Report No. CDOH-DTD-R-88-11

SPRING BREAKUP STUDY

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Final Report
April, 1988

Prepared in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

The effect of an increase in moisture content of subgrade soil was evaluated on S.H. 131 in western Colorado. Dynaflect and moisture/temperature probes were used to obtain pavement surface deflections and subgrade moisture content. Analysis of the data obtained demonstrated that the load-carrying capacity of the pavement decreased rapidly as the moisture content was increased above the plastic limit (PL) during the spring thawing period. High pavement surface deflection taken during this period confirmed this phenomenon.

Implementation

Spring breakup exists and is costly. The results of this study have demonstrated the highway department's need to investigate the magnitude of spring breakup in Colorado and to take measures to alleviate such problems.

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I. INTRODUCTION

Many asphalt pavements in Colorado suffer from annual spring thaw and breakup. During the early spring and late winter, certain soils experience an increase in moisture content and, consequently, a decrease in density. The increase in the moisture content of subgrade soil reduces the supporting capacity of pavement and results in a premature distress of pavement. Pavement distortion not only creates hazardous driving conditions for the motorist but maintaining them is also a costly operation. One of the first signs of spring breakup is the occurrence of alligator cracks, as shown in Photograph 1. These kind of cracks, which result from subgrade softening, eventually turn into chuckholes.

II. OBJECTIVES

The primary objectives of this study were:

a. To establish a data base using the variables of pavement surface deflections, subgrade moisture contents, subgrade temperature, and climatic data.

b. To predict seasonal changes within the pavement structure, and incorporate the results into proposed load restrictions during the critical time of the year.

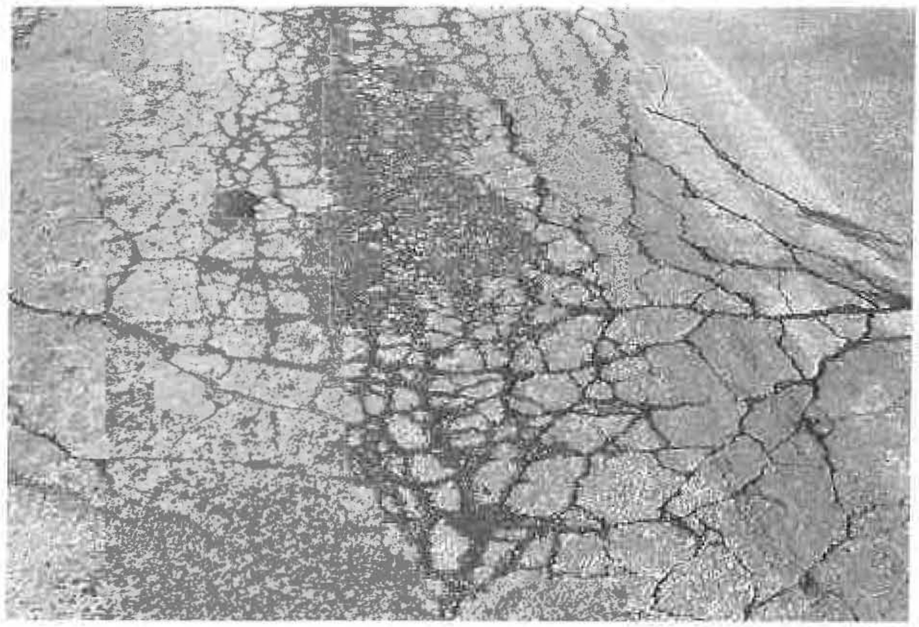
III. SITE SELECTION

The following criteria was used in order to locate a test site for this project:

1. The study site must be located in an area of potential deep frost.

2. The pavement surface must indicate signs typical of spring breakup (alligator cracking and chuckholes).

3. There should be a presence of heavy truck traffic.



Photograph 1: A typical pavement distress caused by spring thaw.

4. Frost susceptible soil (materials which have an affinity for moisture) should be present.

5. The drainage system should be in poor condition.

Based on the above criteria, a site was selected on S.H. 36, near the town of Last Chance, 80 miles east of Denver. This site lies on a gently rolling terrain with an elevation of 5300 feet. The average annual precipitation is 15.6 inches, and the total yearly snowfall is 31 inches. This site was evaluated for a period of two winters; however, because of the severe temperature fluctuation (freeze-thaw cycles) experienced in the area, no conclusive results were obtained.

A second site with a colder climate was selected on S.H. 131 north of Wolcott, approximately 140 miles west of Denver (Figure 1). This site is situated on mountainous terrain with an elevation of 6700 feet. The average daily traffic (ADT) at this location is 1000 with 11 percent of that consisting of truck traffic. The average annual precipitation is 12.1 inches, and the total yearly snowfall is 31 inches. The following table shows the temperature characteristics of this area:

TABLE A

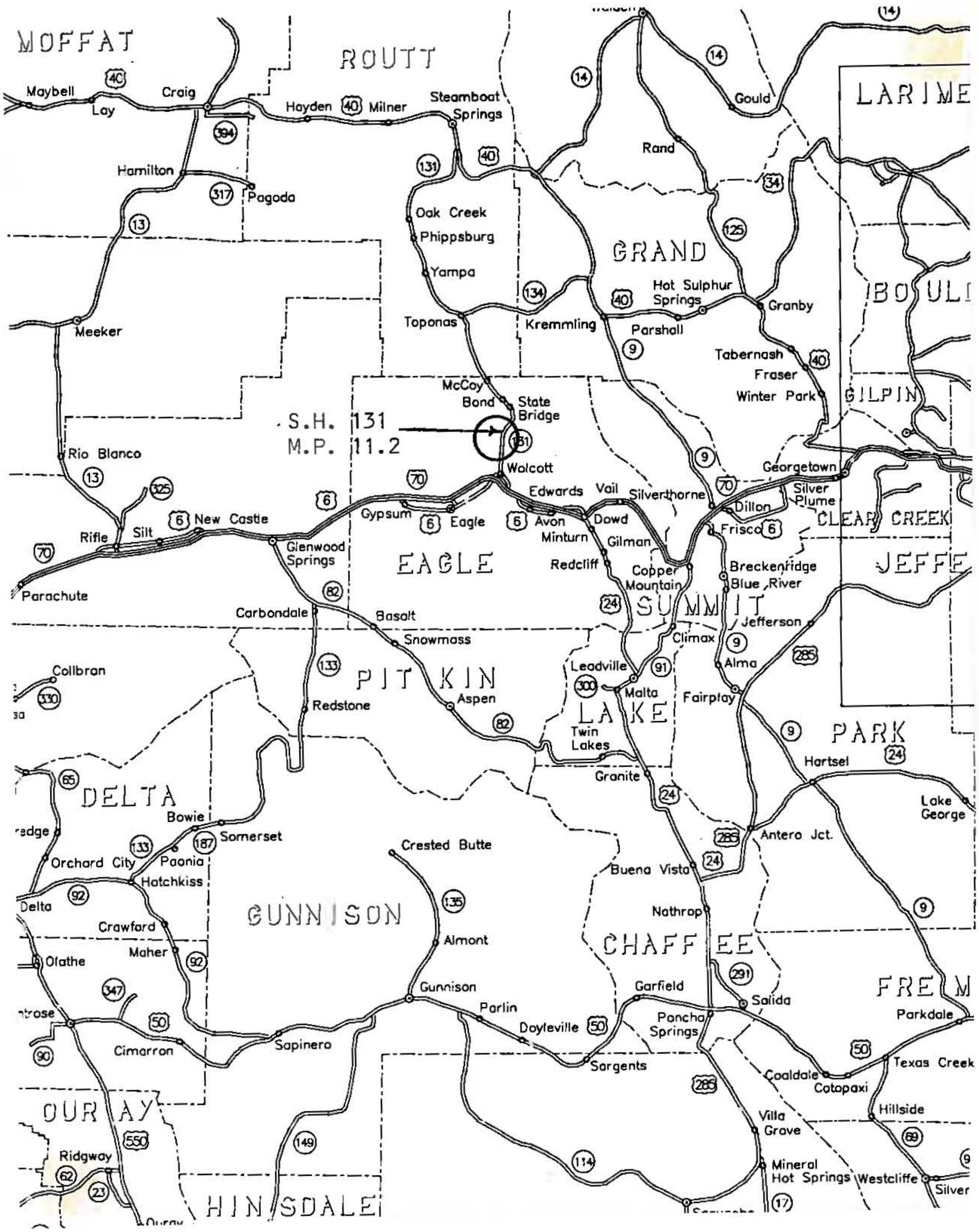
TEMPERATURE CHARACTERISTICS

Days per Year With Temperatures of . . .

High of 90°F or More	High of 32°F or Less	Low of 32°F or Less	Low of 0°F or Less	Years of Data
15	28	214	28	13

Source: Colorado Climate (state climatologist)

SITE LOCATION



The particle size distribution determined by a sieve analysis revealed a subgrade which was predominantly clay, A-7-6(12) with moderate to negligible amounts of coarse material. (Appendix A shows the typical grain size chart and index properties.) Even though the flow of gravitational water is very slow for this type of soil, the capillary pressure that causes moisture to move from the wetter to the drier portions is very great and large expansion can be developed.[1]

IV. Instrumentation

The soil test MC-300A moisture/temperature meter was used to obtain moisture and temperature of the subgrade for this project. The following is a summary of the instrument description and instrument installation:

A. Instrument Description

A thorough description of the instrument used for this project can be found in Appendix B.

