COLD WEATHER PAVING REQUIREMENTS FOR BITUMINOUS CONCRETE

by

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INTRODUCTION

It has long been recognized that the compaction of bituminous concrete in low ambient temperatures is quite difficult and that often pavements placed during cold weather give substandard performance. Usually, the attempts to avoid these problems have been based on the establishment of a minimum air temperature at which paving operations may be conducted. Virginia's 1966 revised specification, given in Appendix A, restricted the season, atmospheric temperature, and compacted course thicknesses for the placement of bituminous pavements.

Although other factors influence the quality of a bituminous paving job, they have been given little or no mention in most specifications because of a lack of quantitative information. Dickson and Corlew [1] developed equations defining the cooling rate of bituminous mats in terms of factors such as laydown temperature, mat thickness, air temperature, base temperature, wind velocity, sun heat, specific heat of the layers, and heat transfer coefficients. Using a computer solution, they evaluated the influence of these factors on the cooling rate, and found the most important to be base temperature, laydown temperature, and thickness of the fresh mat.

Since it was known that paving during cold weather often resulted in inferior jobs and the 1966 Virginia specification prescribed limits for only one of the three most important factors enumerated by Dickson and Corlew, a decision was made to examine the specification with a view to possible revisions.

PURPOSE

The purpose of this investigation was to verify Dickson and Corelew's computer solutions for determining the cooling rate of bituminous mats and to recommend improvements in Virginia's cold weather paving specifications.

METHODOLOGY

To verify the computer solutions, cooling rate measurements were taken in the field under various ambient temperatures for different pavement thicknesses. Curves similar to that shown in Figure 1 were obtained for three projects: one on I-64 in Augusta County, one on I-81 in Montgomery County, and the other on the entrance road to the historical Smithfield Plantation near Blacksburg. The Smithfield Plantation measurements were taken in March and those on I-64 and I-81 in December.

The temperature measurements were taken with a thermocouple and a null balance potentiometer type instrument (Figure 2). Iron-constantan thermocouples were placed at the bottom and middle of the fresh layer, directly behind the paver, and average temperatures of the mat were recorded at time intervals so that a cooling curve could be plotted.

