Study of LTPP Laboratory Resilient Modulus Test Data and Response Characteristics: Final Report

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Foreword

The elastic or resilient modulus of pavement materials is an important material property in any mechanistically based design/analysis procedure for flexible pavements. Repeated load resilient modulus tests are being performed on all unbound materials and soils of the Specific Pavement Studies (SPS) and General Pavement Studies (GPS) test sections that are in the Federal Highway Administration (FHWA) Long Term Pavement Performance (LTPP) program in accordance with LTPP test protocol P46. Previous studies have shown that the resilient modulus test results can be affected by sampling technique, testing procedure, and errors that can occur during the testing program. Thus, the FHWA sponsored a detailed review of the resilient modulus test results that have a Level E status in the LTPP database, i.e., they have passed all levels of the quality control (QC) checks.

This report documents the first comprehensive review and evaluation of the resilient modulus test data measured on pavement materials and soils recovered from the LTPP test sections. The resilient modulus test data were found generally to be in excellent condition with less than 10 percent of the tests exhibiting potential anomalies or discrepancies in the data.

The resilient modulus data were further investigated to evaluate relationships between resilient modulus and the physical properties of the unbound materials and soils. The primary result from these studies is that the resilient modulus can be reasonably predicted from the physical properties included in the LTPP database, but there is a bias present in the calculated values. Thus, until additional test results become available to improve or confirm these relationships, it is recommended that at least some laboratory tests be performed to measure the resilient modulus for unbound pavement materials and soils.

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16. Abstract
The resilient modulus of every unbound structural layer of the Long Term Pavement Performance (LTPP) Specific Pavement and General Pavement Studies Test Sections is being measured in the laboratory using LTPP test protocol P46. A total of 2,014 resilient modulus tests have passed all quality control checks and are included in the LTPP database with a Level E data status. As of October 2000, there were 1,639 resilient modulus tests yet to be performed. In some cases, these missing tests may have been performed, but did not achieve a Level E status (did not pass all quality control checks) in the LTPP database. However, these test results have not been evaluated in detail. This report documents the first comprehensive review and evaluation of the resilient modulus test data measured on pavement materials and soils recovered from the LTPP test sections.

The resilient modulus data were reviewed in detail to identify anomalies or potential errors in the database. From this review, a total of 185 resilient modulus tests were identified with possible problems or data entry errors. These tests were reported to FHWA for further review and/or retesting. The resilient modulus test data were found generally to be in excellent condition with less than 10 percent of the tests exhibiting potential anomalies or discrepancies in the data.

The resilient modulus test data were then studied for the effect of test variables, such as the test and sampling procedures, on the resulting resilient moduli. These data were analyzed by material code for the base and subbase aggregate layers and by soil type for the subgrade. Sampling technique (auger versus test pit) was found to have the most effect on the crushed stone aggregate and uncrushed gravel base materials. For the subgrade soils, sampling technique (Shelby tubes versus auger samples) had the most effect on the clay soils. Sampling technique was found to have little to no effect on the sand base/subbase materials and sand soils.

The resilient modulus data were further investigated to evaluate relationships between resilient modulus and the physical properties of the unbound materials and soils. Using nonlinear regression optimization techniques, equations for each base and soil type were developed to calculate the resilient modulus at a specific stress state from physical properties of the base materials and soils. The primary result from these studies is that the resilient modulus can be reasonably predicted from the physical properties included in the LTPP database, but there is a bias present in the calculated values. Thus, until additional test results become available to improve or confirm these relationships, it is recommended that at least some laboratory tests be performed to measure the resilient modulus for unbound pavement materials and soils.

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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 2002)

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CHAPTER 1. INTRODUCTION

BACKGROUND

The elastic or resilient modulus of pavement materials is an important material property in any mechanistically based design/analysis procedure for flexible pavements. In fact, the resilient modulus (M_R) is the material property required for the 1993 American Association of State Highway and Transportation Officials (AASHTO) Design Guide, which is an empirically based design procedure, and is the primary material input parameter for the 2002 Design Guide.[1] The 2002 Design Guide is being developed based on mechanistically based principles under National Cooperative Highway Research Program (NCHRP) Project 1-37A, "Development of Design Procedure for New and Rehabilitated Pavements."

Repeated load resilient modulus tests are being performed on all unbound materials and soils of the Specific Pavement Studies (SPS) and General Pavement Studies (GPS) test sections that are in the Federal Highway Administration (FHWA) Long Term Pavement Performance (LTPP) program in accordance with LTPP test protocol P46.[2] The M_R of unbound pavement materials and soils is a measure of the elastic modulus of the material at a given stress state. It is mathematically defined as the applied deviator stress divided by the "recoverable" strain that occurs when the applied load is removed from the test specimen.

$$M_R = \frac{\sigma_d}{\varepsilon_r} \tag{1}$$

Where:

σ_d	=	applied deviator stress in a repeated load triaxial test.
ε_r	=	recoverable or resilient strain.

The M_R measured at different stress states have been included in the LTPP Information Management System (IMS), but the test results have not been evaluated for use in future research studies.

Previous studies have shown that the resilient modulus test results can be affected by sampling technique, testing procedure, and errors that can occur during the testing program. Some of these errors include incorrect conditioning/stress sequence, leaks in the membrane, incorrect stress levels, unstable Linear Variable Differential Transducer (LVDT) clamps attached to the specimen, exceeding the LVDT linear range limits, and specimen disturbance at the higher stress states. Thus, FHWA authorized a detailed review of the resilient modulus test results that have a Level E status in the LTPP database, i.e., they have passed all levels of the quality control (QC) checks. This report summarizes the findings from the detailed review of the resilient modulus test data.

STUDY OBJECTIVES

This study focused on determining anomalies in the unbound resilient modulus data in the database to ensure data quality and to identify any bias between different data sets. The M_R data were extracted first from the April 2000 data release and updated with additional M_R tests from the October 2000 release. The M_R data were obtained from the TST_UG07_SS07_WKSHT_ SUM table in the IMS. The following tasks define the work performed to accomplish the goals of the study:

Task 1: Identify any and all of the repeated load resilient modulus data for unbound pavement materials and soils that are not at Level E.

Task 2: Review and evaluate the resilient modulus data to identify any anomalies in the database.

M_R tests with potential anomalies were flagged and a "cleaned" data set was used to determine any bias in the data and identify other factors that influence the tests results. The cleaned data set also was used to perform correlation studies between the M_R of the selected constitutive equation and the physical properties of the unbound materials and soils in support of NCHRP Project 1-37A.

SCOPE OF REPORT

This report summarizes the review of the resilient modulus test results that have a Level E status in the LTPP database. The report is divided into five chapters, including the introduction (chapter 1). Chapter 2 provides the process of identifying missing tests and anomalies in the Level E data. Chapter 3 discusses the effect of test variables on resilient modulus. A correlation between the M_R determined from the selected constitutive equation and physical properties of the tests specimens is presented in chapter 4. Chapter 5 summarizes all of the findings and provides recommendations for future research.

CHAPTER 2. REVIEW OF RESILIENT MODULUS TEST DATA

IDENTIFICATION OF MISSING RESILIENT MODULUS TESTS

A total of 1,970 resilient modulus tests were extracted from the April 2000 LTPP database (most current at the time of data extraction) of unbound materials and soils. The October 2000 data release was cross-checked with the April release for additional tests to update the review and findings. A total of 44 additional resilient modulus tests were extracted from the October release, resulting in a total of 2,014 M_R tests.

The resilient modulus tests in the LTPP database were organized by State and layer type for each SPS project and by State, layer number, layer type, and section identification number for the GPS test sections. The data were cross-checked with the required number of resilient modulus tests per layer for each project to determine the number of missing tests.

Table 1 summarizes the number of completed and missing resilient modulus tests by layer type as of the October 2000 data release. The numbers of completed and missing tests do not add up to the number of tests required because extra tests were performed. The resilient modulus tests in the database that are counted as complete are identified as Level E data. The number of missing tests includes those M_R tests that have not been performed plus those that have been completed, but which have not passed all QC levels.

Table 1. Summary of completed and missing resilient modulus tests as of the October 2000 LTPP data release.

Layer Type	Soil Type	No. of Tests Required	No. of Tests Completed	No. of Tests Missing
Subgrade Soil	All	1886	1347	594
	Clay	652	513	168
	Gravel	262	123	140
	Rock	24	3	21
	Sand	765	580	208
	Silt	169	116	55
	Unknown	14	12	2
Granular Subbase	All	685	259	427
Granular Base	All	956	385	573
Unknown	Unknown	--	23	--
Total		3527	2014	1594

The missing resilient modulus tests were categorized by LTPP region, State, experiment type, and layer type. Data feedback reports for the missing tests were summarized by region and submitted to LTPP. There are a total of 23 M_R tests that cannot be summarized using the layer type due to missing layer structure information. The M_R tests for the subgrade soils were further divided into soil type (i.e., clay, gravel, rock, sand, and silt) since more than half of the total required resilient modulus tests are for the subgrade. Some tests cannot be grouped by soil type due to missing soil classification information.

In summary, more than half of the required testing has been completed and the data have achieved a Level E status. The other half of the required tests either have not been completed or the tests have been performed, but the QC process is incomplete. It is expected that the number of completed M_R tests with a Level E data status will significantly increase in future data releases.

Observation: 2,014 M_R tests of unbound pavement materials and soils have a Level E data status as of the October 200 LTPP data release, while 1,594 have not yet obtained a Level E status.

RESILIENT MODULUS CONSTITUTIVE EQUATION

LTPP test protocol P46 is being used to measure the M_R of unbound pavement materials and subgrade soils. This test is performed over a wide range of vertical stresses and confining pressures to measure the nonlinear (stress-sensitivity) elastic behavior of these materials and soils. Various types of relationships have been used to represent the repeated-load M_R test results of coarse-grained and fine-grained soils. However, Von Quintus and Killingsworth found that the so-called "universal" constitutive equation provided a very good fit to the LTPP M_R test data.[3] The specific equation used is given below:

$$M_R = K_1 P_a \left[\frac{\theta}{P_a}\right]^{K_2} \left[\frac{\sigma_d}{P_a}\right]^{K_3} \tag{2}$$

As noted in chapter 1, the 2002 Design Guide uses M_R as the primary material property for all unbound pavement layers and subgrade soils. The constitutive equation used for determining the M_R of a material is given below and represents an expanded version of equation 2:[4]

$$M_R = k_1 P_a \left[\frac{\theta - 3k_6}{P_a}\right]^{k_2} \left[\frac{\tau_{oct}}{P_a} + 1\right]^{k_3} \tag{3}$$

where: P_a = atmospheric pressure.

θ = bulk stress:

$$\theta = \sigma_1 + \sigma_2 + \sigma_3 . \tag{4}$$

σ_1 = major principal stress.

σ_2 = intermediate principal stress = σ_3 for M_R test on cylindrical specimen.

σ_3 = minor principal stress/confining pressure.

τ_{oct} = octahedral shear stress:

$$\tau_{oct} = \frac{1}{3}\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_1 - \sigma_3)^2 + (\sigma_2 - \sigma_3)^2} \tag{5}$$

k_1, k_2, k_3, k_6 = regression constants.

Coefficient k_1 is proportional to Young's modulus. Thus, the values for k_1 should be positive since M_R can never be negative. Increasing the volumetric stress (θ) should produce a stiffening or hardening of the material, which results in a higher M_R. Therefore, the exponent (k_2) of the bulk stress term for the above constitutive equation should also be positive. Coefficient k_6 is intended to account for pore-water pressure or cohesion and is a measure of the material's ability to resist tension. The values for k_6 are expected to be negative or, when positive, less than or equal to a third of the bulk stress. Coefficient k_3 is the exponent of the octahedral shear stress term. The values for k_3 should be negative since increasing the shear stress will produce a softening of the material, i.e., a lower M_R.

The regression for the four k-coefficients in equation 3 was performed, restraining the regression constants to their physical limits using the LTPP April and October 2000 data releases. Only those resilient modulus tests with 12 or more data points were used, resulting in a total of 1,920 tests. A total of 94 M_R tests (approximately 4 percent of the total number of tests) had less than 12 data points. It is important to note that all regressions were performed using units of *MPa* for M_R and *kPa* for the stress and pressure parameters in equation 3.

More than half of the k_6 values were equal to zero, while the non-zero values were highly variable with a uniform distribution. Therefore, k_6 was set to zero and the regression was repeated. No significant effect was observed on the regression statistics setting k_6 equal to zero. Figure 1 presents the distributions of the final results for the k-coefficients. The values for the k-coefficients are presented in appendix A.

Observation: Coefficient k_6 in equation 3 was found to be zero for more than 50 percent of the M_R tests.

Coefficient k_1 ranged from 0 to 3. These values are actually factors of a thousand because the M_R value used was in *MPa* instead of *kPa*. Coefficient k_2 ranged from 0 to 1.5 and has a bi-normal population. The bi-normal population suggests two different groups of soils. Figures 2 through 4 confirm that the coarse-grained soils are different from the fine-grained soils. Coefficient k_3 ranged from 0 to -7 and has a skewed distribution. About 25 percent of the values were equal to zero. The majority of M_R tests with a k_3 coefficient equal to zero were for the unbound aggregate materials or coarse-grained soils.

Figures 2 through 4 present the distributions of the k-coefficients for the unbound aggregate materials and coarse-grained and fine-grained soils, while table 2 summarizes a comparison of the median and mean values for the coefficients from each data group. As shown, coefficients k_1 and k_2 have a normal distribution, while k_3 has a skewed distribution for the base/subbase materials (figure 2). However, the distributions for k_1 and k_2 become skewed as the material becomes finer, while the distribution for k_3 becomes more normal (figures 3 and 4).

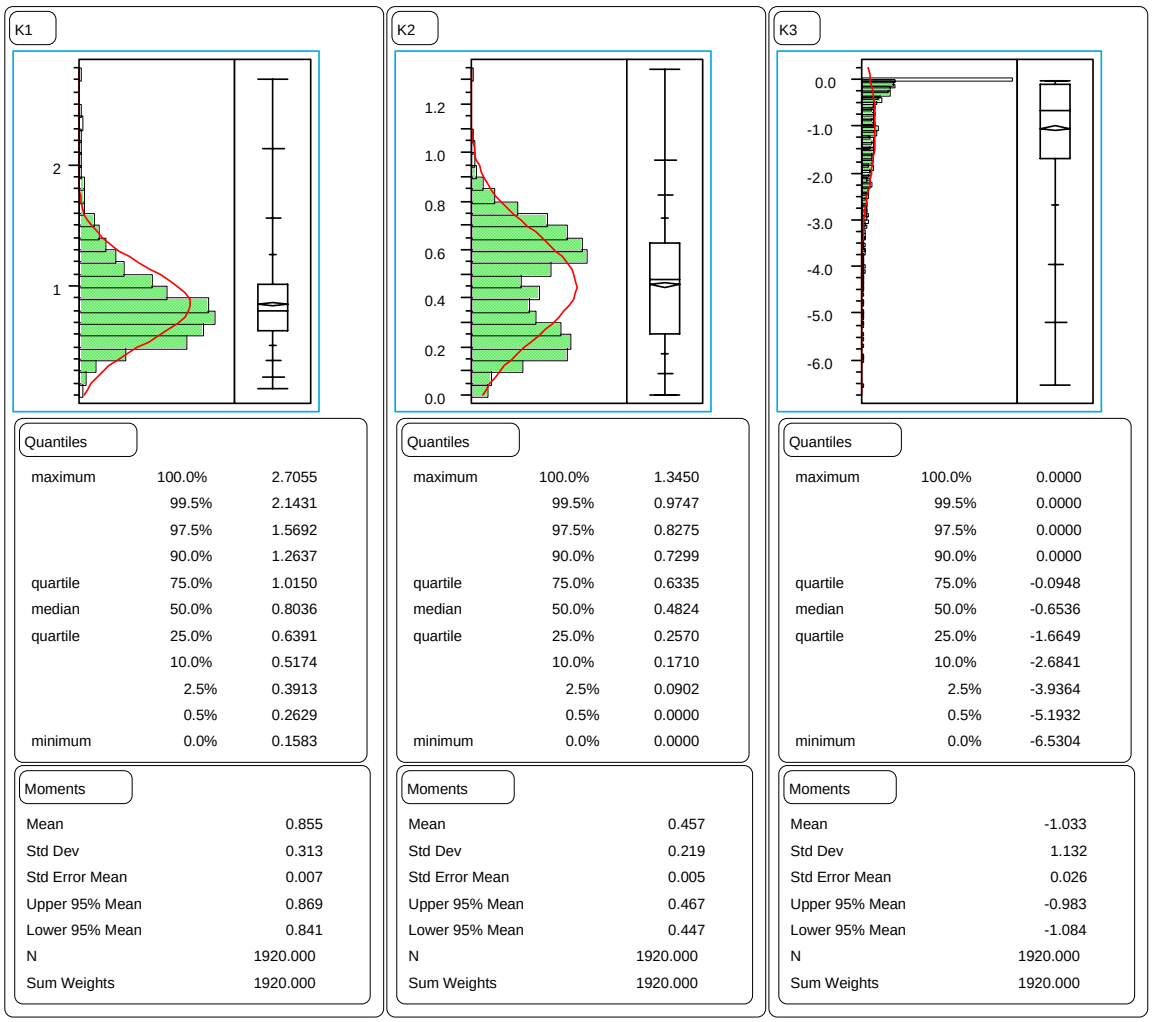

Figure 1. Distribution of the k-coefficients of constitutive equation 3, assuming $k_6 = 0$, for the entire LTPP resilient modulus database.

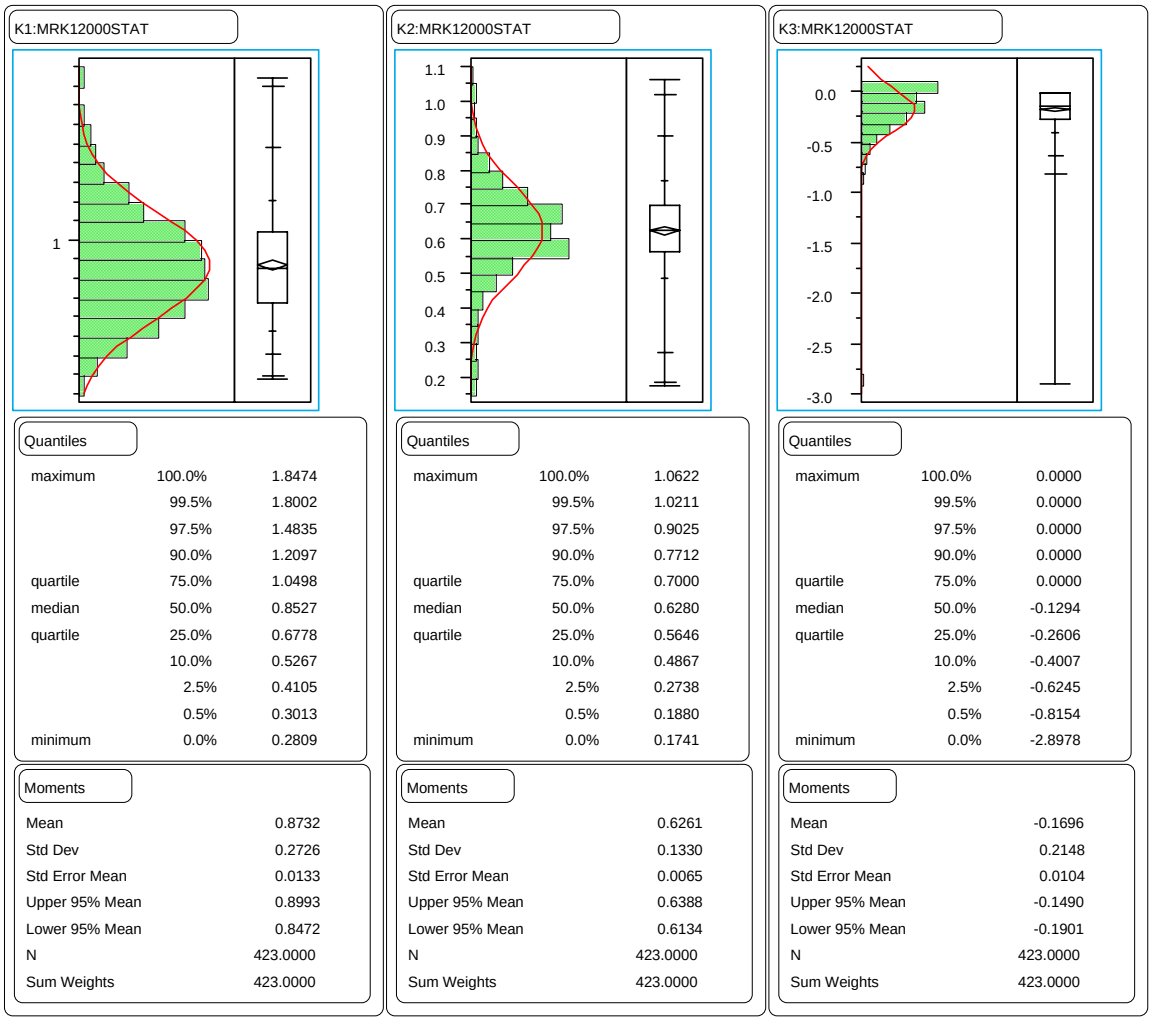

Figure 2. Distribution of the k-coefficients of constitutive equation 3, assuming $k_6 = 0$, for the unbound aggregate base and subbase materials.

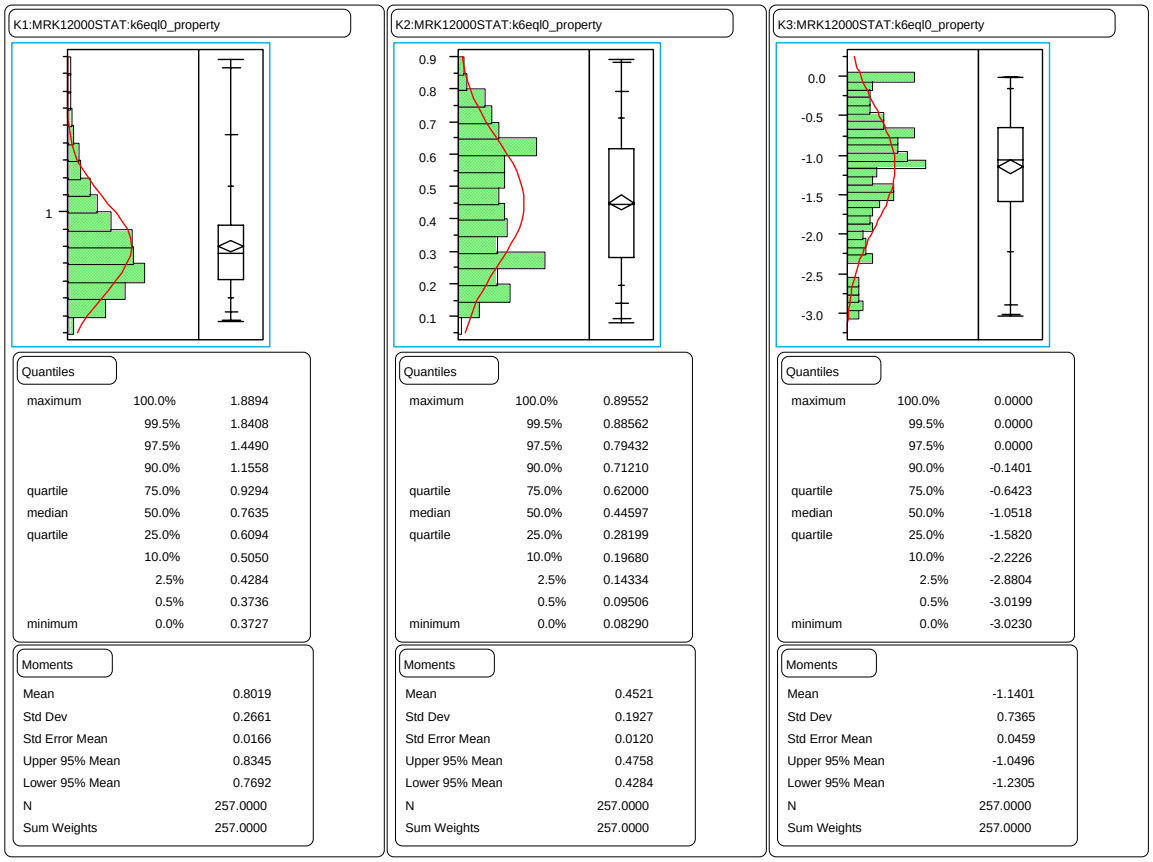

Figure 3. Distribution of the k-coefficients of constitutive equation 3, assuming $k_6 = 0$, for the coarse-grained subgrade soils.

