Long-Term Pavement Performance Bind Online User Guide

PUBLICATION NO. FHWA-HRT-17-010

OCTOBER 2017





U.S. Department of Transportation Federal Highway Administration

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



FOREWORD

This document presents the user guide for the Long-Term Pavement Performance (LTPP) Webbased 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.

Cheryl Allen Richter, Ph.D., P.E. Director, Office of Infrastructure Research and Development

Notice

This document is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. This report does not constitute a standard, specification, or regulation.

The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document.

Quality Assurance Statement

The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No.	2. Government Accession No.	3. R	ecipient's Catalog No).	
4. Title and Subtitle Long-Term Pavement Performance Bind Online User Guide		5. R Octo 6. Pe	5. Report DateOctober 20176. Performing Organization Code		
7. Author(s)		8. Pe	erforming Organizati	on Report No.	
Riaz Ahmad, Jose R. Menendez, and	Nima Kargah-Ostadi		0 0		
9. Performing Organization Name and	1 Address	10. \	10. Work Unit No. (TRAIS)		
iENGINEERING Corporation					
24805 Pinebrook Road, Suite 204		11.0	Contract or Grant No		
Chantilly, VA 20152-4128		DTF	FH61-14-C-00034		
12. Sponsoring Agency Name and Ad	ldress	13.	Type of Report and P	eriod Covered	
Office of Infrastructure Research and	Development	Fina	l Report		
Federal Highway Administration	-	14. \$	Sponsoring Agency C	Code	
6300 Georgetown Pike					
McLean, VA 22101-2296					
15. Supplementary Notes					
The Contracting Officer's Representa	tive was Larry Wiser (HRDI-30).				
16. Abstract					
This document presents the user guide	e for the Long-Term Pavement Per	formance (L	TPP) Web-based too	l used to	
select asphalt binders. LTPPBind Onl	ine was developed to help State tra	nsportation	departments select th	e most	
suitable performance-grade binder for	a particular site based on the Ame	rican Assoc	iation of State and Hi	ghway	
Transportation Officials (AASHTO)	M320-10 and AASHTO M332-14	standards.	" LTPPBind Online I	provides the	
option to use National Aeronautics an	d Space Administration Modern-En	ra Retrospec	tive Analysis for Res	earch and	
Applications climatic data collected g	lobally since 1979, LTPP climatic	data (virtual	weather station or at	itomatic	
Weather station), or manual data.	Creade is calcoted based on a mutting	damaga ma	dal UT aquation is f	Function of	
High-temperature (HT) Performance	Grade is selected based on a rutting	damage mo			
target rut depth, yearly degree-days an	nd latitude of site ⁽³⁾ . Low-temperat	ure (LT) PG	binder is selected us	ing the	
algorithm developed from LTPP clim	atic data. L1 algorithm relates surf	ace low pave	ement temperature to	air	
temperature, latitude, and depth ^(') .					
17. Key Words		18. Distri	bution Statement		
LTPPBind Online, Long-Term Pavem	ent Performance, LTPP, climatic	No restrictions. This document is available			
data, pavement design, pavement perf	ormance, Modern-Era	to the public through the National Technical			
Retrospective Analysis for Research a	nd Application, MERRA,	Information Service, Springfield, VA			
performance grade, PG, binder	-	22161.			
		http://ww	w.ntis.gov		
19. Security Classif. (of this report)	this report) 20. Security Classif. (of this page) 21. No. of Pages 22. Price		22. Price		
Unclassified	Unclassified 24				

Form DOT F 1700.7 (8-72)

Reproduction of completed page authorized.