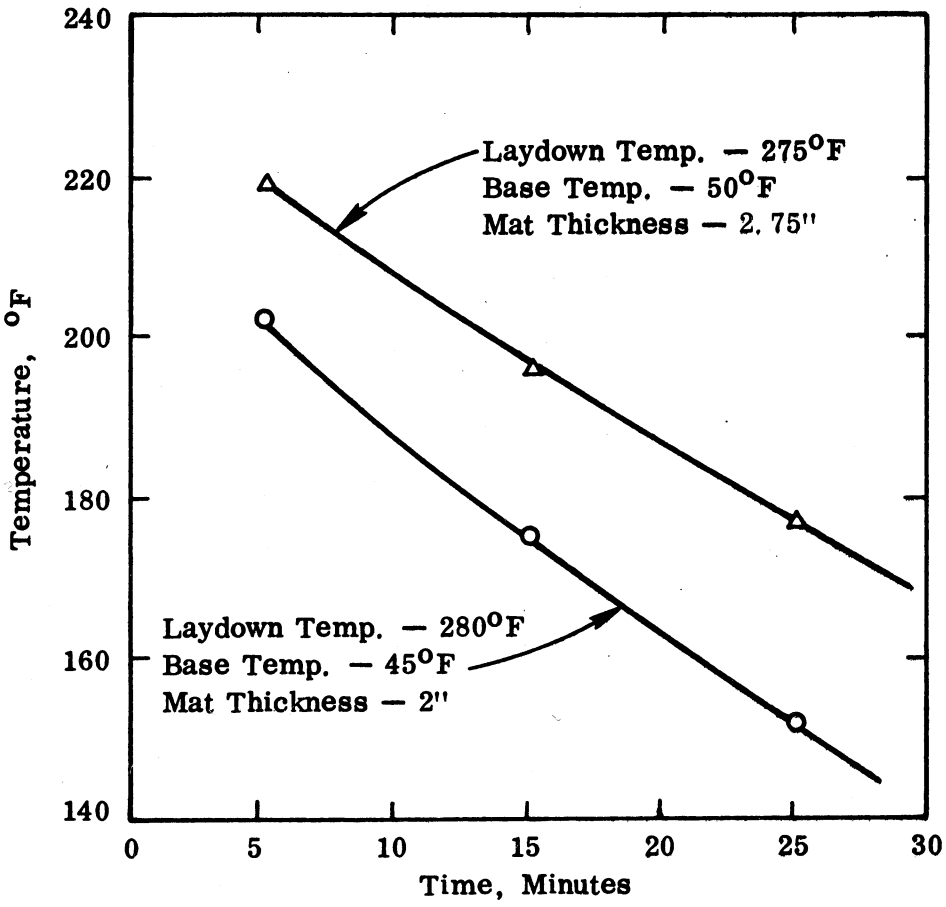

Figure 1. Typical experimental cooling curves.

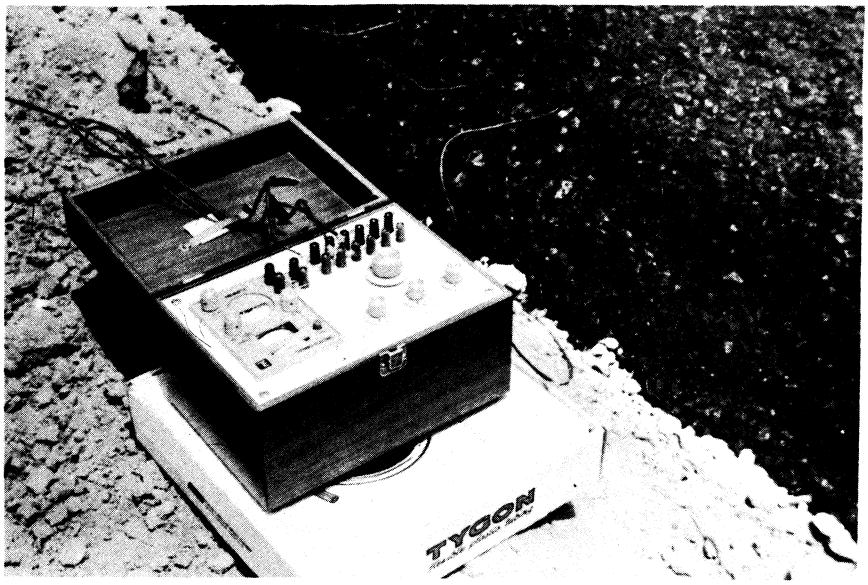

Figure 2. Null balance potentiometer and thermocouples used for taking temperature measurements.

RESULTS

In general, there was good agreement between the measured and computed cooling rates, as can be seen in the last two columns of Table 1. (The reason for selecting the 175°F temperature is discussed later.) These data were used to develop the correlation between the measured and computed results. This correlation, shown in graph form in Figure 3, was as follows:

$$Y = 0.75\,x + 3.5$$

where

Y = computed time to cool to 175°F — minutes
x = measured time to cool to 175°F — minutes

Although the correlation coefficient was 0.9, which is very good, it is believed the results would have been improved if the upper thermocouple could have been located more precisely in the middle of the layer. As discussed in the following section specifications are based on breakdown rolling times of 8 minutes using two rollers and 15 minutes using one roller. Examination of the equation above revealed