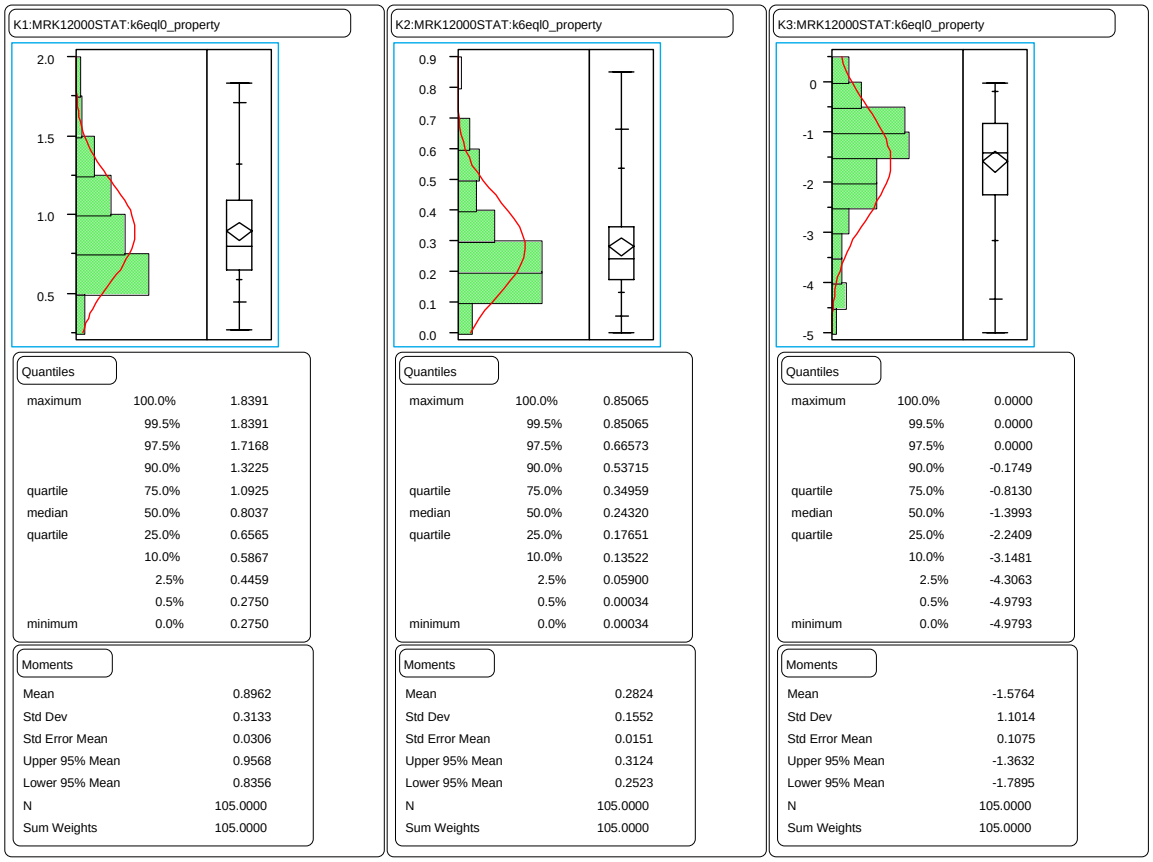

Figure 4. Distribution of the k-coefficients of constitutive equation 3, assuming $k_6 = 0$, for the fine-grained subgrade soils.

Table 2. Summary of the median and mean values for each coefficient of constitutive equation 3, assuming $k_6 = 0$, for each of the base and subbase pavement materials and subgrade soils.

Coefficient		Material/Soil Group		
		Unbound Base-Subbase Materials	Coarse-Grained Soils	Fine-Grained Soils
k_1	Median	0.853	0.764	0.804
	Mean	0.873	0.802	0.896
	Standard Deviation	0.2726	0.2661	0.3133
k_2	Median	0.628	0.446	0.243
	Mean	0.626	0.452	0.282
	Standard Deviation	0.1330	0.1927	0.1552
k_3	Median	-0.129	-1.052	-1.399
	Mean	-0.170	-1.140	-1.576
	Standard Deviation	0.2148	0.7365	1.1014
Number of Tests		423	257	105

Table 2 shows that the median value for coefficient k_2 increases as the amount of fines in the material/soil increases (fine-grained soils to unbound aggregate base material). Similarly, the median value for k_3 becomes more negative as the material/soil becomes more fine-grained. The majority of the zero values for k_3 were from the unbound base materials and coarse-grained soils, approximately 25 percent of the M_R tests for the unbound aggregate base/subbase materials and 10 percent of the tests for the coarse-grained subgrade soils. Thus, the regressed k-coefficients from the LTPP M_R test results are consistent with previous experience.

Figures 5 and 6 compare the calculated M_R from the regressed k-coefficients of the constitutive equation to the measured M_R for the test pit and augured samples, respectively. Figures 7 and 8 compare the calculated M_R from the regressed k-coefficients of the constitutive equation to the measured M_R for the gravel and clay soil groups, respectively. As shown, the constitutive equation provides an excellent fit to the LTPP M_R test data. The universal constitutive equation provides a similar good fit to the other base materials and subgrade soils.

Observation: Equation 3 provides an excellent fit to the LTPP resilient modulus test data.

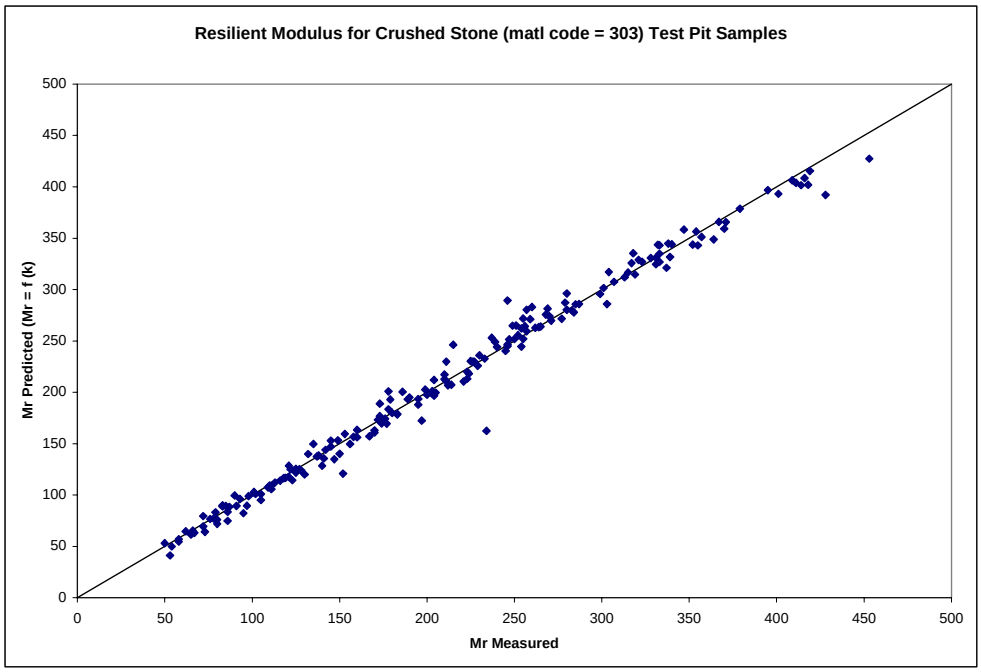

Figure 5. Comparison of measured and predicted resilient modulus (from regressed k values from measured M_R data) for the crushed stone materials sampled from the test pit locations.

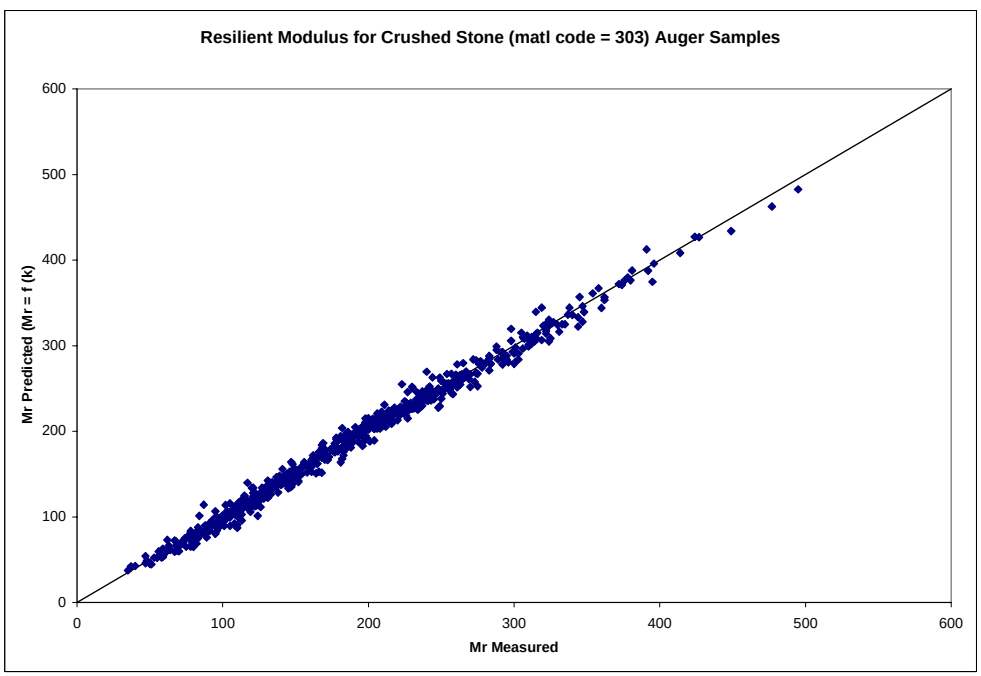

Figure 6. Comparison of measured and predicted resilient modulus (from regressed k values from measured M_R data) for the crushed stone materials sampled from the auger locations.

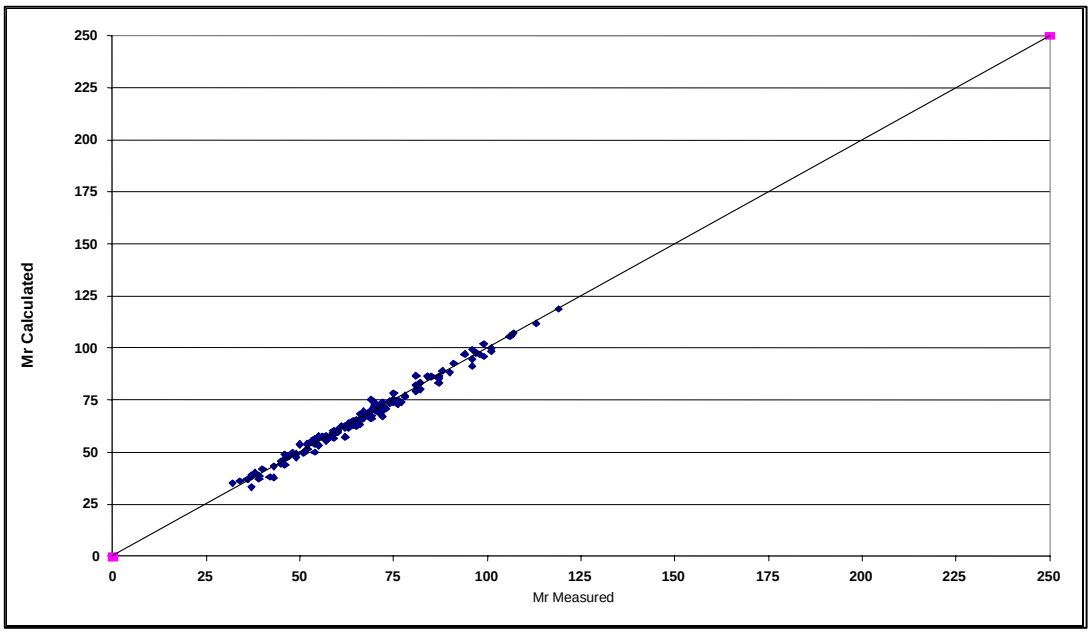

Figure 7. Graphical comparison of the calculated M_R (using the regressed k-coefficients from the LTPP test results) to the measured M_R for the gravel soils.

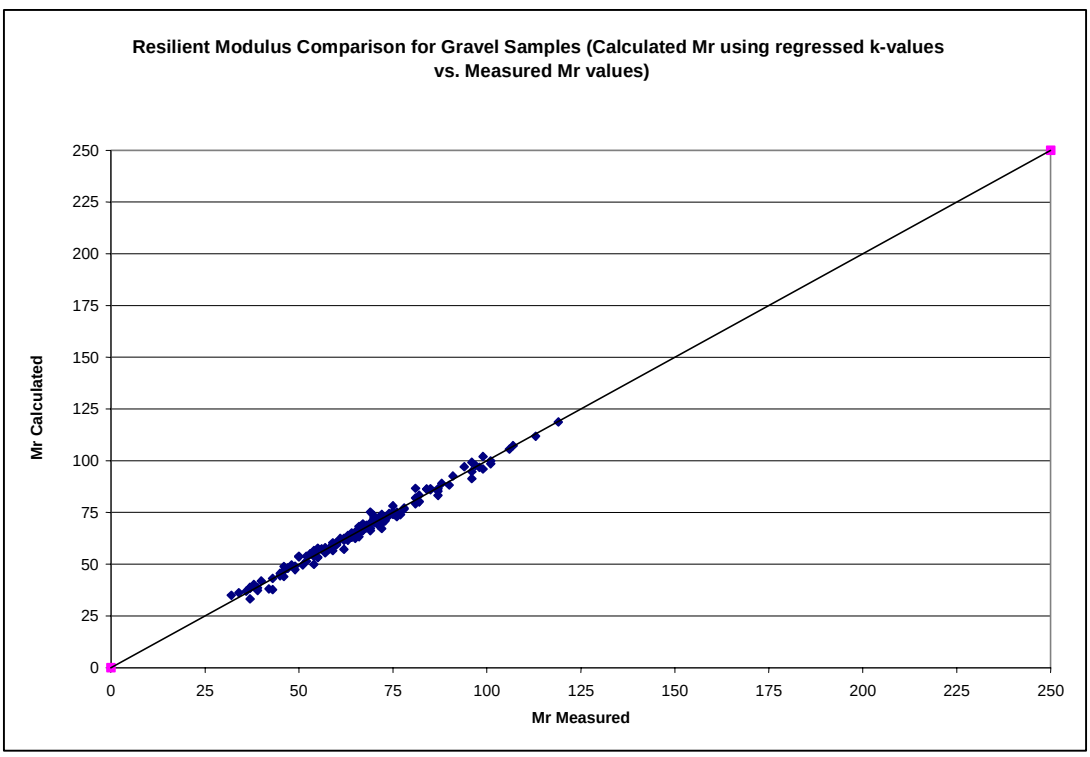

Figure 8. Graphical comparison of the calculated M_R (using the regressed k-coefficients from the LTPP test results) to the measured M_R for the clay soils.

IDENTIFICATION OF TEST DATA ANOMALIES

Approximately 10 percent of the regression results for the k-coefficients have s_e/s_y values greater than 0.5, suggesting that the regressions are not good fits. The reason for the poor fit could be a result of errors that occurred during the test procedure or that the constitutive equation does not represent the actual behavior of selected unbound materials and soils. It is important to ensure that the data are of good quality and without errors prior to making an assessment on the applicability of equation 3. Some possible problems that can occur during the M_R test are listed below:

- Different conditioning sequences or different stress application sequences used in the test program.
- Leaks occurring in the membrane during the test (i.e., an unconfined test).
- Different stress states (applied stress and confining pressure) used in the test program than required by the test protocol.
- Test specimens that begin to fail or exhibit disturbance at the higher stress states.
- LVDT clamps that begin to move or move suddenly because of vibrations during the loading sequence.
- LVDTs that begin to drift during the testing sequence or become restricted due to friction in the measurement system.
- Measured deformations that begin to exceed the linear range of the LVDTs.

The second objective of this study was to identify any possible anomalies that may exist in the resilient modulus database and to determine their possible cause. The process used to identify and flag the resilient modulus test data, with possible anomalies, is summarized below:

Step 1. The resilient modulus test data were organized by material type or code for the review.

Step 2. A regression analysis was conducted of the resilient modulus test data to define selected statistical parameters of the relationship between stress and resilient modulus.

Step 3. A correlation matrix of the resilient modulus test data (resilient modulus correlation with bulk stress and octahedral shear stress) was determined.

Step 4. A summary of the results from the regression (R^2, s_e/s_y) and correlation matrix by material type was prepared.

Step 5. The resilient modulus tests, with possible anomalies, using the following criteria or threshold values, were identified and flagged:

*R^2<0.99

*s_e/s_y>0.50

*Absolute Values of the Correlation Matrix <0.50

Step 6. For those resilient modulus tests that were flagged, a graphical presentation of the data was prepared for a detailed review to confirm the test data anomaly, identify any similarities between these data sets or tests, and determine the probable cause of and recommend an action for the anomaly. If an anomaly could not be observed in the graphical presentation of the data, the M_R test was de-flagged.

Previous studies have found that equation 3 is a good simulation of the measured responses from repeated-load resilient modulus tests. The authors have also found that many anomalies that can and do occur in resilient modulus tests are difficult to identify after the testing has been completed. To ensure that all possible anomalies or discrepancies in the resilient modulus data were identified, fairly restrictive criteria or threshold values were used, as noted in Step 5. These threshold values were used to ensure that the test results were initially reviewed for which equation 3 is not an extremely close mimic of the test results. Simply flagging the test data does not mean that the test results have anomalies. Some of the tests were critically reviewed and were de-flagged because no anomaly could be identified, as noted in Step 6.

Out of 1,920 M_R tests, 212 were flagged using the criteria in Step 5 above. These tests (resilient modulus versus vertical stress) were plotted for the detailed review, as described in step 6. As an example, graphical presentations of the flagged and non-flagged resilient modulus test data summarized in table 3 are shown in figures 9 through 13 and explained briefly below.

- Figures 9 and 10 for test sections 014073 and 480802, respectively, were flagged (see table 3). The resilient modulus test from test section 014073 (figure 9) is characteristic of a coarse-grained soil. The M_R increases with increasing confining pressure as expected. However, the incremental change in M_R increases with repeated vertical stress for the lowest and highest confining pressures, while the incremental change in resilient modulus decreases with increasing repeated vertical stress for the mid-range confining pressure. This characteristic can be the result of binding (friction) in the LVDT core, which can restrict movement of the LVDTs at the lower or smaller repeated vertical loads for a specific confinement level. Figure 10, for test section 480802, shows that the M_R increases with confining pressure between the lower and mid-range confinement, but significantly decreases for the highest confinement, implying a softening effect. In addition, the M_R increases between the first two repeated vertical stresses applied to the test specimen, but then continues to decrease with increasing repeated vertical stresses. This characteristic can be caused by leaks developing in the membrane during the application of the series of vertical loads for the mid-range confinement. Both tests (figures 9 and 10) were identified as questionable.

- The resilient modulus test on section 352007 initially was flagged (see table 3). Figure 11 shows that the resilient modulus test from this test section is characteristic of fine-grained soils. Fine-grained soils typically soften (decreasing resilient modulus) with increasing

vertical pressures. However, no anomalies were observed in the test data. Since no anomaly was observed, this test was de-flagged. The statistical parameters from the regression for the k-coefficients for this test suggest that the constitutive equation may not describe the material/soil response characteristics accurately.

- Figures 12 and 13 for test sections 390209 and 481093, respectively, were not flagged because they meet all of the above criteria. These graphs of non-flagged data are provided for comparative purposes.

After step 6 was completed, 185 M_R tests were flagged for potential anomalies (about 10 percent of the tests). These flagged M_R tests were divided into seven groups of anomalies that are defined in table 4. Figures 14 through 20 are graphical examples for each potential anomaly.

Table 3. Example results of the statistical analyses of the repeated-load resilient modulus tests performed on unbound pavement materials and soils from the LTPP test sections.

STATE CODE	SHRP ID	LAYER NO.	TEST NO.	LOC NO.	SAMPLE NO.	R^2	S_E/S_Y	MATL CODE	N Cycles	Correlations with M_R		M_R Test Initially Flagged
										BULK STRESS	BULK STRESS	
1	4073	3	1	BA*	BG**	0.8508	0.7095	308		0.2039	0.8829	2
35	2007	2	1	BA*	BS**	0.9873	0.8197	309	15	0.6279	-0.3566	2
39	0209	2	1	B22	BG22	0.9996	0.0676	303	15	0.9959	0.7118	
48	0802	3	2	B4	BG01	0.9924	1	302	13	-0.4163	0.0445	2
48	1093	2	1	BA*	BG**	0.9995	0.0469	303	15	0.9985	0.8394	

* - reference to LTPP database code list
** - reference to LTPP database code list

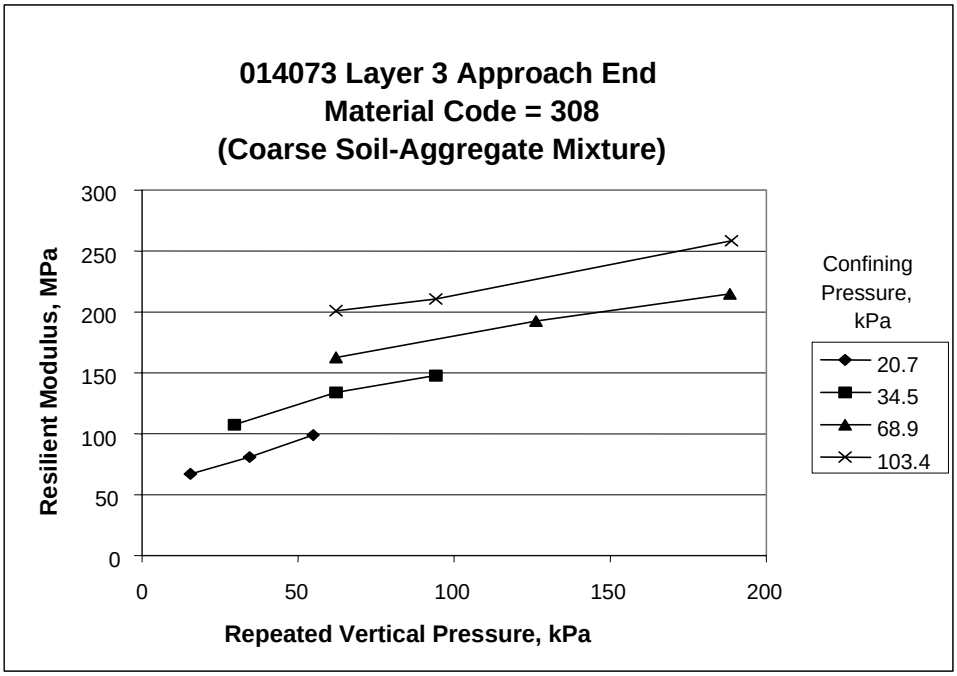

Figure 9. Repeated-load resilient modulus test results for section 014073, layer 3, at the approach end.

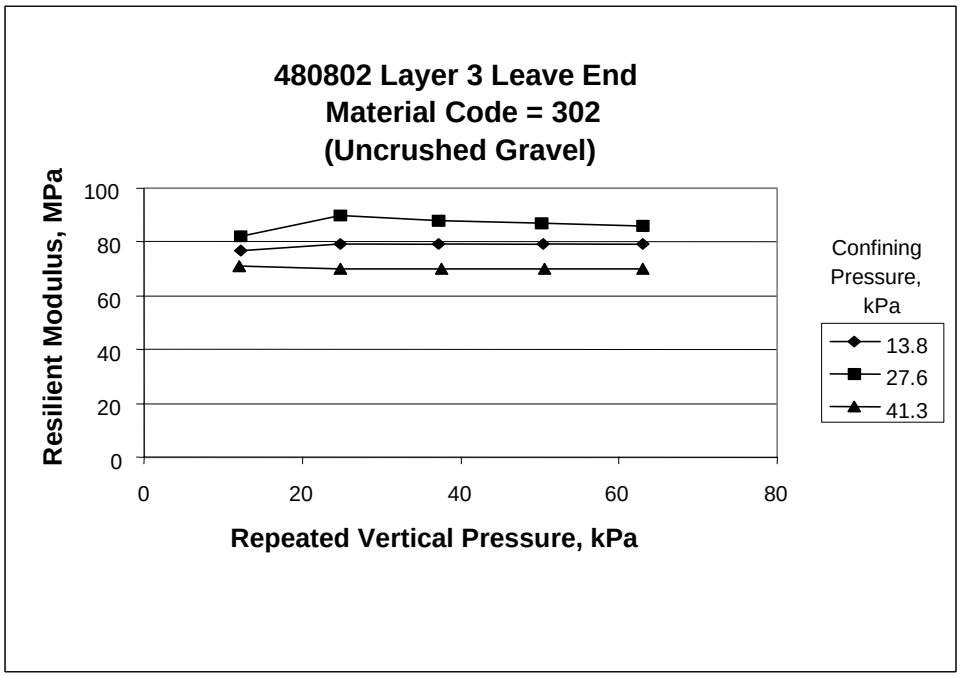

Figure 10. Repeated-load resilient modulus test results for section 480802, layer 3, at the leave end.

