Long-Term Pavement Performance Bind Online User Guide

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Research, Development, and Technology
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McLean, VA 22101-2296

LTPP™

FOREWORD

This document presents the user guide for the Long-Term Pavement Performance (LTPP) Web-based tool to select asphalt binders. The LTPPBind Online tool was developed to help State transportation departments, universities faculties and researchers select the most suitable performance-grade binder for a particular site based on the American Association of State and Highway Transportation Officials (AASHTO) M320-10 and AASHTO M332-14 standards.[1–3]

LTPPBind Online provides the option to use LTPP climatic data (virtual weather station or automatic weather station), manual data, or National Aeronautics and Space Administration Modern-Era Retrospective Analysis for Research and Applications climatic data collected globally since 1979.[4,5]

High-temperature (HT) Performance Grade is selected based on a rutting damage model. HT equation is function of target rut depth, yearly degree-days and latitude of site.[6] Low-temperature (LT) PG binder is selected using the algorithm developed from LTPP climatic data. LT algorithm relates surface low pavement temperature to air temperature, latitude, and depth.[7]

This new software tool provides pavement engineers with the ability to select binder grades that are less restrictive, more cost-effective, and agree with Superpave PG concepts.

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Research and Development

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16. Abstract

This document presents the user guide for the Long-Term Pavement Performance (LTPP) Web-based tool used to select asphalt binders. LTPPBind Online was developed to help State transportation departments select the most suitable performance-grade binder for a particular site based on the American Association of State and Highway Transportation Officials (AASHTO) M320-10 and AASHTO M332-14 standards.[1–3] LTPPBind Online provides the option to use National Aeronautics and Space Administration Modern-Era Retrospective Analysis for Research and Applications climatic data collected globally since 1979, LTPP climatic data (virtual weather station or automatic weather station), or manual data.
High-temperature (HT) Performance Grade is selected based on a rutting damage model. HT equation is function of target rut depth, yearly degree-days and latitude of site[6]. Low-temperature (LT) PG binder is selected using the algorithm developed from LTPP climatic data. LT algorithm relates surface low pavement temperature to air temperature, latitude, and depth[7].

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ABBREVIATIONS

AASHTO	American Association of State and Highway Transportation Officials
AWS	automatic weather station
ESAL	equivalent single-axle load
HT	high temperature
LTPP	Long-Term Pavement Performance
MERRA	Modern-Era Retrospective Analysis for Research and Application
NASA	National Aeronautics and Space Administration
PG	performance grade
SMP	Seasonal Monitoring Program
SPS	Specific Pavement Studies
VWS	virtual weather station

INTRODUCTION

Long-Term Pavement Performance (LTPP) Bind Online is a Web-based tool used to help State transportation departments select the most suitable performance-grade (PG) asphalt binder for pavement construction at a particular site based on the American Association of State and Highway Transportation Officials (AASHTO) M320-10 and AASHTO M332-14 standards.[1–3]

LTPPBind Online provides the option to use the National Aeronautics and Space Administration's (NASA) Modern-Era Retrospective Analysis for Research and Application (MERRA) climatic data, LTPP climatic data, and manual data. Based on the selected climatic data, allowable rut depth, depth of asphalt concrete layer, base high temperature (HT) PG, equivalent single-axle loads (ESALs), and traffic speed, the user will be able to do the following:

- Select binder PGs based on actual temperature conditions at their site and the level of risk designated by their State transportation department.
- Adjust the PG selection for different levels of traffic loading and speed.
- Compare binder PGs between AASHTO M320-10 and AASHTO M332-14 standards.[2,3]

LTPPBIND ONLINE ACCESS

LTPPBind Online is available on the InfoPave™ Web site under the "TOOLS" tab of the InfoPave™ menu bar as shown in figure 1.[1,8] To select LTPPBind Online, users need to register with InfoPave™ using their email address or their social media accounts.

