RESEARCH AND DEVELOPMENT

"Implementing research findings"

EVALUATION OF DEFLECTION DATA AS CRITERIA FOR THE TIMING OF SPRING LOAD LIMITS
Evaluation of Deflection Data
As Criteria For The
Timing of Spring Load Limits

Prepared By
Harvey S. Allen, P.E.
Research Project Engineer
David L. Bullock, E.I.T.
Research Assistant

Physical Research Section
Office of Research and Development
Minnesota Department of Transportation
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This study was undertaken to study the use of deflection data as a criteria in setting time periods for seasonal load limits.

The study was rendered invaluable assistance by District 2 Materials personnel; the Office of Materials Engineering; Research Assistants Karl Keel, EIT and Gerald Teig.

The contents of this report reflect the views of the authors and do not necessarily reflect the official view or policies of the Minnesota Department of Transportation. This report does not constitute a standard specification or regulation.
Background

In January 1985, Deputy Commissioner R. J. McDonald appointed a committee to establish a process and criterion regarding seasonal posting periods. This committee was named the Committee on Seasonal Posting Period. Members serving on the committee are:

Chairman - Patrick C. Hughes, Geotechnical Engineer
Recorder - Harvey Allen, Research Project Engineer
          Paul Jensen, Tests and Inspection Engineer
          Glenn Korfhage, Research Operations Engineer
          George Cochran, Subgrade and Base Design Engineer
          Mark Wikelius, Assistant State Maintenance Engineer
          Steve Oakey, District Materials Engineer
          Marvin Gieseke, District Maintenance Engineer
          Art Hill, District Materials Engineer

This committee began meeting in February 1985 to determine what information should be considered in establishing the process and criterion requested.

Deflection tests have been used in the past by some districts to provide information on the spring thaw period although there has not been a uniform procedure established for statewide use. The committee decided to have additional deflection data collected and analyzed to determine how these tests could be used to establish criteria for the setting or removal of spring load limits.

The type of questions that had to be answered were:

1. Can deflection tests be used to determine when the posting period should start?
2. Can deflection be used to determine when the posting will end?

3. Are deflection tests necessary on all posted highways during the spring thaw period?

4. Should testing be done daily, weekly or bi-monthly?

5. What analysis can be done with deflection data that may lead to the establishment of spring posting period criterion?

6. How many test sections would be needed and where should they be located?

The answers to the above questions were obvious in some cases and uncertain in others. For example, it is not feasible to try and collect deflection data on every posted highway during every spring thaw. It would be too costly and the department does not have enough testing devices to accomplish the task. The question of how often to repeat the testing could also be answered. Past history of deflection testing during spring thaws has shown that testing should be done at least once a week during the first several weeks of thaw to determine the critical part of the spring recovery curve.

The Office of Research and Development has been collecting some spring thaw deflection data on County Road 4 in Washington County for the last several years. A number of these test sections were included in this study along with the previously collected data. The number of additional test sections and their location was established using engineering judgement with input from the nine District Materials and some Maintenance Engineers.

It was anticipated that the deflection data collected and analyzed would help answer the remaining questions.
This report addresses the data collected, the analysis of the data and results.

Data Collection

A listing of test sections selected for the collection of spring thaw data are shown in Table No. 1. The locations of the test sections were selected so that each of the four (north, central, southeast, and south) posting zones would have one or more sections within the zone's boundaries. A map of the four zones and test sections are shown in Figure 1.

Two Dynatest Model 8000 Falling Weight Deflectometers were used to collect deflection data. The sections were tested repeatedly during the period of spring thaw and again in late fall. This was supplemented by data collected by the Office of Research and Development during the spring thaw period in 1982 and 1983 on a county road in Washington County. Depth of thaw was recorded each time deflection data was taken by the use of frost tubes.

Data Analysis

The data analysis consisted of computing:

1. Average D1 and D7 deflections on each test section.
2. The average deflection basin characteristic "Area".
3. Tensile strain in the bituminous pavement adjusted to a temperature of 70 degrees F.
4. Subgrade modulus for each section on each day of testing.

The "Area" parameter is shown in Figure 2. The unit for the "Area" parameter is inch. This parameter is a modification of the deflection basin "Area" parameter.
reported by M. R. Thompson (1). The area values were adjusted to a standard temperature of 70 degrees F.

The average deflections and average "Area" are direct measurements, whereas the tensile strain in the bituminous pavement was calculated from the average number 1 sensor deflection and average "Area" measurements. The subgrade modulus was calculated from average deflection measurements of the number 7 sensor. Graphs showing the four types of data versus time (Julian Date) are included in appendix A of this report.

