Introduction

The SUPERPAVE™ mix design system software contains a database of 5,313 United States' and 1515 Canadian weather stations, which can be used to select a suitable performance grade of asphalt binder for a paving project.

The software guides the mix designer through the selection process in a step-by-step manner. The data for any station can be selected by positioning a cursor on a map of North America at dots representing station locations. For each station the statistical distributions of the yearly 7-day average maximum air temperature and the yearly 1-day minimum air temperature are available. These distributions may be graphically displayed along with the degrees of probable risk associated with the selection of any particular design temperature.

A performance grade of asphalt binder can be selected for a paving project that minimizes the probable design risk for high and (or) low temperature pavement performance, or, as warranted by agency policy, a higher degree of probable risk can be selected on the basis of the class of highway, cost and other relevant factors. The probable design risk is expressed in terms of *reliability*; the higher the reliability selected, the lower the probable design risk.

Tabulation of the Weather Database

Selected contents of the SUPERPAVE ™ weather database are presented in tabular form in Appendix A of this report.

Each page in the appendix is roughly blocked into three parts from left to right across the page. The contents of the first part are the station location and statistical weather data described in Table 1. The second and third parts present calculated design temperatures and resulting asphalt binder performance grades for reliability levels of 50 and 98 percent; the contents of each data column are described in Table 2. In practice, the SUPERPAVE ™ software permits the designer to select any reliability level desired.

TABLE 1. STATION LOCATION AND STATISTICAL WEATHER DATA

COLUMN HEADER	CONTENTS
STATE	Two letter abbreviation for state or province name.
COUNTY ID	For U.S. stations, name of county. For Canadian stations, weather station number.
STATION	Name of weather station.
LONG	Longitude of weather station.

LAT	Latitude of weather station.
ELEV	Elevation of weather station in meters.
AVG LOW TEMP	Coldest temperature in an average year in °C.
STD LOW TEMP	Standard deviation in °C of coldest temperature for all years for which data are available.
AVG HIGH TEMP	Average daytime high temperature during hottest 7-day period in an average year in °C.
STD HIGH TEMP	Standard deviation in °C of average daytime high temperature during hottest 7-day period for all years for which data are available.

TABLE 2. AIR TEMPERATURES, PAVEMENT DESIGN TEMPERATURES AND BINDER PERFORMANCE GRADES CORRESPONDING TO 50 PERCENT AND 98 PERCENT RELIABILITY LEVELS.

COLUMN HEADER	CONTENTS
MAX AIR	Maximum average air daytime high temperature during hottest 7-day period in average year in °C.
MAX PVT	High design temperature. Maximum pavement temperature at 20 mm depth converted from maximum air temperature in °C.
MIN AIR	Minimum air temperature in average year in °C.
MIN PVT	Low design temperature. Minimum pavement temperature at the surface, equal to the minimum air temperature in °C.
BINDER GRADE PG	Performance grade of asphalt binder required for design conditions.
BINDER GRADE HT	High temperature performance grade range required for high design temperature.
BINDER GRADE LT	Low temperature performance grade range required for low design temperature.

Temperature Calculations

In order to calculate the design temperatures described in Table 2, the SUPERPAVE ™ software contains an equation relating design air temperature to design pavement temperature for both high and low design air temperatures. High design pavement temperature is determined 20 mm below the pavement surface. Low design pavement temperature is determined at the pavement surface.

Pavement surface temperature is based upon net heat flow at the pavement surface:

Net heat flow = [direct solar radiation] + [diffuse radiation]±[convection]±[conduction]-[black body radiation]

Energy balance at the pavement surface is a transient phenomenon, continually changing with changing climatic conditions. For the purpose of calculating pavement surface temperature during the hottest 7-day period of the year, solar absorption, radiation transmission through air, atmospheric radiation and wind speed were set at the typical values shown in table 3:

TABLE 3. TYPICAL VALUES FOR CALCULATING PAVEMENT SURFACE TEMPERATURE

PROPERTY	TYPICAL VALUE
SOLAR ABSORPTION	0.90
TRANSMISSION THROUGH AIR	0.81
ATMOSPHERIC RADIATION	0.70
WIND SPEED	4.5 m/s

The resulting energy balance is non-deterministic. The equation contains latitude with air temperature and surface temperature raised to the fourth power requiring a trial and error solution. Using results of a theoretical analysis[1] and five databases of actual measured air and pavement temperature combinations a deterministic equation was developed relating temperature difference between surface and air to latitude:

$$T_{surf}-T_{air}=^{-}0.00618lat^{2}+0.2289lat+24.4 \qquad (1)$$

where T_{surf} and T_{air} are in °C and the latitude, *lat*, is in degrees.