B. Instrument Installation

On September 6, 1986, four moisture/temperature cells (probes) were installed on S.H. 131 north of Wolcott at a predetermined location in the southbound lane at milepost 11.2

Installation of the cells began with an excavation of a trench 2' wide, 4' deep, and 10' long (Figure 2). A gas-powered chisel was used to outline the pavement surface, and a backhoe to remove the material. To protect the cell's leads from being exposed to moisture, 1" PVC pipes were used, and cells were then glued to the end of them. Using a crowbar, pilot holes were punched into the vertical face of the trench at the outside edge of the driving lane. The sharp cell edge was then forced into undisturbed material at 10-12 inches intervals from the bottom of the trench. The trench was backfilled and compaction was obtained by hand tools and by using the backhoe bucket. Table B shows the location of the cells and their corresponding depth, and Table C shows the soil log of the trench for various layers. Photographs 2 through 5 demonstrate parts of the soil cell's installation.

TABLE B

SOIL CELL LOG

Soil Cell Number	Depth	Temperature Coefficient Factor
1	45.6"	0.99
1	36.0"	1.00
3	26.0"	1.00
4	10.0"	1.00

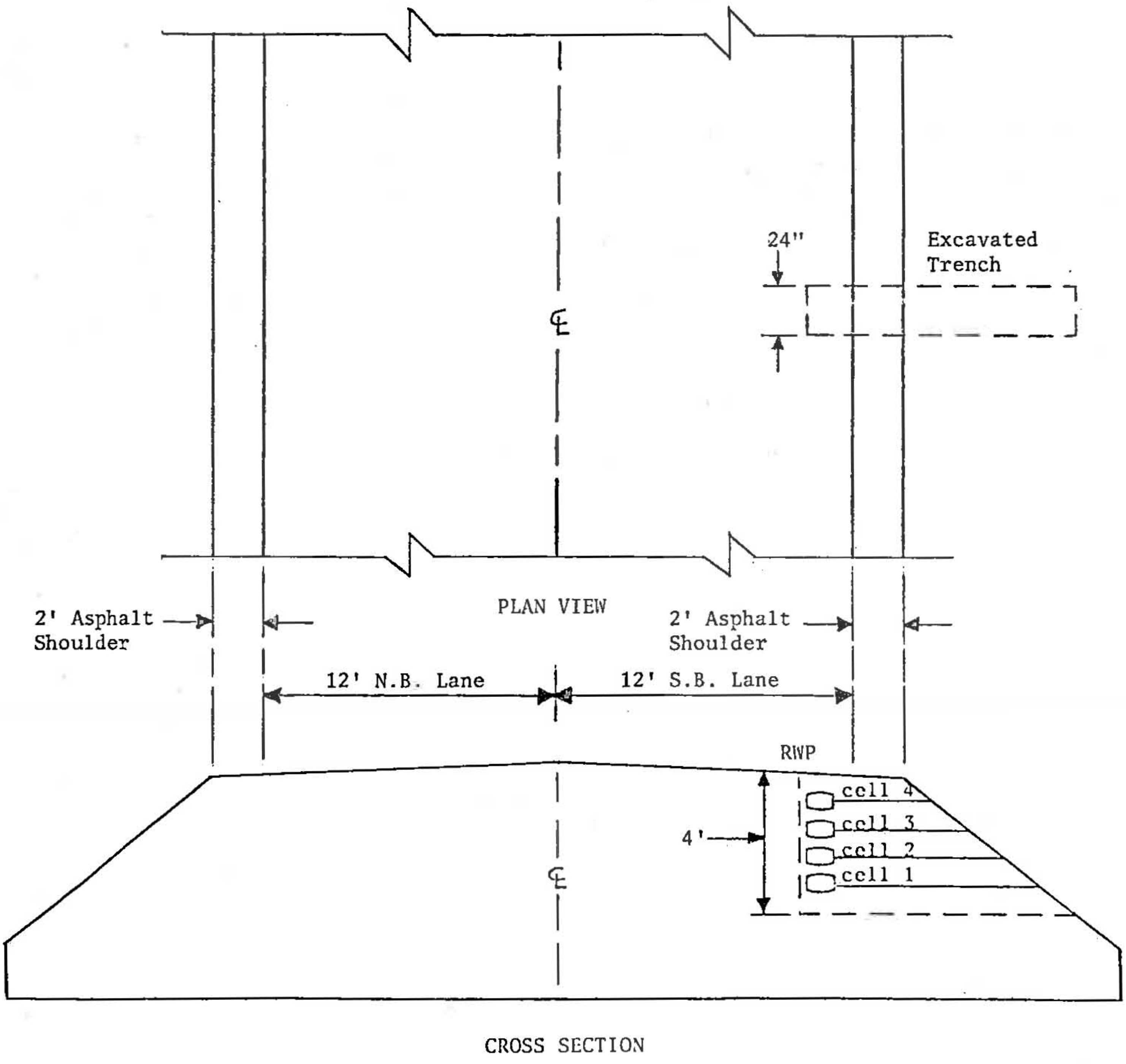
TABLE C

SOIL LOG OF TRENCH

Depth	Description
0-6"	Asphalt mat
6-46"	Subgrade*

*Clay of high plasticity index with occasional gravel

FIGURE 2
PROFILE OF TRENCH
EXCAVATION



Photograph 2: Using the Department's backhoe, a trench was dug.

Photograph 3: A crow bar was used to provide a pilot hole for the soil cell.

Photograph 4: One-inch PVC pipes were used to protect the lead wires from moisture and to secure the cell.

Photograph 5: The soil cell was inserted into the pilot hole under the outside edge of the driving lane.

Photograph 6: Backfill and compaction was accomplished by the use of a front end loader and hand tools.

V. DATA ACQUISITION

Field data was collected for a period of seven months beginning in February and ending in September 1987. The following types of data were collected:

- pavement surface temperature
- ambient air temperature
- subgrade temperature
- subgrade moisture content
- pavement surface deflections using dynaflect

Prior to the above data collection, samples of subgrade materials were obtained in order to calibrate the soil cells for moisture content determination (Appendix B). The above data were collected on a biweekly basis. The deflection data were obtained on ten-foot intervals for 10 points and then averaged. A special device called the "Wahl Heat Spy" infrared thermometer was used to obtain pavement surface temperatures. A MC 300A moisture/temperature meter was used to acquire moisture and temperature data from the soil cells. Air temperature data was collected by a thermometer.

VI. DATA ANALYSIS

The following is the summary of the data analyzed in this study:

A. Deflection Variations

The graph plotting the average deflection data versus the time of the year is shown in Figure 3. According to this figure, early spring was the period of highest deflection (March 4 through March 26). The lowest deflections were detected during February, indicating a frozen subgrade. Deflection data acquired between April and September showed continued recovery of the pavement strength.