		INTE OONVEDOLON		
	APPROXIM	ATE CONVERSION	S TO SI UNITS	
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
n	inches	25.4	millimeters	mm
t	teet	0.305	meters	m
/d	yards	0.914	meters	m
nı	miles	1.61	kilometers	km
2		AREA		2
n ²	square inches	645.2	square millimeters	mm²
ť	square feet	0.093	square meters	mź
/d ²	square yard	0.836	square meters	m²
ac	acres	0.405	hectares	ha
ni⁴	square miles	2.59	square kilometers	km²
		VOLUME		
oz	fluid ounces	29.57	milliliters	mL
al	gallons	3.785	liters	L
ເິ	cubic feet	0.028	cubic meters	m
vd ³	cubic yards	0.765	cubic meters	m³
	NOTE: volu	imes greater than 1000 L sha	II be shown in m°	
		MASS		
)Z	ounces	28.35	grams	g
b	pounds	0.454	kilograms	kg
Г	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
	TE	MPERATURE (exact d	egrees)	
F	Fahrenheit	5 (F-32)/9	Celsius	°C
		or (F-32)/1.8		
		ILLUMINATION		
с	foot-candles	10.76	lux	lx
I	foot-Lamberts	3 426	candela/m ²	cd/m ²
1		0.120		
	FOR	CE and PRESSURE or	STRESS	
bf	FOR	CE and PRESSURE or	STRESS	N
lbf lbf/in ²	FOR poundforce poundforce per square inch	CE and PRESSURE or 4.45 6.89	• STRESS newtons kilopascals	N kPa
lbf lbf/in ²	FOR poundforce poundforce per square inch	CE and PRESSURE or 4.45 6.89	STRESS newtons kilopascals	N kPa
lbf lbf/in ²	FOR poundforce poundforce per square inch APPROXIMA	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS	STRESS newtons kilopascals FROM SI UNITS	N kPa
bf bf/in ² Symbol	FOR poundforce poundforce per square inch APPROXIMA When You Know	CE and PRESSURE or 4.45 6.89 ATE CONVERSIONS Multiply By	STRESS newtons kilopascals FROM SI UNITS To Find	N kPa Symbol
lbf Ibf/in ² Symbol	FOR poundforce poundforce per square inch APPROXIMA When You Know	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH	STRESS newtons kilopascals FROM SI UNITS To Find	N kPa Symbol
bf bf/in ² Symbol	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 000	STRESS newtons kilopascals FROM SI UNITS To Find inches	N kPa Symbol
bf bf/in ² Symbol nm n	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28	STRESS newtons kilopascals FROM SI UNITS To Find inches feet	N kPa Symbol
of bf/in ² Symbol nm n	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards	N kPa Symbol in ft yd
bf bf/in ² Symbol nm n n m	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621	* STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles	N kPa Symbol in ft yd mi
bf bf/in ² Symbol nm n n m	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles	N kPa Symbol in ft yd mi
bf bf/in ² Symbol nm n n m	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches	N kPa Symbol in ft yd mi in ²
bf bf/in ² Symbol nm n n xm nm ² n ²	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters	CE and PRESSURE or 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet	N kPa Symbol in ft yd mi in ² ft ²
bf bf/in ² Symbol nm n n m n m n ² n ²	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters square meters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards	N kPa Symbol in ft yd mi in ² ft ² yd ²
of bf/in ² Symbol nm n n m m ² n ² n ²	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters square meters hectares	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres	N kPa Symbol in ft yd mi in ² ft ² yd ² ac
of bf/in ² Symbol nm n n m m n ² n ² n ² n ² n ² n ² n ² n ²	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters hectares square kilometers	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square feet square yards acres square miles	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ²
of bf/in ² Symbol nm n n m m n n n n n ² n ² n ² na m ² m ²	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters square meters square meters square meters square meters square meters square meters square meters square meters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ²
bf bf/in ² Symbol Symbol nm n n m ² n ² n ² n ² na m ² m	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters hectares square kilometers milliliters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz