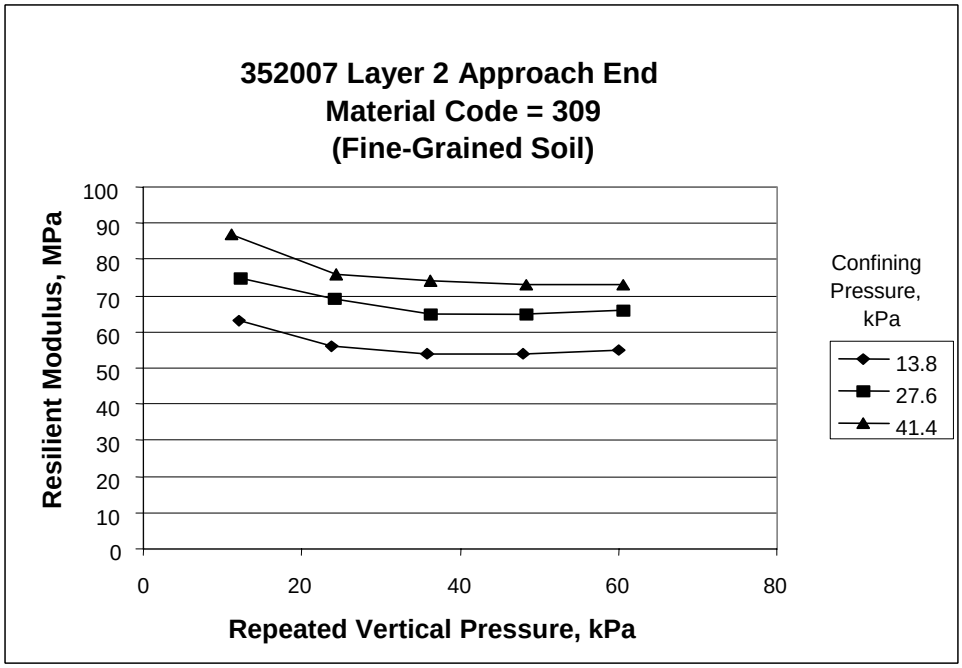

Figure 11. Repeated-load resilient modulus test results for section 352007, layer 2, at the approach end.

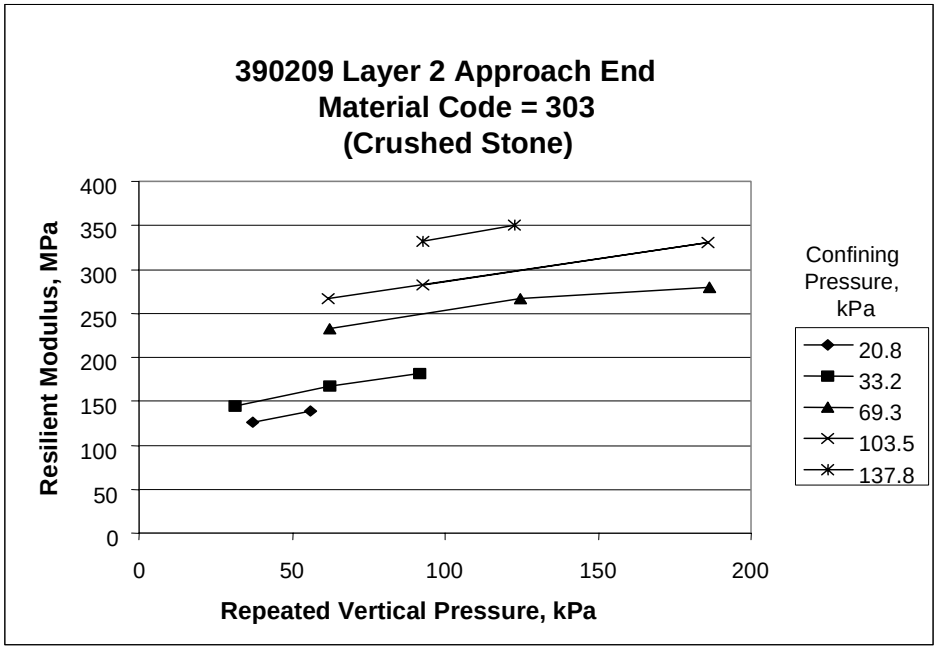

Figure 12. Repeated-load resilient modulus test results for section 390209, layer 2, at the approach end.

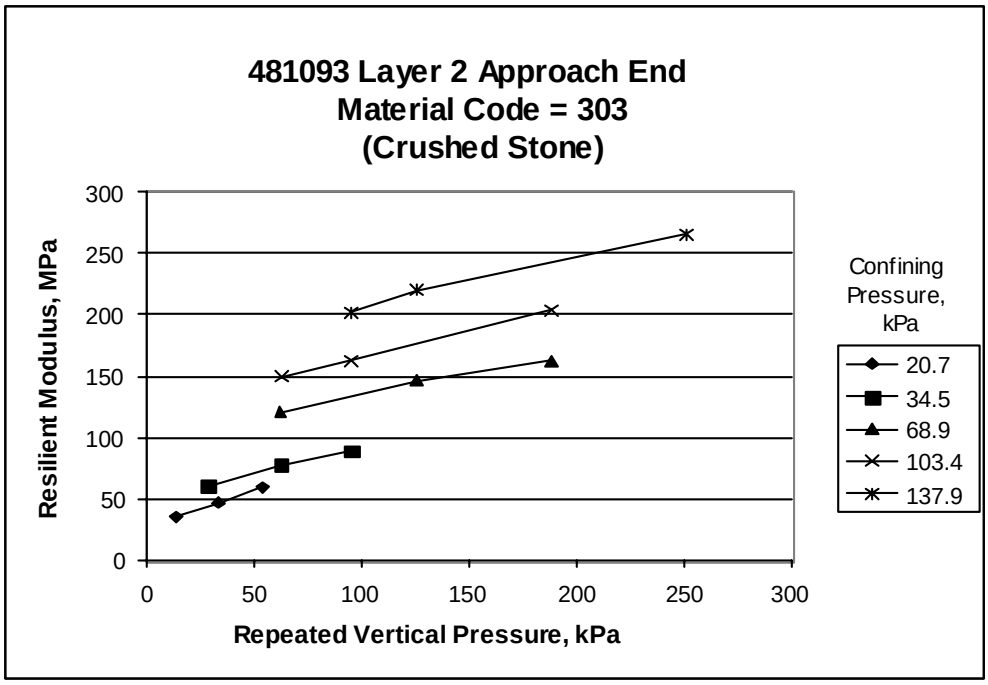

Figure 13. Repeated-load resilient modulus test results for section 481093, layer 2, at the approach end.

Table 4. Summary of identified anomaly types.

Type of Anomaly	Definition of Anomaly	Number of M_R Tests
Type 1	Potential disturbance or excessive softening of test specimen at the higher repeated vertical stresses.	17
Type 2	Big gap between confining pressure for the lower repeated loads, which reduces or begins to merge for the higher loads.	15
Type 3	A sudden drop in M_R for a specific confinement, after which the M_R continues to increase with higher vertical loads.	10
Type 4	The different confinement curves cross – one confinement has a different stress sensitivity than the other confinement curve.	103
Type 5	The curves for each of the confining pressures are completely out of order (e.g., highest confinement below mid-confinement).	11
Type 6	All confinements show nearly the same M_R for the lower repeated vertical loads.	20
Type 7	Possible data entry error with both the M_R and vertical stress at zero.	9

- *Type 1 Anomaly Example – Figure 14.* This test shows that the M_R increases and then decreases with increasing repeated vertical loads for each confining pressure. These results are characteristic of specimen disturbance or excess softening at the higher repeated vertical loads. More examples of type 1 anomalies are presented in appendix B, figures 34 through 37.

- *Type 2 Anomaly Example – Figure 15.* This test shows large gaps between different confining pressures for the lower repeated loads (i.e., significant effect of confining pressure), which decreases to almost no effect of confining pressure at the higher repeated loads. In other words, the M_R for the different confining pressures merge with increasing repeated vertical loads. More examples of type 2 anomalies are presented in appendix B, figures 38 through 41.

- *Type 3 Anomaly Example – Figure 16.* This test shows a sudden drop and then increase in the M_R for the highest confining pressure, while the M_R slightly decreases with increasing repeated vertical loads for the two lower confining pressures. This anomaly can be characteristic of re-zeroing the LVDTs in the middle of the test or an unstable LVDT clamp as the specimen deforms under load. More examples of type 3 anomalies are presented in appendix B, figures 42 through 45.

- *Type 4 Anomaly Example – Figure 17.* The change in M_R with increasing repeated vertical loads do not follow the same trend or have the same stress sensitivity for the different confining pressures. In other words, one confining pressure exhibits stress-hardening characteristics, while another exhibits stress-softening characteristics. This characteristic can be the result of restrictions in LVDT movement or unstable LVDT clamps. A majority of the flagged tests fall into this category (see table 4). More examples of type 4 anomalies are presented in appendix B, figures 46 through 49.

- *Type 5 Anomaly Example – Figure 18.* The curves of resilient moduli for the different confining pressures are out of order. The highest confining pressure results in lower resilient modulus. This anomaly can be characteristic of leaks that develop in the membrane during the test. Additional examples of type 5 anomalies are presented in appendix B, figures 50 through 53.

- *Type 6 Anomaly Example – Figure 19.* All confining pressures show nearly the same resilient modulus at the lower repeated vertical loads. In other words, the resilient modulus is independent of confining pressure for the lower repeated vertical loads, but dependent on confinement for the higher loads, in direct opposition to a type 2 anomaly. Additional examples of type 6 anomalies are presented in appendix B, figures 54 through 57.

- *Type 7 Anomaly Example – Figure 20.* There appears to be a data entry error with both the resilient modulus and the vertical stress at zero. More examples of type 7 anomalies are presented in appendix B, figures 58 through 61.

All anomalous data (measured responses and computations) should be checked to confirm that the data are correct. If correct, the data should be removed, a comment should be added to the test result (i.e., "possible anomalous data"), or the material from the specific layer and location should be retested. It is suggested that the flagged samples be retested, because none of the test sections had the same layer or material flagged from both ends of the same section.

For tests where more than one anomaly type is present, the type that best describes the data anomaly was selected. Anomaly types 3, 4, and 5 are usually a result of laboratory test problems. Anomaly types 1, 2, and 6 could be representative of the inability of the selected constitutive equation to describe the soil's response characteristics. Twenty-seven flagged M_R tests were de-flagged after step 6, resulting in 185 tests that were identified as having potential anomalies. This represents just over 8 percent of the M_R tests for which the constitutive equation does not accurately describe the material/soil response characteristics.

Feedback reports were prepared to identify and document those tests with possible anomalies by the seven groups and the reports were submitted to FHWA. [Tables 17 through 23 in appendix C summarize the anomaly types 1 through 7, respectively, along with the anomaly's initial description for each flagged test.]

Observation: Almost 92 percent of the LTPP M_R tests have response characteristics that are accurately simulated by the "universal" constitutive equation selected for the 2002 Design Guide.

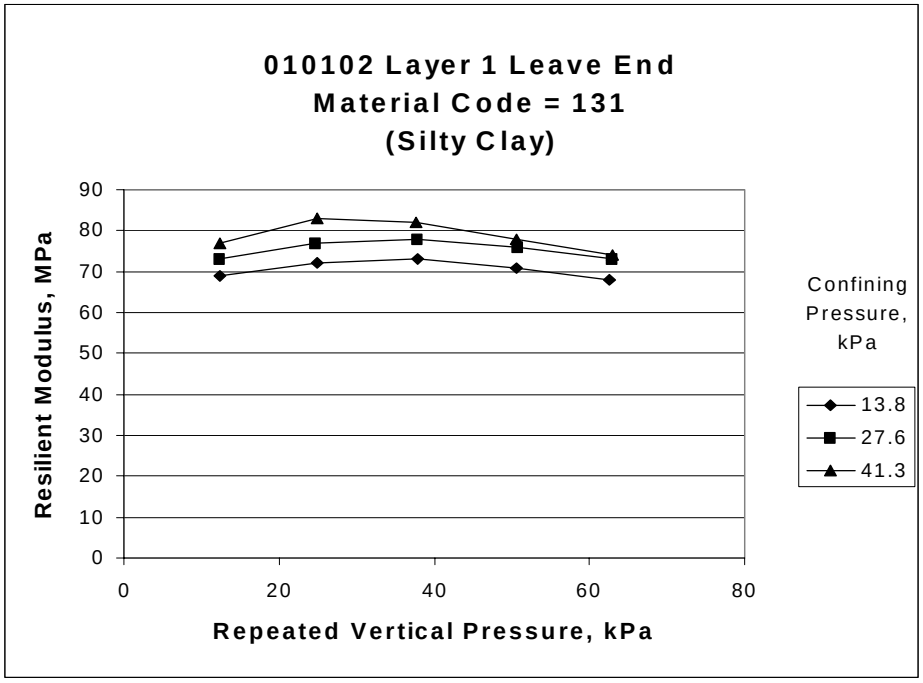

Figure 14. Sample from test section 010102, layer 1, at the leave end exhibits specimen distortion or excess softening.

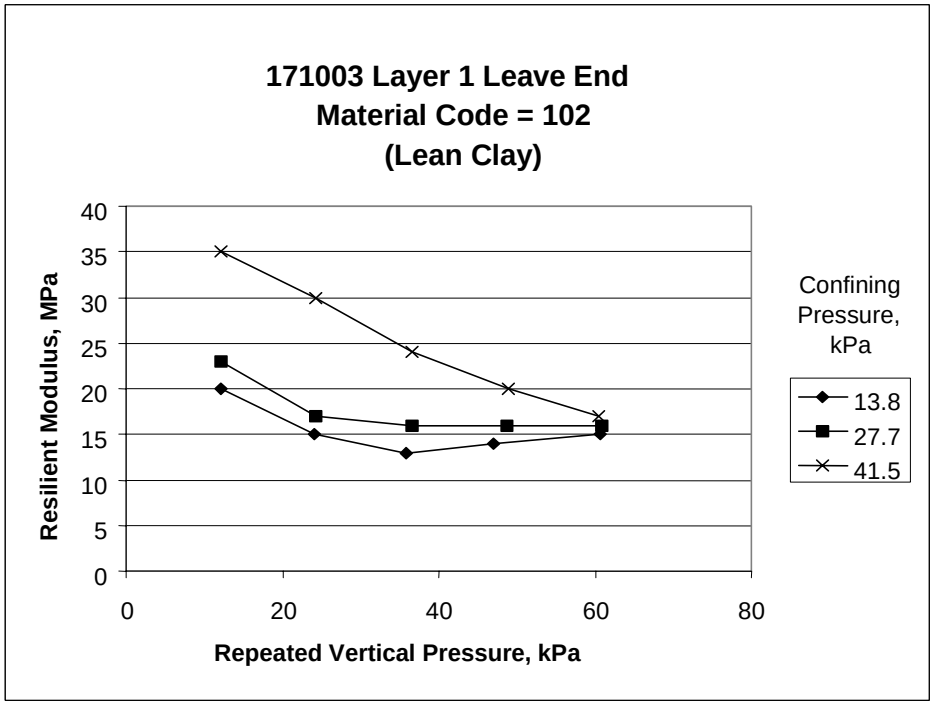

Figure 15. Sample from test section 171003, layer 1, at the leave end shows significant effect of confining pressure on resilient modulus.

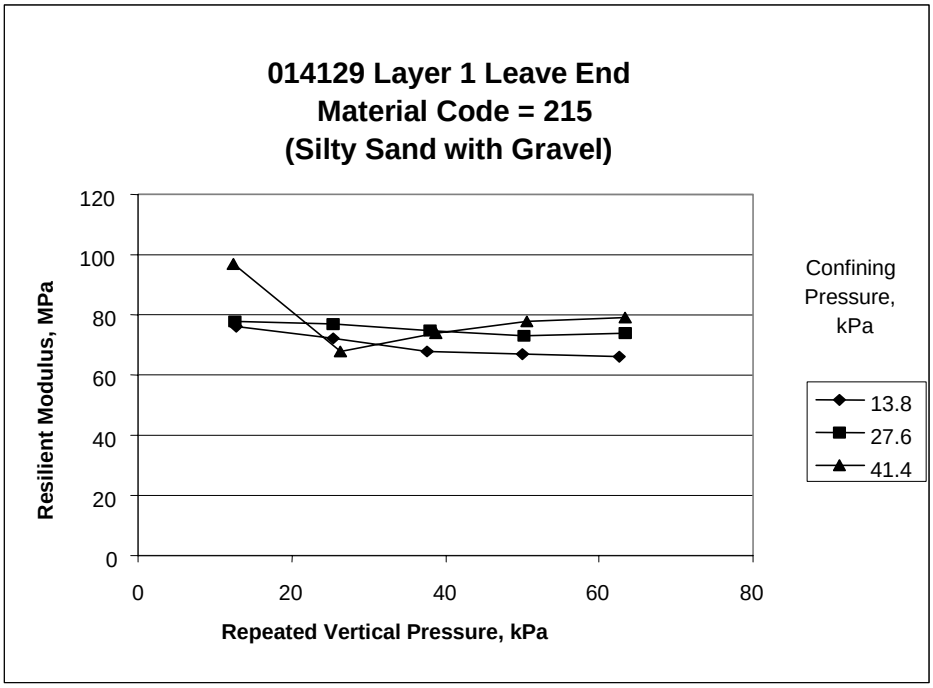

Figure 16. Sample from test section 014129, layer 1, at the leave end shows sudden drop and then increase in resilient modulus.

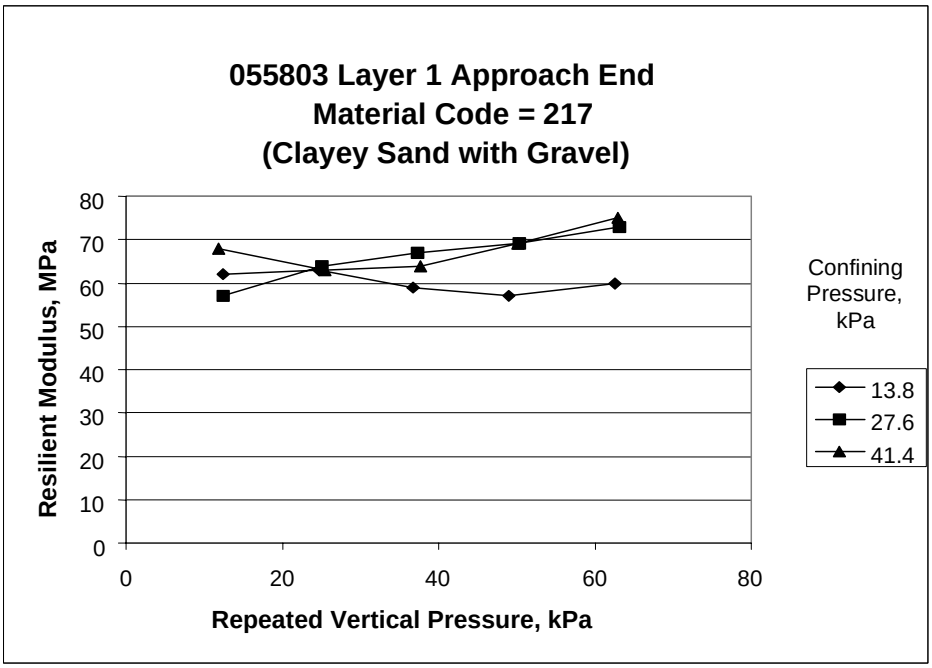

Figure 17. Sample from test section 055803, layer 1, at the approach end exhibiting localized softening or disturbance of the specimen during the test or LVDT movement.

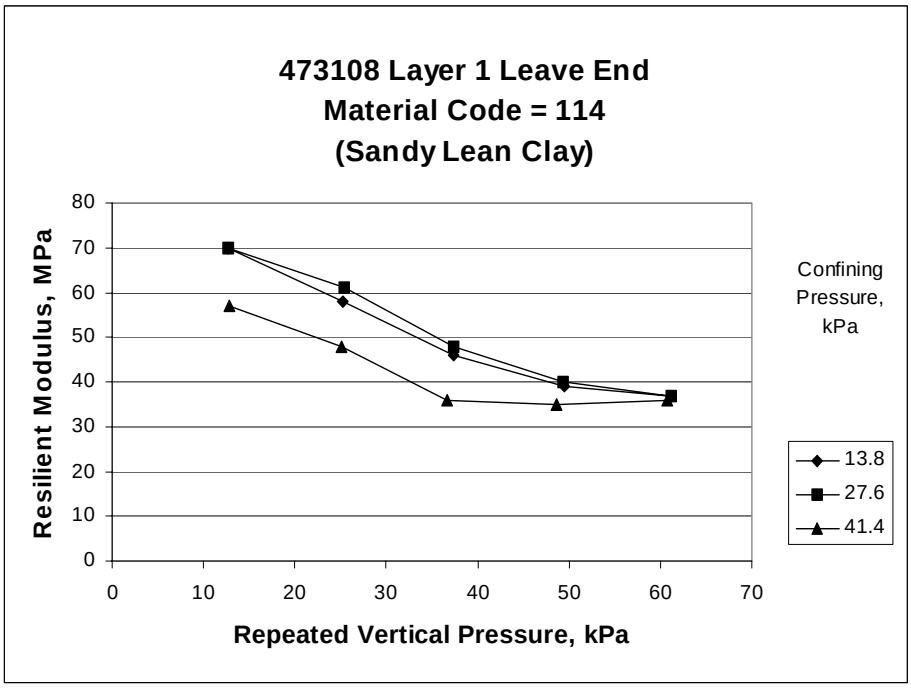

Figure 18. Sample from test section 473108, layer 1, at the leave end shows higher confining pressures result in lower resilient modulus.

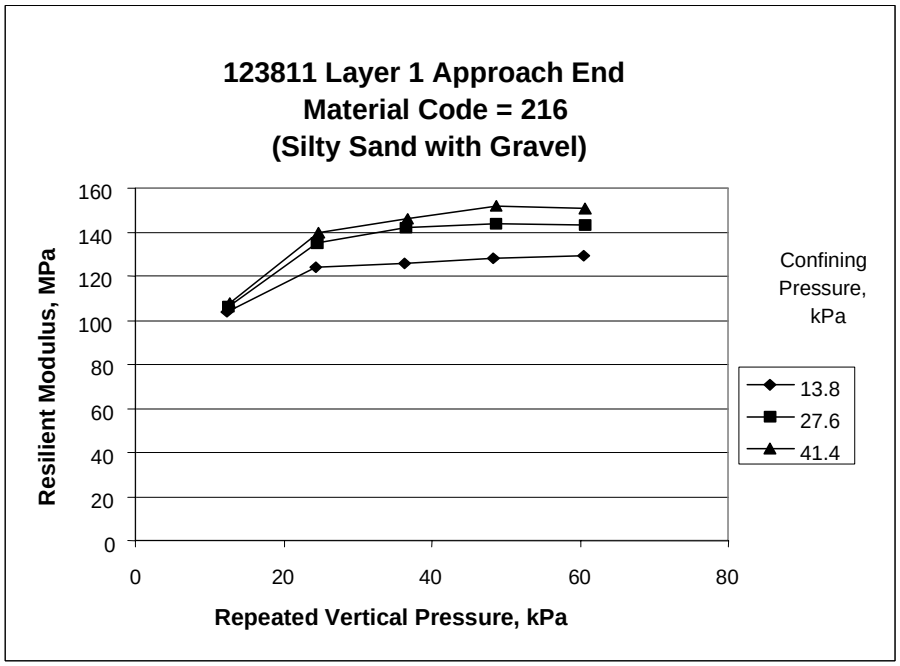

Figure 19. Sample from test section 123811, layer 1, at the approach end shows that resilient modulus is independent of confining pressure at the lowest vertical stress.

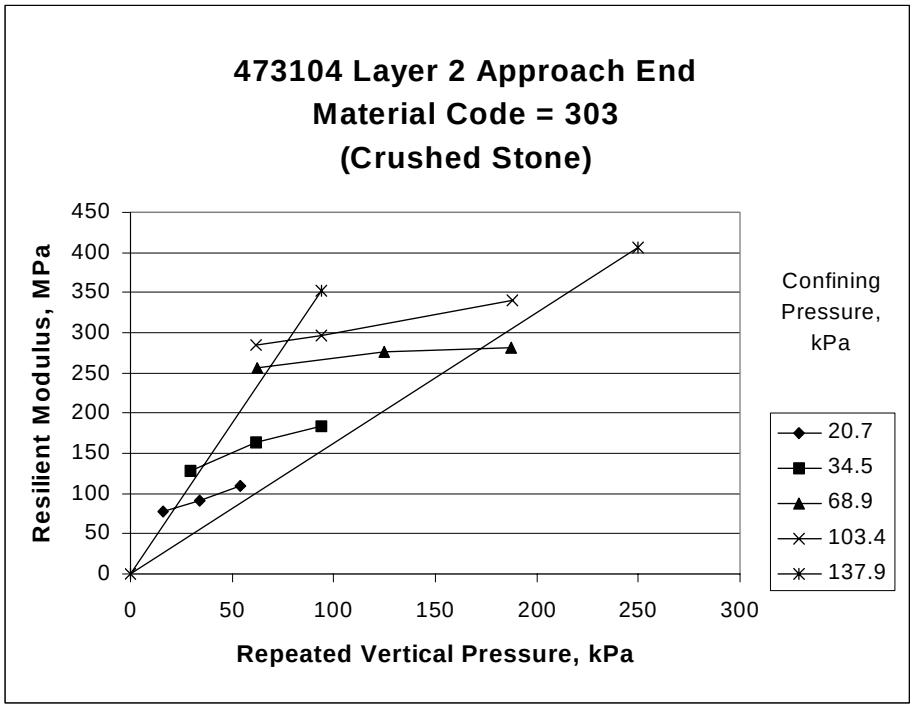

Figure 20. Sample from test section 473104, layer 2, at the approach end shows possible data entry error.