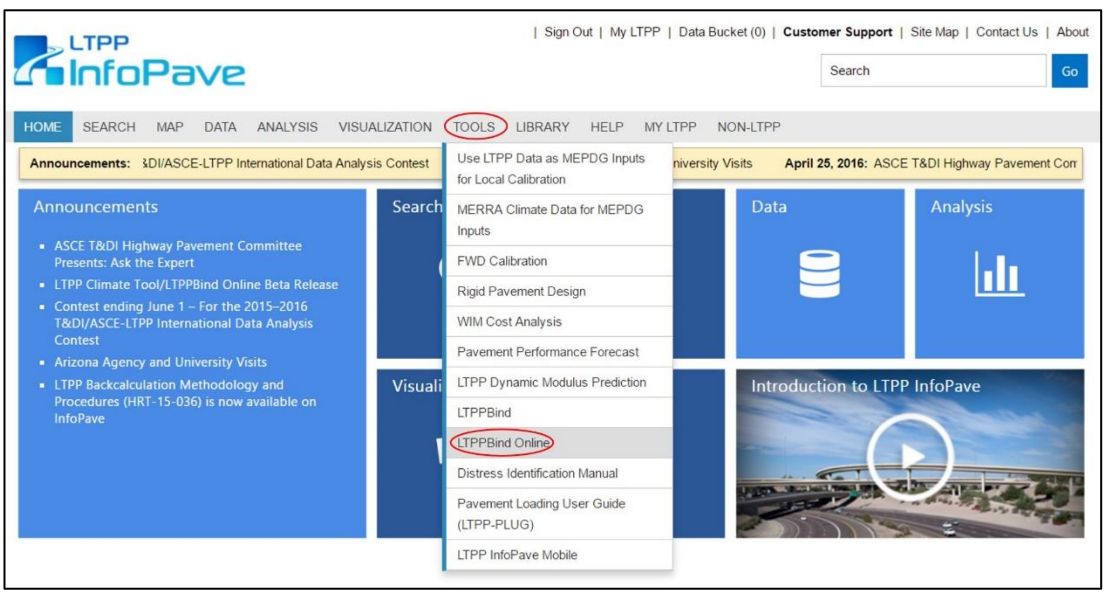


Figure 1. Screenshot. LTPPBind Online on InfoPave™.[1,8]

The LTPPBind Online main screen has two different options under the "Projects" tab: the "New Project" tab open a new project, and the "Open Project" tab allows the user to continue on a previously saved project, as shown in figure 2.(1) Each project includes a project number, a project title, and the date that the project was added. Previously saved projects can be opened or deleted by clicking on the "Open" and "Delete" buttons to the right-hand side of the project information (i.e., project number, project title, and date added).

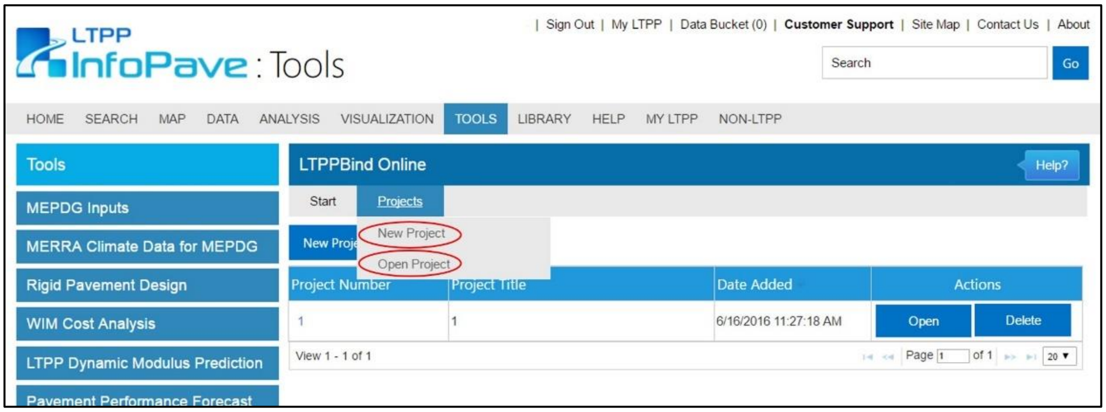


Figure 2. Screenshot. LTPPBind Online.(1)

CALCULATION PROCESS

The calculation process features the following six steps used to calculate the final binder PG:

1. General project information.
2. Climate data source.
3. Climate data.
4. Target rut depth.
5. Temperature adjustments.
6. Traffic adjustments.

General Project Information

At the beginning of a new project, users need to enter a project number, project title, and project description as shown in figure 3. The fields are defined as follows:

- *Project number* is a user-defined unique alpha numeric value for identifying an LTPPBind Online project.(1)
- *Project title* is a user-defined title for an LTPPBind Online project.(1)
- *Project description* is a brief description of an LTPPBind Online project.(1)