bf bf/in ² Symbol Symbol nm n n m ² n ² n ² n ² n ² n ²	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters hectares square meters hectares square millimeters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.034 0.264	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces gallons	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal
bf bf/in ² Symbol Symbol nm n n m m m ² n ² n ² n ² n ² n ²	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters hectares square kilometers milliliters liters cubic meters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces gallons cubic feet	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³
bf bt/in ² Symbol nm n n m r n n m ² n ² n ² n ² n ² n ² n ² n ² n	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters hectares square meters hectares square kilometers milliliters liters cubic meters cubic meters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square feet square miles fluid ounces gallons cubic feet cubic feet cubic yards	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³
bf bf/in ² Symbol mm n m m m m m ² m ² m ² m ² m ² m ² m	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters square meters hectares square kilometers milliliters iters cubic meters cubic meters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square feet square miles fluid ounces gallons cubic feet cubic reet cubic reet cubic reet cubic reet cubic reet	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³
bf bf/in ² Symbol nm n n m ² n ² n ² n ² n ² n ² n ² n ² n	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters hectares square meters hectares square kilometers milliliters liters cubic meters cubic meters cubic meters arams	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces gallons cubic feet cubic reats	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³
bf bf/in ² Symbol nm n n m m ² n ² na n ² na m ² n ² na n ³	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters square meters square meters square meters square meters square meters square meters cubic meters cubic meters cubic meters grams kilograms	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035 2.202	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square geet square feet square miles fluid ounces gallons cubic feet cubic res ounces pounds	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb
bf bf/in ² Symbol nm n n n n n n n n n n n n n	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters square meters hectares square kilometers milliliters liters cubic meters cubic meters grams kilograms megagrams (or "metric ton")	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035 2.202 1.103	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces gallons cubic feet cubic reet cubic syards ounces pounds short tons (2000 lb)	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb T
bf bf/in ² Symbol nm n n ² n ² n ² n ² n ² n ³ n ³ n ³ g g Ag (or "t")	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters hectares square kilometers milliliters liters cubic meters cubic meters	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035 2.202 1.103 MPERATURE (exact d	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square miles fluid ounces gallons cubic feet cubic feet cubic saces short tons (2000 lb)	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb T
bf bf/in ² Symbol Symbol nm n n m ² n ² n ² n ² n ² n ² n ³ n ³ n ³ n ³ g g g g g g g g g g g g g g g g g g	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters hectares square meters hectares square kilometers milliliters liters cubic meters cubic meters megagrams (or "metric ton")	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035 2.202 1.103 MPERATURE (exact d	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces gallons cubic feet cubic syards ounces pounds short tons (2000 lb) egrees)	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb T