FIGURE 3

DEFLECTION VS. TIME-OF-YEAR

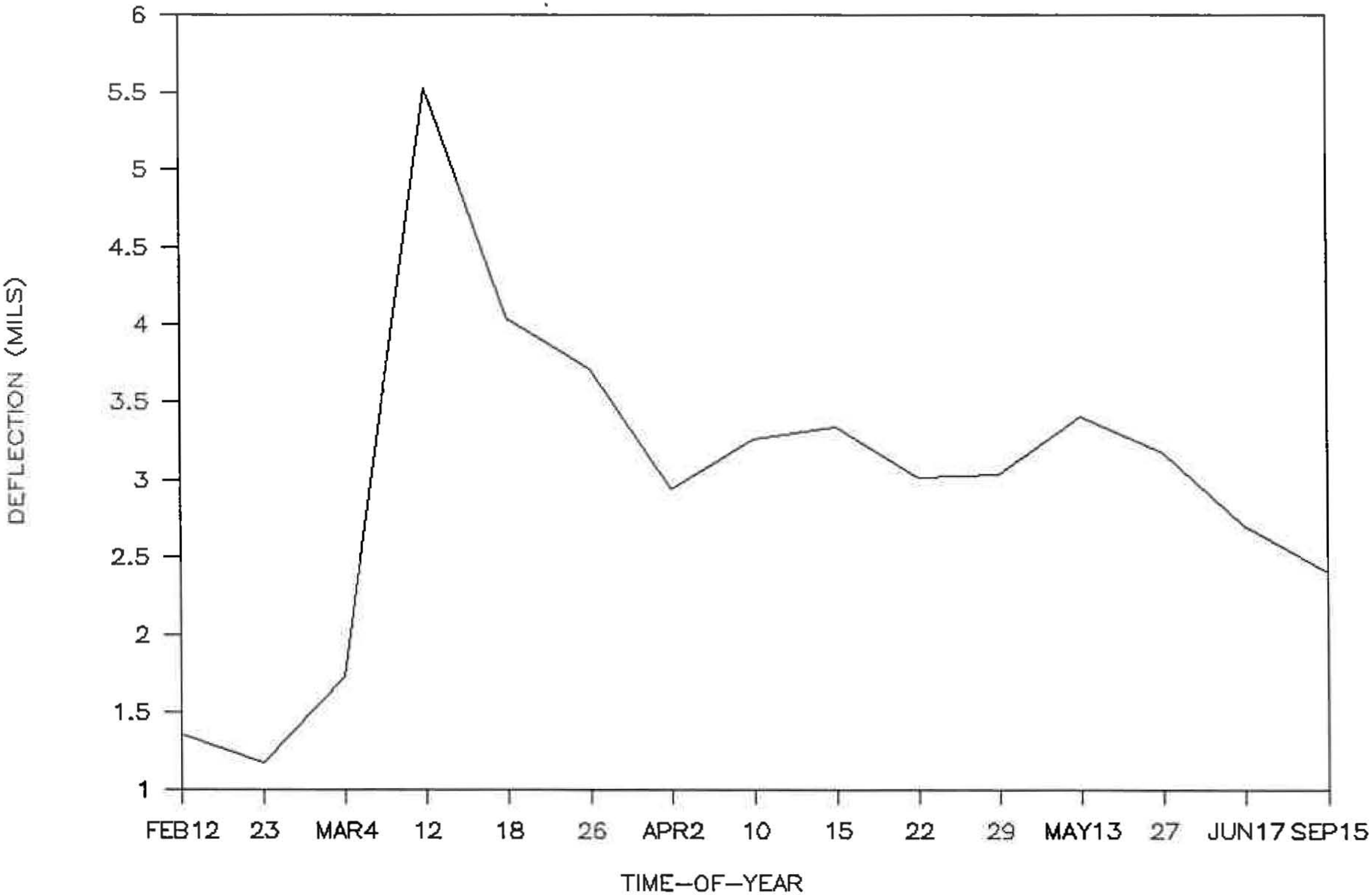


FIGURE 4

MOISTURE VARIATION VS. TIME-OF-YEAR

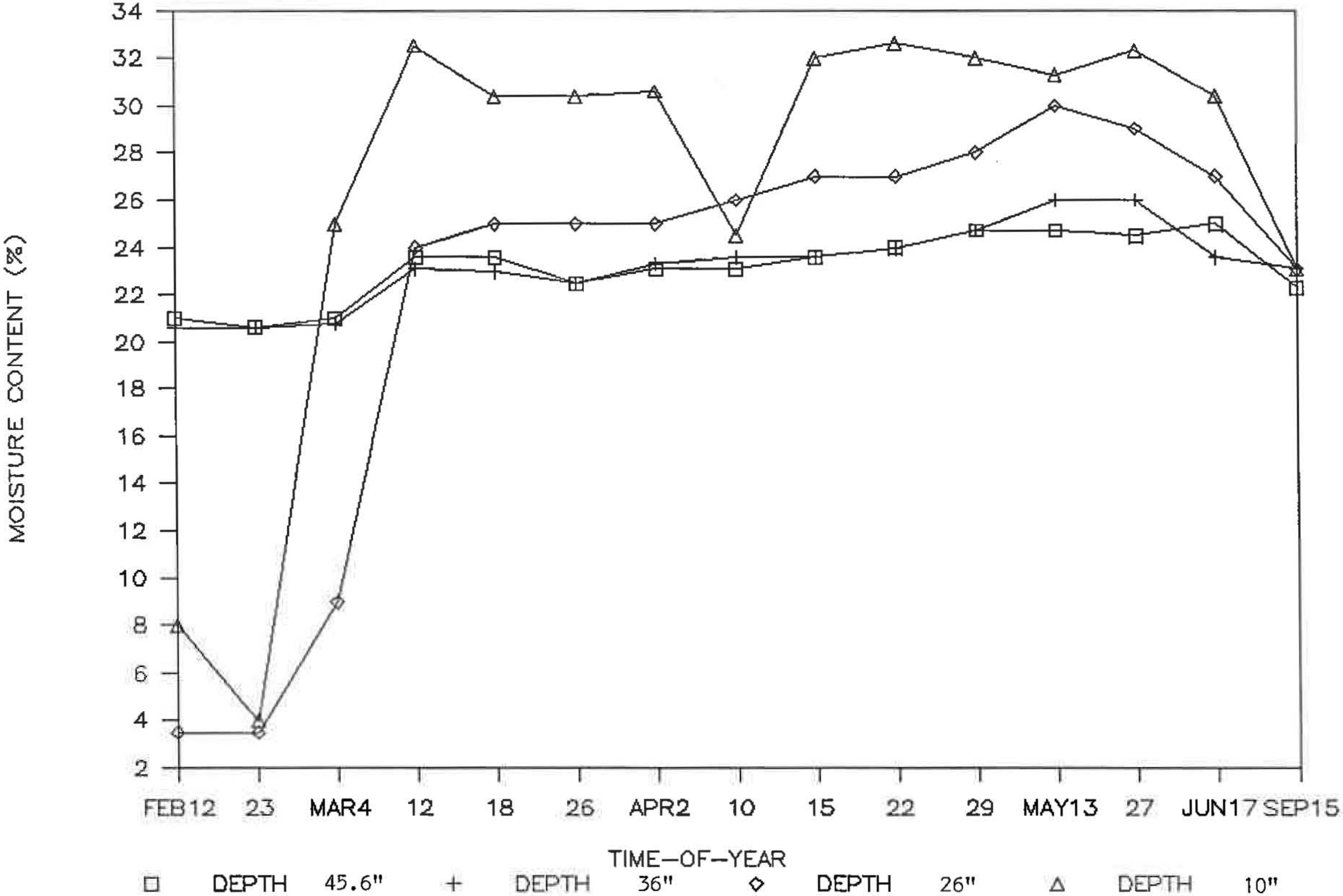


FIGURE 5

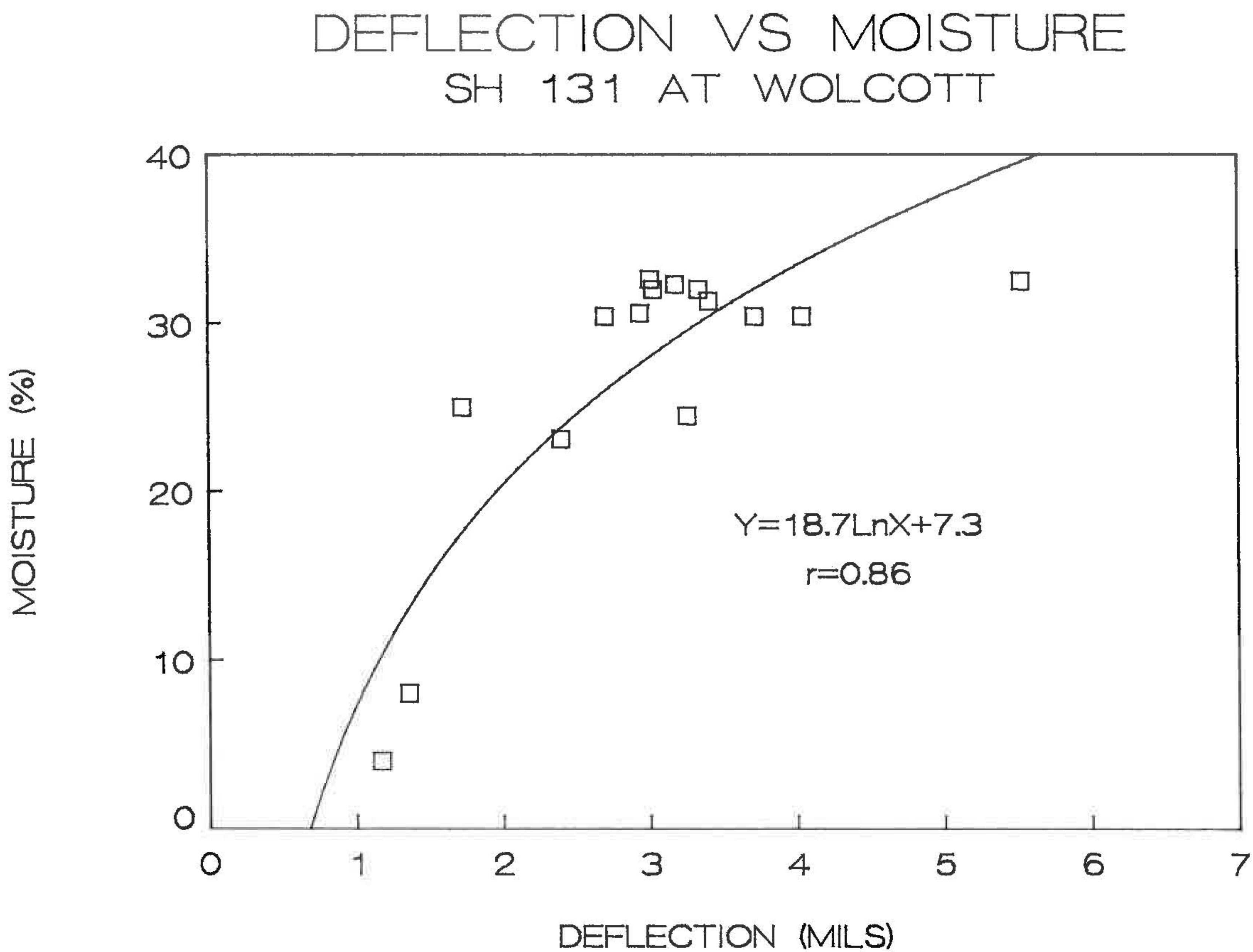
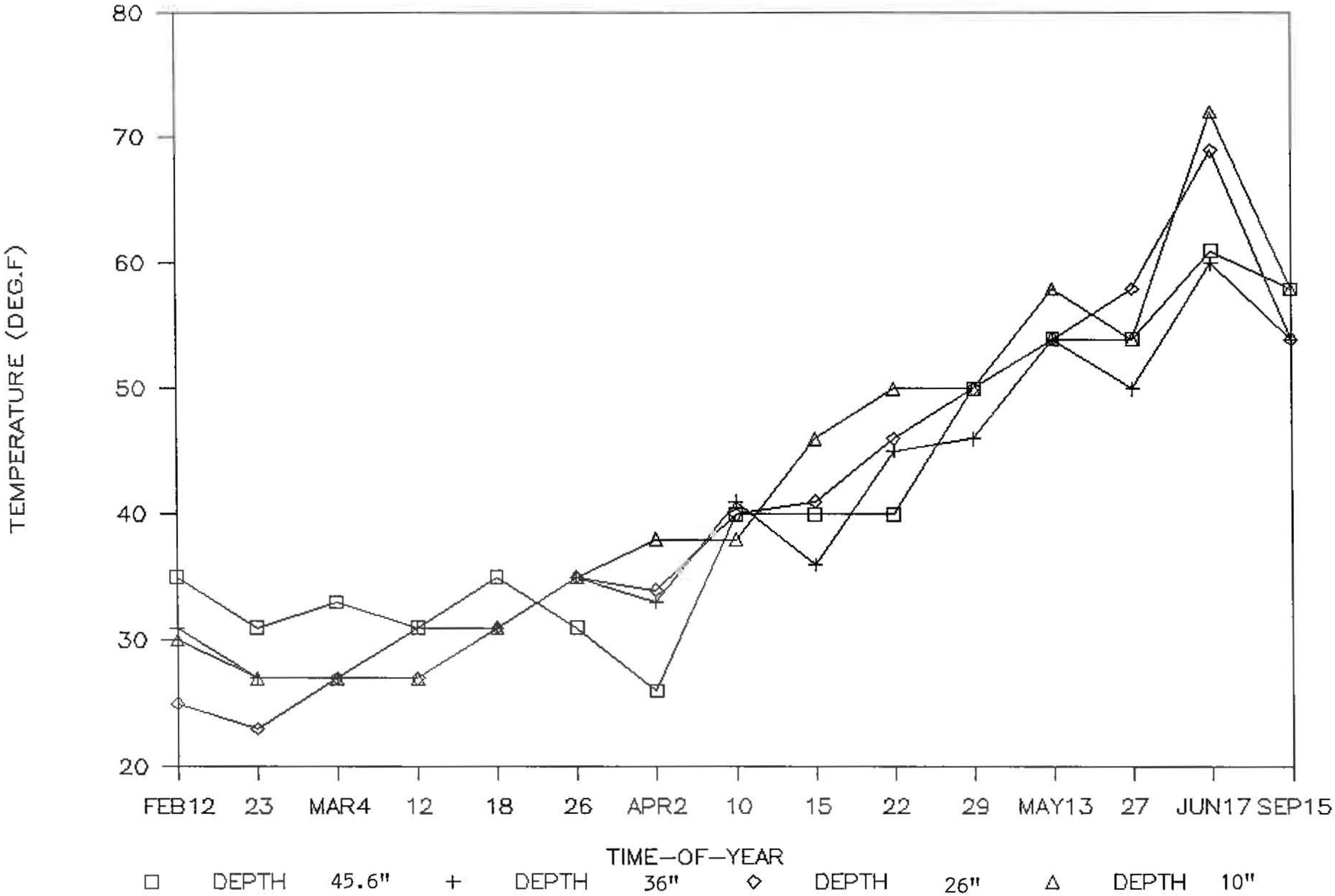

