GUIDELINES FOR SPRING ROAD USE RESTRICTIONS

A Publication of

The University of New Hampshire

Technology Transfer Center

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GUIDELINES FOR SPRING ROAD USE RESTRICTIONS

Introduction

In many areas that have cold weather, especially those above the 40th parallel, pavements become damaged during the thawing periods. Damage usually occurs during late winter and early spring, but also occurs during warm weather periods in the mid-winter months. To prevent potholes and cracks from forming, highway agencies can:

1. Apply truck load restrictions during the thawing (or critical) period, or
2. Change the pavement structure to prevent or reduce damage.

Due to budget constraints, many agencies have only the first alternative.

In the 1980s the Washington State Transportation Center (WSTC) completed studies in cooperation with the Washington State Department of Transportation, Oregon State University, the Federal Highway Administration, and numerous state, city, and country agencies. Prior to these studies, few straightforward procedures existed that would determine the amount of load restrictions needed, when to apply them, and when to remove them. Therefore, a need existed to develop guidelines to help local agencies handle this serious problem. On the following pages a method is described to help local agencies more effectively apply load restrictions. (The method is also described in a videotape available from the UNH T^2 Center).

Douglas Dowey, a Maintenance Supervisor, applied the method during three winters in District 3 of the NH Department of Transportation. Mr. Dowey found that the method worked well for beginning road use restrictions. He found that the user had to exercise judgement to determine when to end restrictions. The factors users should consider are discussed in the section "Estimating the Duration of Road Use Restrictions."

The Problem

Frost action in soils can cause several damaging effects. A commonly known effect is frost heave. Less information is available on an equally serious problem, loss in the ability of the road base to support heavy vehicles. Reduced base course strength occurs during the thaw period (usually late winter or early spring). Water that penetrated the roadway layers freezes during the winter cold. During a thaw the ice melts from the top down, trapping water until the lower ice layers melt. The trapped water saturates the wearing and base course layers.

This effect is similar to the effects of a rising groundwater table, infiltration of water through a porous pavement surface or shoulder, or water penetrating a roadbed cut into a hillside or located in a water-saturated terrain. Whatever the cause, when the amount of moisture is above the amount the pavement was designed for, the strength (or stiffness) of the pavement and its supporting base is reduced.

Most pavement design methods are based on studies of pavement behavior when the subgrade moisture and density are optimum. In other words, design methods are based on the assumption that water will be diverted away from the road or will drain out of the base course.

The damage to a pavement structure, even with acceptable moisture levels, is directly related to the weights and frequency of the applied loads. A majority of the state DOTs use the AASHTO Interim Guide for Design of Pavement Structures[1] for designing their pavement thicknesses. In designing a specific pavement using this method the traffic is changed to equivalent 18,000 lb. single axle loads for a given design period and for known or assumed materials. Any lowering of material strength or increase in the number of equivalent 18,000 lb. single axle loads reduces the life of the pavement. Thus, the method of reducing loads when the strength of the pavement materials is reduced is a reasonable way to maintain the design life and general serviceability of the pavement. Hence, there is often a need for load restrictions during spring thaw because excessive water is present in the subgrade.

The Guidelines

The WSTC researches found that local and state highway agencies have a wide variety of practices for applying load restrictions before the "spring thaw." Truck load enforcement programs differ widely in terms of the load limits applied, the forms the restrictions take, and their implementation. The decision to close or open a highway or street is largely determined by experience and sometimes political pressure. There has been very little information to help decision-makers. Because federal and state research projects generally focus on high volume roads, little information has been available for secondary and lower category highways, even though these types of highways form a large part of county and municipal road systems. Local governments generally have low to modest maintenance budgets; few can afford to overlay the pavements damaged during the spring snowmelt. Therefore, a need exists for criteria for determining truck weight restrictions during the spring thaw.

The following guidelines are based on research and analysis of the WSTC,[2] and Mr. Dowey's use in New Hampshire. These guidelines provide criteria to help determine:

1. Where to apply load restrictions,
2. The amount of the load restrictions to apply, and
3. When to apply and when to remove load restrictions.

The guidelines are general and must be applied with judgment. The time period and degree of the problem are site specific.