CHAPTER 3. EFFECT OF SAMPLING TECHNIQUE ON RESILIENT MODULUS

As mentioned in chapter 1, previous studies have shown that the M_R can be affected by sampling technique and errors that may occur during the testing program. Chapter 2 focused on identifying anomalies in the resilient modulus test data, while this chapter focuses on the effect of sampling technique.

The materials used for the resilient modulus tests were obtained from one of three sampling techniques: (1) pavement materials and soils sampled from the augers, (2) pavement materials and soils removed from test pits, and (3) soils extracted from Shelby tubes. The difference between auger-test pit samples and auger-Shelby tube samples was evaluated using the cleaned data set (i.e., excluding the anomalies).

There are three other factors, however, that can cause variability and possible bias in the resilient modulus test data. These factors include: (1) the use of different testing contractors and/or operators, (2) test specimen preparation technique, and (3) material variation along a project. Each of these potential sources of variation in resilient modulus test data was considered in evaluating the effect of sampling technique on resilient modulus, with the exception of testing contractor and/or operator.

DATA GROUPS EVALUATED – SOURCES OF VARIABILITY

The laboratory test procedure used for coarse-grained soils (base/subbase materials) is different from that used for fine-grained soils. To eliminate the testing procedure effect, the base/subbase materials were evaluated separately from the subgrade soils. Typical testing errors that can occur during repeated load resilient modulus testing were assumed to be random within a specific material/soil group. Random errors should have no bias on the effect of sampling technique on the resilient modulus test results.

In coarse-grained materials, the sampling technique used can change the gradation of the material. The base/subbase materials were grouped by material codes as defined using LTPP terminology. For each base/subbase group, resilient modulus test results for the auger samples were compared to the test pit samples for each site. The auger versus test pit samples analysis was repeated for the subgrade soils since coarse-grained soils also are present in the subgrade. The resilient modulus for both data groups (test pit and auger samples) was measured on test specimens recompacted to the moisture content and density of the in-place materials. Differences caused by the compaction process or moisture content and density differences between the in-place material and test specimens were assumed to be random within a specific materials/soil group.

The subgrade soils were grouped by soil type (i.e., clay, gravel, sand, and silt). The difference between auger and Shelby tube samples was evaluated because the undisturbed samples in thin-walled Shelby tubes were retained for nearly 2 years prior to removal and testing for some of the test sections. As noted above, moisture content and density differences exist between the

undisturbed (Shelby tube sample) test specimens and those recompacted in the laboratory (augured or test pit samples). However, these differences were assumed to be random within each soil group and have no bias on the effect of sampling technique on the resilient modulus test results.

Materials and soils recovered from the test pits were always taken from the leave end of the test section, while the augured materials and soils were taken from the approach end. Although this represents a systematic difference due to sample location, there is no reason these materials and soils would be consistently different between the ends of the test section. The location of the GPS test sections was selected at random along a project. The differences between the ends of a test section due to sample location were assumed to be random.

Table 5 lists the data groups evaluated for both the base/subbase materials and subgrade soils. The test results that were compared included the M_R at specific stress states and the regressed k-coefficients of the constitutive equation (equation 3). The first comparison was completed on the M_R measured at each stress state. This comparison was then followed by a comparison of the regressed k-values from equation 3. Comparisons of the k-values were completed to determine if there is an effect due to sampling differences on a specific part of the constitutive equation that is not detected by the individual M_R.

Table 5. Data groups for the base/subbase and subgrade soils.

Pavement Layer Type	Material Code/Type*	Number of Tests by Sampling Technique			Total Number of Tests
		Auger	Test Pit	Shelby Tube	
Base/Subbase	All	405	212	NA	617
	302, Uncrushed Gravel	48	33	NA	81
	303, Crushed Stone	63	46	NA	109
	304, Crushed Gravel	32	17	NA	49
	306, Sand	47	19	NA	66
	307, Fine-Grained Soil-Aggregate Mixture	22	10	NA	32
	308, Coarse-Grained Soil-Aggregate Mixture	127	60	NA	187
	309, Fine-Grained Soil	65	27	NA	92
Subgrade Soil	All	476	319	456	1,251
	Gravel	78	32	12	122
	Sand	223	150	136	509
	Silt	42	34	32	108
	Clay	133	103	276	512
Total Number of Tests		881	531	456	1,868

Those material codes not listed above had too few M_R tests to be included in the test of significance for the effect of sampling technique.
NA – Not applicable

IDENTIFICATION OF OUTLIERS

The student t-test was used to test any difference in the k-coefficients of samples obtained by different techniques. The student t-test assumes that the data have a normal distribution. Therefore, each data group listed in table 5 was checked initially for normality using the Shapiro-Wilk W Test.[5] The data for some of the groups were not distributed normally. These data then

were checked for outliers using the Mahalanobis outlier distance plot. The identified outliers were removed before the student t-test was performed. For those data sets that were not distributed normally even after removing the outliers, the Welch analysis of variance (ANOVA) test was used to determine if the different data groups were from the same population of data.

COMPARISON OF RESILIENT MODULUS TEST RESULTS

Effect of Stress State

An ANOVA was completed on the M_R measured at the different stress states included in the test procedure to determine if sampling technique has an effect on the test results. The data were first checked for outliers and normality, as noted above. A model of one variable (sampling technique) was used in the ANOVA. The one variable has two choices or discrete values related to sampling the materials – test pits or augers and augers or Shelby tubes.

Results from the one-way ANOVA are summarized in table 6. Table 6 identifies those materials and soils for which the M_R ratio was found to be independent or dependent on stress state. The M_R ratio is defined in table 6. The M_R ratio was found to be independent of stress state for most base/subbase materials and all soils. For the materials and soils for which the M_R ratio is independent of stress state, the M_R ratios determined at each stress state can be combined in the analysis to determine if sampling technique has a significant effect on the test results. Material codes 306 (sand) and 308 (coarse-grained soil-aggregate mixture) were the only materials and soils for which the M_R ratio was dependent on stress state.

Table 6. Results of ANOVA to determine if the resilient modulus ratio (auger versus test pit test specimens) is a function of stress.

Material/Soil Type		ANOVA, Prob.>F	M_R Ratio is a Function of Stress[1]
Base/Subbase Materials	All	0.0238	Yes – Vertical Loads
	302, Uncrushed Gravel	0.3769	No
	303, Crushed Stone	0.2874	No
	304, Crushed Gravel	0.4809	No
	306, Sand	0.0123	Yes – Confinement
	307, Fine-Grained Soil-Aggregate Mixture	0.9112	No
	308, Coarse-Grained Soil-Aggregate Mixture	0.0022	Yes – Vertical Loads
	309, Fine-Grained Soil	0.1057	No
Subgrade Soils	All	0.1598	No
	Gravel	0.4932	No
	Sand	0.6691	No
	Silt	0.8497	No
	Clay	0.3552	No

(1) M_R Ratio = Resilient modulus of test specimens prepared from materials recovered from auger samples divided by the resilient modulus of test specimens prepared from materials recovered from test pits; M_R(Auger)/M_R(Test Pit).

Unbound Aggregate Layers – Test Pit Versus Auger Samples

The samples for the base/subbase resilient modulus test were either obtained from the augering process or from cutting a test pit and removing bulk samples of the material. The augering process can degrade the larger diameter aggregates. Therefore, the resilient modulus test results for the augured samples were compared to the test results for the test pit samples.

The data were first checked for outliers and normality, as noted above. Assuming that the sample variance is equal to the population variance, a student t-test was then performed with a 95-percent confidence level using the following null and alternative hypotheses in comparing the two data sets:

$$H_o: \quad \frac{k_a}{k_{tp}} = 1 \quad \text{or} \quad \frac{M_{Ra}}{M_{Rtp}} = 1$$

$$H_A: \quad \frac{k_a}{k_{tp}} \neq 1 \quad \text{or} \quad \frac{M_{Ra}}{M_{Rtp}} \neq 1$$

Table 7 provides a summary of the results from the ANOVA to determine if the sampling technique auger versus test pits has an effect on resilient modulus. In summary, sampling technique does appear to have a significant effect on the resilient modulus ratio for uncrushed gravel, crushed stone, fine-grained soil-aggregate mixture, and fine-grained soil base material groups. The crushed gravel base material is considered borderline as to the effect of sampling technique on the resilient modulus because the probability value is slightly greater than 0.05 (refer to table 7). Sand and coarse-grained soil-aggregate base materials are the only data groups for which the sampling technique of the base materials appears to have no effect on the M_R ratio.

Table 8 summarizes the probability from the student t-test that the k-coefficients and exponents for the auger and test pit samples are equal. With a 95-percent confidence level, a probability value less than 0.05 rejects the null hypothesis. The shaded cells show the data groups that are indifferent.

No difference was observed when all the base/subbase materials were tested together. However, when the materials are grouped by material codes, k_{1a} and k_{1tp} were different from each other for the uncrushed gravel. For the crushed stone material, both k_1 and k_3 were found to be different between augured and test pit samples. Although not all the k-coefficients for the uncrushed gravel and the crushed stone were different, it is reasonable to conclude that the sampling technique has an effect on the M_R test results since k_1 is directly proportional to M_R.

Table 9 provides a summary of the results from the different analyses for comparing the differences between two populations of data that are defined by different sampling techniques using the k-values and resilient modulus. As tabulated, the results are similar for the base and subbase materials, except for the soil-aggregate mixtures.

Table 7. Summary of ANOVA to determine effect of sampling technique (auger versus test pit) on resilient modulus.

Material/Soil Type		Stress State(1)	Median M_R Ratio	Mean M_R Ratio	Standard Deviation	ANOVA, Prob.>[t]	Null Hypothesis, M_R Ratio = 1(2)
Base/ Subbase Materials	All	Low	0.9706	0.9763	0.1875	0.2022	Accept
		Medium	1.0000	1.0092	0.1264	0.4308	Accept
		High	1.0000	1.0111	0.1183	0.3146	Accept
	302, Uncrushed Gravel	All Values	1.0253	1.0438	0.1712	<0.0001	REJECT
	303, Crushed Stone	All Values	0.9527	0.9391	0.1621	<0.0001	REJECT
	304, Crushed Gravel	All Values	1.0444	1.0323	0.1841	0.0670	Accept
	306, Sand	Low	0.9706	1.0540	0.1882	0.4143	Accept
		Medium	1.0000	0.9971	0.0539	0.8759	Accept
		High	0.9563	0.9735	0.0664	0.2652	Accept
	307, Fine-Grained Soil-Aggregate Mixture	All Values	1.0041	1.0494	0.1660	0.0145	REJECT
	308, Coarse-Grained Soil-Aggregate Mixture	Low	0.9592	0.9321	0.2097	0.0720	Accept
		Medium	1.0000	1.0124	0.1307	0.5631	Accept
		High	1.0327	1.0253	0.1666	0.3303	Accept
	309, Fine-Grained Soil	All Values	1.0092	1.0331	0.1264	<0.0001	REJECT
Subgrade Soils	All	All Values	1.0476	1.0600	0.2810	<0.0001	REJECT
	Gravel	All Values	1.2226	1.2437	0.2690	<0.0001	REJECT
	Sand	All Values	1.0099	0.9990	0.2016	0.8980	Accept
	Silt	All Values	1.1061	1.0886	0.3112	0.0010	REJECT
	Clay	All Values	1.2803	1.1606	0.3283	<0.0001	REJECT

(1) Low: Confinement = 20.7 kPa, Cyclic Load = 18.6 kPa; Medium: Confinement = 68.9 kPa, Cyclic Load = 124.1 kPa; High: Confinement = 137.9 kPa, Cyclic Load = 248.2 kPa.
(2) Null Hypothesis: M_R(Auger)/M_R(Test Pit) = 1.

Table 8. Summary of the student t-test on the difference between augered and test pit samples for the base/subbase materials and subgrade soils.

Material/Soil Type		Student t-Test Probability (Prob > |t|)		
		k_1	k_2	k_3
Base/Subbase Materials	All	0.2378	0.5846	0.5070
	302, Uncrushed Gravel	0.0260	0.0850	0.3919
	303, Crushed Stone	0.0350	0.1868	0.0025
	304, Crushed Gravel	0.5228	0.7903	0.5193
	306, Sand	0.3149	0.1512	0.7767*
	307, Fine-Grained Soil-Aggregate Mixture	0.4134	0.3213	0.8316
	308, Coarse-Grained Soil-Aggregate Mixture	0.3731	0.4863	0.0192*
	309, Fine-Grained Soil	0.3931	0.6256	0.4354
Subgrade Soils	All	0.0328	0.0013	0.6553
	Gravel	0.0710	0.9120	0.0169
	Sand	0.8287	0.0050	0.3052
	Silt	0.1059	0.1569	0.2512
	Clay	0.1153	0.1594	0.9407

*Student t-test not valid because sample population not normally distributed.

Table 9. Comparison of results using k-values and resilient modulus values to determine effect of sampling technique (auger versus test pits) on resilient modulus test data.

Material/Soil Type		k-Values; Hypothesis, $k_a/k_{tp} = 1$			M_R Values; Hypothesis, $M_{Ra}/M_{Rtp} = 1$
		k_1	k_2	k_3	
Base/Subbase Materials	All	Accept	Accept	Accept	Accept
	302	REJECT	Accept	Accept	REJECT
	303	REJECT	Accept	REJECT	REJECT
	304	Accept	Accept	Accept	Accept
	306	Accept	Accept	Accept	Accept
	307	Accept	Accept	Accept	REJECT
	308	Accept	Accept	REJECT	Accept
	309	Accept	Accept	Accept	REJECT
Subgrade Soil	All	REJECT	REJECT	Accept	REJECT
	Gravel	Accept	Accept	REJECT	REJECT
	Sand	Accept	REJECT	Accept	Accept
	Silt	Accept	Accept	Accept	REJECT
	Clay	Accept	Accept	Accept	REJECT

Observation: Sampling technique of base materials (auger versus test pit samples) has an effect on the M_R test results for the uncrushed gravels and crushed stone materials.

Soils – Test Pit Versus Auger Samples

Table 7 summarizes the difference between the resilient modulus measured on test specimens prepared from soils recovered from test pit samples and those from augured samples. As tabulated, the resilient modulus values are different for all subgrade soil groups with the exception of sand. This observation is consistent with previous experience.

The difference between the k-coefficients regressed from M_R tests performed on test specimens compacted from auger and test pit samples was evaluated for the subgrade soils. Table 8 summarizes the findings of the analysis and comparisons. The shaded cells show the data groups that are the same, i.e., student t-test probability greater than 0.05.

Differences were observed for k_1 and k_2 of the overall subgrade data group, k_3 of the gravel group, and k_2 of the sand group. Note that some differences in the exponents were found for the coarse-grained soils, but no differences were found for the fine-grained soils. This observation is consistent with the base/subbase materials, with the exception of the crushed gravels (material code 304) and sands (material code 306).

Based on the results summarized in table 9, the sampling effect on the M_R ratio is dependent on the type of analysis. Since only one k-coefficient was found to be different for the gravel and sand soil groups, the effect of sampling technique (auger versus test pit) is believed to be small. However, comparison of the M_R ratio suggests that there is a difference caused by sampling technique for all soils, but sand.

Soils – Shelby Tubes (Undisturbed) Versus Recompacted (Disturbed) Samples

The undisturbed samples recovered from thin-walled Shelby tubes were retained in the tubes in some cases for nearly 2 years prior to removal and testing. The effect of storage time in the Shelby tubes on resilient modulus is unknown. However, the M_R of some high-plasticity clays is known to be sensitive to sample preparation (disturbed versus undisturbed test specimens). Therefore, the M_R test results in the LTPP database were evaluated to determine if there are significant differences in the regressed k-coefficients between the Shelby tubes (undisturbed) and recompacted (disturbed) samples. The effect of time retained in the Shelby tubes was not studied because there were too few M_R tests within each of the subgroups at different times.

For each of the data groups listed in table 5, the data were first tested for outliers, normality, and equal sample variances. Student t-tests were then performed with a 95-percent confidence level and the following null and alternative hypotheses:

H_o: $k_a = k_{ST}$ or $M_{Ra} = M_{RST}$

H_A: $k_a \neq k_{ST}$ or $M_{Ra} \neq M_{RST}$

Table 10 summarizes the effects of sampling technique on the measured resilient modulus between undisturbed and disturbed subgrade soil samples. As shown, the resilient modulus is affected by sampling technique for all soil groups, with the exception of sand. This finding is consistent with the previous experience of the authors.

Table 10. Summary of ANOVA to determine effect of sampling technique (Shelby tube versus auger) on resilient modulus.

Soil Type	Variances		Welch ANOVA Testing of Means With Unequal Variances, Prob.>*F*	ANOVA Testing of Means With Equal Variances, Prob.>*F* or Prob.>[t]	Absolute Difference — LSD	Null Hypothesis; M_R(Shelby Tube), Undisturbed = M_R(Auger), Disturbed
	Prob.>*F*	Equal Variances?				
All	<0.0001	No	<0.0001	---	6.034	REJECT
Gravel	0.0045	No	<0.0001	---	11.653	REJECT
Sand	<0.0001	No	0.2725	---	-0.514	Accept
Silt	0.5582	Yes	---	<0.0001	9.964	REJECT
Clay	0.9484	Yes	---	<0.0001	10.582	REJECT

Table 11 summarizes the probability from the student t-test that the k-coefficient and exponents for the undisturbed and disturbed samples are equal. With a 95-percent confidence level, a probability value less than 0.05 rejects the null hypothesis. The shaded cells show the data groups that are indifferent. Five of the data groups failed the equal variance test. For these five groups, the Welch ANOVA test was used instead, as noted above.

Table 11. Summary of the student t-test on the difference between disturbed and undisturbed samples for the subgrade soils.

Material Type	Student t-Test Probability (Prob > |t|)		
	k_1	k_2	k_3
All	0.7475	<0.0001*	<0.0001*
Clay	0.0314	0.8948*	0.0002
Gravel	0.5080	0.2379	0.0001
Sand	0.8865	0.0122	0.7961*
Silt	0.9978*	0.1687	<0.0001

* Welch ANOVA testing equal means, allowing unequal variance.

The shaded cells show the data groups that are the same within a 95-percent confidence level (student t-test probability greater than 0.05). As shown, at least one of the k-coefficients for all groups tested was different. The coefficients from the undisturbed (Shelby tube) and disturbed (auger and test pit) data sets were found to be different for k_1 of the clay soils, k_2 of the overall and sand soil groups, and k_3 of all soil groups, except for sand. Separating the subgrade into soil types reduced the sampling effect except for the clay soils. It is recommended that the M_R results for the clay soils be considered different between the disturbed and undisturbed test specimens. Since only one k-coefficient was different for the other soil types, any sampling effect is considered small for these soil types, especially since k_3 was zero for several M_R tests.

Observation: Sampling technique of subgrade soils (undisturbed versus disturbed test specimens) has an effect on the M_R test results for the clay soils.
Observation: Sampling technique of base and subgrade soils has no effect on the M_R test results for sand base materials and soils.

Table 12 summarizes the results from the different analyses for comparing the differences between two populations of resilient modulus data that are defined by different sampling techniques using the k-values and resilient modulus. As shown, the results are similar for the subgrade soils.

Table 12. Comparison of results using k-values and resilient modulus values to determine the effect of sampling technique of undisturbed (Shelby tubes) and disturbed (auger) test specimens on resilient modulus test data.

Soil Type	k-Value; Hypothesis, $k_a = k_{st}$			M_R Values; Hypothesis, $M_{Ra} = M_{Rst}$
	k_1	k_2	k_3	
All	Accept	REJECT	REJECT	REJECT
Gravel	Accept	Accept	REJECT	REJECT
Sand	Accept	REJECT	Accept	Accept
Silt	Accept	Accept	REJECT	REJECT
Clay	REJECT	Accept	REJECT	REJECT

SUMMARY

The data groups listed in table 5 were analyzed for the effects of sampling techniques. All materials were tested for differences between auger and test pit samples. The subgrade soils were also tested for differences between disturbed (auger and test pits) and undisturbed (Shelby tube) samples.

Tables 9 and 12 summarize the results from the different analyses for comparing the differences between two populations of resilient modulus data that are defined by different sampling techniques using the k-values and resilient modulus values. Table 9 shows that the auger and test pit samples are different for some of the material groups. The difference was considered significant for the uncrushed gravel, crushed stone, and the overall subgrade data group. However, the difference was insignificant when the soils were divided into the four major soil types (i.e., clay, gravel, sand, and silt). Table 12 shows that the disturbed and undisturbed test specimens are different for the overall subgrade and clay data groups. The difference is only considered significant for the clay soils when the subgrade is divided into the four soil types.

It is interesting to note that the null hypothesis from the ANOVA was rejected when the resilient modulus ratio was found to be independent of the stress states and was accepted for those materials when the resilient modulus ratio was dependent on stress state in all cases, with the exception of base material code 304 (crushed gravel) and sand subgrades (refer to tables 6 and 7). Another interesting observation is that the coarse-grained soils were found to have equal variances between the resilient modulus values measured on undisturbed (Shelby tubes) test specimens and disturbed (auger) test specimens. The significance of these observations is unknown.

Table 13 provides an overall summary comparison of the different statistical methodologies used. Most of the results from these comparisons are consistent with previous experience. The following summarizes the recommendations for further data analyses for each material and soil type:

- All sand base materials can be combined into one group, independent of sampling technique. In addition, all sand subgrades can also be combined into a single group for analysis purposes.

- The resilient modulus of the crushed stone and uncrushed gravel base materials are dependent on the type of sampling technique used to recover samples for testing. These data groups should be kept separate for further data analyses.

- The resilient modulus of the clay soils is dependent on whether the sample is undisturbed (recovered by Shelby tubes) or disturbed (sampled from augers or recovered from test pits and recompacted). These data groups should be kept separate for further data analyses.

- The effect of sampling technique on the remaining data groups is dependent on the type of analysis used. Thus, it is suggested that the different data groups be combined for simplicity, but caution be taken in analyzing and using these data.

These observations are considered important regarding the future use of the repeated load resilient modulus test data in the LTPP database to accomplish the objectives stated in the introduction chapter to this report and some of the overall LTPP objectives. For example, any differences caused by sampling technique must be clearly defined to determine the relationship between laboratory-measured resilient modulus and backcalculated elastic layer modulus.

Table 13. Summary comparison of the resilient modulus test results for different sampling techniques.

Sampling Technique		Consistently Different Results or Different Populations of Data	Borderline – Dependent on Type of Data Used	Consistently Indifferent Results or Populations of Data are the Same
Auger Versus Test Pit	Base and Subbase	302, Uncrushed gravel	307, Fine-grained soil-aggregate mixture	304, Crushed gravel
				306, Sand
				308, Coarse-grained soil-aggregate mixture
		303, Crushed stone	309, Fine-grained soil	
	Subgrade Soils	None	Gravel	Sand
			Silt	
			Clay	
Undisturbed (Shelby Tubes) Versus Disturbed (Auger)	Subgrade Soil	Clay	Gravel	Sand
			Silt	

CHAPTER 4. EFFECT OF PHYSICAL PROPERTIES ON RESILIENT MODULUS

As stated in chapter 1, the M_R is the material property required for all unbound materials and soils for the 1986 and 1993 AASHTO Design Guide.[1] In 1995, Darter, et al., found that about 75 percent of the State Highway Agencies (SHAs) in the United States use either the 1986 or 1993 versions of the AASHTO Design Guide.[6] However, most of these agencies do not routinely measure the M_R in the laboratory. The design M_R is estimated from experience or from other material or soil properties (for example, CBR, R-value, or physical properties).

A potential benefit of estimating the M_R from physical properties is that seasonal variations in resilient modulus can be estimated from seasonal changes in the materials' physical properties. Seasonal variations are critical for determining the design M_R for a particular project. The concept being used in development of the 2002 Design Guide under NCHRP Project 1-37A is to apply the Enhanced Integrated Climatic Model (EICM) to predict changes in the physical properties of unbound pavement materials and soils and to estimate the effect those changes have on the resilient modulus.

Some SHAs have developed relationships between the physical and/or strength properties of the soil and M_R. Determining the M_R from physical properties of unbound materials can capture the effect of the seasonal variations of the M_R as a result of seasonal changes in the material's physical properties, but it does not capture the effect of stress sensitivity. To capture the effects of stress sensitivity, the coefficients of the selected constitutive equation have been regressed for relationships to the soils physical properties. Von Quintus and Killingsworth and Santha, among others, have developed these types of relationships for use in design to capture the effect of stress sensitivity in determining the design M_R.[3,7]

Previous studies have developed relationships between the soil properties and the regressed k-coefficients and exponents of the constitutive model. Those relationships that have good statistics were generally confined to specific soil types.[7] Other studies that have used a wide range of soil types and conditions have generally resulted in poor correlations.[3] The focus of this chapter is to use the cleaned database and determine those physical properties that have an effect on the M_R test results and to determine the accuracy of developing relationships between physical properties and M_R with the LTPP database.