DEFLECTION VS MOISTURE
SH 131 AT WOLCOTT
MOISTURE (%)
40
30
20
10
0
0
1
2
3
4
5
6
7
DEFLECTION (MILS)
Y=18.7LnX+7.3
r=0.86

FIGURE 6

TEMPERATURE VARIATION VS. TIME-OF-YEAR



B. Moisture Variations

Figure 4 shows the variation of subgrade moisture content at various depths from February through September. The subgrade at the depth of 10" and 26" showed the highest moisture content and the highest variation. The increase in soil moisture was most significant during the spring thawing period (the month of March) for the probe at the 10" depth. The probe at the 26" depth also showed a very sharp increase in moisture content between March 4 and March 18. However, this probe showed continued increase in moisture through May 13. The probes at the depth of 45.6" and 41" exhibited the least variations throughout the entire period. All the probes showed the same moisture content (approximately 23 percent) by mid-September indicating an almost consolidated subgrade. The sharp increase of the subgrade moisture content in early March correlated well with the surface deflections for the same period. The moisture content of the subgrade at the 10" depth was 11 percent higher than the plastic limit indicating a very soft subgrade. The plastic limit (PL) of the subgrade at this site was 22 percent, while the moisture content was 33 percent. Figure 5 shows the relationship between moisture content of the subgrade at the 10" depth and the pavement surface deflection. Inspection of the data plotted in Figure 5 indicated a logarithmic relationship with a fairly good fit.

C. Temperature Variations

The temperature variations for all four probes are shown in Figure 6. Figures 7 through 10 were developed to study the relationship between temperature and moisture content of the subgrade at various depths. However, no conclusive results were obtained. A complete record of temperature, moisture, and their corresponding deflections can be found in Appendix C.