Discussion

The graphs of the data were reviewed and the following observations were noted:

1. The "Area" parameter shows that there is a rapid loss of strength with the onset of thawing (T.S. 1.2, 2.3, 4.0 and 9).

2. Generally the "Area" parameter show a moderate increase as the D1 sensor peaks and then remains somewhat constant.

3. There is an indication that the "Area" parameter is at its lowest value when the thaw depth is between six and twelve inches from the bottom of bituminous surfacing.

4. The average value of the number 1 sensor (D1, center of load) increased rapidly in all test sections during the thaw.

5. The average D1 deflection leveled off and remained high in T.S. 1.2, 2.0, 2.3, 4.0 and 7.0. After the peak there was a rapid decline in the D1 deflection in T.S. 6.2, 6.3, 6.4, 3.0, 5.0, 8.1, 8.2, 9 and 10.
6.0 A minimum of two tests showing a decrease in deflection are needed to define the peak deflection. D1 deflections were corrected for temperature to 70 degrees F in accordance with unpublished correlations developed in Mn/DOT Inv. 210.

7.0 The number 7 sensor (D7) deflection increases moderately during the spring thaw and then gradually decreases over the summer.

8.0 The subgrade modulus calculated from the D7 deflection shows a rapid decrease in strength at the onset of the spring thaw and then a gradual decrease in strength for the remaining portion of the spring thaw. After the spring thaw, the subgrade modulus value increases gradually until fall.

9.0 On those test sections where both summer and fall data was collected (T.S. 6.2, 6.3 and 6.4) there was a weakening in some test sections after fall rains.

10.0 Values of calculated tensile strain corrected to a standard temperature generally have peak values occurring prior to the time of maximum deflection.

11.0 Tensile strain values calculated for the bituminous layer and corrected to a standard temperature show that the peak strain will occur after the sudden loss of strength at the onset of the spring thaw.

The results of the analysis confirm that there is a rapid loss of pavement strength with the onset of the spring thaw period. The "Area" parameter changes the most during the first 12 inches of thaw. The maximum deflections occur later in the thaw period when the depth to frost is generally between 38 and 48 inches of thaw.
Graphs showing depth of thaw, D1 deflections and strain for those test sections with frost data, are included in appendix B of this report. Deflection data was corrected to 80 degrees F in accordance with Inv. 603.

Graphs of D1 deflection (temperature corrected) versus time for the years 1982, 1984 and 1985 on test sections 6.2, 6.3 and 6.4 are included in appendix C of this report.

These graphs clearly show that the magnitude of peak deflections and the date of peak deflection varies from year to year. Because of this, deflection testing during the spring thaw period is one way of determining when to remove spring posting limits. These graphs also suggest that the deflection profile of the recovery curve is different for each test section and may be used to forecast the end of the spring posting period. Table 2 lists the dates that the spring posting period would end if a criteria of three weeks (21 days) after peak deflection was accepted as the criteria for removing spring load restrictions. The table also includes the actual date that the spring load restrictions were removed.
Summary of Findings and Conclusions

The results of the analysis of the deflection surveys provide the following findings:

1. Deflection tests cannot be used to determine when to start the spring posting period because the thaw occurs too fast for deflection tests to provide ample warning.

2. The greatest change in pavement shape as recorded by the "Area" parameter occurs during the first six inches of thaw.

3. The maximum pavement deflection occurs when the thaw depth is between 38 and 48 inches.

4. Deflection tests do profile the loss in pavement strength during the spring thaw period and can be used to establish the time that the spring posting period should end.

5. There appears to be a correlation between depth of thaw and the peak deflection.

Recommendations

1. Deflection tests should not be used to establish the time when spring load limits should start.

2. The spring posting period should have started by the time the thaw depth has reached six inches.

3. The use of deflection tests should be used to aid in determining when to remove spring posting limits.

4. Additional research should be conducted to determine if depth of thaw does define peak deflection (D1) which would eliminate the need for deflection testing.

5. Frost tubes should be installed in all test sections.

6. Three weeks after peak deflection should be considered as the criteria for removing spring posting limits.
## Table 1 - Test Section Information

<table>
<thead>
<tr>
<th>Frost Zone</th>
<th>Section</th>
<th>Location</th>
<th>Highway</th>
<th>Surface</th>
<th>Base/Subbase</th>
<th>Subgrade</th>
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<td>Akeley</td>
<td>TH64NB MP36</td>
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<tr>
<td>North</td>
<td>2.0</td>
<td>Detroit Lakes</td>
<td>TH34EB MP37.5</td>
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<td>2.3</td>
<td>Crookston</td>
<td>TH102NB MP18.4</td>
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<td>9°</td>
<td>SL</td>
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<td>Central</td>
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<td>Little Falls</td>
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<td>4 1/2°</td>
<td>30°</td>
<td>3.5' PEAT/LS</td>
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<tr>
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<td>4.0</td>
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<td>TH238NB MP33.1</td>
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<td>Washington CD 4</td>
<td>2 1/2°</td>
<td>7° Class 5</td>
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<td>May 13</td>
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* Twin Cities Metro Area

