# REEXAMINATION OF COLD WEATHER PAVING SPECIFICATION FOR BITUMINOUS CONCRETE

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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## SUMMARY

The cold weather paving specification for bituminous concrete adopted in 1970 was reexamined to determine its effectiveness and any need for revisions. Density and temperature measurements were obtained on five field projects and observations were made of the rolling practices employed.

The results and feedback from field personnel were used to recommend (1) changes in the nomograph, (2) a prohibition of paving on a frozen base or when the base temperature is less than 35°F, and (3) allowing the use of a vibratory roller for the 8-minute rolling time, if the required density can be achieved.

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## INTRODUCTION

Cold ambient temperatures experienced in fall and winter can cause inadequate compaction of bituminous pavements to an extent that results in poor quality pavements. Specifications usually attempt to avoid compaction problems associated with cold temperatures by forbidding all paving during winter months.

Investigators have developed a systematic approach to the problem in which the cooling rate of a bituminous mat is determined from mat thickness, laydown temperature, base temperature, wind velocity, and solar radiant flux.[1,2] Mathematical relations have been developed to determine the allowable rolling time in terms of the above variables.

Two advantages of a specification developed by this approach are (1) that the purchaser can be assured that the mix will not cool beyond a compactable temperature before rolling can be completed, and (2) that construction may be safely extended into the fall and winter months for thick bituminous mats.

In 1970 a specification of this type was adopted by Virginia. In it the allowable minimum laydown temperature was specified for various combinations of base temperature and mat thickness. Later the specification was revised to allow the determination of the minimum laydown temperature by use of a nomograph (Appendix A).

## PURPOSE AND SCOPE

The purpose of this investigation was to determine the effectiveness of the 1974 cold weather paving specifications as presented in section 320.03 of the Virginia Road and Bridge Specifications (Appendix A). The objective was accomplished by observing paving practices, obtaining pavement densities, and gathering temperature data to determine whether the specification is satisfactory and if compliance is being attained. Data were obtained on five paving projects.

Also feedback from field personnel using the specification has been considered in the recommendations for revisions.

## DATA COLLECTION

An attempt was made to gather data during periods of cold ambient temperatures, but in some instances the ambient temperature warmed during the day to such an extent that the data were not useful. Data were obtained at 10 locations on each of 5 projects (Table 1) during October and November of 1976 and 1977. Three projects included new construction and two projects were maintenance overlays.

Data included nuclear and core densities, mat thickness, rolling practice, base temperature, laydown temperature, and temperature measurements of the mat taken periodically after paving.

Table 1

Projects Monitored

| Job Identification | Type Operation | Mix Type | Average Thickness, in. | Base Temp. Range, °F |
|---|---|---|---|---|
| 1A | New Const. | S-5 | 1.7 | 40-50 |
| 1B | New Const. | S-5 | 1.6 | 45-70 |
| 1C | New Const. | S-5 | 1.5 | 49-78 |
| 2 | Maint. | I-2 | 1.5 | 38-82 |
| 3 | Maint. | I-2 | 1.4<br>1.8<br>2.2 | 55-95 |

## RESULTS

### Verification of Nomograph

Computer solutions of heat transfer equations using the finite difference method can be used to predict the cooling rates

of bituminous mats. Tegler and Dempsey developed a graphical form to predict the cooling rate.[2] Information that must be provided is time of day, date, amount of sunshine, wind velocity, mix temperature, base temperature, and mat thickness.

Dickson and Corlew also developed a similar type of solution for the cooling rate of bituminous mats.[1] The computer is used to predict the cooling rate of a mat under various environmental conditions. Usually the solar flux and wind velocity are considered constant and the cooling rate is estimated from curves for various mix temperature and base temperature combinations.

The nomograph in section 320.03 of the specifications was based on Dickson and Corlew's cooling rate curves. Because of the newness of the specification and a desire not to impose unfair restrictions on the contractor, the allowable laydown temperatures from the nomograph were slightly lower than those obtained from Dickson and Corlew's work.

Although their work was verified by field measurements in Virginia prior to the drafting of a nomograph,[3] additional verification was established in the present study. Table 2 lists the predicted time for a fresh mat to cool to 175°F according to Dickson and the measured time. The predicted times represent an average mat temperature (see Figure 1) whereas the field measurements were of the maximum mat temperature at approximately the middle of the mat because of ease of measurement. Because the maximum temperature time should be slightly longer than average temperature time, the predicted values compare reasonably well with the observed cooling time. Table 2 indicates that the mat cools faster than the method by Tegler and Dempsey predicts. The measurements verify that the predictive method by Dickson and Corlew is reliable and confirm measurements made in a previous study.[3]

The nomograph in the specification should be modified to conform more closely to the predictions by Dickson and Corlew's method. Contractors are now familiar with the specification and the modification will help assure that no compaction failures occur.