FIGURE 7

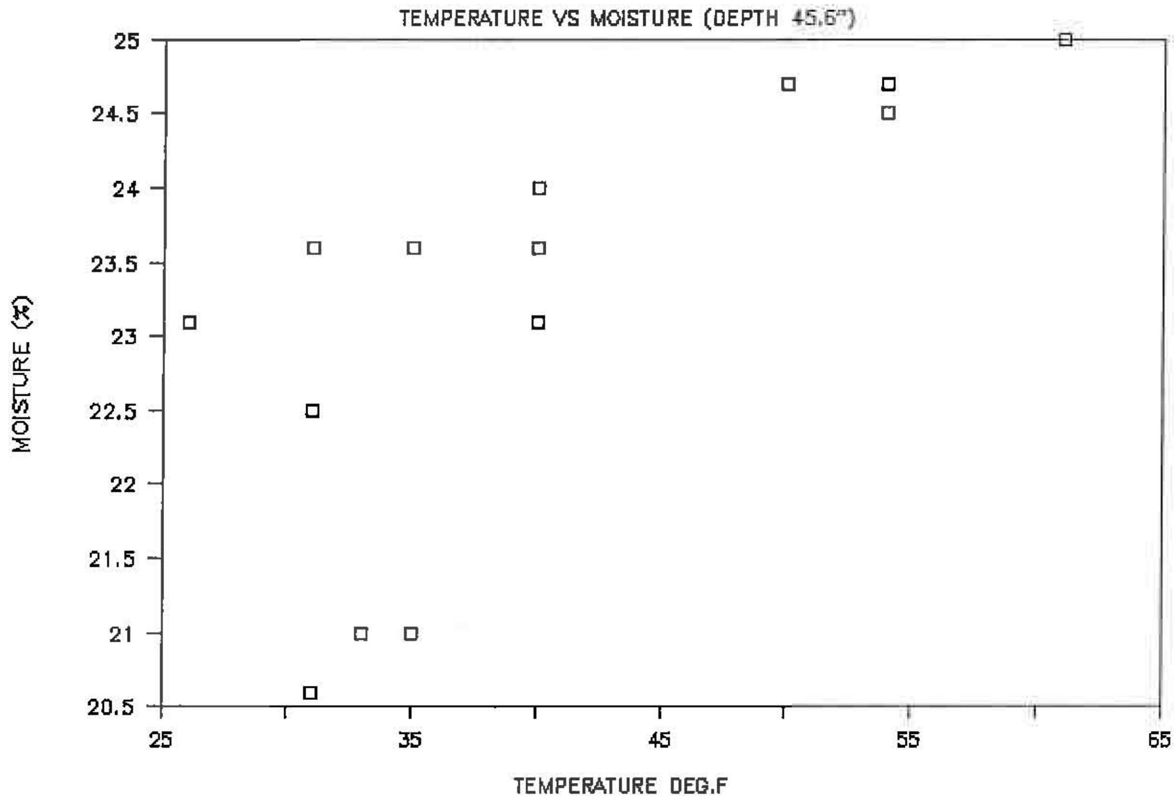


FIGURE 8

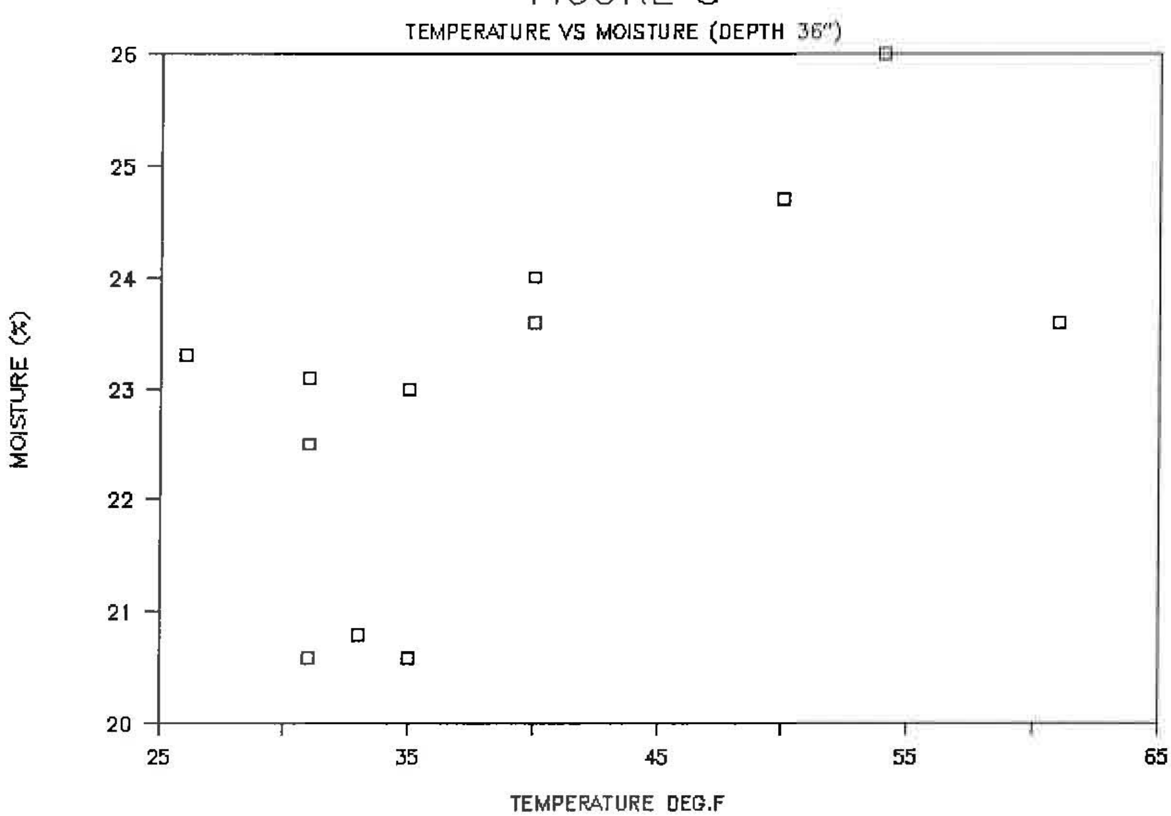


FIGURE 9

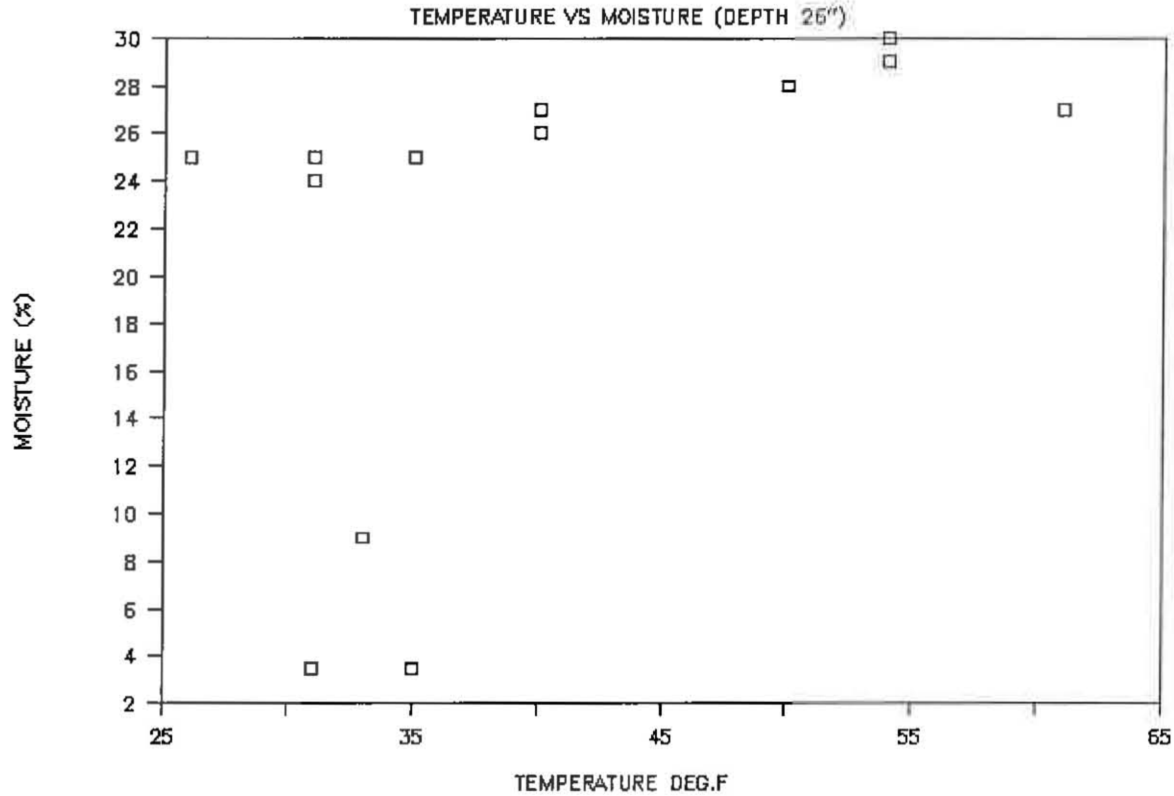
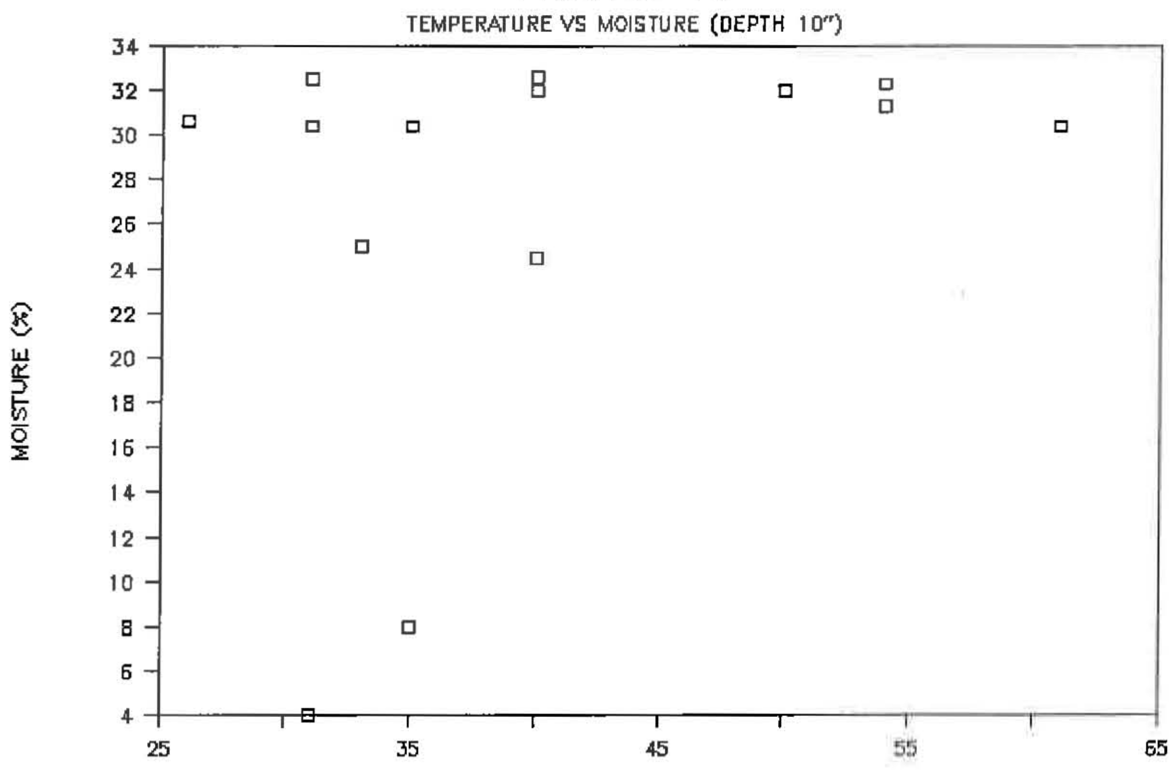


FIGURE 10



VII. LOAD RESTRICTION DURING SPRING THAW

A report was developed by the Washington State Transportation Center and the University of Washington to predict seasonal changes within the pavement structure, and to restrict heavy loads during the critical time of the year. This report, "Guidelines for Spring Highway Use Restrictions" uses the thawing and freezing index to estimate when and where to apply and remove load restrictions. A summary of this guideline can be found in Appendix D. In addition to the guideline, there is a supplemental videotape which can be obtained from the R&D Report Center (HRD-11).

VIII. CONCLUSIONS AND RECOMMENDATIONS

1. Analysis of the data taken in this study demonstrated that the load-carrying capacity of the pavement structure decreased rapidly during the spring thawing period. Deflection data and subgrade moisture content acquired at various depths showed a sharp increase during this period. However, the soil moisture content within the top layer of the subgrade showed the best correlation with surface deflections. The moisture content for this layer increased to a high of 32 percent, approximately 13 percent over the optimum moisture content.

2. No conclusive relation was established between subgrade temperature and surface deflections.

3. The moisture content of the subgrade and the deflection data can be used in assuring the need for load restrictions.

4. Severe temperature fluctuations in Colorado from one day to another makes it difficult to clearly predict the beginning of the thawing period.

IX. IMPLEMENTATION

The results of this study has demonstrated the need for controlling pavement distress during the spring thawing period. Premature distress of pavement on Colorado's highways can be attributed, in part, to the loss of supporting capacity during the spring thawing period. It is recommended that CDOH maintenance and materials engineers initiate a program to survey and identify highways associated with spring breakup and take measures to alleviate such problems.