bf bf/in ² Symbol nm n n n cm n n n n n n n n n n n n n n	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters hectares square meters hectares square kilometers milliliters liters cubic meters cubic meters grams kilograms megagrams (or "metric ton") TEL Celsius	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035 2.202 1.103 MPERATURE (exact d 1.8C+32	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces gallons cubic feet cubic feet cubic feet cubic syards ounces pounds short tons (2000 lb) egrees) Fahrenheit	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb T
$\frac{b}{b} f$	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters hectares square meters hectares square kilometers milliliters liters cubic meters cubic meters cubic meters cubic meters cubic meters cubic meters megagrams (or "metric ton") TE	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035 2.202 1.103 MPERATURE (exact d 1.8C+32 ILLUMINATION 0.0000	STRESS newtons newtons kilopascals FROM SI UNITS To Find inches feet jaches feet yards miles square inches square feet square feet square yards acres square miles fluid ounces gallons cubic feet cubic feet cubic feet cubic yards ounces pounds short tons (2000 lb) egrees) Fahrenheit fact gandles	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb T o F
bf bf/in ² Symbol nm n n m n m m n n m n n n n n n n n n	FOR poundforce poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters square meters hectares square meters hectares square kilometers milliliters iters cubic meters cubic meters cubic meters cubic meters cubic meters megagrams (or "metric ton") TE	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.034 0.264 35.314 1.307 MASS 0.035 2.202 1.103 MPERATURE (exact d 1.8C+32 ILLUMINATION 0.0929 0.2910	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces gallons cubic feet cubic feet cubic yards ounces pounds short tons (2000 lb) egrees) Fahrenheit	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb T oz lb T
bf bf/in ² Symbol nm n n n n n n n n n n n n n n n n n n	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square meters square meters hectares square meters hectares square meters cubic meters cubic meters cubic meters cubic meters cubic meters cubic meters megagrams (or "metric ton") TEL Celsius	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035 2.202 1.103 MPERATURE (exact d 1.8C+32 ILLUMINATION 0.0929 0.2919	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces gallons cubic feet cubic feet <td>N kPa Symbol in ft yd mi in² ft² yd² ac mi² fl oz gal ft³ yd³ oz lb T oz lb T</td>	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb T oz lb T
bf bf/in ² Symbol nm n n m ² n ² na m ² n n ² na m ² m ² m ³ m ³ (g (or "t") C C	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035 2.202 1.103 MPERATURE (exact d 1.8C+32 ILLUMINATION 0.0929 0.2919 CE and PRESSURE of	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square feet square miles fluid ounces gallons cubic feet cubic reet cubic synds ounces pounds short tons (2000 lb) egrees) Fahrenheit foot-candles foot-Lamberts	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb T °F fc fl
bf bf/in ² Symbol nm n n m ² n ² na m ² n n ³ n ³ y g g g g g g g g g g g g g g g g g g	FOR poundforce per square inch APPROXIMA When You Know millimeters meters meters kilometers square millimeters square meters square	CE and PRESSURE of 4.45 6.89 ATE CONVERSIONS Multiply By LENGTH 0.039 3.28 1.09 0.621 AREA 0.0016 10.764 1.195 2.47 0.386 VOLUME 0.034 0.264 35.314 1.307 MASS 0.035 2.202 1.103 MPERATURE (exact d 1.8C+32 ILLUMINATION 0.0929 0.2919 CE and PRESSURE of 0.225 0.225	STRESS newtons kilopascals FROM SI UNITS To Find inches feet yards miles square inches square feet square yards acres square miles fluid ounces gallons cubic feet cubic reet cubic synds ounces pounds short tons (2000 lb) egrees) Fahrenheit foot-candles foot-Lamberts	N kPa Symbol in ft yd mi in ² ft ² yd ² ac mi ² fl oz gal ft ³ yd ³ oz lb T °F fc fl lbf