Table 2 - 1985 Spring Posting Removal Dates
Figure 1 - Frost Zones and Test Section Locations
\[
\text{AREA} = \frac{1}{2D_0} \sum_{i=1}^{n} (D_{i-1} + D_i) (R_i - R_{i-1})
\]

Figure 2 - Deflection Basin Characteristic "Area"
SPRING RECOVERY 1985
TS 1.2 TH64NB MP36.0

JULIAN DATE

D1 (mils)
AREA (in.)
STRAIN (x10E-05)
D7 (mils)
SUBGRADE MODULUS (ksi)
SPRING RECOVERY 1985

TS 6.4 WASH CO 4

SUBGRADE MODULUS (ksi)

STRAIN (x10E-05)

D1 (mils)

AREA (in.)

D7 (mils)

JULIAN DATE

40 60 80 100 120 140 160 180 200 220 240 260 280
SPRING RECOVERY 1985
TS 8.1 TH60NB MP95.2 SHOULDER

![Graph showing spring recovery data for TS 8.1 TH60NB MP95.2 SHOULDER with lines for STRAIN (x10E-05), D1 (mils), SUBGRADE MODULUS (ksi), and AREA (in.).]
SPRING RECOVERY 1985
TS 8.2 TH169NB MP48.5 SHOULDER

JULIAN DATE

AREA (in.)

SUBGRADE MODULUS (ksi)

D7 (mils)

STRAIN (x10E-05)

D1 (mils)
Appendix B
SPRING RECOVERY 1985
TS 2.0 TH34NB MP37.5

D1 (mils) vs Date

FROST TUBE DATA

1 MAR 15 MAR 1 APR 15 APR 1 MAY 15 MAY 1 JUN

0 20 40 60 80 100 120

0 200 400 600 800 1000 1200 1400 1600 1800

STRAIN (10E-06 in/in)

D1

STRAIN

FROST (in.)
SPRING RECOVERY 1985
TS 3.0 TH238SB MP28-3

D1 (mils)

STRAIN

FROST TUBE DATA

DATE
1 MAR 15 MAR 1 APR 15 APR 1 MAY 15 MAY 1 JUN

D1

STRAIN

FROST (in.)
SPRING RECOVERY 1985
TS 4.0 TH238NB MP33, 1

FROST TUBE DATA

DATE
1 MAR 15 MAR 1 APR 15 APR 1 MAY 15 MAY 1 JUN

D1 (mils)

STRAIN (10E-06 in/in)

0

20

40

60

80

100

120

1400

1600

1800
SPRING RECOVERY 1985
TS 5.0 TH73NB MP40.6

D1 (mil)

STRAIN

FROST TUBE DATA

-80 -60 -40 -20 0
FROST (in.)

MAR 15 MAR 1 APR 15 APR 1 MAY 15 MAY 1 JUN

DATE
SPRING RECOVERY 1985
TS 6.4 WASH CO 4

D1[mils]

-20 -40 -60 -80
1 MAR 15 MAR 1 APR 15 APR 1 MAY 15 MAY 1 JUN

FROST TUBE DATA

FROST (ln.)

STRAIN (10E-06 in/in)
SPRING RECOVERY 1985
TS 8.1 TH60NB MP95.2 SHOULDER

FROST TUBE DATA

DATE

1 MAR 15 MAR 1 APR 15 APR 1 MAY 15 MAY 1 JUN

FROST (in.)
SPRING RECOVERY 1985
MAX DEFL. vs DEPTH TO FROST

OCCURRENCE

DEPTH TO FROST (in)

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SPRING RECOVERY
WASH CO 4 TS 6.2

D1 DEFLECTION (mils)

15-Feb 16-Apr 15-Jun 14-Aug 13-Oct 12-Dec

1982 1983 1985

DATE
SPRING RECOVERY
WASH CO 4 TS 6.3

D1 DEFLECTION (mils)

15-Feb 16-Apr 15-Jun 14-Aug 13-Oct 12-Dec

1982 1983 1985
SPRING RECOVERY
WASH CO 4 TS 6.4

D1 DEFLECTION (mils)

15-Feb 16-Apr 15-Jun 14-Aug 13-Oct 12-Dec

—— 1982 —— 1983 —— 1985