Below the pavement surface the temperature is predicted using heat flow models contained in the Federal Highway Administration's Environmental Effects Model. During

[1]M. Solaimanian and P. Bolzan, Analysis of the Integrated Model of Climatic Effects on Pavements: Sensitivity Analysis and Pavement Temperature Prediction. SHRP-A-637.

contained in the Federal Highway Administration's Environmental Effects Model. During the hottest 7-day period in the heat of the day, pavement surface temperature is increasing and heat flows downward into the pavement. Using data from the temperature databases an equation was developed that expresses the change in temperature with depth:

$$T_d = T_{surf}(1 - 0.063d + 0.007d^2 - 0.0004d^3) \tag{2}$$

where T_d and T_{surf} are in °F and the depth, d, is in inches.

Converting to SI units and calculating the temperature at a depth of 20 mm, the equation becomes:

$$T_{20mm} = (T_{surf} + 17.78)(0.9545) - 17.78 \tag{3}$$

where T_{20mm} and T_{surf} are in °C.

By substituting equation (1) into equation (3), the equation contained in the SUPERPAVE ™ software is obtained:

$$T_{20mm} = (T_{air} - 0.00618lat^2 + 0.2289lat + 42.2)(0.9545) - 17.78 \tag{4}$$

where T_{20mm} and T_{air} are in °C and the latitude is expressed in degrees.

Appendix A
Weather Database for Binder Grade Selection

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SUPERPAVE DETERMINATION OF ASPHALT BINDER GRADE
Weather Database Used in SUPERPAVE Software