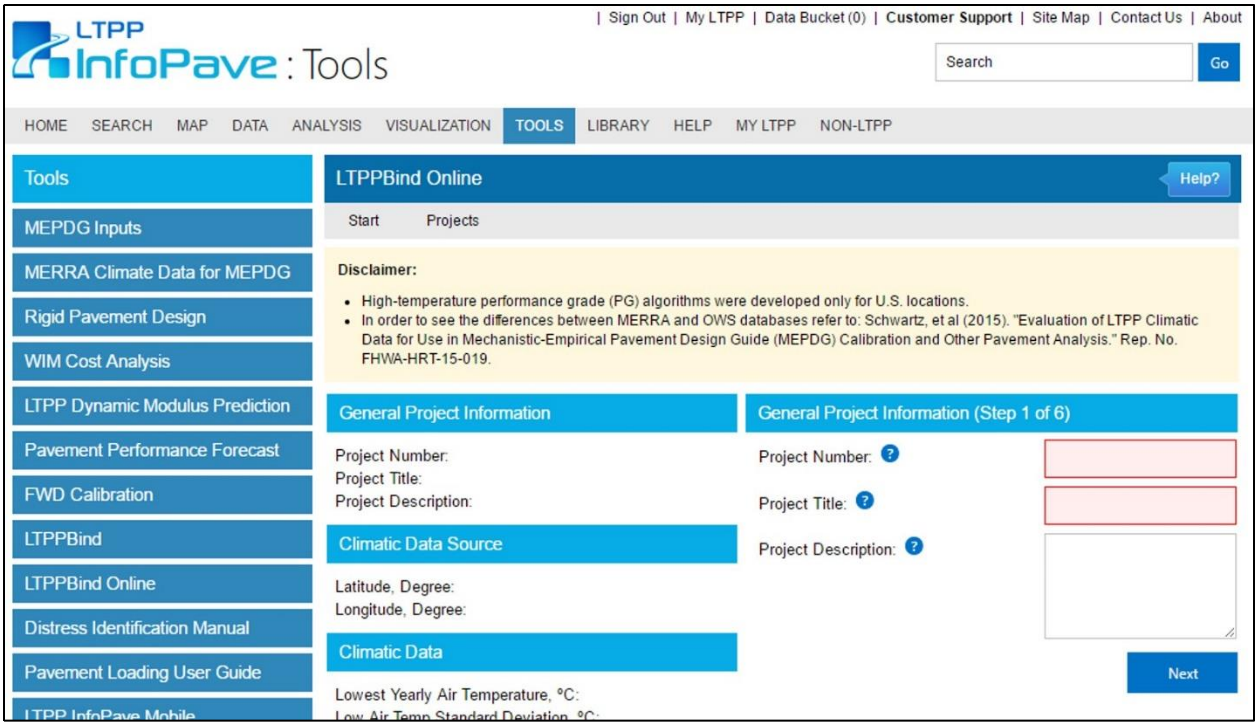


Figure 3. Screenshot. LTPPBind Online—general project information.[(1)]

Climatic Data Source

In LTPPBind Online, users have the flexibility to choose climatic data from MERRA or LTPP or manually input user-defined data as shown in figure 4.[(1)]