Incorporating the application of dynaflect and temperature/moisture probes into load restrictions appears to be the best criterion; however, they are expensive to obtain, especially on a statewide basis.

It is recommended that moisture content within a few inches of the surface of the subgrade be used as the only criterion to apply or remove load restrictions. As with any criterion, judgement must be used. A load limit may be applied when the moisture content increases by approximately 5 percent over the optimum moisture. Depending upon the index properties of the subgrade, higher or lower threshhold may be used.

X. REFERENCES

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Mahoney, J. P., and J. A. Lary, J. Sherman, N. Jackson. An Investigation of Seasonal Load Restriction in Washington State. July 1984.

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APPENDIX A

****

MOISTURE-DENSITY CURVE   Compaction T99

AMAD - RESEARCH

Field Sheet #   Test #

Gradations: % Passing

-4 Material		Total Sample	
#4	100.	#4	95.
#10	95.	#10	90.
#40	88.	#40	84.
#200	64.2	#200	61.0

Liquid Limit 41.   Plasticity Index 22.

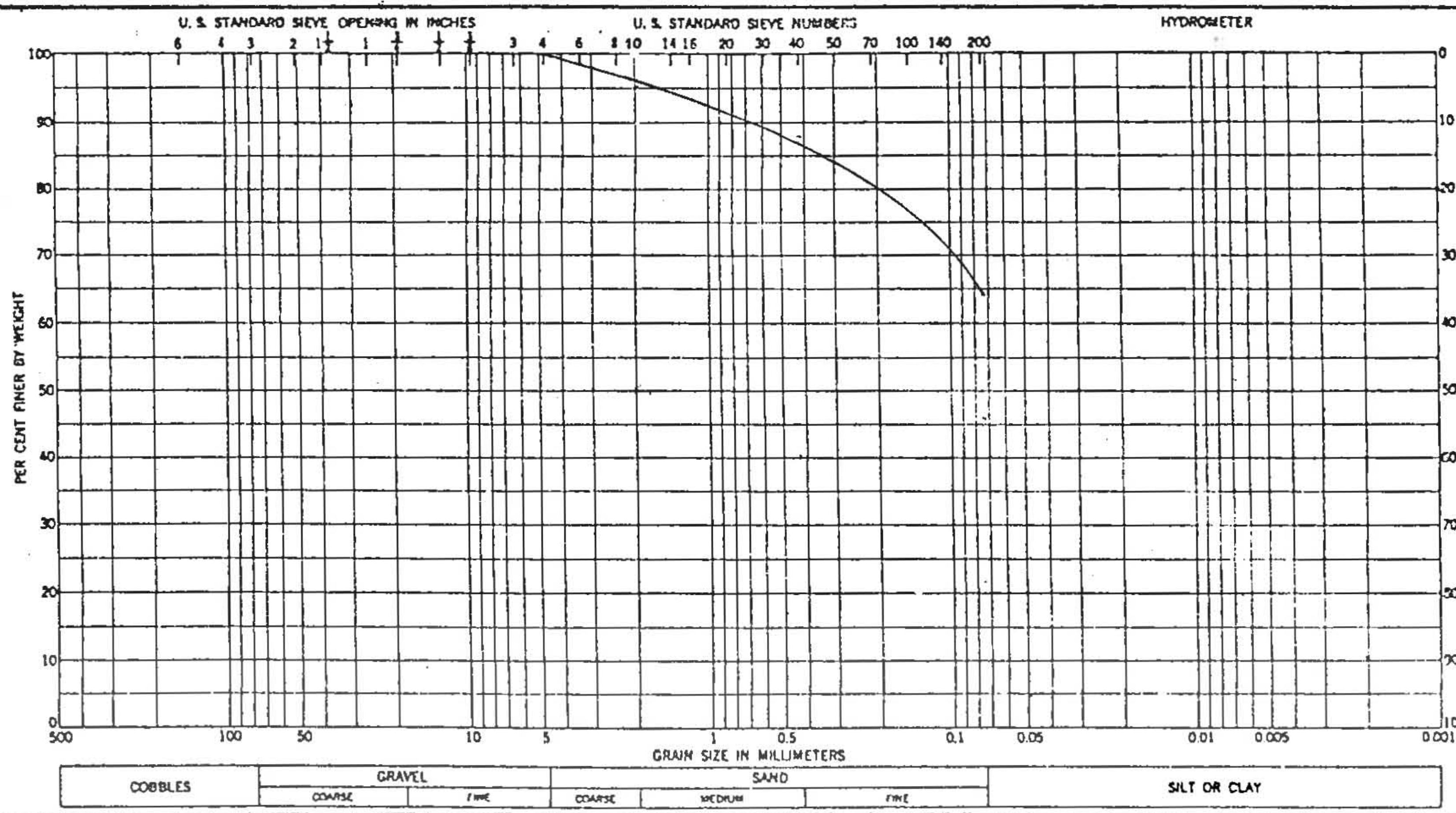
Optimum Moisture 18.1   Maximum Dry Density 105.3

-4 Material Class:A-7-6(12)   Total Sample Class:A-7-6(11)

% H2O	Dry Density	% H2O	Dry Density	% H2O	Dry Density
15.1	103.8	17.1	105.1	19.1	105.1
15.2	103.9	17.2	105.1	19.2	105.1
15.3	104.0	17.3	105.2	19.3	105.0
15.4	104.1	17.4	105.2	19.4	105.0
15.5	104.2	17.5	105.2	19.5	104.9
15.6	104.3	17.6	105.2	19.6	104.9
15.7	104.3	17.7	105.2	19.7	104.9
15.8	104.4	17.8	105.2	19.8	104.8
15.9	104.5	17.9	105.3	19.9	104.7
16.0	104.6	18.0	105.3	20.0	104.7
16.1	104.6	18.1	105.3	20.1	104.6
16.2	104.7	18.2	105.3	20.2	104.6
16.3	104.7	18.3	105.3	20.3	104.5
16.4	104.8	18.4	105.2	20.4	104.4
16.5	104.9	18.5	105.2	20.5	104.3
16.6	104.9	18.6	105.2	20.6	104.3
16.7	104.9	18.7	105.2	20.7	104.2
16.8	105.0	18.8	105.2	20.8	104.1
16.9	105.0	18.9	105.2	20.9	104.0
17.0	105.1	19.0	105.1	21.0	103.9

****

Appendix A



Boring No.	Sample No.	Elev. or Depth	Classification	Nat w %	LL	PL	PI	
	A	2'-3'	A-7-6 (12)		41	19	22	Project Spring Breakup study
								File No. 17.03
REPORT OF SOIL ANALYSIS								Date 10-17-86

APPENDIX B

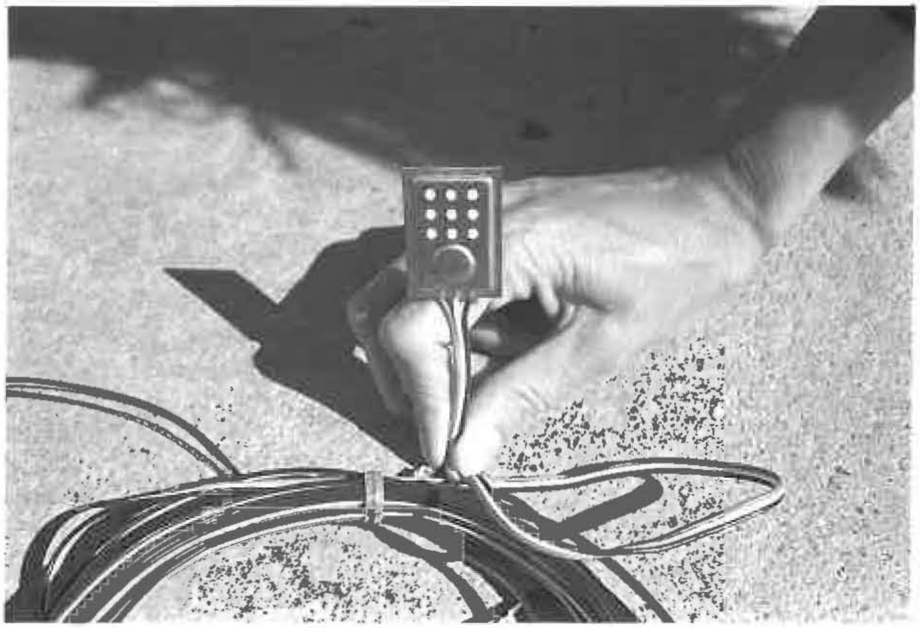
APPENDIX B

Instrument Description:

To monitor the temperature and moisture content of the subgrade, soil cells were used. These cells are made up of two plates separated by a processed fiberglass binding which provides a coupling which varies with the moisture content of the surrounding medium. A small thermistor completes this two-circuit unit.

The standard soil cell is supplied with color-coded leads: white for the thermistor, red for moisture, and black for the lead common to the two. Photograph 7 shows a typical moisture/temperature cell.

The battery-powered MC 300A moisture meter (Photograph 8) is used to acquire moisture and temperature data from the soil cells. Model MC-300A is a 90 cycle AC type ohmmeter with dial readings from 0 to 200. The resistance in ohms, corresponding to any dial reading, is determined by reference to the calibration chart shown in Figure 10. Low scales, which has an effective range from 50 to 10,000 ohms is used for the measurement of thermistor resistance. Both scales may be used for the measurement of moisture resistance. The temperature is easily obtained by referring to Figure 11. However, for obtaining the percent moisture content, soil cells must be first calibrated. Individual cells are placed in soil samples of known moisture content, and resistance readings are obtained for various moisture contents. A plot of these readings results in a graph that can be used at some later time to determine field moisture. Figure 12 represents the calibration curve for SH 131 north of Wolcott.