Guidelines for Where to Apply Load Restrictions

The WSTC researchers concluded that agencies should consider the following criteria when selecting pavements for load restrictions.

1. Surface thickness,
2. Type of subgrade,
3. Local experience relating to observed moisture and pavement distress, and
4. Surface deflections.

Surface Thickness. Agencies should consider load restrictions if the pavement surface thickness is about two inches or less and where the Cumulative Freezing Degree-Days (defined in Degree-Days, page 4) is greater than 400. All areas in New Hampshire will have Cumulative Freezing Degree-Days greater than 400.

Type of Subgrade. Pavements or unpaved roads with a fine-grained subgrade

[1] _____. 1990. Geometric Design of Highways. Washington DC: American Association of State Highway and Transportation Officials.

[2] Rutherford, M.S., J.P. Mahoney, R.G. Hicks, and T.Rwebangera. 1985. "Guidelines for Spring Highway Use Restrictions," Final Report. Olympia WA: Washington State Department of Transportation.

are candidates for load restrictions. Silts and clays, common in New Hampshire, are considered fine-grained soils.

Local Experience. Site drainage and road behaviors are significant in determining the need for load restrictions. Poor drainage from side ditches, available ground water, and high winter precipitation should be considered. Observation of pavement distress, such as fatigue (alligator) cracking and rutting, may also determine the need for load restrictions. If these distress types primarily occur during the spring thaw, load restrictions are needed if options such as strengthening the overall pavement structure are not possible or appropriate. The experience of highway agency managers should be used as much as possible.

Surface Deflections. Finally, WSTC researchers concluded that pavement sections are candidates for load restrictions if the surface deflects 40 to 45 percent more during the spring thaw than during the summer. However, site specific conditions can significantly alter the deflection threshold. For example, a relatively "weak" pavement section may have relatively high summer deflections. Thus, spring thaw deflections less than 40 to 45 percent might still require load reductions. By inference, surface deflection increases of unpaved roads indicates a need for spring road use restrictions.

Guidelines for Load Restriction Amount

The load reductions used by the agencies interviewed in the WSTC studies ranged from about 20 to 60 percent. The average load reduction for seven locations (grouped state areas) was approximately 44 percent. This suggests that reducing the load on individual axles (or tires) by about 40 to 50 percent reduces the associated pavement response to levels that prevent or reduce the resulting pavement distress to acceptable levels.

The research results showed that the more loads are reduced, the greater the increase in the associated pavement life. As shown in Table 1, potential pavement life increases are dependent on load reduction (starting with a load reduction of 20 percent). Thus, if the 44 percent load reduction level is used (average of the several grouped state areas previously noted), this results in a potential improvement in pavement life of about 90 percent.

Table 1

Pavement Load Reduction (%)	Pavement Life Increases (%)
20	62
30	78
40	88
50	95

However, the necessary level of load reductions is not as simple as the preceding numbers suggest. For example, many thin or generally weak pavement structures need high levels of load reduction during the spring thaw period to prevent significant pavement damage (i.e., small or even modest levels of load reduction will not prevent significant pavement damage). Unpaved roads, especially those with a poor subgrade, are even more susceptible to damage from heavy vehicles.

The WSTC study showed that, if load restrictions are to be used, the load reductions should be a minimum of 20 percent. Load reductions greater than 60 percent appear to be excessive for paved roads. The general national practice for paved roads was to use load reductions ranging from 40 to 50 percent. The analysis performed in the study confirmed the 40 to 50 percent range of load reduction for paved roads.

The analysts had insufficient data to draw conclusions about unpaved roads. Because many unpaved roads, especially very old roads, were not designed for modern truck loads, greater reductions than recommended for paved roads might be warranted in some situations. Local experience becomes especially important in the application of these guidelines to unpaved roads.

Degree-Days

The guidelines on when to apply and remove load restrictions are based on air temperature data. From average daily air temperatures the user calculates degree-days.

Degree-days are the number of degrees between some datum and the average temperature for a particular day. The datum for Freezing Degree-Days is 32°F. The summation of Freezing Degree-Days is a measure of the extent to which the road surface and base are subject to below-freezing temperatures. This summation, called Cumulative Freezing Degree-Days (CFDD) indicates the depth of freezing that has occurred.