PHYSICAL PROPERTIES USED IN STUDY

The anomalies identified in chapter 2 were removed from the data set based on the April and October 2000 data releases that were used in a nonlinear optimization regression analysis relating the physical properties of the test specimen to the M_R from the constitutive equation. The classification data (including gradation, Atterberg limits, density, moisture, optimum density, moisture contents, and other physical properties) were extracted from the LTPP database of unbound materials. For most LTPP test sections, the strength (e.g., CBR and R-value) of a material or soil is unavailable in the database. Table 14 summarizes all the variables used in the regression analysis and the IMS tables from which the data were extracted. The range, mean,

and median values for each of these variables are included in appendix D for the base and subbase materials and subgrade soils.

Table 14. Summary of the M_R physical property regression variables.

Variable	Description	Table(s) From the IMS
k_1 *(MPa)*	Regression constant of M_R constitutive equation	--
k_2	Regression constant of M_R constitutive equation	--
k_3	Regression constant of M_R constitutive equation	--
$P_{3/8"}$, *%*	Percentage passing 3/8" sieve	TST_SS01_UG01_UG02
$P_{No.\ 4}$, *%*	Percentage passing No. 4 sieve	TST_SS01_UG01_UG02
$P_{No.\ 40}$, *%*	Percentage passing No. 40 sieve	TST_SS01_UG01_UG02
$P_{No.\ 200}$, *%*	Percentage passing No. 200 sieve	TST_SS01_UG01_UG02
% Silt	Percentage of silt	TST_SS02_UG03
% Clay	Percentage of clay	TST_SS02_UG03
LL, %	Liquid limit of soil	TST_UG04_SS03
PI, %	Plasticity index of soil	TST_UG04_SS03
w_{opt}, *%*	Optimum water content	TST_UG05_SS05
$\gamma_{d,\ opt}$ *(kg/m^3)*	Maximum dry unit weight of soil	TST_UG05_SS05
w_s, *%*	Water content of the test specimen	TST_UG07_SS07_A, TST_UG07_SS07_B
γ_s *(kg/m^3)*	Dry density of the test specimen	TST_UG07_SS07_A, TST_UG07_SS07_B

1 in = 25.4 mm

STATISTICAL PROCEDURE

A nonlinear optimization regression analysis was performed using SAS® statistical analysis system software relating the physical properties (listed in table 14) of the test specimen to the M_R used in the constitutive equation on the "clean" data set. A stepwise regression analysis was initially performed relating the physical properties to the resilient modulus to identify the important variables. The procedure combined the forward and backward stepwise regression methods.

A variable (physical property) with a 0.25 probability was selected to enter the regression and was removed with a 0.1 probability to stay. The regression started with no variables in the model. The F statistics were calculated for each independent variable. The variable with the most significant level greater than 0.25 was entered into the model first. All variables were entered individually with this entry criterion. The variables already in the model did not necessarily remain, because after a variable is added, the stepwise method considers all the variables already included and deletes any variable that does not yield an F statistic at a level of significance greater than 0.1. The process was completed when no more variables outside the model had a level of significance greater than 0.25 to enter and 0.1 to delete.

CORRELATION STUDY FOR MODEL DEVELOPMENT

As discussed in chapter 3, the base/subbase materials should be analyzed separately from the subgrade materials. The base/subbase materials were grouped by material code from LTPP terminology for pavement materials and soils. The crushed stone and uncrushed gravel materials

were separated into auger and test pit samples to see the effect of sampling technique as discussed in chapter 3. The subgrade material was grouped by material type (clay, gravel, silt, and sand) and the clay soils were further grouped into: (1) disturbed samples and (2) undisturbed samples.

The test specimens from the Shelby tubes were taken at various depths through the sampling tubes, while the samples from which the physical properties were measured were confined to the top 0.3 m of the subgrade. As a result, the resilient modulus tests and some of the physical property tests could have been performed on entirely different soils. Von Quintus and Killingsworth identified this fact as a problem in completing similar correlations in 1996.[3] Thus, the undisturbed test specimens (Shelby tube samples) were not included in the correlations between resilient modulus and physical properties.

Appendix E summarizes the properties that were found to be important and the resulting statistical measures of the correlation for each of the data groups analyzed. Table 15 presents an overall summary of those physical properties that were found to be important for each material and soil. Observations from these correlation studies are noted below:

- The maximum or optimum dry unit weight was found to be important for all base and subbase material types, with the exception of the fine-grained soil (LTPP material code 309); while the optimum moisture content and percent passing the 3/8-in (9.5 mm) sieve were found to be important for most coarse-grained base materials.

- The plasticity index and the percent passing the No. 40 sieve were the only properties found to be important for the fine-grained soil base material group (LTPP material code 309).

- The water content and percent clay for the test specimen are important for all soil groups.

- The liquid limit is important for all soils except the silt group, while the percent silt is important for all soils except the gravel group.

Table 15. Summary of the physical properties that were found to be important for predicting resilient modulus for each material and soil type.

Independent Variable	Base/Subbase Material							Soils			
	303, Crushed Stone	304, Crushed Gravel	302, Uncrushed Gravel	306, Sand	308, Coarse-Grained Soil-Aggr. Mixture	307, Fine-Grained Soil-Aggr. Mixture	309, Fine-Grained Soil	Gravel	Sand	Silt	Clay
Percent passing 3/8-in sieve, $P_{3/8}$	√	√		√	√	√		√	√		
Percent passing No. 4 sieve, P_4					√	√			√		√
Percent passing No. 40 sieve, P_{40}	√	√		√	√		√				√
Percent passing No. 200 sieve, P_{200}			√		√	√			√		√
Percent Clay, %Clay								√	√	√	√
Percent Silt, %Silt									√	√	√
Liquid Limit, LL	√	√		√		√		√	√		√
Plasticity Index, PI		√		√	√		√	√		√	
Water content of test specimen, W_s		√	√		√			√	√	√	√
Dry density of test specimen, γ_s		√	√		√	√			√		√
Optimum water content, W_{opt}	√	√	√		√	√			√		√
Maximum dry unit weight, γ_{opt}	√	√	√	√	√	√			√		√
Number of M_R Tests	109	49	81	66	187	32	92	122	509	108	512

1 in = 25.4 mm

Effect of Material/Soil Type

Dividing the base/subbase materials by material code improves the regression statistics from the overall base/subbase model (see appendix E). When the crushed stone material was separated into auger and test pit samples, as recommended in chapter 3, some improvement was observed. However, this improvement is inconclusive and debatable because the greater correlation may be the result of the smaller sample size. The uncrushed gravel was not separated into auger and test pit samples due to a limited number of data points (refer to table 5).

Sorting the subgrade by soil type also improved the regression statistics as compared to the overall soil model (see appendix E). The subgrade materials were not classified in accordance with AASHTO, because the number of data points was limited for some of the classifications. Sampling technique (auger versus test pit samples) did not improve the regression statistics. The remaining part of this chapter presents the regression equations that resulted from the nonlinear optimization for each base material type and soil group. The residuals (bias) for each of the prediction models are provided in appendix E. The symbols used in the following equations were defined in chapter 2 (equation 3) and in table 15.

Unbound Aggregate Base/Subbase Materials

<u>Crushed Stone Materials – LTPP Material Code 303</u>

$$M_R = \left[0.7632 + 0.0084\left(P_{3/8}\right) + 0.0088LL - 0.0371W_{opt} - 0.0001\gamma_{opt}\right]p_a \; * \left[\frac{\theta}{p_a}\right]^{\left(2.2159 - 0.0016P_{3/8} + 0.0008LL - 0.038W_{opt} - 0.0006\gamma_{opt} + 2.4x10^{-7}\left[\frac{\gamma^2_{opt}}{P_{40}}\right]\right)} * \left[\frac{\tau_{oct}}{p_a} + 1\right]^{-1.1720 - 0.0082LL - 0.0014W_{opt} + 0.0005\gamma_{opt}} \quad (6)$$

Number of points	=	853
Mean squared error	=	1699.6
S_e	=	41.23
S_y	=	87.42
S_e/S_y	=	0.4716

Figure 21 shows a comparison of the measured and predicted resilient modulus using equation 6 at the appropriate stress states used to test crushed stone base materials.

Crushed Gravel – LTPP Material Code 304

$$M_R = \begin{bmatrix} -0.8282 - 0.0065(P_{3/8}) + 0.0114LL + 0.0004PI - 0.0187W_{opt} + 0.0036W_s + \\ 0.0013\gamma_s - 2.6x10^{-6}\left(\frac{\gamma_{opt}^2}{P_{40}}\right) \end{bmatrix}$$

$$p_a\left[\frac{\theta}{p_a}\right]^{\left(4.9555-0.0057LL-0.0075PI-0.0470W_s-0.0022\gamma_{opt}+2.8x10^{-6}\left[\frac{\gamma^2{}_{opt}}{P_{40}}\right]\right)}\left[\frac{\tau_{oct}}{p_a}+1\right]^{-3.514+0.0016\gamma_s} \tag{7}$$

Number of points	=	404
Mean squared error	=	854.4
S_e	=	29.23
S_y	=	66.74
S_e/S_y	=	0.4380

Figure 22 shows a comparison of the measured and predicted resilient modulus using equation 7 at the appropriate stress states used to test crushed gravel base materials.

Uncrushed Gravel – LTPP Material Code 302

$$M_R = \left[-1.8961 + 0.0014(\gamma_s) - 0.1184\left(\frac{W_s}{W_{opt}}\right)\right]p_a\left[\frac{\theta}{p_a}\right]^{\left(0.4960-0.0074P_{200}-0.0007\gamma_s+1.6972\left(\frac{\gamma_s}{\gamma_{opt}}\right)+0.1199\left(\frac{W_s}{W_{opt}}\right)\right)} *$$

$$\left[\frac{\tau_{oct}}{p_a}+1\right]^{\left(-0.5979+0.0349W_{opt}+0.0004\gamma_{opt}-0.5166\left[\frac{W_s}{W_{opt}}\right]\right)} \tag{8}$$

Number of points	=	461
Mean squared error	=	475.9
S_e	=	21.81
S_y	=	63.05
S_e/S_y	=	0.3460

Figure 23 shows a comparison of the measured and predicted resilient modulus using equation 8 at the appropriate stress states used to test crushed gravel base materials.

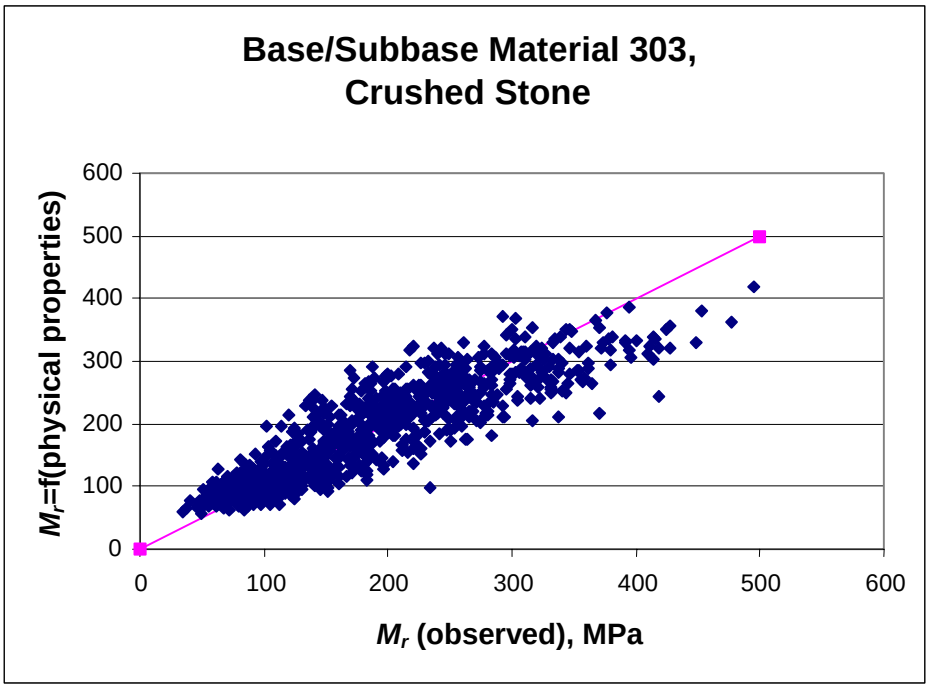

Figure 21. Graphical comparison of the predicted and measured resilient modulus for the crushed stone base materials.

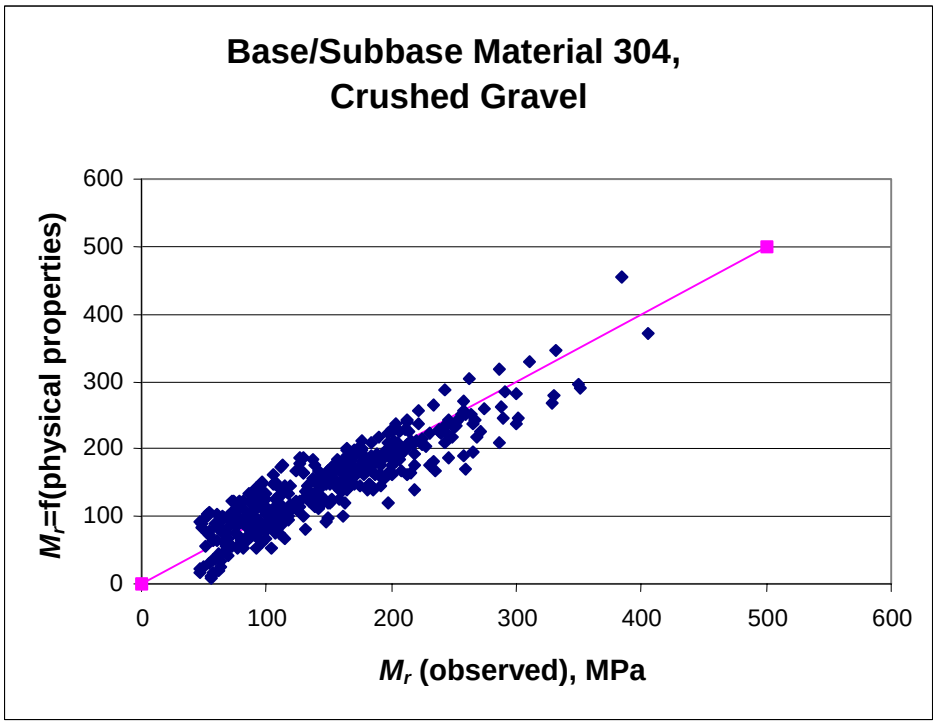

Figure 22. Graphical comparison of the predicted and measured resilient modulus for the crushed gravel base materials.

Sand – LTPP Material Code 306

$$M_R = \left[-0.2786 + 0.0097P_{3/8} + 0.0219LL - 0.0737PI + 1.8x10^{-7}\left(\frac{\gamma_{opt}^2}{P_{40}}\right)\right] p_a * \left[\frac{\theta}{p_a}\right]^{\left(1.1148 - 0.0053P_{3/8} - 0.0095LL + 0.0325PI + 7.2x10^{-7}\left(\frac{\lambda_{opt}^2}{P_{40}}\right)\right)} \left[\frac{\tau_{oct}}{p_a} + 1\right]^{\left(-0.4508 + 0.0029P_{3/8} - 0.0185LL + 0.0798PI\right)} \quad (9)$$

Number of points	=	519
Mean squared error	=	512.7
S_e	=	22.64
S_y	=	51.61
S_e/S_y	=	0.4388

Figure 24 shows a comparison of the measured and predicted resilient modulus using equation 9 at the appropriate stress states used to test sand base materials.

Coarse-Grained Soil-Aggregate Mixture – LTPP Material Code 308

$$M_R = \left[\begin{array}{l} -0.5856 + 0.0130P_{3/8} - 0.0174P_4 + 0.0027P_{200} + 0.0149PI + 1.6x10^{-6}\left(\gamma_{opt}\right) \\ -0.0426W_s + 1.6456\left(\frac{\gamma_s}{\gamma_{opt}}\right) + 0.3932\left(\frac{W_s}{W_{opt}}\right) - 8.2x10^{-7}\left(\frac{\gamma_{opt}^2}{P_{40}}\right) \end{array} \right] p_a * \left[\frac{\theta}{p_a}\right]^{\left(0.7833 - 0.0060P_{200} - 0.0081PI + 0.0001\gamma_{opt} - 0.1483\left(\frac{W_s}{W_{opt}}\right) - 2.7x10^{-7}\left(\frac{\gamma_{opt}^2}{P_{40}}\right)\right)} \left[\frac{\tau_{oct}}{p_a} + 1\right]^{\left(-0.1906 - 0.0026P_{200} + 8.1x10^{-7}\left(\frac{\gamma_{opt}^2}{P_{40}}\right)\right)} \quad (10)$$

Number of points	=	2,323
Mean squared error	=	1883.9
S_e	=	43.40
S_y	=	80.19
S_e/S_y	=	0.5413

Figure 25 shows a comparison of the measured and predicted resilient modulus using equation 10 at the appropriate stress states used to test coarse-grained soil-aggregate base materials.

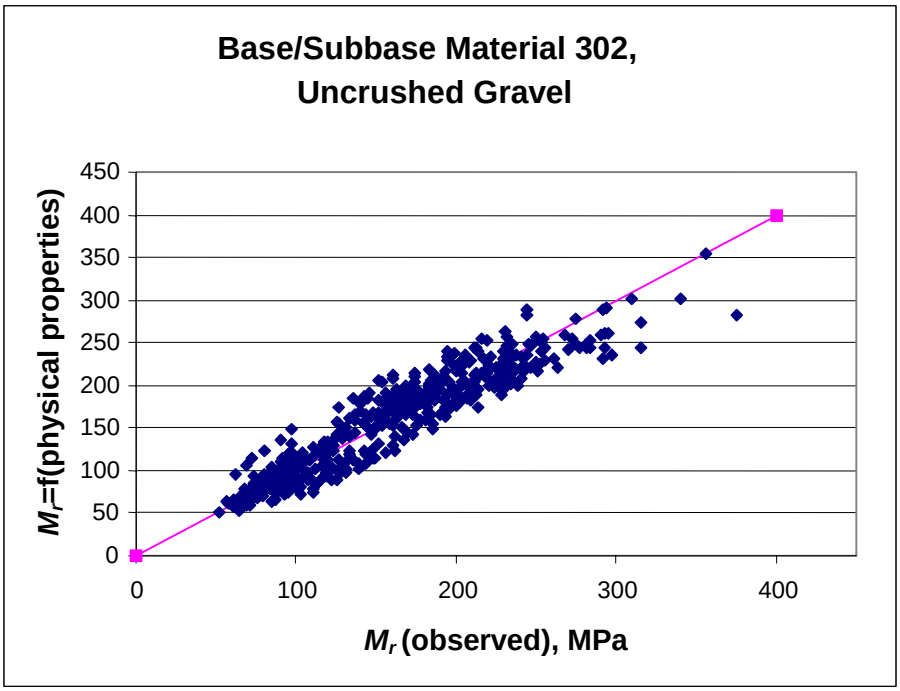

Figure 23. Graphical comparison of the predicted and measured resilient modulus for the uncrushed gravel base materials.

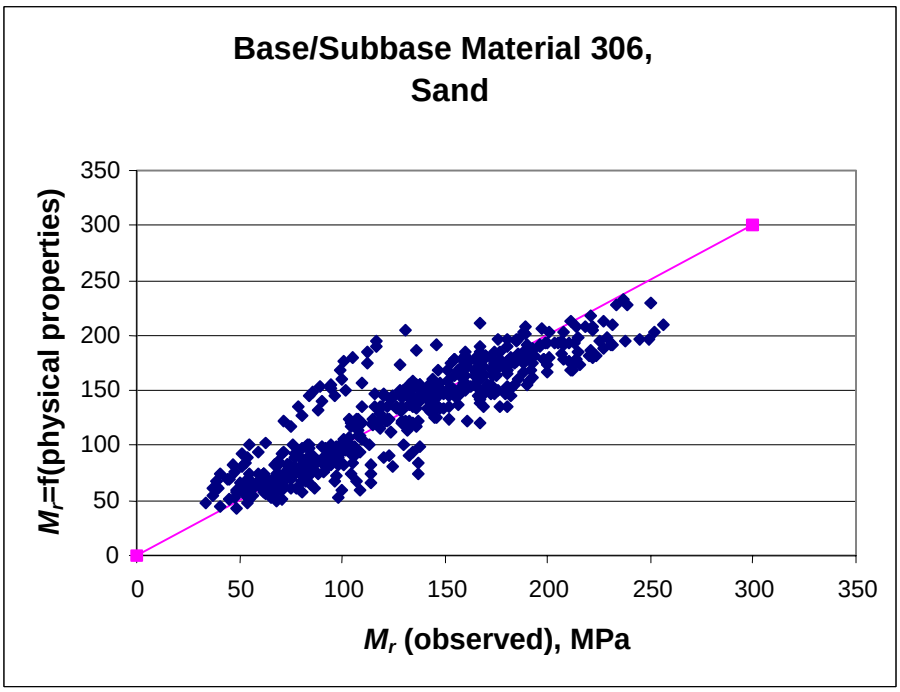

Figure 24. Graphical comparison of the predicted and measured resilient modulus for the sand base materials.

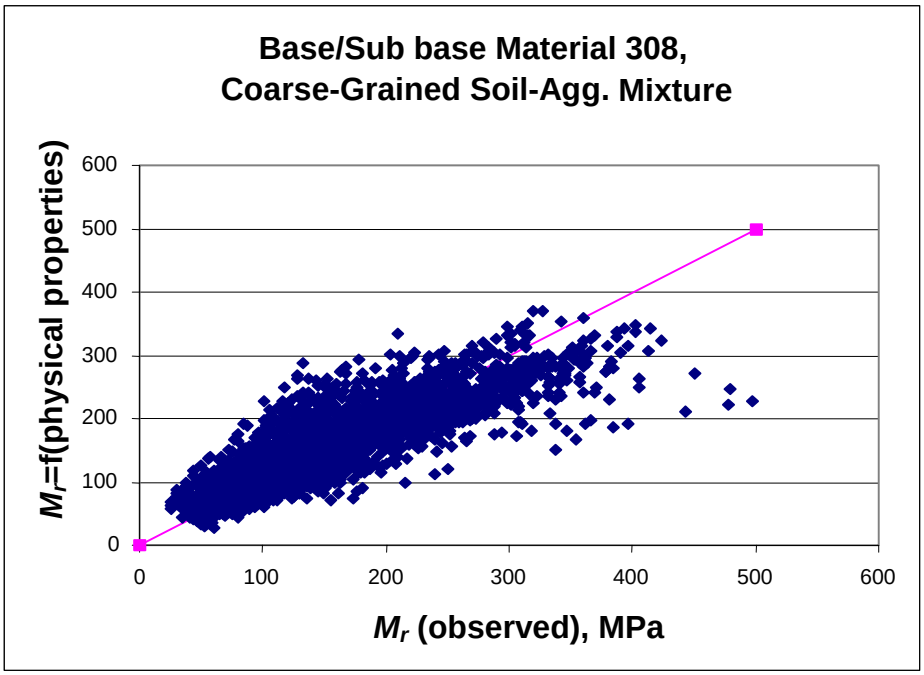

Figure 25. Graphical comparison of the predicted and measured resilient modulus for the coarse-grained soil-aggregate base materials.

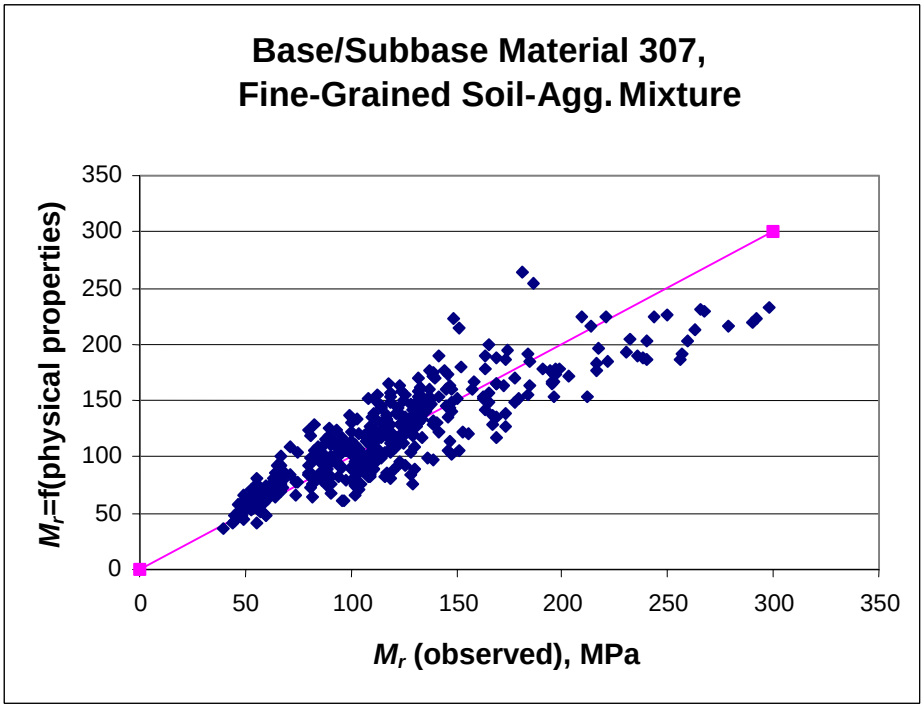

Figure 26. Graphical comparison of the predicted and measured resilient modulus for the fine-grained soil-aggregate base materials.