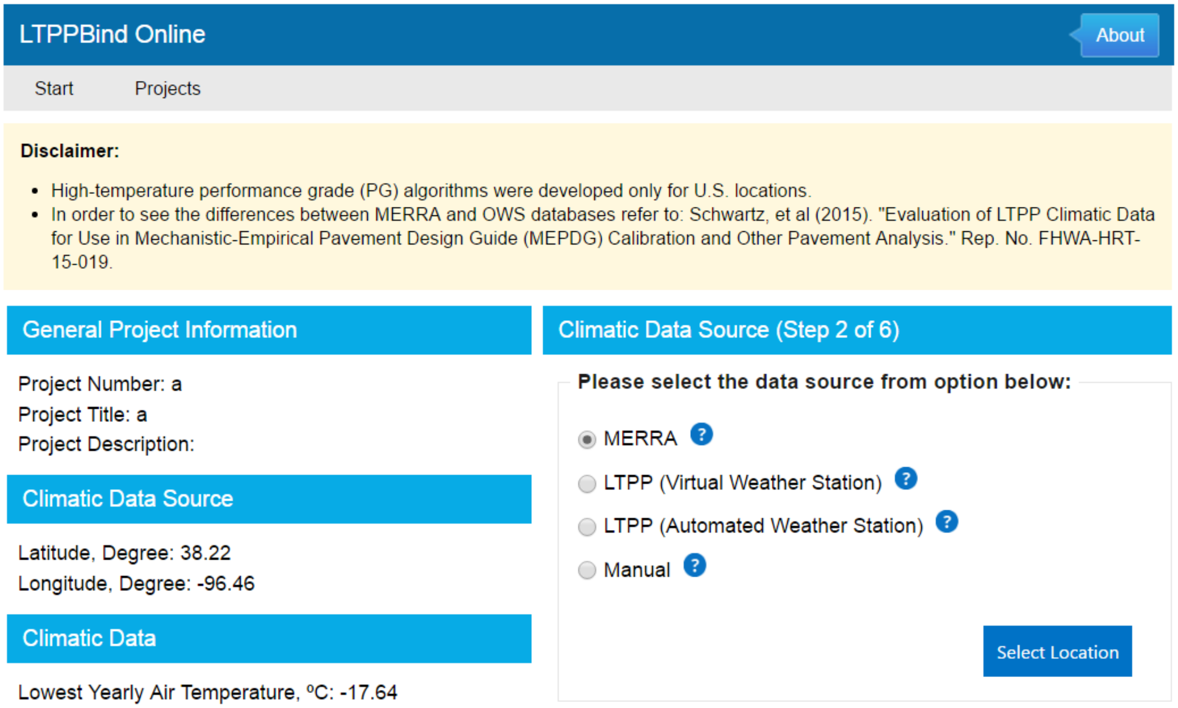


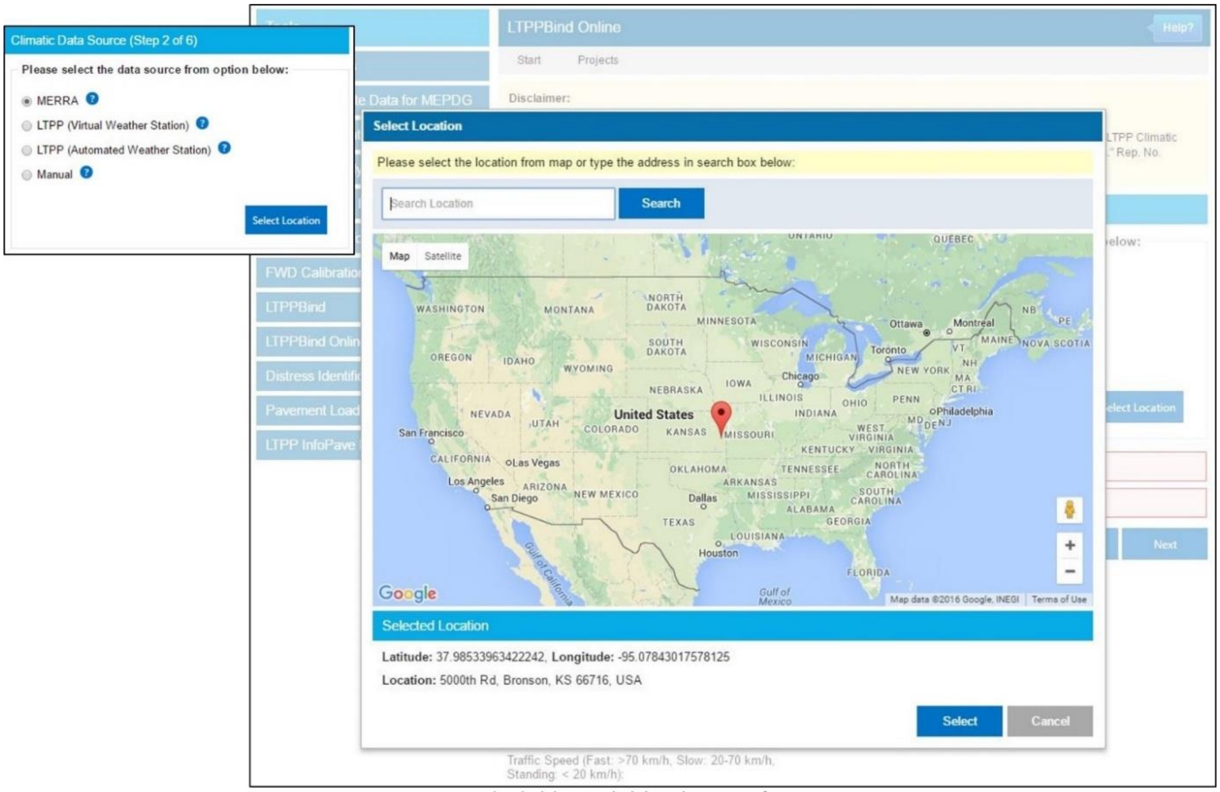
Figure 4. Screenshot. LTPPBind Online—selecting climatic data source.[1]

MERRA Climatic Data

MERRA climatic data are electronically collected by a NASA server in a 0.5-degree latitude by 0.67-degree longitude horizontal spatial grid.[5] This grid translates into approximately 31.3 by 37.3 mi at mid-latitudes and atmospheric elevations, including the ground surface. Detailed information about MERRA data is available in *Evaluation of Long-Term Pavement Performance (LTPP) Climatic Data for Use in Mechanistic-Empirical Pavement Design Guide (MEPDG) Calibration and Other Pavement Analysis*.[9]

MERRA climatic data comprise a grid-point, worldwide dataset. If any assigned coordinate does not match exactly with any grid point, then climatic data for that particular point are calculated from the adjacent grid points.

The user checks the MERRA radio button and then selects the “Select Location” button to open a window for users to select the location by clicking on the map, entering the city/location name, or entering coordinates in the search box (see figure 5). After that, the user presses the “Select” button to move forward.



Source: FHWA LTPP InfoPave

Figure 5. Screenshot. LTPPBind Online—select location for MERRA data.[1]

MERRA climatic data are then displayed on the next window under the Climatic Data status bar. These climatic data include the lowest annual air temperature, low air temperature standard deviation, yearly degree days above 10 ºC, high air temperature of the annual hottest 7 consecutive d, and standard deviation of the high 7 d.

LTPP (Virtual Weather Station (VWS))

The LTPP climatic data are selected with VWSs or automatic weather stations (AWSs) as shown in figure 6. LTPP developed the VWS concept to advance climatic statistics to represent the site conditions at each LTPP test section (because LTPP test sections are rarely located near an operating weather station). The method of selecting VWSs and how the VWS concept has been implemented for LTPP test sections ha been reported in *Evaluation of Long-Term Pavement Performance (LTPP) Climatic Data for Use in Mechanistic-Empirical Pavement Design Guide (MEPDG) Calibration and Other Pavement Analysis*.[9] In the VWS option, the LTPP section is selected by State code and section identification. The climatic data information is then updated automatically for the selected LTPP test section location.

