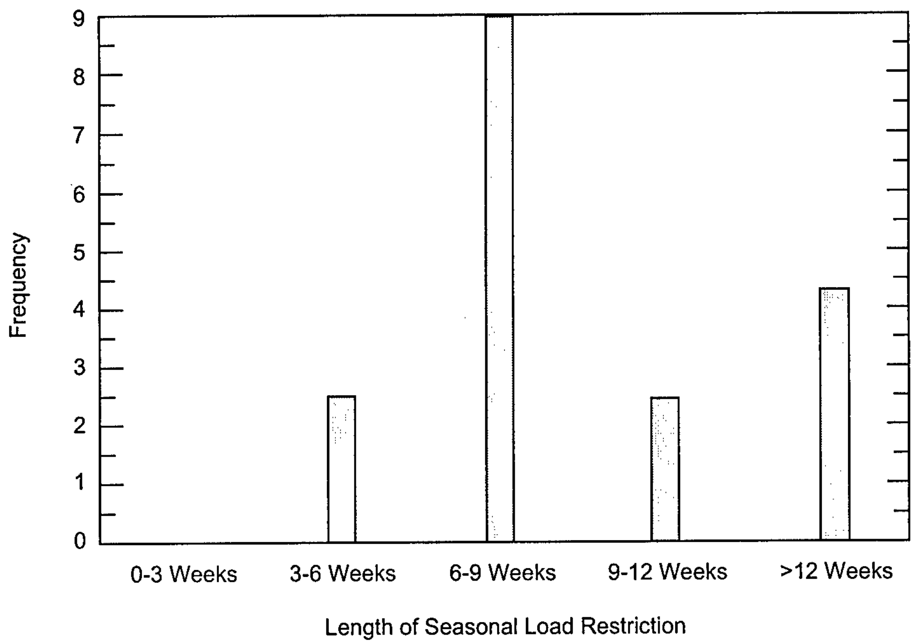


Figure 5. Length of time over which load restrictions are posted.

the wide range of length of time during which load restrictions are in effect (Fig. 5). Some roads are restricted for as long as a third of a year. Generally, the longer the load restrictions are in place, the more complaints were received from loggers and contractors. Table 2 lists typical DOT responses regarding user feedback.

While some states annually post load restrictions immediately after the first signs of springtime pavement distress are observed, a few states are taking a progressive approach to the problem of thaw weakening, and have researched, or are currently researching, relationships among pavement stiffness and other parameters. The USFS is currently evaluating correlations between pavement stiffness and soil moisture in search of a reliable, cost-effective method for determining when to suspend or commence timber hauling (Kestler et al. 1997). It is believed that permanently installed time domain reflectometry (TDR) and radio frequency (RF) soil moisture sensors, correlated with strength recovery, strategically located throughout the forest road network will provide this affordable solution.

Table 2. Road user feedback to DOTs and USFS on spring thaw load restrictions.

- Restricting the flow of goods makes shipping inconvenient.
- Some routes too restrictive; length of time too long.
- Numerous complaints from contractors and loggers.
- "Don't post my road."
- Haulers want restrictions lifted as soon as possible and more frequent FWD testing done in these areas.
- DOT met with trucking industry association, and they have jointly funded research on load restrictions.
- Using quantitative methods for shutting down roads but using subjective and arbitrary methods for determining when to reopen roads.

SUMMARY

Low volume roads subjected to seasonal freezing are highly susceptible to damage from traffic during spring thaw. Although reduced tire pressure technology is currently being evaluated as a method for minimizing traffic-induced road damage during thaw-weakened periods, at this time the most widely accepted and effective practice is to limit or prohibit heavy loads.

A survey distributed to state Departments of Transportation showed that most states in the northern third of the United States post load restrictions during spring thaw. However, the level of restriction, method of determining when to place restrictions, and length of restricted haul vary widely.

The economy of many industries, such as logging, relies on continuous movement of materials. Direct contact with some loggers indicated that the economic loss caused by load restrictions is substantial. However, until an alternative method is proven and accepted, millions of dollars per year (per state) for road maintenance are saved annually by load restrictions. Even greater road maintenance savings could be met if some of the DOTs that currently await the first signs of springtime pavement distress were to adopt an alternative, more quantitative, technique for placing load restrictions. Regarding removal of load restrictions, the feasibility of using TDR technology to determine when to resume hauling will primarily depend on the cost of the equipment.

Recommended follow-up is to investigate further which techniques for determining when to place and remove load restrictions are most cost effective (as a tradeoff between road maintenance costs and industry economics). Such information could not be evaluated at this time because not enough road maintenance costs/savings information was returned.

LITERATURE CITED

Bradley, A. H. (1997) *The Effect of Reduced Tire Inflation Pressures on Road Damage: A Literature Review.* Vancouver, B.C., Canada: Forest Engineering Research Institute of Canada (FERIC).

Davies, T. L., T. F. Wall, and A. Carpentier (1998) Reduced tire pressure initiative. *Transportation Research Record 1589,* Washington, D.C.

Kestler, M.A., B. Wright, D. Bull, G. Hanek, and M. Truebe (1997) Freeze-thaw testing of time domain reflectometry (TDR) and radio frequency (RF) sensors. *International Seasonally Frozen Soils Symposium, Anchorage, Alaska.*

Kestler, M. A., R. L. Berg, and T. L. Moore (1998) Reducing damage to low volume roads by using trucks with reduced tire pressures. *Transportation Research Record 1589,* Washington, D.C.

Mahoney, J. P., R. L. Copstead, R. R. Keller, and B. R. Sweet (1994) The potential use of central tire inflation during highway load restriction periods. Technical Paper 942445, Society of Automotive Engineers, Warrendale, Penn.

Moore, T. L. (1997) Variable tire pressure technology, reducing transportation costs and protecting forest ecosystem. Research pays off. *TR News,* no. 189.

U.S. Army and the Air Force (1985) *Pavement Design for Seasonal Frost Conditions.* Army TM 5-818-2, Air Force AFM 88-6, Chap 4.

Yoder, E.J., and M.W. Witczak (1975) *Principles of Pavement Design.* New York: Wiley.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YY)*
June 2000

2. REPORT TYPE
Technical Report

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Thaw Weakening and Load Restriction Practices on Low Volume Roads

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)
Maureen A. Kestler, Thomas Knight, and Audrey S. Krat

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center
Cold Regions Research and Engineering Laboratory
72 Lyme Road
Hanover, New Hampshire 03755-1290

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CRREL Technical Report 00-6

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR / MONITOR'S ACRONYM(S)

11. SPONSOR / MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

Available from NTIS, Springfield, Virginia 22161.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Low volume roads subjected to seasonal freezing are highly susceptible to damage from traffic during midwinter and spring thaws. Such traffic-induced damage can be minimized by a variety of design methods; however, most are not economically feasible. As a result, loads are often restricted or prohibited during thaw-weakened periods. While this practice reduces road maintenance costs, the economic impact on industries that rely on continued heavy trucking can be significant. This report reviews the process of ice segregation and thaw weakening, and then discusses both quantitative and qualitative results from a survey on load restriction practices that was distributed to state departments of transportation (DOTs). Survey topics include state DOT load restriction practices, types and mileage of roads posted, methods for determining dates for imposing and removing load restrictions, enforcement of restrictions, and feedback from road users.

15. SUBJECT TERMS
Load restrictions
Low volume roads
Seasonal freezing
Spring thaw
Thaw weakening
Traffic restrictions

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER (include area code)
U	U	U	U	14	