The nomograph should also be modified to include a maximum application rate of 420 psy (3.6 inches). The current specified minimum laydown temperature cannot be less than that for a 2-inch mat; therefore, the contractor cannot take advantage of heat retention of mats thicker than 2 inches. Both of the suggested revisions are shown in the nomograph in Appendix B.

Table 2

Time for Fresh Mat to Cool to 175°F

| Job I.D. | Test No. | Thickness, in. | Base Temp., °F | Laydown Temp., °F | Time in Minutes | | |
|---|---|---|---|---|---|---|---|
| | | | | | Measured Max. Mat. Temp. | Avg. Mat. Temp. | |
| | | | | | | Corlew | Tegler |
| 1B | 8 | 1.7 | 50 | 300 | 17 | 15 | 20 |
| 2 | 2 | 1.5 | 70 | 300 | 18 | 15 | 20 |
| 2 | 9 | 1.4 | 70 | 260 | 18* | 10 | 10 |
| 3 | 9 | 1.8 | 55 | 275 | 17 | 12 | 23 |
| 3 | 3 | 0.9 | 85 | 285 | 17 | 10 | 12 |
| 1C | 18 | 1.6 | 52 | 270 | 15 | 12 | 17 |
| 1C | 19 | 1.2 | 49 | 285 | 9 | 8 | 11 |
| 1B | 17 | 1.3 | 48 | 285 | 12 | 9 | 12 |

*Interpolated value.