INTRODUCTION	1
LTPPBIND ONLINE ACCESS	1
CALCULATION PROCESS	2
GENERAL PROJECT INFORMATION	2
CLIMATIC DATA SOURCE	3
MERRA Climatic Data	4
LTPP (Virtual Weather Station (VWS))	5
LTPP (AWS)	6
Manual Climatic Data	7
CLIMATIC DATA RESULTS	7
Target Rut Depth	8
TEMPERATURE ADJUSTMENT	8
TRAFFIC ADJUSTMENTS	9
REPORT	9
LOW-TEMPERATURE PG SELECTION	10
HT PG SELECTION USING RUTTING DAMAGE MODEL	11
Estimate PG Variation	11
Adjust PG for Reliability	11
PG Bumping for HT	12
PG designation for traffic loading	12
Adjusting PG with Depth	13
REFERENCES	15

TABLE OF CONTENTS

LIST OF FIGURES

Figure 1. Screenshot. LTPPBind Online on InfoPave TM	1
Figure 2. Screenshot. LTPPBind Online	2
Figure 3. Screenshot. LTPPBind Online—general project information	3
Figure 4. Screenshot. LTPPBind Online—selecting climatic data source	4
Figure 5. Screenshot. LTPPBind Online—select location for MERRA data	5
Figure 6. Screenshot. LTPPBind Online—select LTPP station	6
Figure 7. Screenshot. LTPPBind Online—select LTPP AWS	7
Figure 8. Screenshot. LTPPBind Online—generated climatic data	8
Figure 9. Screenshot. LTPPBind Online—target rut depth	8
Figure 10. Screenshot. LTPPBind Online—Temperature adjustments	9
Figure 11. Screenshot. LTPPBind Online—traffic adjustments	9
Figure 12. Screenshot. LTPPBind Online—report	10
Figure 13. Equation. Low pavement temperature at surface	10
Figure 14. Equation. HT PG damage at rut depth	11
Figure 15. Equation. PG coefficient of variation	11
Figure 16. Equation. HT PG adjusted for reliability	11
Figure 17. Equation. PG bumping for HT	12
Figure 18. Equation. Pavement temperature below surface	13

LIST OF TABLES

Table 1. Grade bumping.	
Table 2. Designation for traffic loading.	

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 InfoPaveTM Web site under the "TOOLS" tab of the InfoPaveTM menu bar as shown in figure 1.^(1,8) To select LTPPBind Online, users need to register with InfoPaveTM using their email address or their social media accounts.



Figure 1. Screenshot. LTPPBind Online on InfoPaveTM.^(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).

	Tools	Sig	n Out My I	TPP Data	Bucket (0) Custome	r Support Site M Search	Nap Contact Us	Abou Go
HOME SEARCH MAP DATA AN	ALYSIS VISUALIZATIO	ON TOOLS LIBRARY	Y HELP	MY LTPP	NON-LTPP			
Tools	LTPPBind Onlin	e					Не	lp?
MEPDG Inputs	Start Project	s						
MERRA Climate Data for MEPDG	New Proje	Project						
Rigid Pavement Design	Project Number	Project Title			Date Added		Actions	
WIM Cost Analysis	1	1			6/16/2016 11:27:18 AM	/ Open	Delete	
LTPP Dynamic Modulus Prediction	View 1 - 1 of 1					ra 🛛 Page	1 of 1 -> >1 2	20 🔻
Revement Performance Forecast								

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⁾

	Sign Out My LTP	P Data Bucket (0) Customer Support Site Map Contact Us About
InfoPave : 1	ools	Search Go
HOME SEARCH MAP DATA ANA	ALYSIS VISUALIZATION TOOLS LIBRARY HELP	MY LTPP NON-LTPP
Tools	LTPPBind Online	Help?
MEPDG Inputs	Start Projects	
MERRA Climate Data for MEPDG	Disclaimer:	
Rigid Pavement Design	 High-temperature performance grade (PG) algorithms we In order to see the differences between MERRA and OWS 	re developed only for U.S. locations. databases refer to: Schwartz, et al (2015). "Evaluation of LTPP Climatic vide (WEDD) optimizer of Other Development Analysis," Day, No.
WIM Cost Analysis	FHWA-HRT-15-019.	Suide (MEPDG) Calibration and Other Pavement Analysis. Rep. No.
LTPP Dynamic Modulus Prediction	General Project Information	General Project Information (Step 1 of 6)
Pavement Performance Forecast	Project Number:	Project Number: 😨
FWD Calibration	Project Title: Project Description:	Project Title: 1
LTPPBind	Climatic Data Source	Project Description: 1
LTPPBind Online	Latitude, Degree:	
Distress Identification Manual	Climatic Data	
Pavement Loading User Guide	I owest Yearly Air Temperature °C	Next
ITPP InfoPave Mohile	Low Air Temp Standard Deviation °C	

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⁾

LTPPBind Online	About
Start Projects	
 Disclaimer: High-temperature performance grade (PG) algorithms were e In order to see the differences between MERRA and OWS d for Use in Mechanistic-Empirical Pavement Design Guide (N 15-019. 	developed only for U.S. locations. atabases refer to: Schwartz, et al (2015). "Evaluation of LTPP Climatic Data IEPDG) Calibration and Other Pavement Analysis." Rep. No. FHWA-HRT-
General Project Information	Climatic Data Source (Step 2 of 6)
Project Number: a Project Title: a Project Description:	Please select the data source from option below:
Climatic Data Source	LTPP (Virtual Weather Station)
Latitude, Degree: 38.22 Longitude, Degree: -96.46	Manual
Climatic Data	Select Location
Lowest Yearly Air Temperature, ºC: -17.64	

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 °C, 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.