TABLE 1

COMPARISON OF COMPUTED AND MEASURED COOLING RATES

Route	Test No.	Mat Thickness, inches	Laydown Temp., deg. F	Base Temp., deg. F	Time to cool to 175°F, minutes	
					Computed	Measured
I-64	12-3-1	1.5	280	45	12.0	15
I-64	12-3-2	1.5	275	45	11.5	19
I-64	12-3-3	1.5	270	51	12.5	11
I-64	12-3-4	1.5	270	51	12.5	13.5
I-81	12-10-2	2.75	270	45	13	15
I-81	12-10-3	2.75	285	45	15	13
I-81	12-10-4	2.75	285	50	16	12
I-81	12-10-5	2.75	275	50	13	11
Smithfield Plantation	SP-1	1.5	300	45	11	10
Smithfield Plantation	SP-2	1.5	295	60	11.5	10
Smithfield Plantation	SP-3	3.0	295	70	35	38
Smithfield Plantation	SP-4	3.0	295	78	36	41
Smithfield Plantation	SP-5	3.0	275	70	32	32
Smithfield Plantation	SP-6	3.0	285	60	29	36
Smithfield Plantation	SP-7	2.0	285	65	19	26
Smithfield Plantation	*SP-8	1.5	285	60	12	23

* Suspected thermocouple displacement

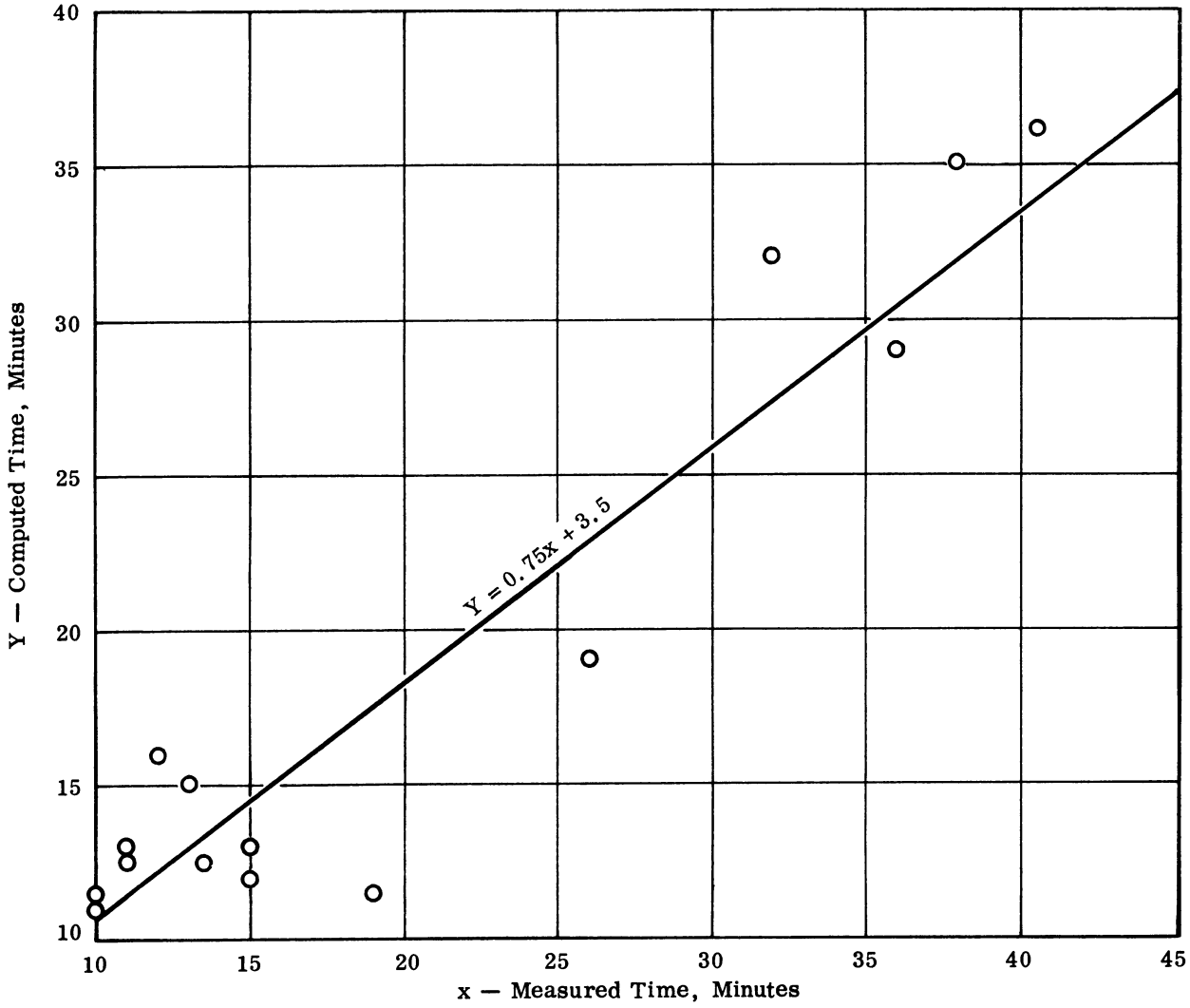

Figure 3. Measured vs. computed time for mat to cool to 175°F.

satisfactory agreement between computed and measured results at 8 and 15 minute time levels. The 8 minutes measured time compares to 9.5 minutes computed time and the 15 minutes measured time compares to 15 minutes computed time.

The computed cooling time appears to be a good predictor of the measured cooling time, therefore the computed cooling rates are considered to represent the actual cooling rates of fresh bituminous mats in the field.

RECOMMENDED REVISIONS TO VIRGINIA SPECIFICATION

In addition to the cooling rate, it was necessary to know the lowest possible mat temperature under which adequate compaction could be obtained and the required rolling time before recommended revisions to the Virginia specification could be developed. In 1968 the NAPA Quality Improvement Committee distributed questionnaires requesting information on the lowest compaction temperature and required rolling time necessary to