Photograph 7:

Typical moisture/ temperature cell

Photograph 8:

Battery-powered MC 300A Moisture/ Temperature Meter

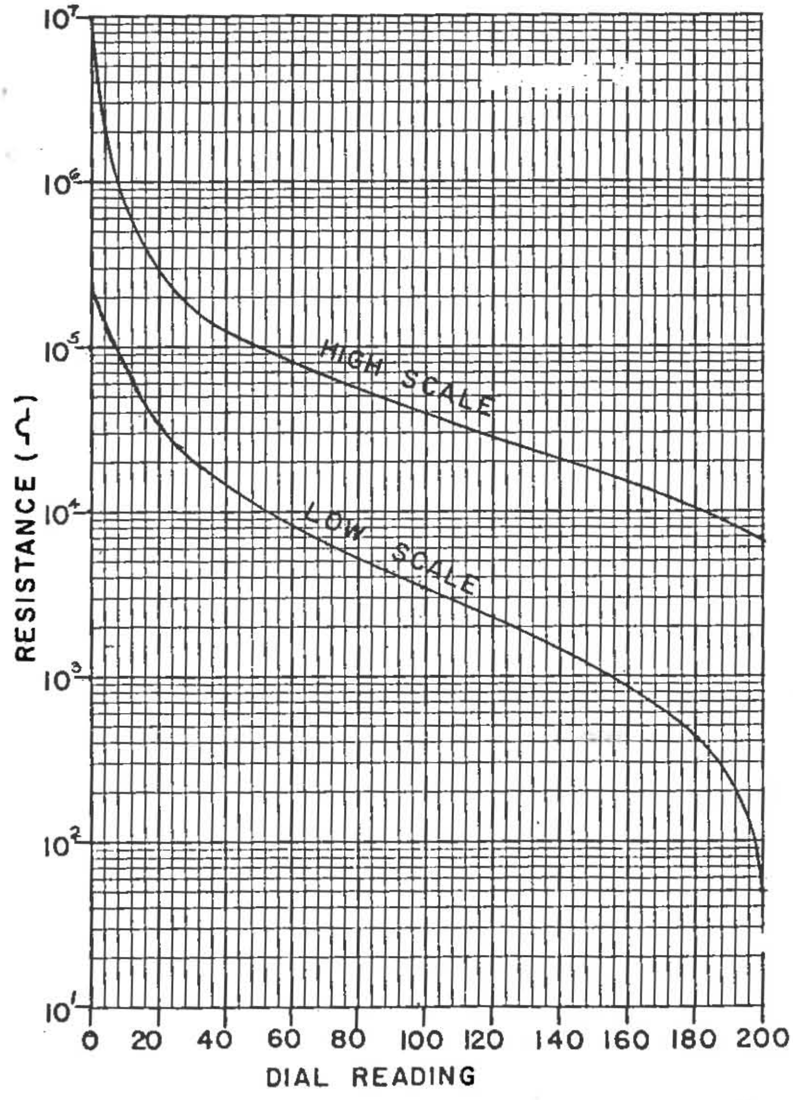


FIGURE 10

Typical calibration chart for MC-300A Moisture Meter

Calibration Chart

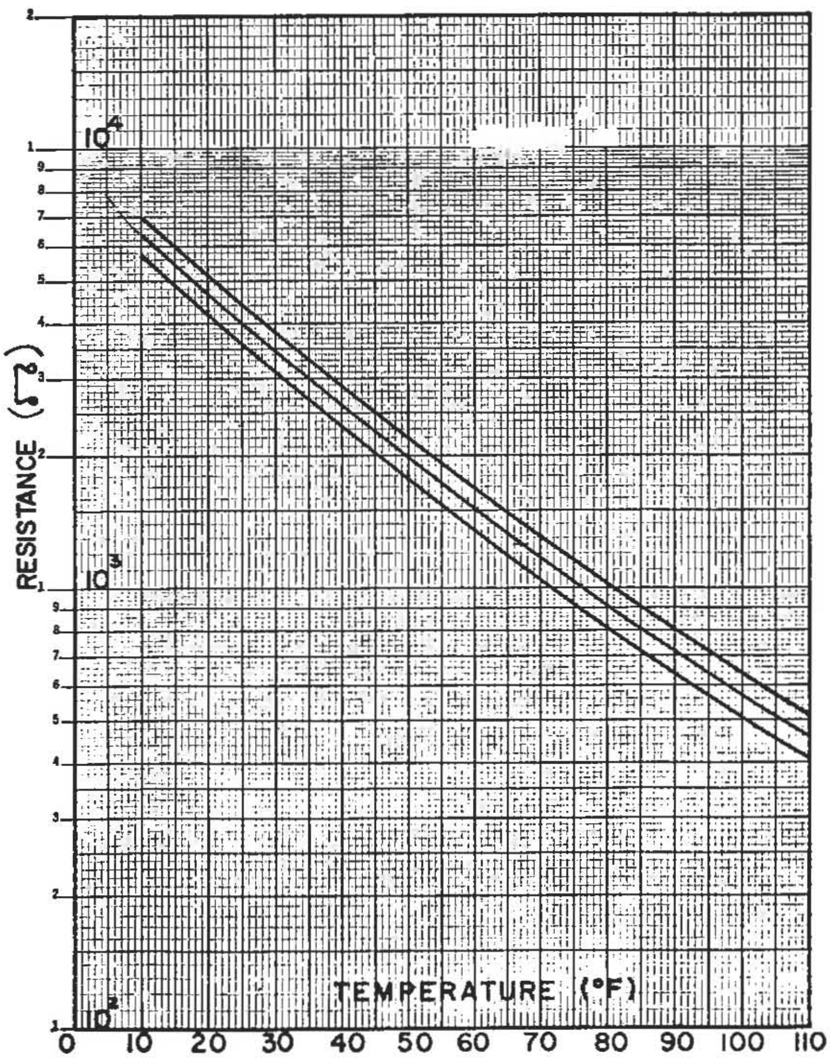
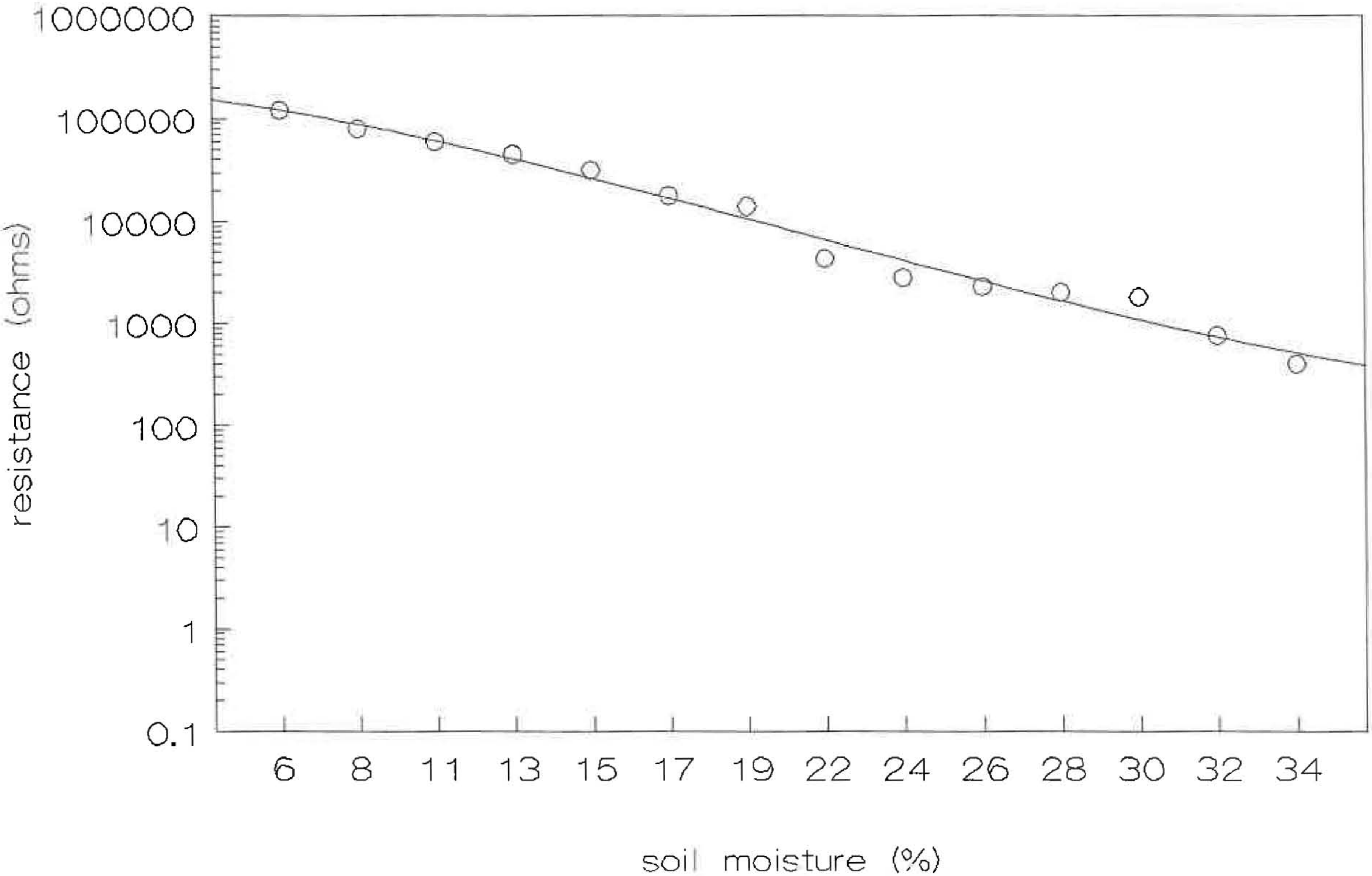