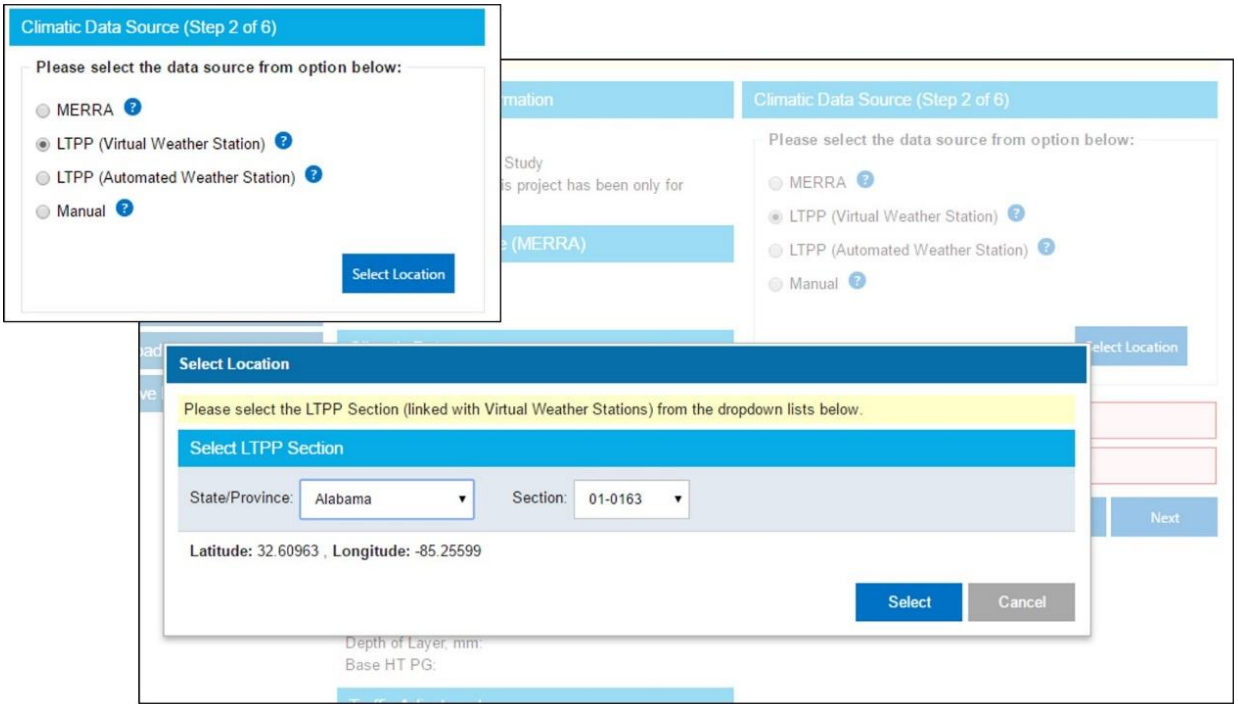
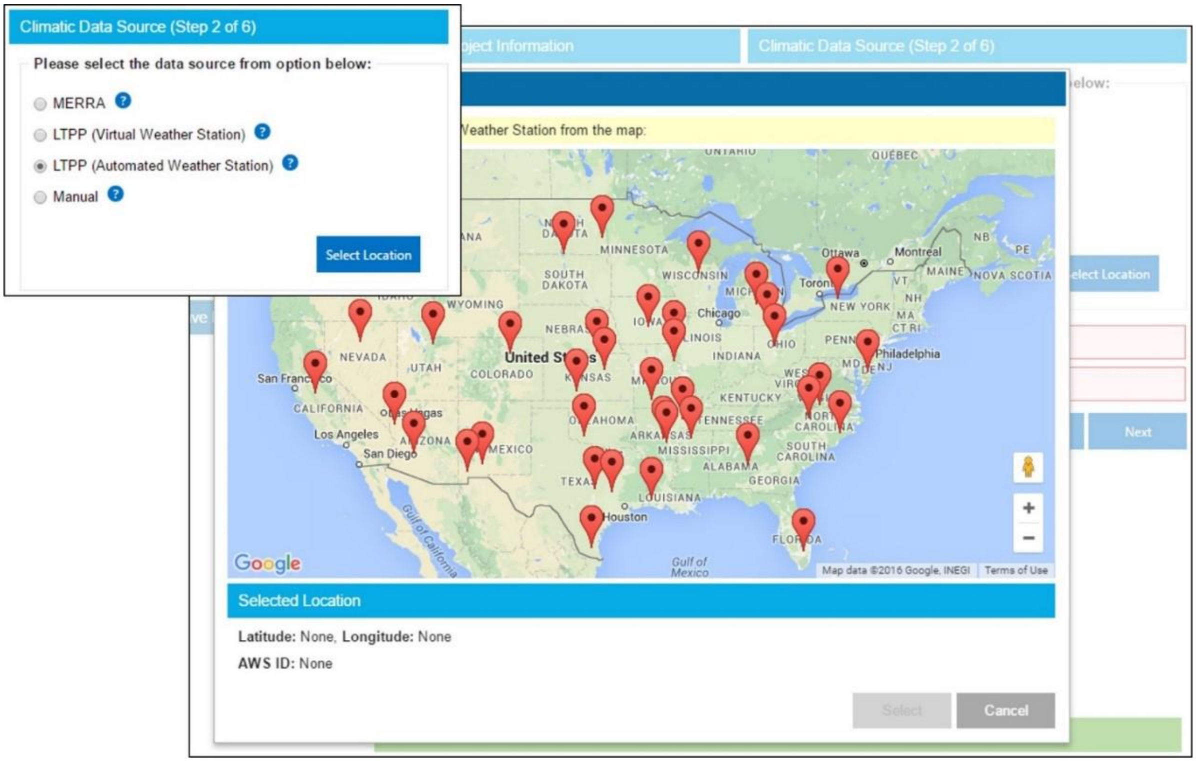


