TECHBRIEF

LTPP Data Analysis: Improved Low Pavement Temperature Prediction

FHWA Contact: Monte Symons, HNR-30, (703) 285-2730

Introduction

This TechBrief announces the completion of a Federal Highway Administration (FHWA) study that is fully documented in a separate report, LTPP Seasonal Asphalt Concrete Pavement Temperature Models (Publication No. FHWA-RD-97-103). (See report-ordering information on the last page of this summary.)

Background

The Seasonal Monitoring Program (SMP),[1] an element of the Long-Term Pavement Performance (LTPP) study, was initiated in 1991. One of the key objectives of SMP is to provide field data to validate models for relating environmental conditions and in situ properties of pavement materials. The initial phase (Loop-1) of the program—collecting pavement and air temperatures at 30 test sites throughout North America—was completed in 1995. The availability of these data made it possible to evaluate and refine existing low pavement temperature models for asphalt binder selection.

Objectives

This LTPP data analysis was conducted to verify the existing Strategic Highway Research Program's (SHRP) low pavement temperature models and to develop an LTPP model for SUPERPAVE binder selection.

Research Products

This study produced the following research products:

- LTPP low pavement temperature model for SUPERPAVE binder selection.
- New Seasonal AC [Asphalt Concrete] Pavement Temperature (SAPT) database.

Product Benefits

SUPERPAVE binders are selected based on the lowest and highest pavement temperatures expected at a site. The original binder specifications used the lowest air temperature as a surrogate for the lowest pavement temperature. LTPP data prove that the pavement temperature is never as low as the lowest air temperature. Hence, SUPERPAVE binder grades were more restrictive than may have been needed.

The Long-Term Pavement Performance (LTPP) program is a 20-year study of inservice pavements across North America. Its goal is to extend the life of highway pavements through various designs of new and rehabilitated pavement structures, using different materials and under different loads, environments, subgrade soil, and maintenance practices. LTPP was established under the Strategic Highway Research Program, and is now managed by the Federal Highway Administration.

U.S. Department of Transportation
Federal Highway Administration

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

The results of this research provide pavement engineers with a new set of tools for selecting asphalt binders. The benefits of these new tools include:

- Ability to select binder grades that are less restrictive, more cost-effective, and meet SUPERPAVE performance-grade concepts.
- Ability to select binder grades based on reliability and statistical data.
- Ability to refine temperature models for regional or local conditions.

Research Approach

Database Development

To evaluate existing low pavement temperature models, a new low pavement temperature database was created using field data from SMP.

A summary daily database was constructed from lowest air and pavement temperature data for November through March that were collected from 24 asphalt SMP sites. Other data, such as geographic location, pavement thickness, and weather data from the closest weather station to the section, were collected from two other sources—SHRPBIND and LTPP Data Sampler computer programs—and added to the summary daily database. This summary database is the new SAPT database and is available on 3.5-in floppy disks from LTPP headquarters.

To develop the low pavement temperature model, a database of monthly low temperatures was constructed. This database includes SMP monthly low air and pavement temperatures at three different locations (approximately 25 mm below the top, at mid-layer, and 25 mm over the bottom of the layer) within the surface layer for cold months (November through March) in addition to latitude, longitude, and elevation for 411 data points. Table 1 shows the ranges of data in the new database.

LTPP Low Pavement Temperature Model Development

A correlation analysis was performed on the monthly low pavement temperature database to identify potential independent variables. Variables considered were air temperature, latitude, elevation, pavement temperature, and depth into the AC layer. Results from this analysis indicated that air temperature, latitude, and depth into the AC layer were key independent variables. These were then graphed against the pavement temperature (i.e., the dependent variable) to determine the type of relationship (linear versus non-linear) between the model's dependent and independent variables. Finally, a stepwise regression method was used to select the strongest variables for the model.

EQUATION 1

Low Pavement Temperature Model

$$T_{pav} = -1.56 + 0.72\, T_{air} - 0.004\, Lat^2 + 6.26 \log_{10}(H + 25) - z\,(4.4 + 0.52\, \sigma^2_{air})^{1/2}$$

Where:

T_{pav} = Low AC pavement temperature below surface, °C.

T_{air} = Low air temperature, °C.

Lat = Latitude of the section, degrees.

H = Depth to surface, mm.

z = From the standard normal distribution table, z=2.055 for 98-percent reliability.

σ_{air} = Standard deviation of the annual low air temperature, °C.

Statistics: R^2 = 96%, N = 411, SEE = 2.1

TABLE 1

Ranges of data in low temperature model database

		Mean	Minimum	Maximum
T_{pav}	(Low AC pavement temperature, °C)	-9.13212	-33.01	13.67
T_{air}	(Low air temperature, °C)	-17.9542	-41.53	4.61
Lat	(Latitude of the section, degrees)	41.69345	26.983	51.908
H	(Depth into AC layer, mm)	87.80613	25.4	274.32
Elev	(Elevation of the section, m)	568.146	11	1586

Equation 1 represents the best working model of those tested and reviewed for variability and boundary conditions.