FIGURE 11

Resistance VS. Temperature

FIGURE 12
MOISTURE RESISTANCE CURVE



APPENDIX C

APPENDIX C

SPRING DATA COLLECTION
WOLCOTT COLORADO

FILE # 17.03
AHMAD ARDANI

CELL #	TEMP. DIAL	TEMP. OHMS	TEMP. DEG.F	MOST. DIAL	MOST. OHMS	% MOST.	DEFL. MILS	DATE
1	105	3000	35	75	5500	21	136	2-12-87
2	100	3400	31	66	7000	20.6	136	"
3	92	4000	25	4	150000	3.5	136	"
4	98	3500	30	8	70800	8	136	"
1	100	3400	31	68	7000	20.6	117	2-23-87
2	95	3800	27	68	7000	20.6	117	"
3	90	4200	23	4	150000	3.5	117	"
4	95	3800	27	5	130000	4	117	"
1	102	3200	33	75	5500	21	173	3-4-87
2	97	3750	27	72	6200	20.8	173	"
3	97	3750	27	10	75000	9	173	"
4	95	3800	27	115	2500	25	173	"
1	100	3400	31	105	3000	23.6	553	3-12-87
2	100	3400	31	100	3400	23.1	553	"
3	95	3800	27	107	2900	24	553	"
4	95	3800	27	170	620	32.5	553	"
1	105	3000	35	105	3000	23.6	404	3-18-87
2	100	3400	31	98	3500	23	404	"
3	100	3400	31	115	2500	25	404	"
4	100	3400	31	140	1500	30.4	404	"
1	100	3400	31	97	3750	22.5	372	3-26-87
2	106	3000	35	97	3750	22.5	372	"
3	106	3000	35	115	2500	25	372	"
4	105	3000	35	140	1500	30.4	372	"
1	107	2900	26	99	3400	23.1	294	4-2-87
2	102	3200	33	102	3200	23.3	294	"
3	104	3100	34	115	2500	25	294	"
4	111	2700	38	142	1400	30.6	294	"
1	112	2600	40	100	3400	23.1	326	4-10-87
2	115	2500	41	105	3000	23.6	326	"
3	112	2600	40	117	2400	26	326	"
4	110	2700	38	110	2700	24.5	326	"

CELL #	TEMP. DIAL	TEMP. OHMS	TEMP. DEG.F	MOST. DIAL	MOST. OHMS	% MOST.	DEFL. MILS	DATE
1	113	2600	40	105	3000	23.6	334	4-15-87
2	107	2900	36	105	3000	23.6	334	"
3	116	2500	41	121	2200	27	334	"
4	120	2200	46	164	750	32	334	"
1	114	2600	40	107	2900	24	301	4-22-87
2	119	2250	45	107	2900	24	301	"
3	120	2200	46	121	2200	27	301	"
4	124	2000	50	172	580	32.6	301	"
1	125	2000	50	113	2600	24.7	303	4-29-87
2	120	2200	46	114	2600	24.7	303	"
3	125	2000	50	125	2000	28	303	"
4	125	2000	50	164	750	32	303	"
1	130	1750	54	113	2600	24.7	341	5-13-87
2	130	1750	54	117	2400	26	341	"
3	130	1750	54	129	1800	30	341	"
4	135	1600	58	150	1100	31.3	341	"
1	130	1750	54	110	2700	24.5	318	5-27-87
2	125	2000	50	117	2400	26	318	"
3	135	1600	58	128	1900	29	318	"
4	130	1750	54	165	730	32.3	318	"
1	100	3400	61	115	2500	25	270	6-17-87
2	140	1500	60	105	3000	23.6	270	"
3	145	1200	69	120	2200	27	270	"
4	150	1100	72	140	1500	30.4	270	"
1	135	1600	58	95	3800	22.3	240	9-15-87
2	130	1750	54	100	3400	23.1	240	"
3	130	1750	54	100	3400	23.1	240	"
4	135	1600	58	100	3400	23.1	240	"

APPENDIX D

GUIDELINES FOR SPRING HIGHWAY USE RESTRICTIONS

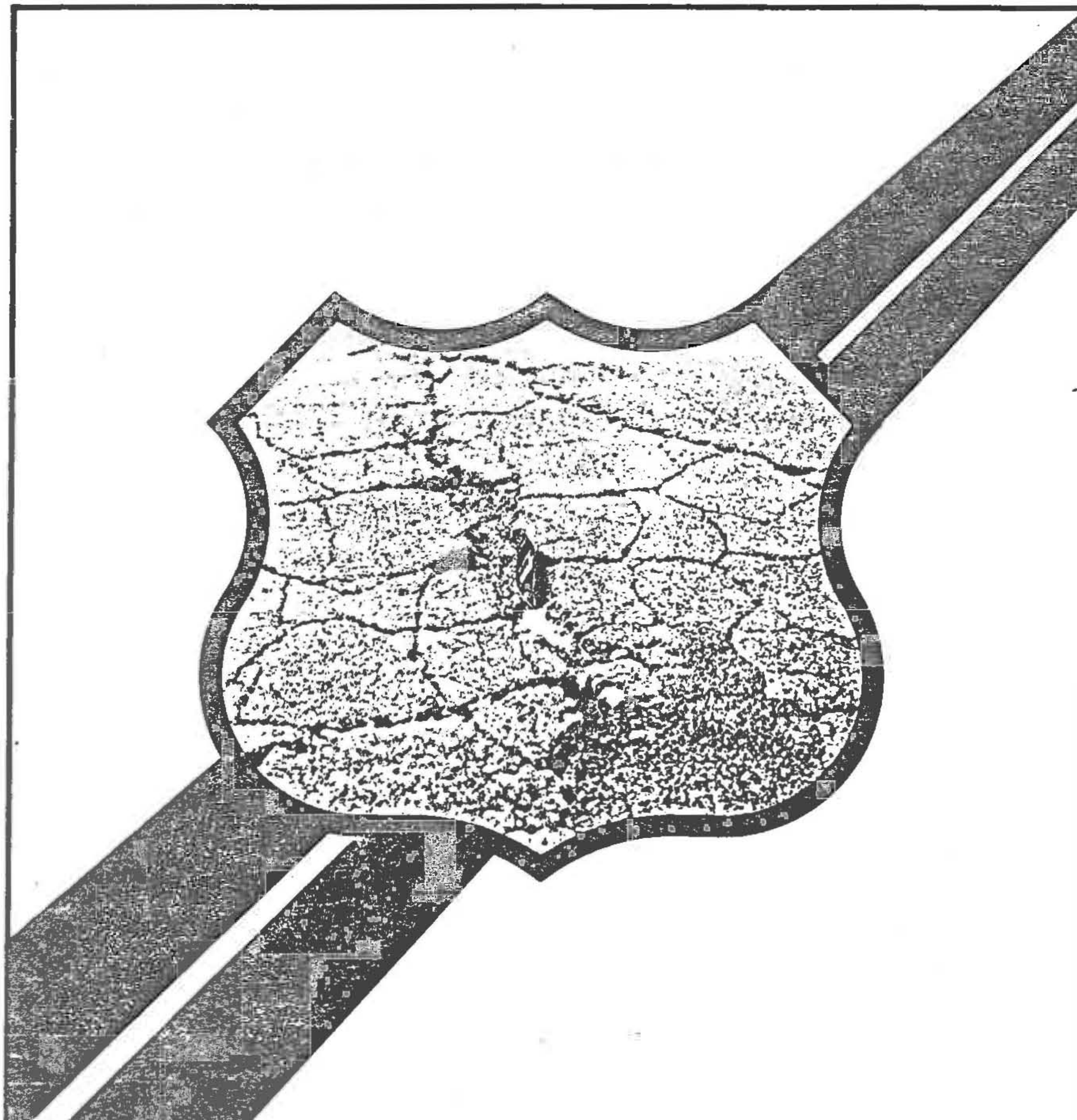
Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, Virginia 22101-2296

Report No:
FHWA-TS-87-209

U.S. Department of Transportation

Federal Highway Administration

Video Supplement
January 1987



SUMMARY OF GUIDELINES FOR SPRING HIGHWAY USE RESTRICTIONS

Where to apply:

1. Surface thickness < 2 inches

2. Type of subgrade (silts & clays)

3. Pavement distress (alligator cracking & rutting)

4. Surface deflections (surface deflections of 45 to 50 percent higher during spring than during summer.

Amount of restriction:

"General national practice is to use load reductions ranging from 40 to 50 percent."

When to apply:

When the thawing index reaches:

a) Should level 10 to 25 degree days

b) Must level 40 to 50 degree days

Duration of load restrictions:

The load restriction should last until complete thawing is achieved. Complete thawing can be obtained through 2 equations:

1. TI = 4.15 + 0.26 (Freezing Index)

2. TI = 0.3 (Freezing Index)