achieve maximum density. The committee decided that 175°F would be taken as the temperature below which no appreciable increase in density occurred and that rolling times of 8 minutes and 15 minutes for thin and thick lifts, respectively, would be reasonable. The reason for selecting two rolling times was that thin lifts might require fewer passes than thick lifts.

An examination of Virginia's roller patterns revealed that thin lifts do not always require a significantly fewer number of passes; therefore, use of the 8 minute rolling time for a single roller on thin lifts did not appear warranted unless 2 breakdown rollers were to be used. Consequently, the recommended revisions developed were based on the three main factors cited by Dickson and Corlew (base temperature, laydown temperature, and mat thickness), a 175°F minimum rolling temperature, and a 15 minute rolling time when using 1 breakdown roller and an 8 minute rolling time when using 2 breakdown rollers.

In 1970 the recommended revisions were put into effect by the Department. Under them, the minimum laydown temperature is specified for combinations of thickness and base temperature in tabular form (Appendix B). If the necessary laydown temperature is more than the maximum allowable (280° design) it is impossible to pave. However, if paving isn't allowable using one roller (15 minute rolling time) it may be possible if 2 breakdown rollers (8 minute rolling time) are used.

The author recently proposed to the Department that the present specification be put into the form of a nomograph (Figure 4) because it is felt that if would be more versatile and also be easier for inspectors to use in the field. It would eliminate the interpolation of the tabular values by the inspectors. The nomograph should be substituted for the tabular data in the specification in the near future.