Fine-Grained Soil-Aggregate Mixture – LTPP Material Code 307

$$M_R = \left[-0.7668 + 0.0051P_4 + 0.0128P_{200} + 0.0030LL - 0.0510W_{opt} + 1.1729\left(\frac{\gamma_s}{\gamma_{opt}}\right)\right] p_a * \left[\frac{\theta}{p_a}\right]^{\left(0.4951 - 0.0141P_4 - 0.0061P_{200} + 1.3941\left(\frac{\lambda_s}{\gamma_{opt}}\right)\right)} \left[\frac{\tau_{oct}}{p_a} + 1\right]^{\left(0.9303 + 0.0293P_{3/8} + 0.0036LL - 3.8903\left(\frac{\gamma_s}{\gamma_{opt}}\right)\right)} \tag{11}$$

Number of points	=	390
Mean squared error	=	588.2
S_e	=	24.25
S_y	=	49.37
S_e/S_y	=	0.4912

Figure 26 shows a comparison of the measured and predicted resilient modulus using equation 11 at the appropriate stress states used to test fine-grained soil-aggregate base materials.

Fine-Grained Soil – LTPP Material Code 309

$$M_R = [0.8409 + 0.0004P_{40} + 0.0161PI]p_a \left[\frac{\theta}{p_a}\right]^{(0.6668 - 0.0007P_{40} - 0.0139PI)} \left[\frac{\tau_{oct}}{p_a} + 1\right]^{(-0.1667 - 0.0207PI)} \tag{12}$$

Number of points	=	1,079
Mean squared error	=	1,167
S_e	=	34.16
S_y	=	62.80
S_e/S_y	=	0.5440

Figure 27 shows a comparison of the measured and predicted resilient modulus using equation 12 at the appropriate stress states used to test fine-grained soil base materials.

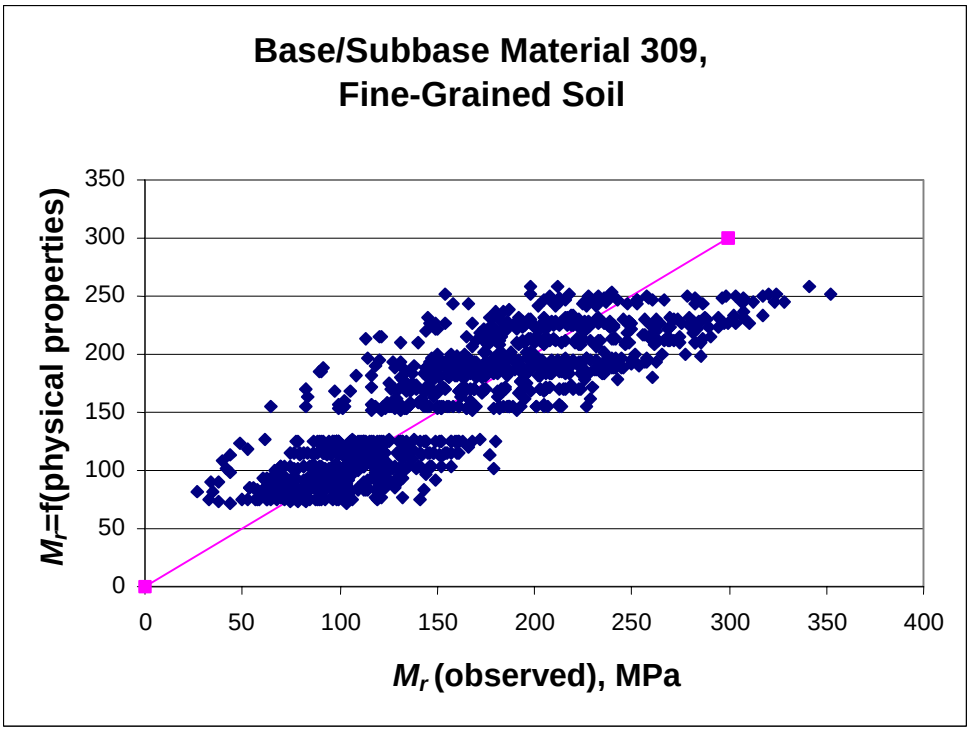

Figure 27. Graphical comparison of the predicted and measured resilient modulus for the fine-grained soil base materials.

Subgrade Soils

Coarse-Grained Gravel Soils

$$M_R = [1.3429 - 0.0051P_{3/8} + 0.0124(\%Clay) + 0.0053LL - 0.0231W_s]p_a * \left[\frac{\theta}{p_a}\right]^{(0.3311+0.0010P_{3/8}-0.0019(\%Clay)-0.0050LL-0.0072PI+0.0093W_s)} * \left[\frac{\tau_{oct}}{p_a}+1\right]^{(1.5167-0.0302P_{3/8}+0.0435(\%Clay)+0.0626LL+0.0377PI-0.2353W_s)} \quad (13)$$

Number of points	=	957
Mean squared error	=	301.3
S_e	=	17.36
S_y	=	26.81
S_e/S_y	=	0.6474

Figure 28 shows a comparison of the measured and predicted resilient modulus using equation 13 at the appropriate stress states used to test coarse-grained gravel soils.

Coarse-Grained Sand Soils

$$M_R = \left[3.2868 - 0.0412P_{3/8} + 0.0267P_4 + 0.0137(\%Clay) + 0.0083LL - 0.0379W_{opt} - 0.0004\gamma_s\right]p_a \; * \left[\frac{\theta}{p_a}\right]^{\left(0.5670+0.0045P_{3/8}-2.98x10^{-5}(P_4)-0.0043(\%Silt)-0.0102(\%Clay)-0.0041LL+0.0014W_{opt}-3.41x10^{-5}\gamma_s-0.4582\left(\frac{\gamma_s}{\gamma_{opt}}\right)+0.1779\left(\frac{W_s}{W_{opt}}\right)\right)} * \left[\frac{\tau_{oct}}{p_a}+1\right]^{\left(-3.5677+0.1142P_{3/8}-0.0839P_4-0.1249P_{200}+0.1030(\%Silt)+0.1191(\%Clay)-0.0069LL-0.0103W_{opt}-0.0017\gamma_s+4.3177\left(\frac{\gamma_s}{\lambda_{opt}}\right)-1.1095\left(\frac{W_s}{W_{opt}}\right)\right)} \quad (14)$$

Number of points	=	3,117
Mean squared error	=	357.7
S_e	=	18.91
S_y	=	24.79
S_e/S_y	=	0.7630

Figure 29 shows a comparison of the measured and predicted resilient modulus using equation 14 at the appropriate stress states used to test coarse-grained sand soils.

Fine-Grained Silt Soils

$$M_R = \left[1.0480 + 0.0177(\%Clay) + 0.0279PI - 0.370W_s\right]p_a\left[\frac{\theta}{p_a}\right]^{(0.5097-0.0286PI)} * \left[\frac{\tau_{oct}}{p_a}+1\right]^{(-0.2218+0.0047(\%Silt)+0.0849PI-0.1399W_s)} \quad (15)$$

Number of points	=	464
Mean squared error	=	193.0
S_e	=	13.89
S_y	=	24.71
S_e/S_y	=	0.5622

Figure 30 shows a comparison of the measured and predicted resilient modulus using equation 15 at the appropriate stress states used to test fine-grained silt soils.

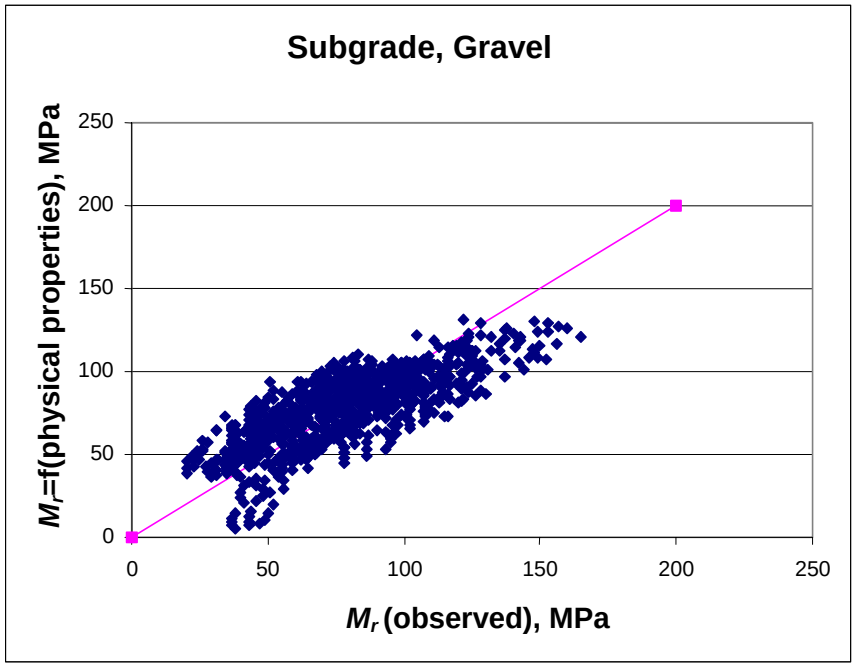

Figure 28. Graphical comparison of the predicted and measured resilient modulus for the coarse-grained gravel soils.

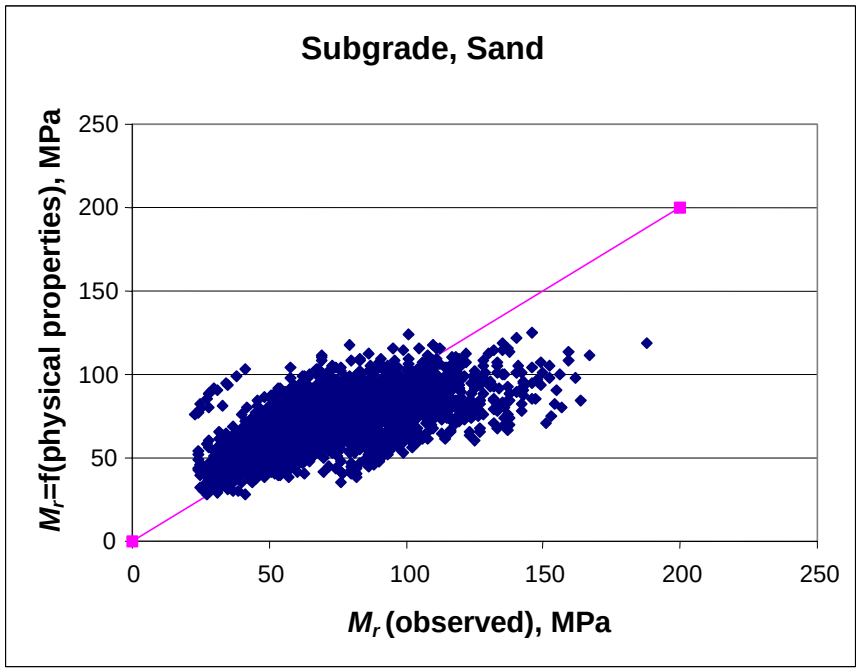

Figure 29. Graphical comparison of the predicted and measured resilient modulus for the coarse-grained sand soils.

Fine-Grained Clay Soils

$$M_R = [1.3577 + 0.0106(\%Clay) - 0.0437W_s]p_a\left[\frac{\theta}{p_a}\right]^{(0.5193-0.0073P_4+0.0095P_{40}-0.0027P_{200}-0.0030LL-0.0049W_{opt})} *$$

$$\left[\frac{\tau_{oct}}{p_a}+1\right]^{\left(1.4258-0.0288P_4+0.0303P_{40}-0.0521P_{200}+0.0251(\%Silt)+0.0535LL-0.0672W_{opt}-0.0026\gamma_{opt}+0.0025\gamma_s-0.6055\left(\frac{W_s}{W_{opt}}\right)\right)} \quad (16)$$

Number of points	=	1,484
Mean squared error	=	557.9
S_e	=	23.62
S_y	=	29.22
S_e/S_y	=	0.8082

Figure 31 shows a comparison of the measured and predicted resilient modulus using equation 16 at the appropriate stress states used to test fine-grained clay soils.

SUMMARY

The results from the nonlinear optimization regression study were compared to those from earlier studies. The statistical parameters for some of the unbound aggregate base and subbase layers improved, indicating that the defined anomalies and use of nonlinear regression techniques were important. In summary, the physical properties show fair to good correlations between the physical properties and M_R. The following are some of the more important findings from these correlation studies:

- Several key factors affect the correlation between the material physical properties of the pavement materials and soils and M_R. For example, recompacting the materials may have changed some of the physical features of the test specimens from what was measured for the bulk samples.

- The statistics for all models were generally fair to good for both the unbound aggregate materials and the subgrade soils. Breaking the data groups into subgroups by sampling technique did improve on the regression statistics. Most of the s_e/s_y terms are less than 0.7. The base materials generally have better statistical parameters than the soils.

- The primary result from these correlation studies is that the resilient modulus from constitutive equation 3 can be reasonably predicted from the physical properties that are included in the LTPP database.

- The physical properties of percent clay and test specimen moisture content or density are important for all soil groups.

- Percent silt was an important property for all soil groups, except for the gravelly soils.

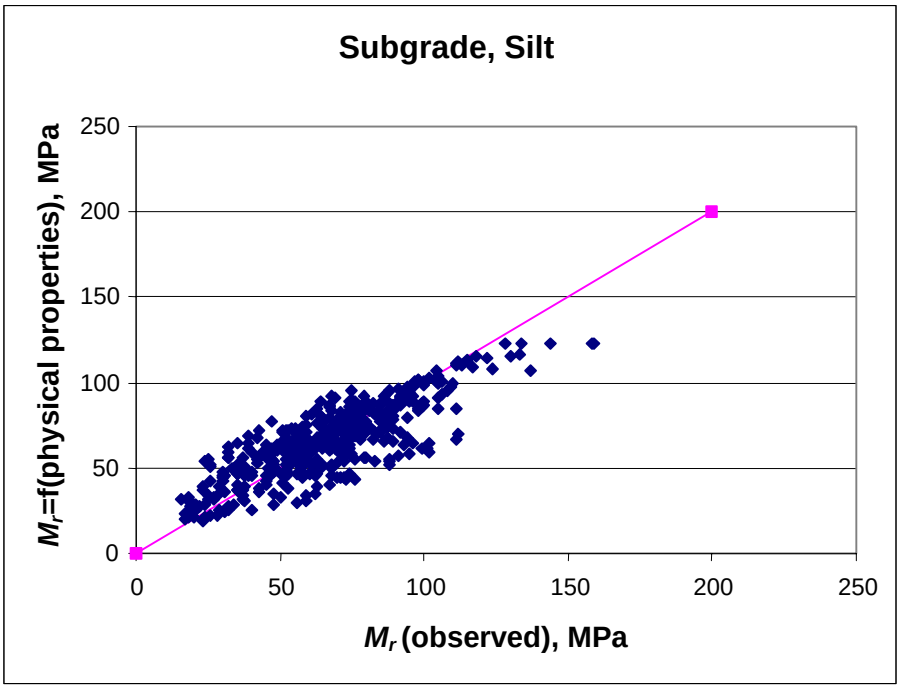

Figure 30. Graphical comparison of the predicted and measured resilient modulus for the fine-grained silt soils.

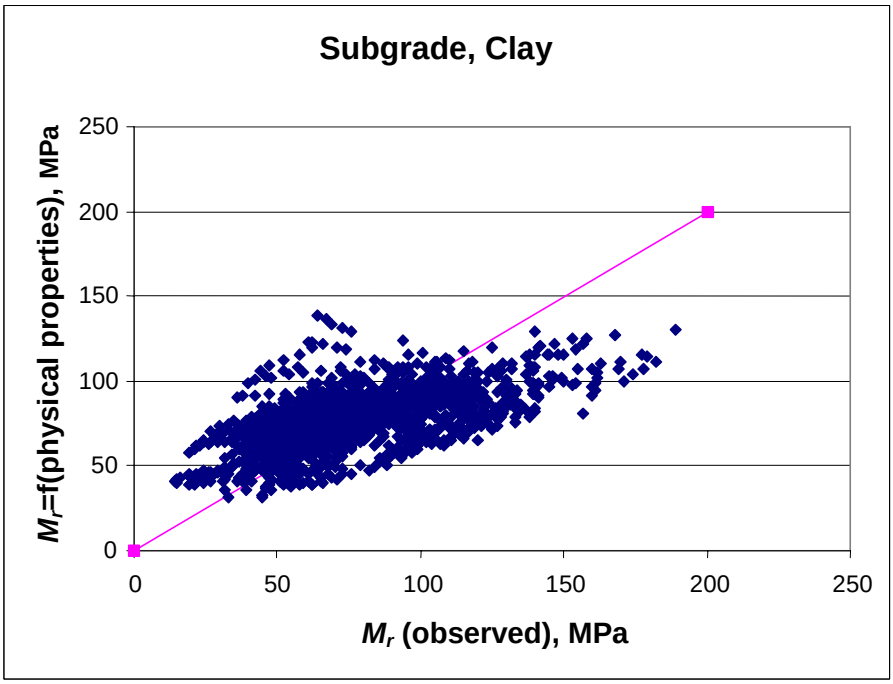

Figure 31. Graphical comparison of the predicted and measured resilient modulus for the fine-grained clay soils.

Figure 32 shows a comparison of the calculated M_R between the test pit and augered samples using the regression equations to estimate the k-coefficients. A bias is present in the calculated M_R values between the test pit and augered samples and supports the previous observation that there is an effect of sampling technique for the crushed stone base materials included in the LTPP database.

Figure 33 shows the comparison of the predicted M_R using the regression models developed for the different sampling techniques for sand. The error in the calculated M_R using the physical properties overshadows any difference caused by the different sampling techniques used.

The physical properties correlated to the resilient modulus varied between the different base/subbase material groups. No one physical property was included for all material types. However, the liquid limit, plasticity index, and the amount of material passing the smaller sieve sizes are important for the lower strength unbound base/subbase materials, while a measure of the moisture content and density are important for the higher strength materials. The amount of material passing the larger sieve sizes are related to the resilient modulus of the unbound base/subbase materials with the larger aggregate particles, as expected.

Until additional test results become available to improve or confirm these relationships, it is recommended that at least some resilient modulus tests be performed to measure the M_R for unbound pavement materials and soils.

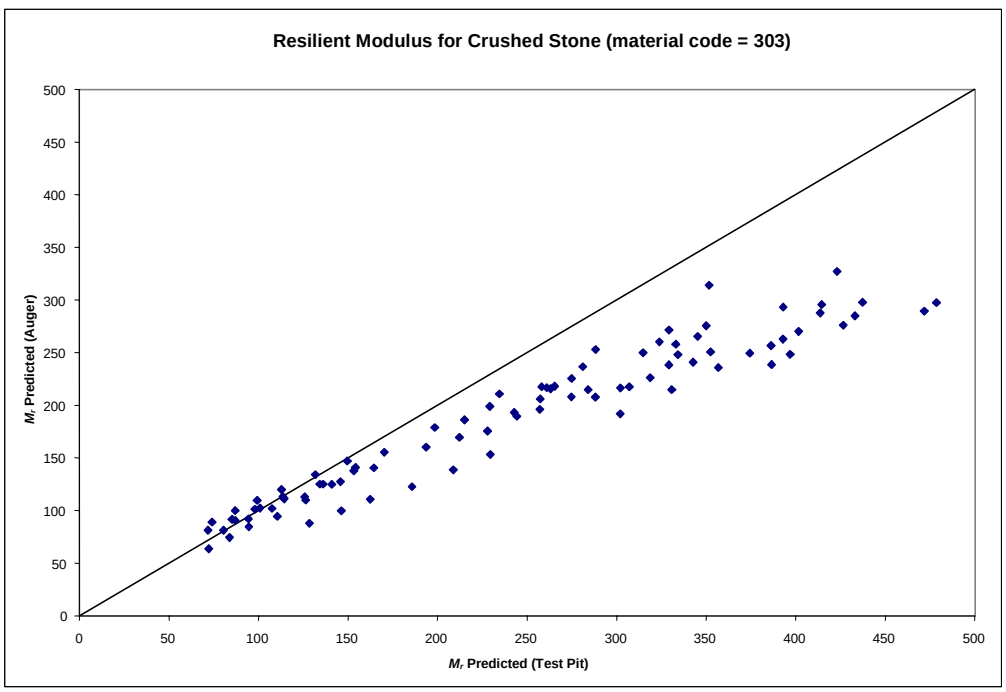

Figure 32. Comparison of the resilient modulus predicted from the data sets for crushed stone materials sampled from the test pit and auger locations.

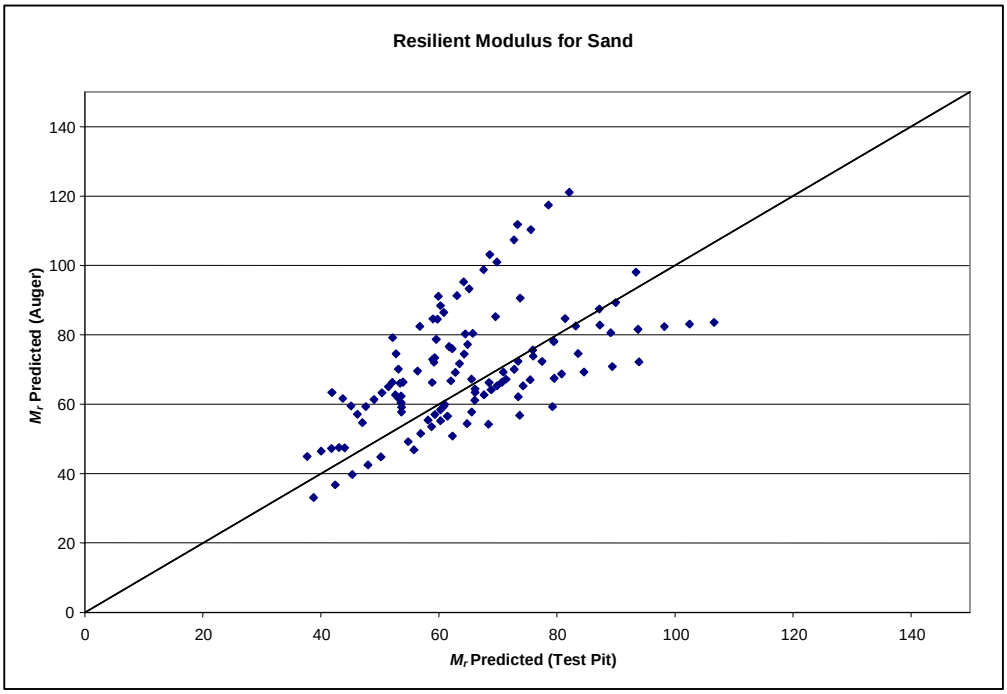

Figure 33. Graphical comparison of the calculated M_R using the regressed k-coefficients from the physical properties of the sand soil group sampled from augers and test pits.

CHAPTER 5. SUMMARY AND FUTURE RECOMMENDATIONS

Repeated-load resilient modulus tests are being performed on all unbound pavement materials and soils from the SPS and GPS test sections included in FHWA's LTPP program in accordance with LTPP test protocol P46. The overall goal of this study was to complete a detailed review of the LTPP M_R data and to identify potential anomalies and bias in those data. To accomplish that goal, correlation studies and regression analysis were completed in evaluating M_R test results. The correlation and regression studies included:

- Regression of the k-coefficients of equation 3.
- Comparison of the distributions of each k-coefficient for different data groups to identify any bias or differences between different data sets.
- Identification of the physical properties and other parameters that affect the response characteristics of the materials and soils tested.

FINDINGS AND OBSERVATIONS

The following is a summary of the findings and recommendations from this study:

- A total of 2,014 M_R tests of unbound pavement materials and soils have a Level E data status, while 1,594 tests have not yet obtained a Level E status in the LTPP database as of the October 2000 data release. It is expected that the number of completed M_R tests with a Level E status will significantly increase in future data releases.
- Constitutive equation 3 was found to be an excellent fit to the M_R test results included in the LTPP database. Specifically, almost 92 percent of the LTPP M_R test results have response characteristics that can be accurately simulated by constitutive equation 3. Constitutive equation 3 is the equation selected for use in development of the 2002 Design Guide. It is important to note that the values for the k_1 coefficient reported herein from the regression studies were determined using units of *kPa* for the pressure and stress parameters and units of *MPa* for the M_R.
- Coefficient k_6 (pore-water pressure or cohesion term) in equation 3 was found to be zero for more than 50 percent of the M_R tests. The non-zero values of k_6 were highly variable and have a uniform distribution. Thus, k_6 was assumed to be zero for all of the correlation studies and analyses performed on the M_R test data. This assumption should be checked and confirmed as additional M_R test results reach a Level E data status in the LTPP database.
- Coefficient k_3 was found to be zero for nearly 25 percent of the M_R tests performed on the unbound aggregate base/subbase materials and about 10 percent of the tests performed on the coarse-grained subgrade soils.

- There were 185 M_R tests (approximately 8 percent) that were flagged with potential anomalies. Most of the anomalous tests (103 of 185 flagged tests) were defined as a type 4 anomaly. A type 4 anomaly exhibits a different stress sensitivity between the different confining pressures. Some of these differences are large enough that the higher confining pressure will result in a lower M_R than a lower confining pressure at the same repeated vertical load. Samples that exhibit this type of anomaly should be retested.