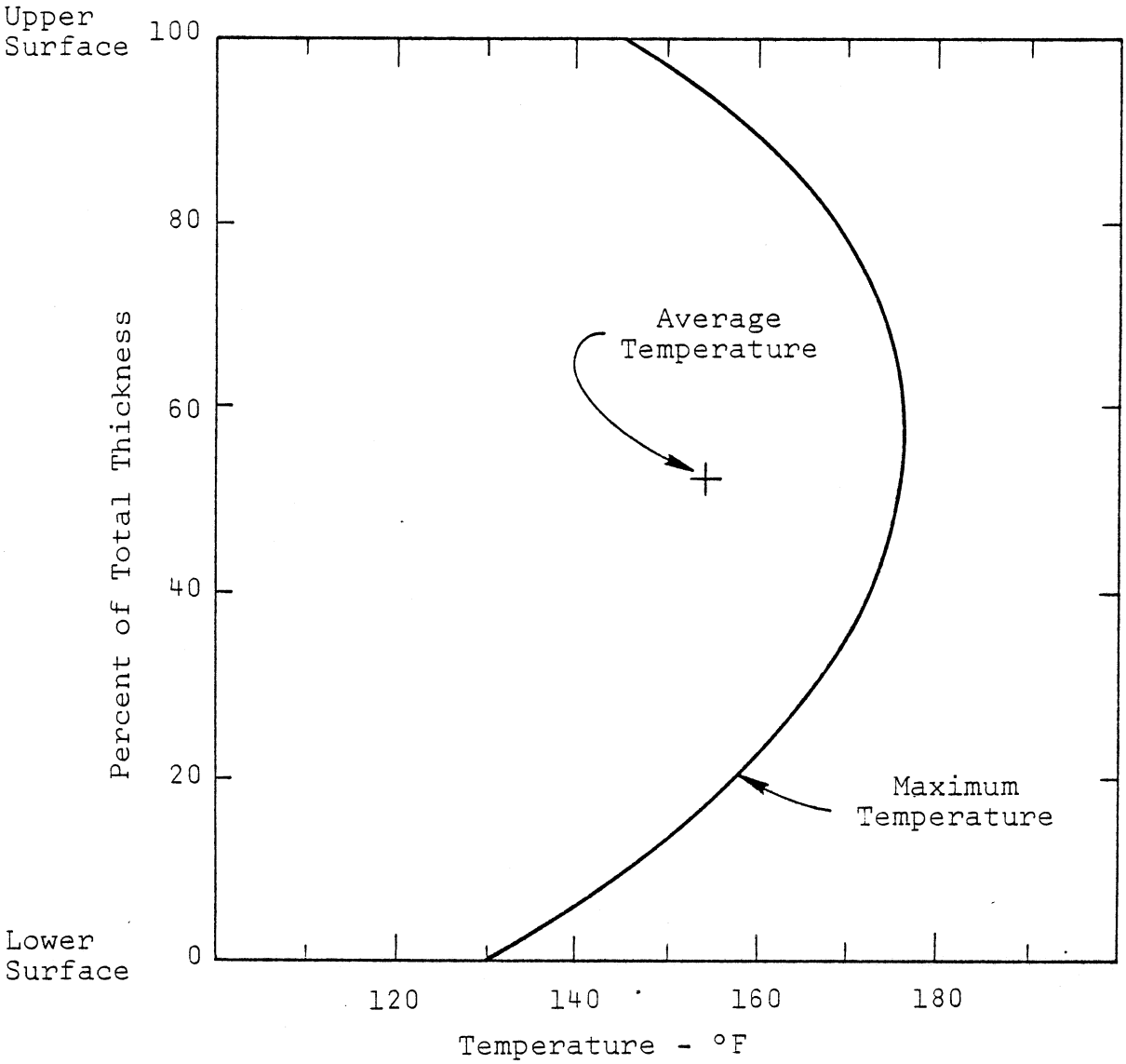



Figure 1. Typical mat temperature profile.

The 165 psy application rate in part (a) of the specification does not agree with the rate of application on the nomograph for an 80°F base temperature and 300°F laydown temperature (maximum allowable). The rate of application should be specified at 160 psy.

Because there is a possibility that a base may thaw and become unstable under a hot plant mix, it is preferable that this type mix not be placed on a frozen base. A minimum base temperature of 35°F would seem reasonable.

## Density Results and Observations of Rolling Practice

Tabulated observations of rolling practice and density results are listed in Table 3.

The number of roller passes was generally less than the number required by an established roller pattern. This practice probably contributed to the low density (percent compaction) achieved on project 1C. The density of project 2 was slightly low, but an examination of the results indicated that the mat temperature did not drop below 175°F before breakdown rolling was completed. The low densities experienced in these two cases were not the result of a faulty specification.

One of the assumptions that was necessary to develop the specification was that breakdown rolling can be completed in 15 minutes using one breakdown roller and in 8 minutes with two breakdown rollers. Only one breakdown roller was used on each project. The data (Table 3) reveal that very few rolling times exceeded 15 minutes; therefore, the assumed 15-minute rolling time appears to be valid. No data were collected using two breakdown rollers and an 8-minute rolling time.

Two breakdown rollers are now required to complete breakdown rolling in the 8-minute time period. Vibratory rollers normally require less time to complete breakdown rolling; therefore, a contractor should be allowed to use a single vibratory roller in lieu of two static breakdown rollers if rolling can be completed in 8 minutes.

Table 3

Rolling and Density Data

| Project | Mat Thickness, in. | Required Roller Passes | Applied Roller Passes | Average Rolling Time, Min. | Range of Rolling Time, Min. | Temp. at Completion of Rolling, °F | Percent Compaction |
|---|---|---|---|---|---|---|---|
| 1A | 1.7 | 5 | 2.8 | 11 | 6-15 | 220 | 93.7 |
| 1B | 1.6 | 5 | 3 | 9 | 7-11 | 250 | 92.2 |
| 1C | 1.5 | 3 | 1.2 | 9 | 6-15 | 210 | 88.8 |
| 2 | 1.5 | * | 6.7 | 9 | 5-16 | 242 | 91.2 |
| 3A | 1.5 | 4 | 3.2 | 13 | 6-23 | 215 | 94.4 |
| 3B | 1.8 | 5 | 6 | 19* | 9-29** | 225 | 94.2 |
| 3C | 2.2 | 5 | 4 | 13 | 10-16 | 220 | 93.7 |

*No roller pattern.

**Included a roller pattern which required more time.

## CONCLUSIONS

1. The results of this study have reaffirmed that the method developed by Dickson and Corlew can be used to predict the cooling rate of freshly placed bituminous mats.

2. The data support the assumption made in the original specification that the rolling time using one breakdown roller is 15-minutes.

3. From the limited number of projects observed it appears that the specification is producing adequate compaction, if a satisfactory rolling practice is followed.