The datum for Melting Degree Days is 29°F. An air temperature datum of 29°F is used to account for bituminous pavement surface heating effects since the pavement surface is about 32°F when the air temperature is 29°F. The 29°F datum is also used for unpaved roads for consistency.

The summation of Melting Degree-Days is a measure of the extent to which the road surface and base are subject to above-freezing, i.e., melting, temperatures. This summation, called Cumulative Melting Degree-Days (CMDD), indicates the rate of thawing over time.

Calculating Cumulative Freezing Degree Days

Freezing Degree-Days (FDD) are the differences between the 32°F and the average daily temperature. Cumulative Freezing Degree-Days (CFDD) are the amount and duration of temperature differences during the freezing period. CFDD are the sum of FDD over time.

The Degree-Days Log at the end of this booklet eases calculation of CFDD. In many instances, average daily temperatures for each are available from newspapers, government weather stations, private meteorologists, or businesses such as heating oil companies. These are entered in Column E. If average temperatures are not available, highs and lows will be available from these sources. Highs and lows are entered into Columns C and D of the Log. Their difference divided by "2" is entered in Column E.

Subtraction of the average from 32 yields the Freezing Degree-Days for that day, and is entered in Column F. The CFDD, the running total of these values, is recorded in Column G.

To minimize errors, one should indicate positive and negative values when recording FDD. For an average temperature less than 32°F, the FDD should be recorded with a "+"

sign and the value added to the CFDD from the prior day. Conversely, an average greater than 32°F yields a negative FDD, which should be recorded with a "-" sign and its value subtracted from the CFDD for the previous day.

The positive and negative notation also helps a user determine when to start the accumulation for CFDD. Average daily temperatures often fluctuate above and below 32° during November and early December. As they fluctuate, the road base freezes but then thaws. To be a measure of freezing depth, CFDD must be for that period of continuing freezing temperatures. Therefore, when the user identifies a clear pattern of positive FDD, he or she continues calculation of CFDD.

When it is clear that the maximum CFDD has been reached, recording FDD and CFDD can cease. It is the maximum CFDD that will be used later to calculate road use restriction duration.

Calculating Cumulative Melting Degree Days

Melting Degree-Days (MDD) are the differences between the average daily temperature and 29°F. Cumulative Melting Degree-Days (CMDD) are the amount and duration of temperature differences during the thawing period. Cumulative Melting Degree Days are the sum of MDD over time.

The Degree-Days Log also eases calculation of CMDD. When averages occur above 29°F, subtract 29 from the average and enter it in Column H. This is the MDD for that day. CMDD is the running total of these values and are recorded in Column I.

One should also indicate positive and negative values when recording MDD. When an average for a given day is more than 29°F, the MDD should be recorded with a "+" sign and the value added to the CMDD from the prior day. Conversely, an average less than 29°F yields a negative MDD, which should be recorded with a "-" sign and its value subtracted from the CMDD for the previous day.

Similar to the CFDD calculation, the positive and negative notation helps determine when to start CMDD calculation. In the spring, average daily temperature vary above and below 29°F. The user begins CMDD when there is a clear pattern of positive MDD. This will indicate a period of consistent melting of the road base.

CMDD are used to determine when to establish load limits. CFDD and CMDD are used together to determine when to remove them. Their applications are described below. It should be noted that the data for the study came from paved roads. The researchers suggest that the values for thin pavements be used for unpaved roads until the agency has data based on its experiences.

Guidelines for When to Apply Load Restrictions

As shown in Table 2, thermal analyses performed in the WSTC study resulted in two possible times for applying load restrictions. They are also a function of total pavement thickness.

Should Post

The "should" load restriction application time occurs after thin pavements accumulate 10 Cumulative Melting Degree-Days. For thick pavements, load restrictions "should"

Table 2

Pavement Structure	Pavement Thickness (Inches)	Base Course Thickness (inches)	Cumulative Melting Degree Day: Should Post	Cumulative Melting Degree Day: Must Post
Thin	2 inches or less	6 inches or less	10	40
Thick	More than 2 in.	More than 6 in.	25	50

begin when they accumulate 25 CMDD following the start of the thawing period. These thresholds are estimates of when thawing will be sufficient to reduce pavement strength. The "Should Post" threshold of 10 CMDD for thin pavements is also recommended for unpaved surfaces.