- Sampling technique (auger versus test pit samples) does have an effect on the M_R test results for the uncrushed gravel and crushed stone base/subbase materials. No significant difference was found between the augered and test pit samples of the other base/subbase materials.

- Sampling technique also has an effect on the M_R test results for the subgrade soils. However, only one of the k-coefficients regressed from the M_R test data for the augered and test pit samples were found to be different for the coarse-grained soils and no difference was found for the fine-grained soils. Conversely, at least one of the k-coefficients was found to be different for all soil groups when comparing undisturbed and disturbed test specimens. Multiple k-coefficients (including k_1) were found to be different for the clay soils. Thus, it appears that there is a significant difference in the M_R test results for selected data groups that can be attributed to, or explained by, the use of different sampling techniques. These data groups include undisturbed versus disturbed test specimens for the clay soils and augered versus test pit specimens for the crushed stone base/subbase materials. At a minimum, these data groups should be considered as different populations of M_R test data.

- The physical properties correlated to resilient modulus varied between the different materials and soils. No one physical property was included for all materials and soils. However, the following summarizes the properties related to the k-coefficients for many of the data groups:

  - Liquid limit, plasticity index, and the amount of material passing the smaller sieve sizes were found to be important as related to the resilient modulus for the lower strength unbound aggregate base/subbase materials, while the moisture content and density were important as related to the higher strength materials.

  - The amount of material passing the larger sieve sizes was important for the unbound aggregate base/subbase materials with larger aggregates.

  - Percent clay and test specimen moisture content or density are important for all soil groups.

  - Percent silt was important for all soil groups except gravel.

- The statistics for all models relating the resilient modulus to physical properties were fair to good for most data groups. Breaking the data groups into subgroups by sampling technique and material or soil type did improve on the regression statistics. Thus, the primary result from these regression studies is that the resilient modulus can be reasonably predicted from those physical properties that are included in the LTPP database. It should be noted that

these correlation and regression studies did not consider any effect that may have been caused by the use of different testing contractors.

RECOMMENDATIONS

Two important recommendations are a result of this study:

1. The review process identified in chapter 2 should be performed on the resilient modulus test results after each test is completed. In other words, the review process to identify anomalous data should become a part of the QC process, but the review should be performed immediately after testing. Retests can then be scheduled and performed for those tests that are flagged.

2. The findings and observations from this study should be verified and confirmed after all M_R tests have been completed, checked through the QC process, and have reached a Level E data status in the LTPP database.

The final recommendation or suggestion is to determine if there is any effect or bias in the resilient modulus test results between the different testing contractors (i.e., operator- or equipment-dependent). The bias for each prediction model was provided in appendix E. The resilient modulus data should be studied in more detail to identify any causes of the bias that appear to be material- and/or stress-state-dependent.

APPENDIX A.

SUMMARY OF k-COEFFICIENTS FOR THE LTPP RESILIENT MODULUS TESTS

Appendix A, table 16, provides a tabulation of the k-coefficients that were determined for each resilient modulus test using nonlinear regression techniques for the "universal" constitutive equation. Various statistical parameters are also tabulated for each test. These statistical parameters include the following:

RMSE = Root Mean Squared Error
MSE = Mean Squared Error
R^2
S_e/S_y

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials.

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
1	0101	1	2	B6	BS06	0.7371	0.1236	-0.7748	15	4.1656	2.0358	4.1447	0.9991	0.4887
1	0102	1	2	B7	BS07	0.7810	0.1497	-0.4579	15	4.3337	2.4088	5.8023	0.9990	0.5558
1	0103	1	2	B5	BS05	0.7471	0.1952	-1.2825	15	5.9738	1.9974	3.9898	0.9991	0.3344
1	0106	1	2	B4	BS04	0.7514	0.1787	-0.2832	15	4.6260	1.8647	3.4770	0.9994	0.4031
1	0107	1	2	B1	BS01	0.6701	0.2137	-1.0366	15	4.9454	1.4704	2.1620	0.9994	0.2973
1	0108	1	2	B2	BS02	0.7619	0.1612	-0.4410	15	4.1196	1.6944	2.8708	0.9995	0.4113
1	0111	1	2	B3	BS03	0.7628	0.1344	-0.2691	15	4.1827	2.7063	7.3239	0.9988	0.6470
1	0502	1	1	TP1	BS55	0.6190	0.3902	0.0000	15	9.0806	1.9745	3.8986	0.9992	0.2174
1	0502	2	1	TP1	BG56	0.6188	0.5133	-0.0405	15	33.6647	1.1438	1.3084	0.9999	0.0340
1	0502	2	2	TP1	BG56	0.5948	0.4399	0.0000	15	9.8985	1.9707	3.8836	0.9991	0.1991
1	1001	2	2	TP1	BG56	0.7172	0.7705	-0.0458	15	78.1141	6.6861	44.7042	0.9987	0.0856
1	1001	2	2	TP1	BG57	0.7268	0.7067	-0.1472	15	62.5584	5.6975	32.4613	0.9988	0.0911
1	1011	1	1	A1	TS01	0.8228	0.1655	-2.2042	15	9.7575	4.6641	21.7535	0.9946	0.4780
1	1011	1	2	A2	TS03	1.7600	0.4354	-3.1476	15	25.0337	4.9273	24.2783	0.9984	0.1968
1	1011	2	1	BA*	BG**	0.9145	0.5503	0.0000	15	57.9386	4.5896	21.0643	0.9994	0.0792
1	1011	2	2	BA*	BG**	0.9613	0.6280	-0.1737	15	65.4470	5.6762	32.2189	0.9992	0.0867
1	1011	3	1	BA*	BG**	0.5700	0.9897	0.0000	15	103.5283	6.7758	45.9112	0.9990	0.0654
1	1019	1	1	A1	TS02	1.2501	0.4131	-1.2442	15	15.3623	5.3629	28.7604	0.9978	0.3491
1	1019	1	2	A2	TS03	0.5343	0.4178	0.0000	15	8.9320	3.2359	10.4713	0.9971	0.3623
1	1019	2	1	BA*	BG**	0.9962	0.6250	0.0000	15	80.1910	17.8706	319.3589	0.9934	0.2229
1	1019	2	2	TP1	BG55	0.7799	0.6658	-0.1396	15	61.1355	6.8790	47.3208	0.9984	0.1125
1	1021	1	1	A1	TS01	0.8648	0.5048	-2.3817	15	12.6630	4.1558	17.2709	0.9963	0.3282
1	1021	1	2	A2	TS03	1.2172	0.2507	-2.9302	15	15.9592	5.0640	25.6442	0.9966	0.3173
1	1021	2	1	BA*	BG**	0.9483	0.6619	-0.1447	15	72.2560	4.8052	23.0902	0.9994	0.0665
1	1021	2	2	TP1	BG55	0.8984	0.7054	-0.2732	15	70.3500	8.9635	80.3441	0.9979	0.1274
1	3028	1	1	BA*	BS**	1.2131	0.2656	0.0000	15	24.3307	21.2344	450.8977	0.9750	0.8727
1	3028	1	2	BA*	BS**	1.8894	0.2760	-2.2448	15	20.6635	2.8790	8.2887	0.9996	0.1393
1	3028	2	1	BA*	BG**	1.4464	0.5184	-0.0799	15	77.6224	17.7199	313.9942	0.9956	0.2283
1	3028	2	2	BA*	BG**	1.2310	0.7180	-0.6733	15	76.8463	22.2049	493.0587	0.9905	0.2890
1	3028	3	1	BA*	BG**	1.0271	0.6810	0.0000	15	90.4006	11.0833	122.8406	0.9979	0.1226
1	3028	3	2	BA*	BG**	1.5955	0.5814	0.0000	15	110.8525	14.2134	202.0195	0.9982	0.1282
1	3998	1	2	BA*	BS**	1.0637	0.3231	-1.0555	15	10.6735	3.7247	13.8734	0.9986	0.3490
1	3998	3	1	BA1	BG**	0.9738	0.5864	-0.2905	15	52.9351	6.8765	47.2866	0.9985	0.1299
1	3998	3	2	BA4	BG04	0.8006	0.6053	-0.2377	14	45.7415	3.5012	12.2582	0.9994	0.0765
1	4007	1	1	BA*	BS**	0.8141	0.4355	-3.0154	15	12.1330	4.3485	18.9090	0.9944	0.3584
1	4007	1	2	BA*	BS**	1.3948	0.2649	-2.8767	15	17.6589	2.3832	5.6795	0.9994	0.1350
1	4007	2	1	BA*	BG**	0.9494	0.5808	-0.1435	15	57.4057	7.0918	50.2932	0.9985	0.1235
1	4007	2	2	BA*	BG**	0.8383	0.5634	0.0000	15	54.5472	10.8640	118.0265	0.9959	0.1992
1	4007	3	1	BA*	BG**	1.3816	0.5590	0.0000	15	91.1401	12.7308	162.0725	0.9979	0.1397
1	4007	3	2	BA*	BG**	0.9497	0.7222	0.0000	15	94.7404	13.2385	175.2568	0.9969	0.1397
1	4073	1	1	BA*	BS**	0.9002	0.1355	-0.2725	15	6.4609	5.2374	27.4301	0.9968	0.8106
1	4073	1	2	A2	TS03	0.7229	0.1997	0.0000	15	16.3509	15.4884	239.8912	0.9618	0.9473
1	4073	3	1	BA*	BG**	0.9836	0.2466	0.0000	15	84.1259	81.9652	6718.2890	0.7186	0.9743
1	4073	3	2	BA*	BG**	0.8174	0.7952	-0.1003	15	90.1776	6.7010	44.9029	0.9990	0.0743
1	4084	1	1	A1	TS01	0.8795	0.1582	-0.4664	15	5.0256	2.5857	6.6857	0.9991	0.5145
1	4084	1	2	BA*	BS**	1.0375	0.2973	-0.5501	15	10.1901	4.1911	17.5656	0.9984	0.4113
1	4084	2	1	BA*	BG**	0.5990	0.7892	-0.1143	15	63.8606	3.1233	9.7553	0.9996	0.0489
1	4084	2	2	BA*	BG**	0.7972	0.5885	0.0000	15	69.4017	50.4695	2547.1710	0.9121	0.7272
1	4084	3	1	BA*	BG**	0.6778	0.7146	0.0000	15	64.6516	9.1687	84.0648	0.9970	0.1418
1	4084	3	2	BA*	BG**	0.7800	0.8275	-0.0167	15	97.7705	5.2889	27.9730	0.9995	0.0541
1	4125	1	1	BA*	BS**	0.8059	0.1801	-0.3696	15	7.6389	6.1378	37.6726	0.9944	0.8035
1	4125	1	2	BA*	BS**	1.1292	0.2901	-1.0669	15	10.8659	4.6570	21.6877	0.9980	0.4286
1	4125	2	1	BA*	BG**	0.8139	0.6263	-0.1825	15	53.9916	5.5835	31.1760	0.9989	0.1034
1	4125	2	2	BA*	BG**	1.1805	0.5535	-0.7258	15	43.2580	15.0289	225.8680	0.9924	0.3474
1	4126	1	1	A1	TS01	0.7751	0.2980	-1.6994	15	8.9400	4.5929	21.0945	0.9951	0.5137
1	4126	1	2	BA*	BS**	0.7809	0.4647	-1.1358	15	10.8483	3.5572	12.6540	0.9977	0.3279
1	4126	2	1	BA*	BG**	1.0471	0.6218	0.0000	15	80.4536	7.2282	52.2470	0.9990	0.0898
1	4126	2	2	BA*	BG**	0.6490	0.7825	0.0000	15	73.9168	7.9356	62.9744	0.9980	0.1074
1	4127	1	1	A1	TS01	1.1422	0.3306	-2.7938	15	14.2538	2.6335	6.9355	0.9990	0.1848
1	4127	1	2	BA*	BS**	1.3265	0.0829	-1.7482	15	13.6162	6.0374	36.4507	0.9969	0.4434
1	4127	2	1	BA*	BG**	0.7026	0.7705	0.0000	15	77.0454	8.5414	72.9563	0.9980	0.1109
1	4127	2	2	BA*	BG**	0.5337	0.7125	0.0000	15	52.2137	16.6248	276.3824	0.9845	0.3184
1	4129	1	1	BA*	BS**	1.1543	0.3027	-2.8987	15	15.1453	3.7856	14.3305	0.9979	0.2499
1	4129	1	2	TP1	BS55	0.8461	0.1659	-0.9872	15	7.4661	5.4494	29.6957	0.9951	0.7299
1	4129	2	2	TP1	BG56	0.8022	0.8315	-0.6935	15	62.8943	5.7104	32.6087	0.9989	0.0908

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
1	4129	3	1	BA*	BG**	1.1371	0.6745	0.0000	15	100.0928	7.6607	58.6858	0.9992	0.0765
1	4129	3	2	TP1	BG55	1.0055	0.6922	0.0000	15	91.2690	10.4864	109.9647	0.9981	0.1149
1	4155	1	1	BA*	BS**	1.0195	0.7429	-0.7080	15	28.4700	15.6947	246.3234	0.9799	0.5513
1	4155	1	2	A2	TS03	2.0801	0.4302	-2.2159	15	26.3755	5.4274	29.4568	0.9989	0.2058
1	4155	2	1	BA*	BG**	1.2935	0.5532	0.0000	15	84.6003	16.1815	261.8409	0.9961	0.1913
1	4155	2	2	BA*	BG**	1.1041	0.6834	-0.0930	15	92.5873	6.6830	44.6630	0.9993	0.0722
1	5008	1	1	A1	TS01	1.0711	0.2380	-3.5698	15	16.1103	5.9652	35.5836	0.9927	0.3703
1	5008	1	2	A2	TS03	0.7008	0.3522	-1.7352	15	8.1650	3.1471	9.9044	0.9972	0.3854
1	6012	1	1	A1	TS01	0.6492	0.3830	-0.5643	15	8.5206	3.4496	11.8995	0.9973	0.4049
1	6012	1	2	A2	TS03	0.7752	0.5601	-1.7078	15	11.9012	3.1382	9.8480	0.9979	0.2637
1	6012	2	1	BA*	BG**	0.8778	0.5954	-0.1138	15	57.2686	4.1081	16.8766	0.9995	0.0717
1	6012	2	2	TP1	BG55	1.0494	0.7489	-0.4188	15	80.4753	15.7269	247.3352	0.9952	0.1954
1	6019	1	1	A1	TS01	0.7928	0.3903	-0.9354	15	9.8595	3.9358	15.4902	0.9973	0.3992
1	6019	1	2	BA*	BS**	0.8190	0.4979	-0.6530	15	12.7906	2.6269	6.9006	0.9990	0.2054
1	6019	2	1	BA*	BG**	0.7012	0.7925	-0.3774	15	61.9985	3.7865	14.3375	0.9995	0.0611
1	6019	2	2	BA*	BG**	0.8196	0.6743	-0.2775	15	57.5630	5.5761	31.0933	0.9989	0.0969
4	0114	1	2	B309	BS09	1.3826	0.2588	-1.5020	15	12.2991	1.9360	3.7482	0.9997	0.1574
4	0115	1	2	B303	BS03	0.9022	0.5984	-2.0181	15	14.4413	3.1117	9.6824	0.9983	0.2155
4	0213	1	2	B311	BS11	0.8746	0.5885	-2.1306	15	13.6249	2.7469	7.5452	0.9986	0.2016
4	0216	1	2	B306	BS06	0.9361	0.5105	-1.9370	15	13.0978	2.5639	6.5734	0.9989	0.1957
4	0217	1	2	B309	BS09	0.7398	0.6783	-1.8964	15	13.2388	2.6095	6.8093	0.9984	0.1971
4	0222	1	2	B303	BS03	0.9586	0.6219	-2.2077	14	15.2084	1.9614	3.8471	0.9994	0.1290
4	0223	1	2	B308	BS08	0.8278	0.7128	-1.8388	14	16.0995	3.0501	9.3029	0.9983	0.1895
4	0608	1	2	B*	BS**	0.6853	0.4443	-1.5710	15	8.7977	2.7190	7.3927	0.9980	0.3091
4	1001	1	1	BA*	BS**	0.4998	0.4101	-1.1300	15	5.9936	1.5315	2.3456	0.9989	0.2555
4	1001	1	2	TP1	BS91	0.7853	0.3092	-0.9687	15	7.4687	2.2560	5.0894	0.9991	0.3021
4	1003	1	1	BA*	BS**	0.8319	0.3211	-1.1004	15	7.9000	1.4748	2.1751	0.9996	0.1867
4	1003	1	2	TP1	BS92	0.7813	0.2274	-1.4264	15	6.6783	1.6462	2.7100	0.9994	0.2465
4	1006	1	1	BA*	BS**	0.6460	0.4283	-1.5221	15	8.2016	2.5962	6.7405	0.9979	0.3166
4	1006	1	2	TP1	BS92	0.8157	0.2828	-0.9575	15	7.1581	2.2317	4.9804	0.9992	0.3118
4	1006	2	2	TP1	BG91	0.4255	0.5981	-0.0512	15	28.7498	1.3155	1.7306	0.9998	0.0458
4	1007	1	1	BA*	BS**	0.7197	0.2933	-1.0219	15	6.8125	2.6900	7.2359	0.9984	0.3949
4	1007	1	2	TP1	BS91	0.6616	0.5148	-1.5365	15	9.4708	1.8007	3.2424	0.9991	0.1901
4	1015	1	1	BA*	BS**	0.9300	0.2290	0.0000	15	8.3995	3.0906	9.5517	0.9990	0.3679
4	1015	1	2	TP1	BS92	1.0206	0.1451	0.0000	15	7.1933	4.7344	22.4147	0.9981	0.6582
4	1016	2	1	BA*	BG**	0.8553	0.4920	-0.4112	15	32.5506	10.2399	104.8550	0.9940	0.3146
4	1017	1	1	BA*	BS**	1.0919	0.1256	0.0000	15	10.0247	8.6811	75.3617	0.9945	0.8660
4	1018	1	2	TP1	BS92	0.3435	0.3740	-2.3961	15	4.2840	1.1042	1.2193	0.9983	0.2578
4	1018	2	1	BA*	BG**	1.0551	0.2786	-0.1404	15	21.7065	1.3288	1.7656	0.9999	0.0612
4	1021	1	1	BA*	BS**	0.5579	0.6154	-1.3122	15	9.7458	2.1006	4.4126	0.9984	0.2155
4	1021	1	2	TP1	BS92	0.5287	0.6330	-1.6658	15	9.1766	2.3003	5.2912	0.9977	0.2507
4	1022	1	2	TP1	BS93	0.9034	0.2029	0.0000	15	7.0697	2.2604	5.1096	0.9995	0.3197
4	1024	1	1	BA*	BS**	1.0553	0.2244	0.0000	15	10.2502	5.3602	28.7313	0.9978	0.5229
4	1024	1	2	TP1	BS92	1.0418	0.1763	-0.5128	15	5.7677	1.3073	1.7091	0.9998	0.2267
4	1024	2	1	BA*	BG**	1.3847	0.2193	0.0000	15	26.1743	6.0040	36.0478	0.9989	0.2294
4	1034	1	2	TP1	BS92	0.7936	0.3787	-1.5099	15	8.9016	2.0526	4.2131	0.9991	0.2306
4	1036	1	2	TP1	BS70	0.7304	0.2685	-0.7325	15	6.2587	2.2873	5.2318	0.9990	0.3655
4	1062	1	1	BA*	BS**	0.6933	0.2804	-0.2882	15	6.8334	2.6882	7.2262	0.9986	0.3934
4	1065	1	1	BA*	BS**	0.8859	0.2622	-0.4837	15	7.4782	2.4435	5.9709	0.9993	0.3268
4	6053	1	1	BA*	BS**	0.7658	0.3751	-1.3903	15	8.3569	1.4713	2.1647	0.9995	0.1761
4	6053	1	2	TP1	BS92	0.7798	0.3288	-0.6940	15	7.9809	2.5445	6.4745	0.9989	0.3188
4	6054	1	1	BA*	BS**	0.6366	0.5542	-1.5157	15	9.7897	2.1944	4.8154	0.9986	0.2242
4	6054	1	2	TP1	BS92	0.6613	0.5143	-1.2380	15	9.6204	2.0383	4.1547	0.9989	0.2119
4	6054	2	1	BA*	BG**	0.4914	0.5684	-0.0938	15	29.7610	4.0400	16.3213	0.9982	0.1357
4	6055	1	1	BA1	BS63	0.8699	0.2678	-0.5267	15	7.7263	3.1824	10.1275	0.9987	0.4119
4	6060	1	2	TP1	BS92	1.0603	0.1957	-0.7465	15	6.7068	1.7628	3.1075	0.9997	0.2628

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
4	7079	1	1	TP1	BG92	0.7094	0.1720	0.0000	15	4.9828	2.2408	5.0212	0.9991	0.4497
4	7614	1	1	BA*	BS**	0.5153	0.6683	-1.1108	15	10.0887	1.9554	3.8236	0.9985	0.1938
4	7614	1	2	BA*	BS**	0.5464	0.6406	-1.4908	15	9.7356	2.2565	5.0919	0.9980	0.2318
5	0809	1	1	A1	TS01	1.1977	0.2272	-1.3215	15	9.5534	1.3115	1.7199	0.9998	0.1373
5	0809	1	2	B2	BS02	1.0976	0.2637	-1.6926	15	10.3730	1.5268	2.3312	0.9997	0.1472
5	0810	1	2	B3	BS03	0.7958	0.4785	-1.7610	15	10.6583	2.0967	4.3962	0.9991	0.1967
5	3011	1	2	A2	TS03	0.8035	0.1570	-0.8411	15	6.0174	4.0411	16.3302	0.9972	0.6716
5	3048	1	1	A1	TS01	0.5393	0.4559	-4.7896	15	8.1492	1.5051	2.2654	0.9979	0.1847
5	3048	1	2	A2	TS03	0.7728	0.0727	-0.0652	15	4.3403	3.9048	15.2474	0.9977	0.8997
5	3058	1	1	A1	TS02	0.7875	0.2825	-3.7571	15	10.8575	1.4862	2.2089	0.9992	0.1369
5	3058	1	2	A2	TS04	0.5751	0.5593	-1.4822	15	8.7576	1.4011	1.9631	0.9993	0.1600
5	3059	1	1	A1	TS01	0.7745	0.3783	-0.6541	15	8.9815	1.3285	1.7650	0.9997	0.1479
5	3059	1	2	A2	TS03	0.6421	0.5358	-0.8646	15	10.3293	1.8870	3.5607	0.9991	0.1827
5	3073	1	1	BA*	BS**	1.2130	0.1555	-0.9743	15	11.1471	8.3210	69.2397	0.9945	0.7465
5	3073	1	2	A2	TS03	1.7246	0.4174	-1.9475	15	20.9955	3.3692	11.3516	0.9994	0.1605
5	3073	2	2	BA*	BG**	0.7711	0.5753	-0.0042	15	51.6329	3.3592	11.2845	0.9996	0.0651
5	3073	3	2	BA*	BG**	0.9091	0.6159	-0.5333	15	44.9817	8.4644	71.6458	0.9970	0.1882
5	3074	1	1	A1	TS01	0.5447	0.4050	-3.2925	15	7.6239	2.2466	5.0474	0.9966	0.2947
5	3074	1	2	A2	TS03	0.6514	0.3682	-2.2002	15	8.1929	3.0916	9.5578	0.9965	0.3773
5	4019	1	1	A1	TS01	0.5482	0.4429	-0.8866	15	7.3601	1.6951	2.8734	0.9990	0.2303
5	4019	1	2	A2	TS03	0.4647	0.4165	-0.4198	15	6.4343	1.2036	1.4486	0.9994	0.1871
5	4019	2	1	BA*	BG**	0.5626	0.6400	-0.0409	15	43.5697	2.2207	4.9314	0.9997	0.0510
5	4019	2	2	BA*	BG**	0.6635	0.6286	-0.2518	15	42.0982	3.3810	11.4309	0.9993	0.0803
5	4021	1	1	A1	TS01	0.5824	0.0000	-0.7731	15	7.4661	6.9580	48.4139	0.9841	0.9319
5	4021	1	2	A2	TS03	0.9402	0.4058	-3.6363	15	13.8192	4.1893	17.5499	0.9956	0.3031
5	4021	2	1	BA*	BG**	0.9836	0.6125	-0.3278	15	56.0750	7.3651	54.2453	0.9984	0.1313
5	4021	2	2	BA*	BG**	0.9931	0.6600	-0.3497	15	63.3222	8.7766	77.0290	0.9980	0.1386
5	4021	3	1	BA1	BG01	0.8281	0.5985	0.0000	15	60.2221	5.7339	32.8770	0.9989	0.0952
5	4021	3	2	BA*	BG**	1.0234	0.6369	-0.0277	15	79.9328	3.0210	9.1261	0.9998	0.0378
5	4023	1	2	A2	TS03	0.4008	0.0827	-3.4340	15	5.6273	2.6811	7.1881	0.9909	0.4764
5	4046	1	1	A1	TS01	0.6732	0.1544	-1.9907	15	6.6833	2.0732	4.2980	0.9985	0.3102
5	4046	1	2	A2	TS03	0.8173	0.2922	-3.8799	15	11.5293	1.5947	2.5429	0.9991	0.1383
5	5803	1	1	BA*	BS**	0.6256	0.1622	0.0000	15	5.4467	4.0120	16.0961	0.9964	0.7366
5	5803	1	2	BA*	BS**	0.7263	0.2834	-0.1316	15	7.5957	2.7507	7.5666	0.9988	0.3621
5	5803	2	2	BA*	BG**	0.8995	0.5434	-0.7994	15	30.2501	10.1542	103.1070	0.9935	0.3357
5	5805	1	1	BA*	BS**	1.6165	0.3330	-1.6501	15	16.8797	3.4987	12.2411	0.9994	0.2073
5	5805	1	2	BA*	BS**	0.6384	0.2468	0.0000	15	7.3310	4.5288	20.5105	0.9958	0.6178
6	1253	1	1	BA*	BS**	0.8830	0.2074	0.0000	15	8.3341	5.0314	25.3147	0.9972	0.6037
6	2002	1	1	BA*	BS**	0.5407	0.4460	-1.4504	15	6.8813	1.6833	2.8334	0.9988	0.2446
6	2004	1	1	BA*	BS**	0.5721	0.4024	-2.1477	15	7.3549	2.4186	5.8499	0.9972	0.3288
6	2004	2	1	BA*	BG**	0.4943	0.6108	-0.1061	15	33.3267	2.5404	6.4536	0.9994	0.0762
6	2004	2	2	TP1	BG91	0.5026	0.6098	-0.0964	15	34.1735	1.8080	3.2689	0.9997	0.0529
6	2038	1	1	BA*	BS**	0.4972	0.6936	-2.3137	15	8.8919	1.8030	3.2507	0.9981	0.2028
6	2038	1	2	TP1	BS92	0.6524	0.5741	-2.5869	15	10.1151	2.1687	4.7034	0.9982	0.2144
6	2051	1	2	TP1	BG55	1.0052	0.1877	0.0000	15	7.7662	3.5491	12.5962	0.9989	0.4570
6	2053	1	1	A1	TS01	0.8825	0.1566	-0.2485	15	4.6260	1.5040	2.2621	0.9997	0.3251
6	2647	2	1	BA*	BG**	0.5444	0.5276	-0.1809	15	27.2446	4.3768	19.1567	0.9980	0.1607
6	3010	1	2	BA*	BS**	1.3127	0.2247	0.0000	15	14.8622	10.1830	103.6940	0.9949	0.6852
6	3013	1	1	BA*	BS**	0.8532	0.2000	-0.5983	15	5.7296	2.4640	6.0711	0.9991	0.4300
6	3013	1	2	BA*	BS**	0.4936	0.6305	-1.0905	15	9.0275	1.4499	2.1021	0.9991	0.1606
6	3019	1	1	BA*	BS**	0.7663	0.4057	-0.2891	15	10.4449	1.4168	2.0072	0.9997	0.1356
6	3019	1	2	BA*	BS**	0.7604	0.2688	-1.5229	15	7.2058	2.1095	4.4500	0.9990	0.2927
6	3019	2	1	BA*	BG**	0.5335	0.5526	-0.1776	15	28.8139	3.7393	13.9823	0.9985	0.1298
6	3019	2	2	BA*	BG**	1.0167	0.2303	-0.2524	15	14.1596	4.1284	17.0438	0.9989	0.2916
6	3021	1	1	BA*	BS**	0.5388	0.5868	-1.5125	15	8.7723	2.0862	4.3521	0.9982	0.2378
6	3021	1	2	BA*	BS**	0.5064	0.6617	-1.0518	15	9.8043	1.9581	3.8342	0.9985	0.1997