Figure 6. Screenshot. LTPPBind Online—select LTPP station.[(1)]

LTPP (AWS)

In the LTPP Specific Pavement Studies (SPS)-1, SPS-2, and SPS-8 experiments, AWSs were installed, as shown in figure 7.[(10)] These weather stations were installed and operated by the LTPP Program at or near the SPS projects. The concept of AWSs ha been described in *Evaluation of Long-Term Pavement Performance (LTPP) Climatic Data for Use in Mechanistic-Empirical Pavement Design Guide (MEPDG) Calibration and Other Pavement Analysis*.[(9)] In the AWS option, the location has been selected by clicking on the available AWSs available only in the United States. The climatic data information is then automatically updated for the selected AWS location.



Source: FHWA LTPP InfoPave

Figure 7. Screenshot. LTPPBind Online—select LTPP AWS.[(1)]

Manual Climatic Data

To calculate the binder PG for manual climatic data, users need to manually enter the coordinates of the location, lowest annual air temperature, low air temperature standard deviation, yearly degree days above 10ºC, high air temperature of the annual hottest 7 consecutive days, and standard deviation of the high 7 days in the designated boxes.

Climatic Data Results

After the data source is selected, LTPPBind Online determines a binder PG based on the input values.[(1)] Figure 8 shows the generated climatic data after the MERRA data option for a specific location was selected.

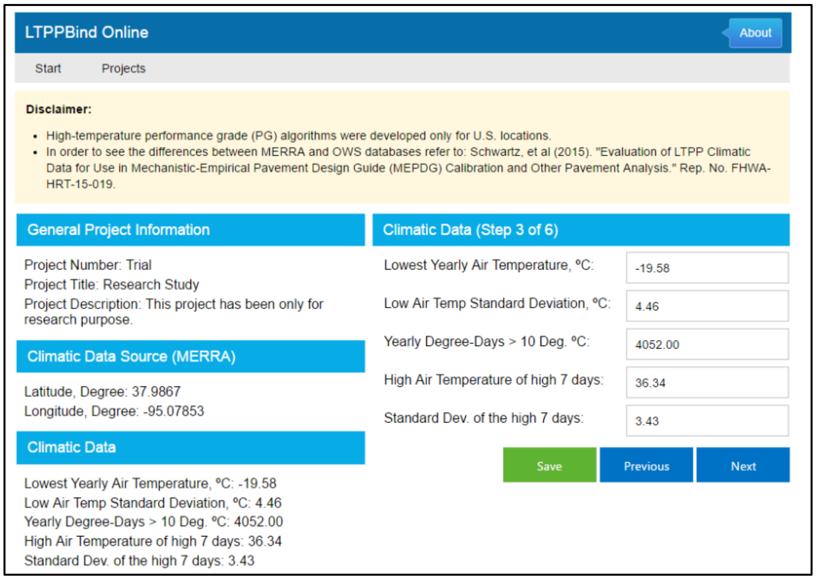


Figure 8. Screenshot. LTPPBind Online—generated climatic data.[(1)]

Target Rut Depth

The Mohseni model was developed for a target rut depths between 5.1 to 12.7 mm.[(6)] The AASHTO *Mechanistic-Empirical Pavement Design Guide* provides a range of recommended rut depth values at the end of design life as a function of the functional class; those values can be seen clicking on the question mark next to the Target Rut Depth title (see figure 9).[(11)]

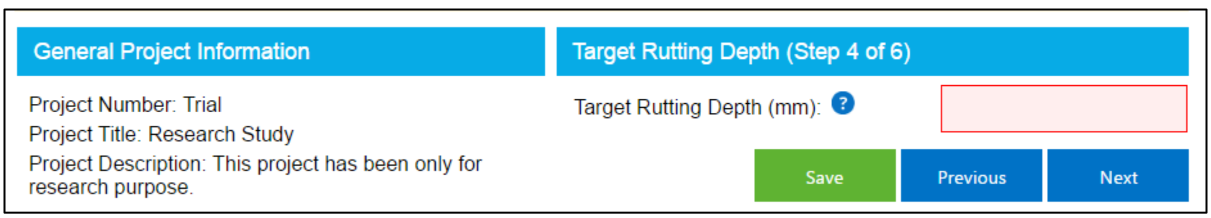


Figure 9. Screenshot. LTPPBind Online—target rut depth.[(1)]

Temperature Adjustment

Temperature adjustment is applied to calculated the PG for a binder course layer below the surface course. As is shown in figure 10 the depth of the upper layer is provided Base HT grade is an initial estimate of the HT PG. When the depth of the layer is provided, the HT is calculated at any other depth ranges from 0 to 200 mm. The equations