						AIR TEMP				50% RELIABILITY							98% RELIABILITY						
						LOW TEMP		HIGH TEMP		TEMPERATURES				BINDER GRADE			TEMPERATURES				BINDER GRADE		
ST	COUNTY_ID	STATION	LONG	LAT	ELEV	AVG	STD	AVG	STD	MAX AIR	MAX PVT	MIN AIR	MIN PVT	PG	HT	LT	MAX AIR	MAX PVT	MIN AIR	MIN PVT	PG	HT	LT
CT	FAIRFIELD	BRIDGEPORT WSO AP	73.13	41.17	3	-17	3	31	2	31	51	-17	-17	PG	52	-22	35	55	-23	-23	PG	58	-28
CT	LITCHFIELD	BULLS BRIDGE DAM	73.48	41.65	79	-23	4	32	1	32	52	-23	-23	PG	52	-28	34	54	-31	-31	PG	58	-34
CT	HARTFORD	BURLINGTON	72.93	41.80	156	-22	3	31	1	31	51	-22	-22	PG	52	-22	33	53	-28	-28	PG	58	-28
CT	NEW LONDON	COLCHESTER 2 W	72.37	41.55	146	-21	3	30	2	30	50	-21	-21	PG	52	-22	34	54	-27	-27	PG	58	-28
CT	TOLLAND	COVENTRY	72.35	41.80	146	-27	4	30	2	30	50	-27	-27	PG	52	-28	34	54	-35	-35	PG	58	-40
CT	LITCHFIELD	CREAM HILL	73.32	41.90	396	-23	4	30	2	30	50	-23	-23	PG	52	-28	34	54	-31	-31	PG	58	-34
CT	FAIRFIELD	DANBURY	73.47	41.38	156	-21	3	32	2	32	52	-21	-21	PG	52	-22	36	56	-27	-27	PG	58	-28
CT	LITCHFIELD	FALLS VILLAGE	73.37	41.95	168	-26	3	32	2	32	52	-26	-26	PG	52	-28	36	56	-32	-32	PG	58	-34
CT	NEW LONDON	GROTON	72.05	41.35	12	-20	3	30	1	30	50	-20	-20	PG	52	-22	32	52	-26	-26	PG	52	-28
CT	HARTFORD	HARTFORD WSO AP	72.68	41.93	49	-22	4	32	2	32	52	-22	-22	PG	52	-22	36	56	-30	-30	PG	58	-34
CT	TOLLAND	MANSFIELD HOLLOW LAKE	72.18	41.75	76	-25	4	32	2	32	52	-25	-25	PG	52	-28	36	56	-33	-33	PG	58	-34
CT	MIDDLESEX	MIDDLETOWN 4 W	72.72	41.55	113	-19	3	31	2	31	51	-19	-19	PG	52	-22	35	55	-25	-25	PG	58	-28
CT	NEW HAVEN	MOUNT CARMEL	72.90	41.40	55	-21	4	32	2	32	52	-21	-21	PG	52	-22	36	56	-29	-29	PG	58	-34
CT	NEW HAVEN	NEW HAVEN	72.93	41.30	220	-17	2	33	2	33	53	-17	-17	PG	58	-22	37	57	-21	-21	PG	58	-22
CT		NEW HAVEN AIRPORT	72.88	41.27	3	-17	3	30	1	30	50	-17	-17	PG	52	-22	32	52	-23	-23	PG	52	-28
CT	LITCHFIELD	NORFOLK 2 SW	73.22	41.97	409	-24	3	28	2	28	48	-24	-24	PG	52	-28	32	52	-30	-30	PG	52	-34
CT		NORWALK	73.45	41.13	37	-22	4	32	2	32	52	-22	-22	PG	58	-22	36	56	-30	-30	PG	58	-34
CT	FAIRFIELD	NORWALK GAS PLANT	73.42	41.12	12	-18	3	32	2	32	52	-18	-18	PG	58	-22	36	56	-24	-24	PG	58	-28
CT	NEW LONDON	NORWICH PUB UTIL PLANT	72.07	41.53	6	-21	3	31	3	31	51	-21	-21	PG	52	-22	37	57	-27	-27	PG	58	-28
CT		PUTNAM	71.92	41.92	92	-23	5	31	2	31	51	-23	-23	PG	52	-28	35	55	-33	-33	PG	58	-34
CT	LITCHFIELD	SHEPAUG DAM	73.30	41.72	256	-24	3	30	2	30	50	-24	-24	PG	52	-28	34	54	-30	-30	PG	58	-34
CT	FAIRFIELD	STAMFORD 5 N	73.55	41.13	58	-22	3	32	2	32	52	-22	-22	PG	58	-22	36	56	-28	-28	PG	58	-28
CT	TOLLAND	STORRS	72.25	41.80	198	-22	3	30	2	30	50	-22	-22	PG	52	-22	34	54	-28	-28	PG	58	-28
CT	MIDDLESEX	WESTBROOK	72.43	41.30	12	-22	4	30	2	30	50	-22	-22	PG	52	-22	34	54	-30	-30	PG	58	-34
CT	WINDHAM	WEST THOMPSON LAKE	71.90	41.95	110	-25	3	31	2	31	51	-25	-25	PG	52	-28	35	55	-31	-31	PG	58	-34