Must Post

The "must" load restriction application time occurs after thin pavements accumulate a 40 CMDD and thick pavements accumulate 50 CMDD following the start of the thawing period. These thresholds are estimates of when thawing will reach approximately four inches into the base course.

Discussion

A note should be entered in Column J of the Degree-Days Log when "Should Post" and "Must Post" values are calculated in Column I. In addition, users should note road conditions in Column J.

It is recommended that users apply the most conservative values during the initial years of application. Then, using the suggested documentation, they can determine the best thresholds for all or groups of their roads.

The above criteria are best suited for use during the start of the spring thaw period, generally February through April. A different condition exist for mid-winter thawing cases. The sun angle is lower during a mid-winter thaw and is less than the sun angle calculated in the analysis. A higher MDD base temperature (such as 31°F) might better predict mid-winter road restrictions. However, the researchers did not develop a specific value. Local experience remains the best basis for mid-winter restrictions.

The temperature based Melting Degree Days criteria are best applied to fine-grained soils. The analysis performed in the study showed more consistent results for this soil type than for course-grained soils. Fine-grained soil bases are common in local roads in New Hampshire.

Guidelines for Duration of Load Restrictions

The length of the load restriction period should approximate the time required to achieve complete thawing. The WSTC equation to estimate the time required for complete thawing is

$$CMDD = 0.3 \cdot CFDD_{max}$$

In words, Cumulative Melting Degree Days for ending load restrictions equals 0.3 times the maximum value for Cumulative Freezing Degree Days (CFDD). Experience in New Hampshire, however, has indicated that the 0.3 multiplier varies due to a number of factors.

- Variations in road construction -- pavement thicknesses, base thicknesses and materials, shoulders and ditches.
- Shaded areas that limit sunlight reaching the road surface.
- Elevation differences sufficient to influence average daily temperatures.
- Water remaining on roadsides due to residual snow and ice.

The suggested procedure is to make duration judgements based on experience during the initial years of applying the guidelines. Users should note the maximum CFDD in Column J. They should also document road conditions relative to the CMDD for specific road types. After several years, they can determine a factor that applies to road types, and substitute it for 0.3 in the equation $CMDD = 0.3 \cdot CFDD_{max}$.

Summary of Restriction Start and Duration

The following is a summary of the steps to determine when to begin and how long to apply spring road use restrictions.

1. Using the Degree Days Log calculate degree days, freezing degree days (FDD), and melting degree days (MDD) as described on pages 4 and 5.
2. Begin calculating CFDD -- cumulative freezing degree-days -- when there is a clear pattern of positive FDD.
3. Begin calculating CMDD -- cumulative melting degree-days -- when there is a clear pattern of positive MDD.
4. Consider posting roads when CMDD reaches the values in Table 2 on page 5.
5. Continue to calculate CMDD to determine the duration of load restrictions. During the first years of applying the guidelines, make duration judgements based on judgement. Calculate the multiplier “m” for future determinations using the equation $CMDD = m \cdot CFDD_{max}$.

Placing Load Restrictions

When a highway agency sets a load restriction, it should notify the public through the press or letters. It should place temporary signs on all limited roadways.

It is recommended that agency staff notify contractors and loggers who frequently use the affected roads. Because the need for restriction happens quickly, this notification should be by telephone, fax, and/or email. If the agency has a policy for partial road use, such as early morning for certain roads, it should provide affected users with the procedures to apply the policy. The agency should also establish exceptions to the policy. For example, transport of perishable or essential products such as milk or fuel oil.

The agency should keep a record of the effective dates of posting and removal for each road or set of roads. Once it has applied load restrictions, it should monitor roadways to determine when it can remove restrictions. These records will document specific road behaviors, and be useful in applying the guidelines in future years.

Degree-Days Log

A	B	C	D	E	F	G	H	I	J
Month	Day	High Temp	Low Temp	Avg. Temp (C-D)/2	FDD 32-Avg.	Cumu-lative FDD	MDD Avg.-29	Cumu-lative MDD	Notes
	1								
	2								
	3								
	4								
	5								
	6								
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	31								

FDD = Freezing Degree Days
MDD = Melting Degree Days