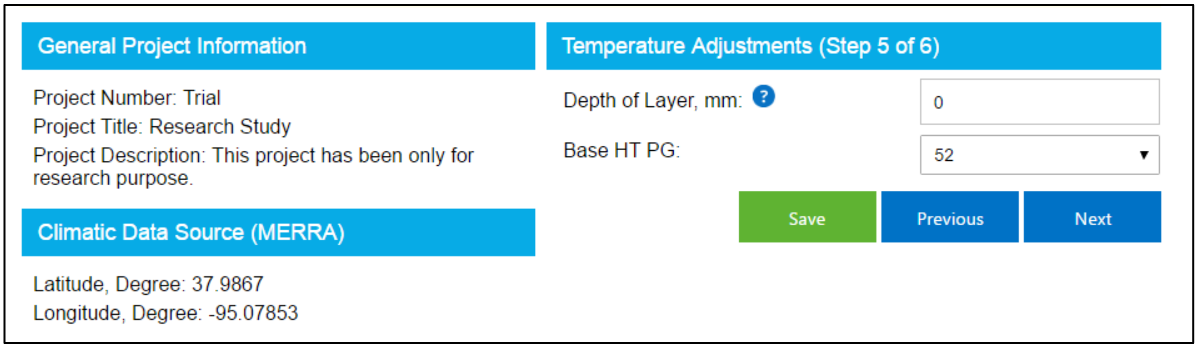


Figure 10. Screenshot. LTPPBind Online—Temperature adjustments.[1]

Traffic Adjustments

The Traffic Adjustments step has two inputs: traffic loading in ESAL units for the design period in millions and traffic speed, as shown in figure 11. Traffic speed is categorized as fast, slow, and standing. After users enter these traffic adjustment parameters and press "Calculate," to obtain the PG value.

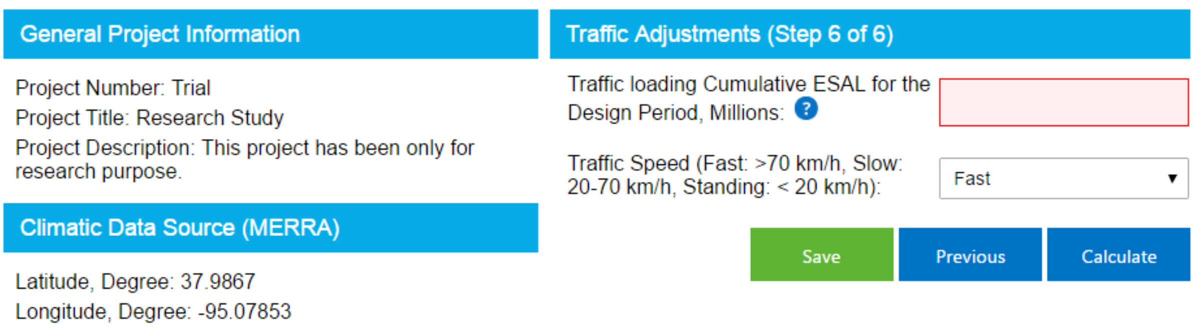


Figure 11. Screenshot. LTPPBind Online—traffic adjustments.[1]

Report

PG binder is calculated based on AASHTO M320-10 and also AASHTO M332-14.[2,3] Traffic adjustment according to AASHTO M320-10 is executed by changing the grade directly.[2] PG binder by AASHTO M332-14 standard includes one extra parameter for traffic in addition to HT and low-temperature grades.[3] "S," "H," "V," and "E" stand for standard, high, very high, and extremely high traffic loading, respectively.

The final PG report is in tabular format with all the input parameters at the top, as shown in figure 12. The report includes all the information used to calculate the PG binder, and the report can be converted to a digital file or printed.

Performance Grade		
AASHTO M320-10 Performance-Graded Asphalt Binder		
PG Temperature	High	Low
Performance Grade Temperature at 50% Reliability	64.2	-12.7
Performance Grade Temperature at 98% Reliability	66.2	-20.6
Adjustment for Traffic (AASHTO M323-13)	7.8	
Adjustment for Depth	0.0	0.0
Adjusted Performance Grade Temperature	74.0	-20.6
Selected PG Grade	**76**	**-22**
PG Grade	**M320, PG 76-22**	

AASHTO M 332-14 Performance-Grade Asphalt Binder using Multiple Stress Creep Recovery (MSCR) Test		
PG Temperature	High	Low
Performance Grade Temperature at 50% Reliability	64.2	-12.7
Performance Grade Temperature at 98% Reliability	66.2	-20.6
Designation for traffic loading	S	
Selected PG Grade	**70**	**-22**
PG Grade	**M332, PG 70S-22**	

Print

Figure 12. Screenshot. LTPPBind Online—report.[1]

ALGORITHMS

This section includes information about the required input parameters, the temperature calculation steps, and the PG calculation procedure according to the rutting damage model developed by Mohseni et al.[6]

Low-Temperature PG Selection

Low-temperature PG binder is selected using the algorithm developed from LTPP climatic data. The empirical algorithm was developed from LTPP's Seasonal Monitoring Program (SMP) data.[4] The algorithm relates low pavement temperature to air temperature, latitude, and depth, as shown in figure 13:

$$T_{L,pav} = -1.56 + 0.72\, T_{air} - 0.004\, Lat^2 + 6.26\, log(H + 25) - Z\left(4.4 + 0.52\ \sigma^2_{T_{air}}\right)^{0.5}$$

Figure 13. Equation. Low pavement temperature at surface.