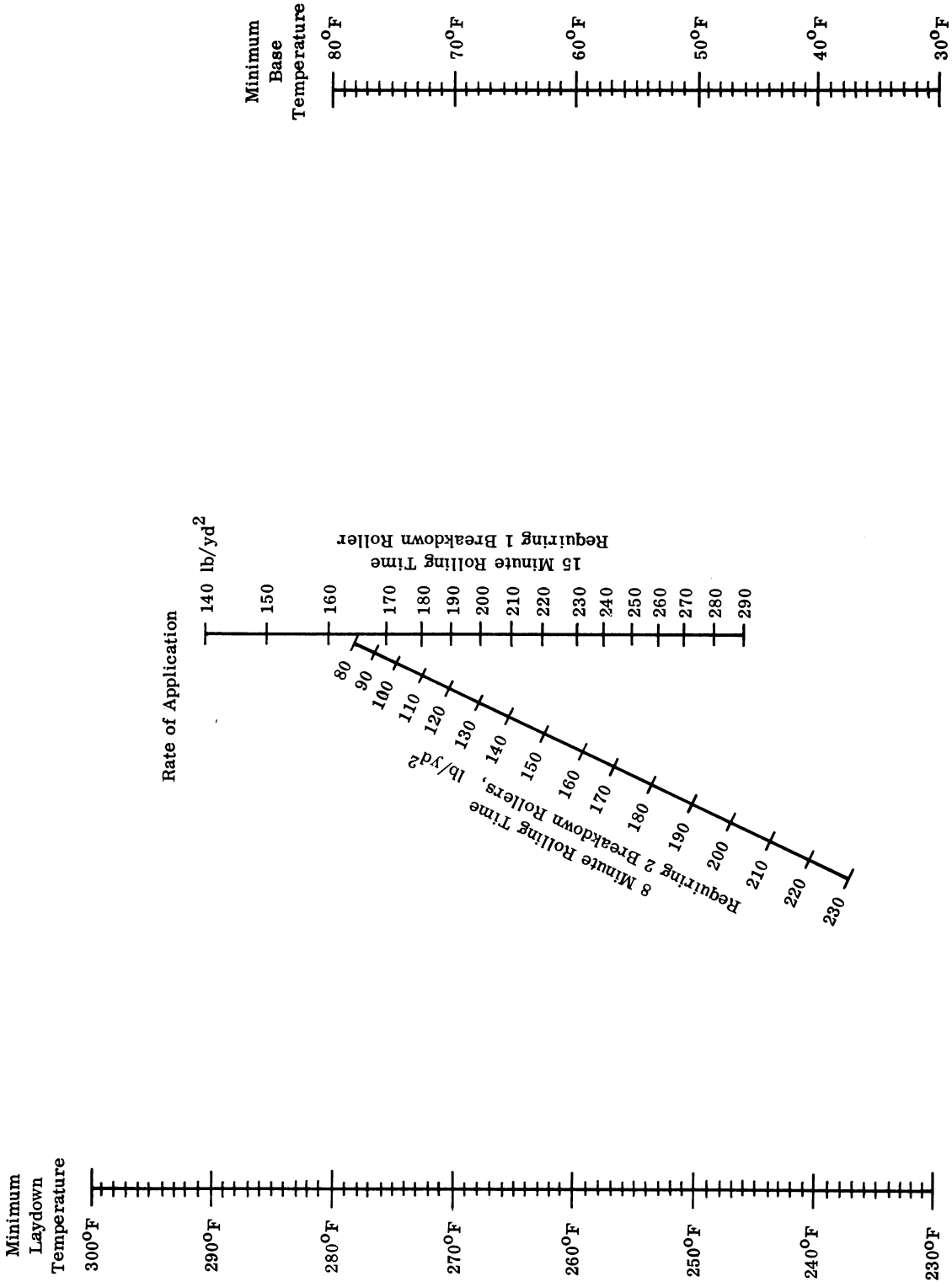

Figure 4. Cold weather paving limitations.

REFERENCES

1. Dickson, Philip F., and J. S. Corlew, "Data Computations for QIP Project Requirements for Cessation of Paving," NAPA Project 263-2D, January 15, 1969.