CT	LITCHFIELD	WIGWAM RESERVOIR	73.15	41.68	174	-23	4	31	2	31	51	-23	-23	PG	52	-28	35	55	-31	-31	PG	58	-34
DE	SUSSEX	BRIDGEVILLE 1 NW	75.62	38.75	15	-16	4	33	1	33	54	-16	-16	PG	58	-16	35	55	-24	-24	PG	58	-28
DE	KENT	DOVER	75.52	39.15	9	-15	3	34	2	34	54	-15	-15	PG	58	-16	38	58	-21	-21	PG	64	-22
DE	SUSSEX	GEORGETOWN 5 SW	75.45	38.63	15	-17	3	33	1	33	54	-17	-17	PG	58	-22	35	56	-23	-23	PG	58	-28
DE	SUSSEX	LEWES	75.13	38.77	6	-14	4	32	2	32	53	-14	-14	PG	58	-16	36	56	-22	-22	PG	58	-22
DE	NEW CASTLE	MIDDLETOWN 3 E	75.67	39.45	18	-17	5	33	2	33	53	-17	-17	PG	58	-22	37	57	-27	-27	PG	58	-28
DE	SUSSEX	MILFORD 2 WSW	75.47	38.90	9	-16	3	34	2	34	54	-16	-16	PG	58	-16	38	58	-22	-22	PG	64	-22
DE	NEW CASTLE	NEWARK UNIV FARM	75.73	39.67	28	-17	3	33	2	33	53	-17	-17	PG	58	-22	37	57	-23	-23	PG	58	-28
DE	NEW CASTLE	WILMINGTON WSO AP	75.60	39.67	24	-16	4	33	2	33	53	-16	-16	PG	58	-16	37	57	-24	-24	PG	58	-28
DE	NEW CASTLE	WILMINGTON PORTER RESVR	75.53	39.77	82	-16	3	32	2	32	52	-16	-16	PG	58	-16	36	56	-22	-22	PG	58	-22
FL	LAKE	ALEXANDER SPRINGS 3 SE	81.55	29.05	21	-6	2	36	1	36	58	-6	-6	PG	64	-10	38	60	-10	-10	PG	64	-10
FL	FRANKLIN	APALACHICOLA WSO AP	85.03	29.73	6	-4	3	33	1	33	55	-4	-4	PG	58	-10	35	57	-10	-10	PG	58	-10
FL	DE SOTO	ARCADIA	81.85	27.23	18	-3	2	35	1	35	57	-3	-3	PG	58	-10	37	59	-7	-7	PG	64	-10
FL	HIGHLANDS	ARCHBOLD BIOLOGIC STN	81.35	27.18	43	-5	2	36	1	36	58	-5	-5	PG	64	-10	38	60	-9	-9	PG	64	-10
FL	HIGHLANDS	AVON PARK 2 W	81.53	27.60	46	-2	2	36	1	36	58	-2	-2	PG	64	-10	38	60	-6	-6	PG	64	-10
FL	POLK	BARTOW	81.85	27.90	37	-2	2	35	1	35	57	-2	-2	PG	58	-10	37	59	-6	-6	PG	64	-10
FL	PALM BEACH	BELLE GLADE EXP STN	80.63	26.65	6	-1	2	34	1	34	57	-1	-1	PG	58	-10	36	58	-5	-5	PG	64	-10
FL	MANATEE	BRADENTON EXP STATION	82.55	27.48	3	-1	2	34	1	34	56	-1	-1	PG	58	-10	36	58	-5	-5	PG	64	-10
FL	MANATEE	BRADENTON 5 ESE	82.47	27.45	6	-2	2	34	1	34	56	-2	-2	PG	58	-10	36	58	-6	-6	PG	64	-10
FL	HERNANDO	BROOKSVILLE CHIN HILL	82.37	28.62	73	-3	3	34	1	34	56	-3	-3	PG	58	-10	36	58	-9	-9	PG	64	-10
FL	PALM BEACH	CANAL POINT USDA	80.62	26.87	9	1	2	34	1	34	57	1	1	PG	58	-10	36	58	-3	-3	PG	64	-10
FL	LEE	CAPTIVA	82.18	26.53	0	4	3	33	1	33	56	4	4	PG	58	-10	35	58	-2	-2	PG	58	-10
FL	FRANKLIN	CARRABELLE 1 NNW	84.67	29.87	3	-6	3	34	1	34	56	-6	-6	PG	58	-10	36	58	-12	-12	PG	64	-16
FL	LEVY	CEDAR KEY 1 WSW	83.05	29.13	3	-3	2	34	1	34	56	-3	-3	PG	58	-10	36	58	-7	-7	PG	64	-10
FL	WASHINGTON	CHIPLEY 3 E	85.48	30.78	40	-8	3	35	1	35	57	-8	-8	PG	58	-10	37	59	-14	-14	PG	64	-16
FL	PINELLAS	CLEARWATER	82.77	27.97	21	0	3	33	1	33	55	0	0	PG	58	-10	35	57	-6	-6	PG	58	-10
FL	LAKE	CLERMONT 7 S	81.75	28.45	37	-2	2	35	1	35	57	-2	-2	PG	58	-10	37	59	-6	-6	PG	64	-10
FL	HENDRY	CLEWISTON U S ENG	80.92	26.75	6	1	2	34	1	34	57	1	1	PG	58	-10	36	58	-3	-3	PG	64	-10