Where:

$T_{L,pav}$ = Low asphalt concrete pavement temperature at surface, °C.
T_{air} = Low air temperature, °C.
Lat = Latitude of the section, degrees.
H = Depth to surface, mm.
$\sigma^2_{T_{air}}$ = Standard deviation of the mean low air temperature, °C.
Z = Standard normal distribution value 2.055 for 98 percent reliability.

More detailed information on the LTPP models are included in the corresponding literature.[7, 12, 13] The LTPP HT model was not used in this version of the program because it provided very similar results to the Strategic Highway Research Program model at 98-percent reliability.

HT PG Selection Using Rutting Damage Model

This model was developed for HT PG based on the rutting damage model developed under the National Cooperative Highway Research Program 1-37A project.[14] Hourly pavement temperatures for a 20-year period were generated for 186 sites throughout the United States and PG was calculated based on a rutting damage model.[6, 14]

The algorithm consists of an equation that estimates base PG binder using a degree-days concept and target rut depth for 50-percent reliability (figure 14). Another equation estimates the PG variability with latitude, then the base PG is adjusted for higher reliability than 50 percent (Figure 16).

$$PG_{H,d} = 48.2 + 14\,DD - 0.96\,DD^2 - 2\,RD$$

Figure 14. Equation. HT PG damage at rut depth.

Where:

$PG_{H,d}$ = PG damage at a rut depth.
DD = Average Yearly Degree-Days Air Temp. Over 10°C, x1000ºC.
RD = Rut depth (5–13 mm).

Estimate PG Variation

PG variation is estimated from the latitude and rut depth. The adjustment is minimal for the latitudes of less than 30 degrees or rut depths of less than 7.62 mm. As site latitude or rut depth increases, the yearly PG variation also increases.

$$CVPG = 0.000034\,(Lat - 20)^2\,RD^2$$

Figure 15. Equation. PG coefficient of variation.

Where:

$CVPG$ = Yearly PG coefficient of variation, percent.

Adjust PG for Reliability

The damage-based HT PG transfer function calculated with Figure 14 is adjusted for yearly PG variation adding a reliability term as is shown in Figure 16.

$$PG_{H,rel} = PG_{H,d} + (Z)\left(PG_{H,d}\right)\frac{CVPG}{100}$$

Figure 16. Equation. HT PG adjusted for reliability.

Where:

$PG_{H,rel}$ = PG at a reliability level Z, °C.

DD = Average Yearly Degree-Days Air Temp. Over 10°C, x1000.

PG Bumping for HT

PG adjustments for traffic loading and speed that were described by Mohseni are used in this version of the program.(6) The adjustments were developed based on the rutting damage concept used for the development of performance-based PG. Adjustments were developed as the difference between PG for standard traffic conditions (ESAL of 3 million and high speed) and PG for a different condition as seen in figure 17:

$$Adj = PG_n - PG_s$$

Figure 17. Equation. PG bumping for HT.

Where:

Adj = PG adjustments for a site.

PG_n = PG at a specific traffic loading and speed.

PG_s = PG at standard loading (3 million axles) and high speed.

The grade bumping table is shown in table 1. For example, the HT calculated with the rutting performance model will be increased by 9.5 if the traffic speed is slow, traffic loading is 8 ESAL million, and the asphalt HT base grade is 58.(14)

Table 1. Grade bumping.

Speed	**Base Grade**	**Traffic Loading ESAL, millions**			
		<3	**3–10**	**10–30**	**30**
Fast	52	0.0	7.8	13.2	15.5
	58	0.0	7.1	12.3	14.5
	64	0.0	6.5	11.3	13.4
	70	0.0	5.8	10.4	12.4
Slow	52	2.8	10.3	15.5	17.7
	58	2.7	9.5	14.5	16.6
	64	2.6	8.8	13.5	15.5
	70	2.4	8.0	12.4	14.4

PG designation for traffic loading

Under AASHTO M332-14 standard, he binder grade is calculated based on HT PG without “grade bumping” and low-temperature PG without any adjustment.(3) It is included a designation for traffic loading per table 2.

Table 2. Designation for traffic loading.

Designation	Traffic Loading ESAL, Millions	Conditional	Traffic Speed (km/h)
S	<10	And	>70
H	10–30	Or	20–70
V	>30	Or	<20
E	>30	And	<20

Adjusting PG with Depth

LTPP pavement temperature algorithms were used to adjust selected PGs for a certain depth into the pavement. The LTPP algorithms are empirical models developed from LTPP SMP data.[4] These algorithms relate pavement temperatures (low and high) to air temperature, latitude, and depth.[12,13] The PG selection for HT was made using the HT algorithm using rut damage concept. The LTPP HT model shown in figure 18 was only used for adjusting PGs with depth.

$$T_{H,pav} = 54.32 + 0.78\, T_{air} - 0.0025\, Lat^2 - 15.14\, log(H + 25) - Z\left(9 + 0.61\ \sigma^2_{T_{air}}\right)^{0.5}$$

Figure 18. Equation. Pavement temperature below surface.

Where:

$T_{H,pav}$ = High asphalt concrete pavement temperature below surface, °C.
T_{air} = High air temperature, °C.
$\sigma^2_{T_{air}}$ = Standard deviation of the high 7-days mean air temperature, °C.

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