## RECOMMENDED REVISIONS TO SPECIFICATION

1. Modify nomograph to more closely approximate cooling rate predictions by the Dickson and Corlew method and extend application rate to 420 psy (3.6 in.).

2. Change part (a) of section 320.03 to read 160 psy rather than 165 psy so that it will agree with the nomograph.

3. Specify that no paving will be allowed on a frozen base or when the base temperature is less than 35°F.

4. Allow the use of a single vibratory roller operating in the vibratory mode for the 8-minute rolling time, if the required density can be achieved within 8-minutes.

# REFERENCES

1. Dickson, P. F. and J. S. Corlew, "Thermal Computations Related to the Study of Pavement Compaction Cessation Requirements," Proceedings, Association of Asphalt Paving Technologists, Vol. 39 (1970).

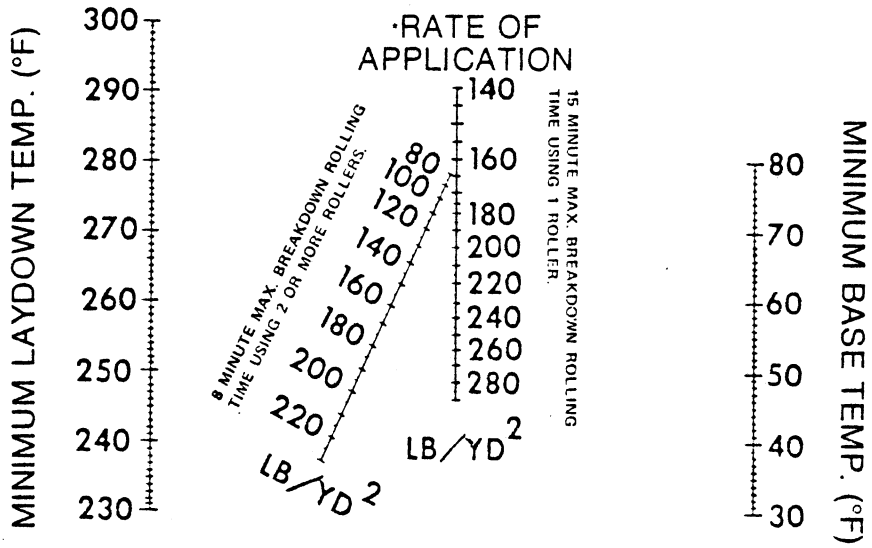
2. Tegler, Phillip A., and Barry J. Dempsey, "A Method Predicting Compaction Time for Hot-Mix Bituminous Concrete," Highway Engineering Series No. 43, Engineering Experiment Station, University of Illinois, May 1972.

3. Maupin, G. W., Jr., "Cold Weather Paving Requirements for Bituminous Concrete," Virginia Highway Research Council, February 1973.

**TABLE III-2**

## COLD WEATHER PAVING LIMITATIONS






*THE RATE OF APPLICATION IS BASED ON AN AVERAGE WEIGHT OF 115 POUNDS PER SQUARE YARD PER INCH OF DEPTH.

**Sec. 320.03 Placing 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 surface upon which bituminous mixtures are to be placed shall be reasonably free of moisture at the time such materials are spread.

The Nomograph, Table III-2, shall be used to determine the minimum laydown temperature of the bituminous concrete, except as follows:

(a) When the bituminous concrete course is less than 1½-inches (165 lbs. per square yard) and one roller is used for the 15 minute breakdown rolling, the surface temperature of the base shall be 80° F or above.

(b) When the bituminous concrete is less than ¾-inch (85 lbs. per square yard) and two or more rollers are used for the 8 minute breakdown rolling, the surface temperature of the base shall be 80° F or above.

(c) When the base temperature is above 80° F, laydown will be permitted at any mix temperature within the specification limits.

Bituminous concrete intermediate and base courses which exceed the rate of application of the Nomograph shall conform to the Nomograph requirements for a 2-inch course. The rate of application is based on an average weight of 115 pounds per square yard per inch of depth.

Should the Contractor be unable to complete the breakdown within the applicable 8 minute or 15 minute period, the placing of bituminous mixture shall cease until sufficient rollers are available, or other corrective action taken, to complete the breakdwon rolling within the specified time.

When placing bituminous porous friction course mixture, the temperature of the mixture shall not be less than 180° F when placed on the roadway. The weather limitations of Section 318.03 shall apply to the porous friction course.

APPENDIX B

Proposed Revised Nomograph

COLD WEATHER PAVING LIMITATIONS