Climatic Data Source (Step 2 of 6)		
MERRA	mation	Climatic Data Source (Step 2 of 6)
 LTPP (Virtual Weather Station) LTPP (Automated Weather Station) Manual 	Study is project has been only for	Please select the data source from option below: MERRA MERRA MERRA Please select the data source from option below: MERRA Please select the data source from option below: Please select the data source from option
Select Loc	e (MERRA)	 LTPP (Automated Weather Station) Manual
Select Location Ve Please select the LTPP Section (I Select LTPP Section State/Province: Alabama Latitude: 32.60963 , Longitude: Depth of I Base HT	inked with Virtual Weather Stations) from t Section: 01-0163 -85.25599 Layer, mm: PG:	the dropdown lists below.

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 10°C, 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.

LTPPBind Online		About
Start Projects		
Disclaimer: • High-temperature performance grade (PG) algorithms were • In order to see the differences between MERRA and OWS Data for Use in Mechanistic-Empirical Pavement Design G HRT-15-019.	e developed only for U.S. locations. databases refer to: Schwartz, et al (2015). "Eva uide (MEPDG) Calibration and Other Pavement	luation of LTPP Climatic Analysis." Rep. No. FHWA-
General Project Information	Climatic Data (Step 3 of 6)	
Project Number: Trial	Lowest Yearly Air Temperature, ºC:	-19.58
Project file: Research study Project Description: This project has been only for research purpose.	Low Air Temp Standard Deviation, °C:	4.46
Climatic Data Source (MERRA)	Yearly Degree-Days > 10 Deg. ºC:	4052.00
Latitude, Degree: 37.9867	High Air Temperature of high 7 days:	36.34
Longitude, Degree: -95.07853	Standard Dev. of the high 7 days:	3.43
Climatic Data	Sava	Provious Novt
Lowest Yearly Air Temperature, °C: -19.58 Low Air Temp Standard Deviation, °C: 4.46 Yearly Degree-Days > 10 Deg. °C: 4052.00 High Air Temperature of high 7 days: 36.34 Standard Dev. of the high 7 days: 3.43		

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

General Project Information	Temperature Adjustments (Step 5 of 6)			
Project Number: Trial Project Title: Research Study	Depth of Layer, mr	m: 😮	0	
Project flue, research study Project Description: This project has been only for research purpose.	Base HT PG:		52	•
Climatic Data Source (MERRA)		Save	Previous	Next
Latitude, Degree: 37.9867 Longitude, Degree: -95.07853	-			

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.

General Project Information	Traffic Adjustments (Step 6 of 6)		
Project Number: Trial Project Title: Research Study Project Description: This project has been only for research purpose.	Traffic loading Cumulative ESAL fo Design Period, Millions: ? Traffic Speed (Fast: >70 km/h, Slov 20-70 km/h, Standing: < 20 km/h):	r the v: Fast	•
Climatic Data Source (MERRA)	Saus	Desuisure	Coloulate
Latitude, Degree: 37.9867 Longitude, Degree: -95.07853	Save	Previous	Carculate

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.

AACHTO M220 10 Dayfawaanaa Cyadad Aanhalt Binday		
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 u PG Temperature	ising Multiple Stress Creep Recove High	ry (MSCR) Test Low
Performance Grade Temperature at 50% Reliability	64.2	-12.7
Performance Grade Temperature at 98% Reliability	66.2	-20.6
	S	
Designation for traffic loading	70	-22
Designation for traffic loading Selected PG Grade	70	

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:

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

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.