APPENDICES

APPENDIX A

Section 320.03 of the 1966 edition of the Road and Bridge Specifications is completely replaced by the following:

Sec. 320.03 Weather and Seasonal Limitations — Bituminous mixtures shall not be placed when weather or surface conditions are such that the material cannot be properly handled, finished or compacted. The surfaces upon which bituminous mixtures are to be placed shall be reasonably free of moisture at the time such materials are spread. Base and intermediate mixtures shall not be placed at atmospheric temperatures below 35°F in the shade when the material is placed in layers 2-$\frac{1}{2}$ inches and greater in compacted thickness or at atmospheric temperatures below 40°F in the shade when placed in layers less than 2-$\frac{1}{2}$ inches in compacted thickness. Surface mixtures shall not be placed at atmospheric temperatures below 40°F in the shade when the material is placed in layers $\frac{1}{2}$-inch and greater in compacted thickness or at atmospheric temperatures below 50°F in the shade when placed in layers less than $\frac{1}{2}$-inch in compacted thickness.

Bituminous concrete surface mixtures and intermediate mixtures placed in layers less than 2-$\frac{1}{2}$ inches in compacted thickness shall not be placed between the dates of November 15 and April 1 without written approval. There will be no seasonal limitation on the placement of intermediate mixtures placed in layers 2-$\frac{1}{2}$ inches and greater in compacted thickness or bituminous base concrete.

APPENDIX B

SPECIAL PROVISION FOR SECTION 320 — BITUMINOUS CONCRETE PAVEMENTS

Rev. 1-15-71

The second and third paragraphs of Section 320.03 of the 1970 Specifications are completely replaced by the following:

The placing of bituminous mixtures shall conform to the following requirements:

15 Minute Maximum Breakdown Rolling Time

Thickness	Base Temperature	Minimum Laydown Temperature
2" +	30°F	290°F
	40°F	280°F
	50°F	270°F
	60°F	260°F
$1\frac{1}{2}$" to 2"	60°F	290°F
	70°F	280°F
	80°F	270°F
Less than $1\frac{1}{2}$"	Min. 80°F	—

Note 1. When the base temperature is above 80°F, any laydown temperature within specification limits will be allowed.

Note 2. When the thickness is less than $1\frac{1}{2}$", the minimum base temperature required will be 80°F irrespective of the laydown temperature.

Note 3. Should the Contractor be unable to complete the breakdown rolling within 15 minutes, the placing of bituminous mixture shall cease until sufficient rollers are available, or other corrective action taken, to complete the breakdown rolling within 15 minutes.

Note 4. The thicknesses stated herein are based upon a weight of 115 pounds per square yard per inch of depth.

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8 Minute Maximum Breakdown Rolling Time Using Not Less Than 2 Breakdown Rollers

Thickness	Base Temperature	Minimum Laydown Temperature
2" +	30°F	240°F
	40°F	240°F
	50°F	230°F
	60°F	230°F
1½" to 2"	30°F	270°F
	40°F	265°F
	50°F	260°F
	60°F	255°F
	70°F	250°F
1¼" to 1½"	30°F	290°F
	40°F	285°F
	50°F	280°F
	60°F	270°F
	70°F	260°F
1" to 1¼"	50°F	290°F
	60°F	280°F
	70°F	275°F
	80°F	265°F
3/4" to 1"	65°F	290°F
	70°F	285°F
	75°F	280°F
	80°F	275°F
Less than 3/4"	Min. 80°F	—

Note 1. When the base temperature is above 80°F the provisions of the table for 15 minute maximum breakdown rolling time will apply.

Note 2. When the thickness is less than 3/4", the minimum base temperature required will be 80°F irrespective of the laydown temperature.

Note 3. Should the Contractor be unable to complete the breakdown rolling within 8 minutes, the placing of bituminous mixture shall cease until sufficient rollers are available or other corrective action taken, to complete the breakdown rolling within 8 minutes.

Note 4. The thicknesses stated herein are based upon a weight of 115 pounds per square yard per inch of depth.

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