Data and Model Comparisons

Data and model comparisons were performed to validate the LTPP low pavement temperature model and quantify differences with existing SHRP models. Following are some of these comparisons.

Comparing SHRP Low Pavement Temperature Models With SMP Data

The actual SMP measured pavement temperatures at a depth of 25 mm were compared to calculated temperatures using SHRP low pavement temperature models. This comparison is illustrated in figure 1. It reveals that there is a significant difference between data estimates of existing models and SMP data, especially for lower air temperatures. Specifically, the SHRP estimates at 25 mm of depth are up to 15 degrees lower than SMP data, while Canadian SHRP (C-SHRP) estimates are about 7 degrees lower.

Comparing LTPP and SHRP Low Pavement Temperature Models

The LTPP model was compared with the SHRP models at 50-percent reliability. This comparison is illustrated in figure 2. It shows the pavement surface temperature calculated using SHRP and C-SHRP for any latitude and pavement surface temperature calculated using the LTPP model for three different latitudes (30, 40, and 50 degrees for the Southern, Central, and Northern United States, respectively). This comparison shows that the SHRP low pavement temperature can be as much as 15 degrees lower than the temperature estimated by the LTPP model for the air temperature of -40°C. Thus, the SHRP model is very conservative, especially at lower air temperatures.

FIGURE 1

SMP low pavement temperature at 25 mm of depth versus air temperature

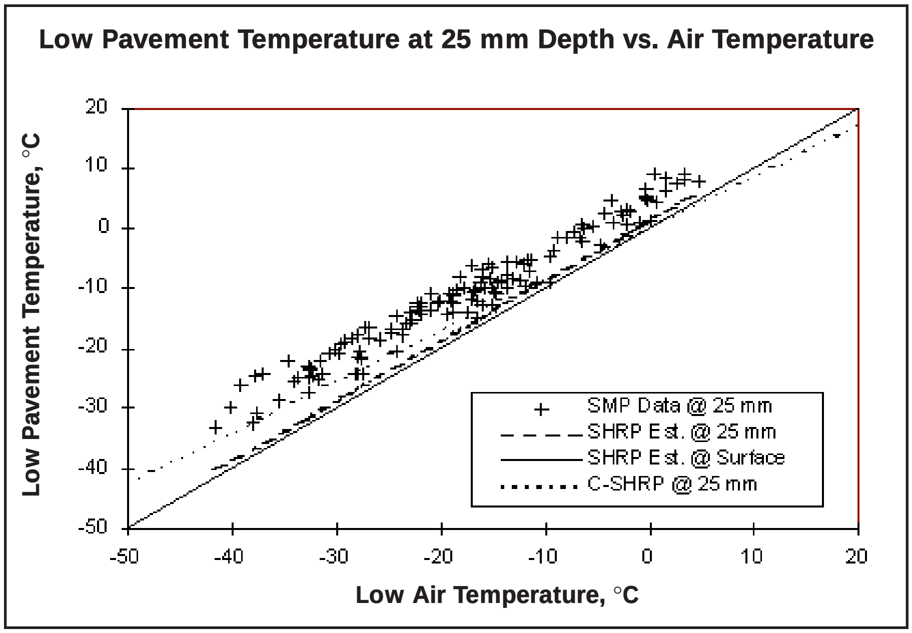
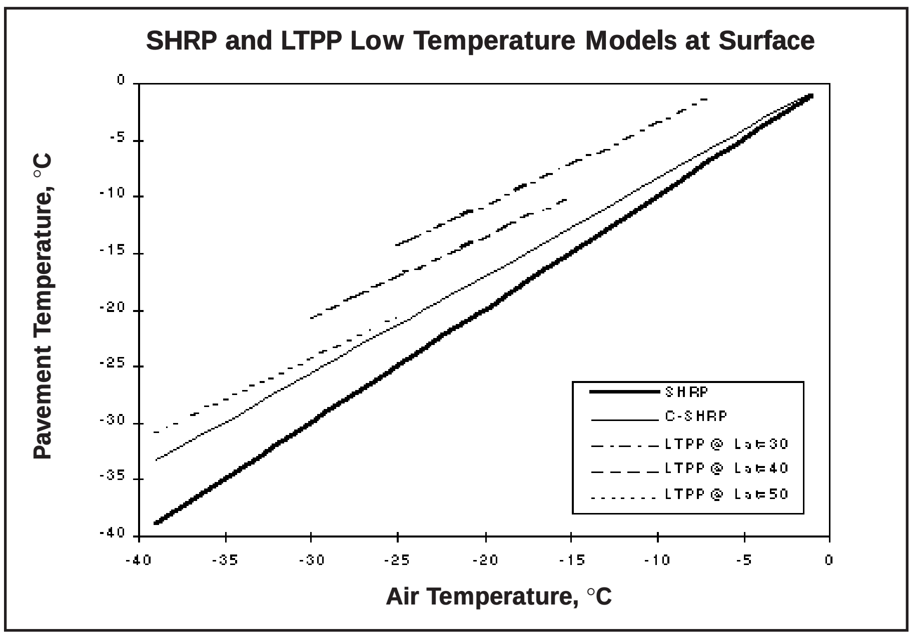