 $\sigma_{T_{air}}^2$ = 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, x1000°C. 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⁾

		Traffic Loading ESAL, millions			
Speed	Base Grade	<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

Table	1.	Grade	humping.
Labic	т.	Orauc	vumping.

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.

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

Table 2. Designation for traffic loading.

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.

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

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. $\sigma_{T_{air}}^2$ = Standard deviation of the high 7-days mean air temperature, °C.

REFERENCES

- 1. FHWA. (2016). *Long-Term Pavement Performance Bind Online Tool*, Federal Highway Administration, Washington, DC., obtained from: https://infopave.fhwa.dot.gov/Tools /LTPPBindOnline, last accessed December 12, 2016.
- AASHTO. (2014). "Standard Specification for Performance-Graded Asphalt Binder, AASHTO Designation M 320-10," *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, Report No. M 320-1-M 320-7, American Association of State Highway and Transportation Officials, Washington, DC.
- AASHTO. (2014). "Standard Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test, AASHTO Designation M 332-14," *Standard Specification for Transportation Materials of Sampling and Testing*, Report No. M 332-1-M 332-7, American Association of State Highways and Transportation Officials, Washington, DC.
- 4. Rada, G. R., Elkins, G. E., Henderson, B., Van Sambeek, R. J., and Lopez, J., A. (1995). *LTPP Seasonal Monitoring Program: Instrumentation Installation and Data Collection Guidelines*, Report No. FHWA-RD-94-110, Federal Highway Administration, Washington, DC.
- NASA. (2015). MERRA: Modern-Era Retrospective Analysis for Research and Applications, Goddar Space Flight Center, Global Modeling and Assimilation Office, Greenbelt, MD, obtained from: http://gmao.gsfc.nasa.gov/merra/, last accessed March 9, 2015.
- Mohseni, A., Carpenter, S. H., and D'Angelo, J. (2005). "Development of Superpave High-Temperature Performance Grade (PG) Based on Rutting Damage (With Discussion and Closure)," *Journal of the Association of Asphalt Paving Technologists*, 74 (1), pp. 197– 254, The Association of Asphalt Paving Technologists, Lino Lakes, MN.
- Mohseni, A. (1998). LTPP Seasonal Asphalt Concrete (AC) Pavement Temperature Models, Report No. FHWA-RD-97-103, Federal Highway Administration, Washington, DC.
- 8. FHWA. (2016). *LTPP InfopaveTM*, Federal Highway Administration, Washington, DC., obtained from: https://infopave.fhwa.dot.gov/, last accessed December 15, 2016.
- Schwartz, C. H., Elkins, G. E., Li, R., Visintine, B. A., Forman, B., Rada, G. R., and Groeger, J. L. (2015). Evaluation of LTPP Climatic Data for Use in Mechanistic-Empirical Pavement Design Guide (MEPDG) Calibration and Other Pavement Analysis, Report No. FHWA-HRT-15-019, Federal Highway Administration, Washington, DC.
- FHWA. (2016). Specific Pavement Studies, Federal Highway Administration, Washington, DC., obtained from: https://www.fhwa.dot.gov/research/tfhrc/programs /infrastructure/pavements/ltpp/sps.cfm, last accessed February 21, 2017.
- 11. AASHTO. (2015). *Mechanistic-Empirical Pavement Design Guide: A Manual of Practice, Second Edition*, American Association of State Highway and Transportation Officials, Washington, DC.

- 12. Mohseni, A., and Symons, M. (1998). *Improved AC Pavement Temperature Models from LTPP Seasonal Data, 77th Annual Meeting Transportation Research Board*, Transportation Research Board, Washington, DC.
- Mohseni, A., and Symons, M. (1998). Effect of Improved LTPP AC Pavement Temperature Models on SuperPave Performance Grades, 77th Annual Meeting Transportation Research Board, Transportation Research Board, Washington, DC.
- 14. NCHRP. (2004). *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures*, Report No. 1-37A, National Cooperative Highway Research Program, Washington, DC.

HRDI-30/10-17(500)E