FIGURE 2

Low pavement temperature at surface by SHRP and LTPP models

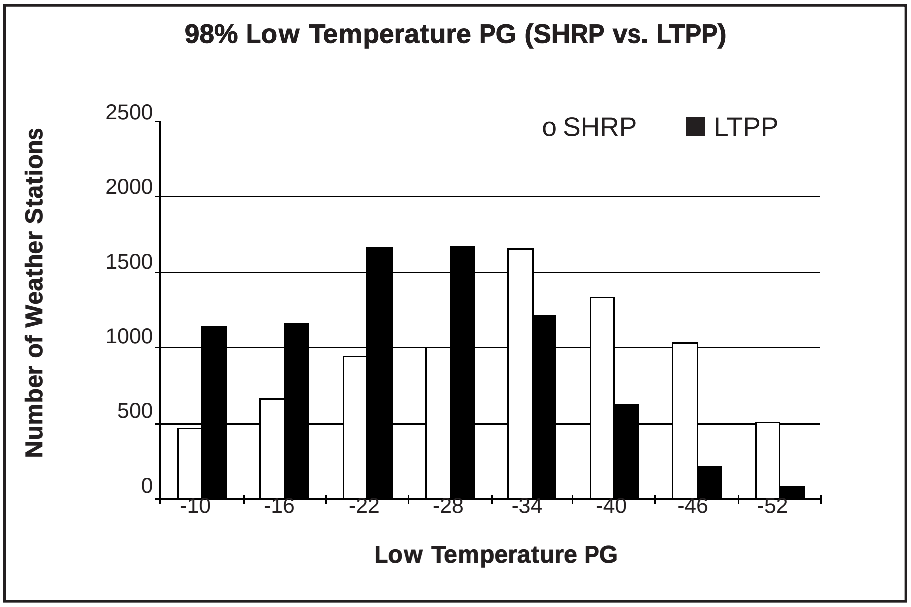


Comparing Performance Grades Derived From LTPP and SHRP Models

Asphalt binder performance grades for SUPERPAVE are calculated from low pavement temperatures starting at -10°C and are

FIGURE 3

Distribution of 98-percent low temperature performance grades by SHRP and LTPP models



decreased at 6°C increments. The asphalt low temperature performance grades required using the SHRP model and those derived from the LTPP model were compared for all 7,801 weather stations in the SUPERPAVE database.[3]

Figure 3 shows the distribution of low temperature performance grades for 98-percent reliability. This comparison indicates that the impact of the LTPP model in determining low temperature performance grades is very significant, especially at lower air temperatures.

References

1. *LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guide,* Publication No. FHWA-RD-94-110, Federal Highway Administration, McLean, VA.

2. Solaimanian, M. and Bolzan, P., *Analysis of the Integrated Model of Climatic Effects on Pavements.* Report No. SHRP-A-637, Strategic Highway Research Program, June 1993.

3. Huber, G.A. *Weather Database for the SUPERPAVE Mix Design System.* Report No. SHRP-A-648A, Strategic Highway Research Program, February 1994.

4. Mohseni, A. and Symons, M. “Improved AC Pavement Temperature Models From LTPP Seasonal Data,” prepared for presentation at the 77th Annual Transportation Research Board (TRB) Conference, Washington, DC, 1998.

5. Mohseni, A. and Symons, M. “Effect of Improved LTPP AC Pavement Temperature Models on SUPERPAVE Performance Grades,” prepared for presentation at the 77th Annual TRB Conference, Washington, DC, 1998.

Researcher: This study was performed by Pavement Systems (PavSys), P.O. Box 2131, Rockville, MD 20847-2131. Contract No. DTFH61-95-Z-00086.

Distribution: This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to the Regions and Divisions.

Availability: The publication will be available in June 1998. Please reference report number FHWA-RD-97-103. Copies will be available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. A limited number of copies will be available from the R&T Report Center, HRD-11, FHWA, 9701 Philadelphia Court, Unit Q, Lanham, MD 20706, Telephone: (301) 577-0818, Fax: (301) 577-1421.

Key Words: SUPERPAVE, LTPP SMP, asphalt binder grade, performance grades, SHRP, pavement temperature.