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
6	3021	2	1	BA*	BG**	0.4928	0.6465	-0.2440	15	32.9003	2.5309	6.4056	0.9994	0.0769
6	3021	2	2	BA*	BG**	0.5105	0.5973	-0.2913	15	28.6124	4.7970	23.0112	0.9974	0.1677
6	3024	1	1	BA*	BS**	0.5822	0.5992	-1.2084	15	9.9676	2.4363	5.9355	0.9981	0.2444
6	3024	1	2	BA*	BS**	0.7776	0.2866	-1.3810	15	7.5612	2.8038	7.8610	0.9983	0.3708
6	3030	1	1	BA*	BS**	0.8068	0.1653	-1.0192	15	5.8611	2.9328	8.6010	0.9984	0.5004
6	3030	1	2	BA*	BS**	0.9139	0.1248	-0.9845	15	6.0340	2.8551	8.1513	0.9988	0.4732
6	3042	1	1	A1	TS01	0.6981	0.2199	-0.9301	15	5.3745	2.4178	5.8458	0.9986	0.4499
6	3042	1	2	A2	TS03	0.9515	0.2904	-0.8062	15	8.4724	2.3378	5.4654	0.9993	0.2759
6	6044	1	1	BA*	BS**	0.9247	0.1324	0.0000	15	5.4406	3.0952	9.5801	0.9990	0.5689
6	6044	1	2	TP1	BS93	0.7369	0.1989	-2.3643	15	8.2537	1.3385	1.7916	0.9994	0.1622
6	7452	1	2	A2	TS03	0.6432	0.3418	-1.2512	15	6.7767	2.2228	4.9408	0.9985	0.3280
6	7455	1	1	BA1	BS01	0.8728	0.1182	0.0000	15	4.6547	2.7182	7.3885	0.9991	0.5840
6	7456	1	2	A2	TS03	0.8811	0.0643	-0.4024	15	2.4339	0.8551	0.7311	0.9999	0.3513
6	7493	1	1	BA*	BS**	0.5549	0.6356	-1.0915	15	10.2181	1.9574	3.8316	0.9987	0.1916
6	8149	1	2	TP1	BS91	0.9513	0.1694	-0.1897	15	5.8538	2.5974	6.7465	0.9993	0.4437
6	8150	1	2	TP1	BS92	0.4707	0.6219	-1.1504	15	8.4080	1.6630	2.7654	0.9987	0.1978
6	8150	2	1	BA*	BG**	0.4453	0.6237	-0.1413	15	30.1870	2.5970	6.7446	0.9992	0.0860
6	8151	1	2	TP1	BS91	0.5315	0.5758	-0.8936	15	9.1063	1.2846	1.6502	0.9994	0.1411
6	8153	1	1	BA*	BS**	0.7594	0.1639	-0.7032	15	4.4315	1.7877	3.1959	0.9994	0.4034
6	8153	1	2	TP1	BS94	0.6883	0.1763	-2.0942	15	7.0488	0.9471	0.8969	0.9997	0.1344
6	8153	1	3	TP1	BG93	1.1350	0.1914	-0.3936	15	10.6225	4.4039	19.3948	0.9988	0.4146
6	8153	2	2	TP1	BG93	0.4428	0.5861	-0.0425	15	29.6008	1.1971	1.4332	0.9998	0.0404
6	8153	2	3	TP1	BG93	1.1350	0.1914	-0.3936	15	10.6225	4.4039	19.3948	0.9988	0.4146
6	8153	3	2	TP1	BG92	0.4420	0.5875	-0.0444	15	29.5751	1.1627	1.3520	0.9998	0.0393
6	8201	1	1	BA*	BS**	0.5413	0.5647	-1.9937	15	8.5161	2.6525	7.0357	0.9966	0.3115
6	8201	1	2	TP1	BS92	0.6662	0.3175	0.0000	15	8.0593	1.9978	3.9911	0.9993	0.2479
6	8201	2	2	TP1	BG91	0.5414	0.6000	-0.2937	15	30.4806	4.0225	16.1808	0.9984	0.1320
6	8202	1	1	BA*	BS**	0.4824	0.7120	-1.1406	15	9.9833	1.5382	2.3662	0.9990	0.1541
6	8202	1	2	TP1	BS91	0.3727	0.5896	-1.0324	15	6.6640	2.0966	4.3955	0.9967	0.3146
6	8534	1	1	BA*	BS**	0.7072	0.2134	-1.4977	15	5.9096	0.5461	0.2982	0.9999	0.0924
6	8534	1	2	TP1	BS93	0.4252	0.3246	-2.6240	15	5.2915	1.2751	1.6259	0.9984	0.2410
6	8534	2	2	TP1	BG92	0.5610	0.5810	-0.0542	15	36.5819	1.4494	2.1009	0.9998	0.0396
6	8535	1	1	A1	TS01	0.5029	0.3376	-1.9250	15	5.5908	1.4715	2.1653	0.9987	0.2632
6	8535	1	2	A2	TS03	0.5417	0.3562	-1.3171	15	5.7005	1.3056	1.7045	0.9993	0.2290
6	9048	1	1	BA*	BS**	0.5375	0.6285	-1.3856	15	9.4481	2.1530	4.6355	0.9982	0.2279
6	9048	1	2	BA*	BS**	0.5465	0.6292	-1.3501	15	9.8377	2.8307	8.0129	0.9970	0.2877
6	9049	1	1	A1	TS01	0.7127	0.1235	-0.9651	15	4.0178	0.4537	0.2059	1.0000	0.1129
6	9049	1	2	A2	TS03	0.7360	0.1862	-1.2697	15	5.4746	1.1072	1.2259	0.9997	0.2022
8	0214	1	2	B2	BG02	1.1189	0.3250	-2.0816	14	12.3003	2.1884	4.7892	0.9994	0.1779
8	0217	1	2	B4	BG04	1.3112	0.1767	-1.4419	15	10.2377	1.1300	1.2770	0.9999	0.1104
8	0219	1	2	B3	BG03	1.3788	0.2140	-1.6695	15	12.2618	1.6644	2.7703	0.9998	0.1357
8	0221	1	2	B6	BG06	0.9585	0.1916	-2.3908	15	10.6023	0.9962	0.9925	0.9998	0.0940
8	0223	1	2	B7	BG07	0.6255	0.7108	-0.9095	14	13.8320	1.6283	2.6513	0.9994	0.1177
8	0224	1	2	B5	BG05	1.2216	0.2435	-1.5363	15	10.7491	1.4619	2.1371	0.9998	0.1360
8	0501	1	1	B*	BS**	1.1849	0.2166	-1.2534	15	9.0370	1.0671	1.1387	0.9999	0.1181
8	0505	1	1	TP2	BS91	1.3927	0.2213	-0.9915	15	9.7688	0.9878	0.9757	0.9999	0.1011
8	0508	1	1	B*	BS**	0.9520	0.1973	-2.2349	15	10.0915	1.3494	1.8208	0.9997	0.1337
8	1029	1	1	A1	TS01	0.9247	0.2617	-0.2430	15	8.4363	2.9342	8.6097	0.9991	0.3478
8	1029	1	1	BA*	BS**	0.5784	0.2836	-1.3818	15	5.3301	1.4073	1.9804	0.9992	0.2640
8	1029	1	2	TP1	BS93	0.4591	0.6161	-1.8004	15	7.6083	1.8823	3.5430	0.9978	0.2474
8	1047	1	1	A1	TS01	0.8582	0.2892	-2.0809	15	9.2864	1.6277	2.6493	0.9994	0.1753
8	1047	1	1	BA*	BS**	0.9428	0.1879	-0.1674	15	6.1085	1.5757	2.4828	0.9997	0.2579
8	1047	1	2	TP1	BS94	0.8107	0.1773	-1.0178	15	5.3966	1.3862	1.9216	0.9997	0.2569
8	1047	2	2	TP1	BS94	0.8763	0.1689	-0.6857	15	7.6830	4.4079	19.4298	0.9973	0.5737
8	1053	1	2	A2	JS03	0.5975	0.3772	-1.4540	15	6.5444	1.0662	1.1369	0.9996	0.1629
8	1053	1	2	TP1	BS93	0.7768	0.1609	-1.4560	15	6.2503	1.3835	1.9141	0.9996	0.2213

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
8	1057	1	2	A2	TS03	0.3642	0.3101	-3.3758	15	5.0775	1.3795	1.9029	0.9969	0.2717
8	1057	1	2	TP1	BG93	0.6293	0.3166	-1.8557	15	6.7153	1.2149	1.4759	0.9995	0.1809
8	2008	1	1	A1	TS01	0.6497	0.3169	-3.1272	15	8.5790	1.4344	2.0575	0.9990	0.1672
8	2008	1	1	BA*	BS**	0.6313	0.1892	-1.2603	15	4.9058	1.7088	2.9201	0.9991	0.3483
8	2008	1	2	TP1	BS93	0.6182	0.1704	-0.9772	15	4.2235	1.8128	3.2863	0.9990	0.4292
8	2008	2	2	TP1	BG92	1.3752	0.2144	0.0000	15	24.9279	4.2035	17.6696	0.9995	0.1686
8	6002	1	1	A1	TS01	0.8081	0.1188	-1.0092	15	5.0351	1.9369	3.7515	0.9993	0.3847
8	6002	1	1	BA*	BS**	0.6856	0.1867	-2.6215	15	8.1211	0.9616	0.9247	0.9996	0.1184
8	6002	1	2	A2	TS03	0.6370	0.1238	-1.4454	15	5.0803	1.4370	2.0649	0.9993	0.2829
8	6002	1	2	TP1	BS92	0.7331	0.1433	-0.7818	15	3.9857	1.2319	1.5176	0.9997	0.3091
8	6013	1	1	BA*	BS**	0.6407	0.3661	-0.3677	15	7.8237	2.1590	4.6613	0.9990	0.2760
8	6013	1	2	TP1	BS93	1.1514	0.2051	0.0000	15	9.4315	3.7882	14.3503	0.9991	0.4017
8	6013	2	1	BA*	BG**	0.5359	0.5580	-0.0894	15	31.8523	1.9124	3.6571	0.9997	0.0600
8	6013	2	2	TP1	BG**	0.5387	0.5594	-0.0662	15	32.7039	2.0364	4.1469	0.9996	0.0623
8	7035	1	1	BA*	BS**	0.6074	0.3382	-2.7277	15	7.6669	1.2863	1.6546	0.9992	0.1678
8	7035	1	2	A2	TS04	0.5484	0.2235	-1.7124	15	5.3745	2.0893	4.3652	0.9979	0.3887
8	7035	1	2	BA*	BS**	0.6203	0.1806	-1.0651	15	4.4668	1.7725	3.1418	0.9990	0.3968
8	7035	2	1	BA*	BG**	0.4811	0.5986	-0.0881	15	31.9707	1.6310	2.6602	0.9997	0.0510
8	7035	3	1	BA*	BG**	0.4806	0.5932	-0.0714	15	31.7352	2.3839	5.6831	0.9994	0.0751
8	7035	3	2	BA*	BG**	0.7105	0.4240	-0.2531	15	23.7531	3.3991	11.5540	0.9990	0.1431
8	7036	1	1	A1	TS01	0.3881	0.5582	-2.8959	15	6.0929	1.7446	3.0437	0.9963	0.2863
8	7036	1	1	BA*	BS**	0.7979	0.2077	0.0000	15	6.1412	0.8793	0.7732	0.9999	0.1432
8	7036	1	2	A2	TS03	0.4793	0.3088	-2.6789	15	5.9745	1.3679	1.8710	0.9985	0.2289
8	7036	1	2	BA*	BS**	0.7042	0.2395	-1.0344	15	5.5403	1.7052	2.9077	0.9993	0.3078
8	7776	1	1	BA*	BS**	0.7249	0.3053	-0.6783	15	6.7273	1.4822	2.1968	0.9996	0.2203
8	7776	1	1	BA1	BS01	0.9382	0.2499	-0.7301	15	7.2585	1.9369	3.7517	0.9995	0.2669
8	7776	1	2	BA*	BS**	0.7562	0.2275	-0.5597	15	5.4362	1.6924	2.8641	0.9995	0.3113
8	7776	2	1	BA*	BG**	1.0640	0.2134	-0.1404	15	15.5649	3.2166	10.3466	0.9994	0.2067
8	7781	1	1	A1	TS01	0.6418	0.2204	-0.8799	15	4.7539	1.7793	3.1659	0.9991	0.3743
8	7781	1	1	BA*	BS**	0.7049	0.1353	-0.9915	15	4.6731	2.1478	4.6132	0.9989	0.4596
8	7781	1	2	BA*	BS**	0.7338	0.3807	-1.6433	15	8.3478	1.8657	3.4807	0.9991	0.2235
8	7783	1	2	TP1	BS93	0.2536	0.0824	-3.0950	15	3.7771	1.9410	3.7673	0.9876	0.5139
8	9019	1	1	A1	TS01	0.3696	0.3750	-0.8599	15	4.1346	0.9031	0.8155	0.9994	0.2184
8	9019	1	1	BA*	BS**	0.9485	0.2802	0.0000	15	12.3508	7.5625	57.1918	0.9947	0.6123
8	9019	1	2	A2	TS03	0.6984	0.2732	-1.9740	15	7.3140	1.5861	2.5157	0.9992	0.2169
8	9019	1	2	BA*	BS**	0.4042	0.5291	-2.3357	15	6.0922	2.1659	4.6913	0.9955	0.3555
8	9020	1	2	BA*	BS**	1.0004	0.1542	-0.7844	15	5.6627	1.8133	3.2881	0.9996	0.3202
9	4008	1	1	BA3	BS03	0.6505	0.3644	0.0000	15	9.8329	4.6889	21.9862	0.9958	0.4769
9	4008	1	2	BA*	BS**	0.5737	0.8205	-0.9856	15	14.2618	2.4301	5.9052	0.9984	0.1704
9	4020	1	1	BA2	BS02	0.7663	0.7455	-1.2817	15	16.2299	2.4766	6.1335	0.9989	0.1526
9	4020	2	1	BA*	BG**	0.5391	0.7107	-0.0837	15	48.4510	2.8189	7.9459	0.9995	0.0582
9	5001	1	1	BA2	BS02	0.5722	0.7457	0.0000	15	19.1067	10.7988	116.6134	0.9767	0.5652
10	0102	1	1	B2	BS02	0.4871	0.5315	-0.9233	15	7.7870	2.0947	4.3880	0.9981	0.2690
10	0102	1	2	B9	BS09	0.5034	0.5382	-0.2964	15	9.2644	1.3894	1.9306	0.9994	0.1500
10	0102	1	3	A5	TS09	0.5967	0.5457	-0.2679	15	11.1688	1.5807	2.4987	0.9994	0.1415
10	0103	1	2	B10	BS10	0.5404	0.5512	-0.6219	15	9.3859	1.5664	2.4536	0.9992	0.1669
10	0103	1	3	A9	TS17	0.5965	0.5502	-0.3580	15	10.9991	1.6094	2.5901	0.9994	0.1463
10	0103	1	1	B3	BS03	0.8096	0.1229	-0.2659	15	3.9677	2.4820	6.1605	0.9991	0.6256
10	0104	1	1	B7	BS07	0.4675	0.6321	-0.4759	15	9.7209	1.2112	1.4671	0.9994	0.1246
10	0107	1	1	B1	BS01	0.6174	0.4327	-0.9619	15	8.0131	2.3818	5.6729	0.9984	0.2972
10	0107	1	2	B8	BS08	0.4873	0.5850	-0.1576	15	10.2251	1.7274	2.9838	0.9990	0.1689
10	0107	1	3	A2	TS03	0.5169	0.5536	0.0000	15	10.8724	2.4980	6.2399	0.9983	0.2298
10	0108	1	1	B5	BS05	0.5706	0.5549	-1.3240	15	8.9576	2.1710	4.7134	0.9983	0.2424
10	0108	1	3	A14	TS28	0.5804	0.4935	-2.2309	15	8.1387	2.0369	4.1491	0.9981	0.2503
10	0112	1	1	B11	BS11	0.5580	0.5114	-0.7176	15	8.8172	2.0666	4.2710	0.9987	0.2344
10	0112	1	2	B4	BS04	0.8166	0.2650	-0.9352	15	7.2230	3.1764	10.0897	0.9983	0.4398

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
10	0201	1	2	B12	BS06	0.4610	0.5518	-0.4218	15	8.5228	1.8790	3.5306	0.9986	0.2205
10	0201	1	3	A17	TS33	0.5080	0.5210	0.0000	15	10.0048	2.0051	4.0205	0.9988	0.2004
10	0201	2	1	B6	BG06	0.4745	0.6041	-0.2803	15	9.9403	1.6500	2.7226	0.9990	0.1660
10	0202	1	1	B3	BG03	0.5146	0.6021	-0.3152	15	10.8641	3.0002	9.0010	0.9972	0.2762
10	0202	1	2	B9	BS03	0.5223	0.5351	-0.7636	15	8.5846	1.8367	3.3736	0.9988	0.2140
10	0204	1	3	A2	TS03	0.5974	0.4958	0.0000	15	11.5726	3.8093	14.5104	0.9969	0.3292
10	0204	2	2	B1	BG01	0.5278	0.6023	-0.5789	15	10.1254	1.4023	1.9663	0.9994	0.1385
10	0207	1	1	B10	BS04	0.7416	0.3477	-1.4035	15	8.0000	2.5807	6.6600	0.9985	0.3226
10	0207	1	3	A11	TS21	0.5275	0.4735	0.0000	15	9.5334	2.4055	5.7863	0.9984	0.2523
10	0207	2	2	B4	BG04	0.5149	0.5627	-0.4112	15	9.5877	1.3647	1.8625	0.9994	0.1423
10	0211	1	2	B11	BS05	0.6758	0.3955	-1.1849	15	8.0196	2.5438	6.4710	0.9983	0.3172
10	0211	1	3	A14	TS27	0.5715	0.4488	0.0000	15	9.6174	1.8783	3.5280	0.9992	0.1953
10	0212	1	1	B2	BG02	0.5013	0.5471	-0.3572	15	9.1963	1.3752	1.8911	0.9994	0.1495
10	0212	1	2	B8	BS02	0.5802	0.5153	-0.8925	15	8.9857	2.0707	4.2878	0.9987	0.2304
10	1201	1	1	BA**	BS**	0.9346	0.5452	-1.4123	14	14.1229	4.2089	17.7146	0.9977	0.2980
10	1201	1	2	BA**	BS**	0.8074	0.5196	-0.7583	15	12.9585	2.8740	8.2597	0.9988	0.2218
10	1201	2	1	BA1	BG03	0.6557	0.7192	-0.3295	14	50.8403	3.7755	14.2546	0.9993	0.0743
10	4002	2	1	BA*	BG**	0.8164	0.6761	-0.3259	15	55.3411	6.6851	44.6902	0.9984	0.1208
10	4002	2	2	BA*	BG**	0.6919	0.7114	-0.3183	15	52.1586	3.7721	14.2287	0.9993	0.0723
10	5004	2	1	BA2	BG02	0.6689	0.7362	-0.1552	14	58.6943	3.1649	10.0163	0.9996	0.0539
10	5004	2	2	BA*	BG**	0.7930	0.6578	-0.2301	14	55.4522	5.1026	26.0365	0.9990	0.0920
10	5005	1	1	BA1	BS01	0.7943	0.6288	-1.1734	15	14.2839	2.7062	7.3232	0.9988	0.1895
10	5005	1	2	BA6	BS06	0.6353	0.5872	0.0000	15	15.0943	5.9591	35.5111	0.9936	0.3948
10	5005	2	1	BA*	BG**	0.7074	0.7208	-0.2847	15	55.6949	4.2563	18.1164	0.9993	0.0764
12	0101	1	1	B5	BS05	0.5973	0.5024	0.0000	15	11.2088	1.6014	2.5645	0.9994	0.1429
12	0104	1	2	B4	BS04	0.6657	0.4732	0.0000	15	11.9236	2.6877	7.2239	0.9987	0.2254
12	0106	1	2	B2	BS02	0.6817	0.4674	-0.2324	15	11.4547	3.4737	12.0663	0.9978	0.3033
12	0107	1	2	B1	BS01	0.6119	0.6186	-0.1422	15	13.6845	2.0042	4.0167	0.9992	0.1465
12	0112	1	2	B3	BS03	0.6652	0.5724	-0.2718	15	13.2259	1.9549	3.8217	0.9993	0.1478
12	1030	1	1	A1	TS01	0.7635	0.8401	-1.0871	15	20.2395	7.2234	52.1774	0.9917	0.3569
12	1030	1	2	TP1	BS55	1.0741	0.5049	0.0000	15	20.5735	3.9253	15.4082	0.9990	0.1908
12	1030	2	1	BA*	BG**	1.1649	0.5985	-0.2235	15	69.8153	3.9118	15.3021	0.9997	0.0560
12	1030	2	2	TP1	BG56	1.0276	0.5576	0.0000	15	66.2582	6.3145	39.8731	0.9991	0.0953
12	1030	3	1	BA*	BG**	0.7311	0.7292	-0.0214	15	71.7623	12.6045	158.8739	0.9953	0.1756
12	1030	3	2	TP1	BG55	0.9320	0.6805	0.0000	15	82.1426	10.4899	110.0383	0.9978	0.1277
12	1370	2	1	BA*	BG**	0.7739	0.7513	-0.2882	15	68.6942	11.3641	129.1437	0.9959	0.1654
12	1370	2	2	TP1	BG56	0.7039	0.6223	0.0000	15	53.6308	5.1446	26.4664	0.9989	0.0959
12	1370	3	2	TP1	BG55	0.9465	0.7224	-0.1113	15	86.1236	6.7845	46.0291	0.9991	0.0788
12	3804	1	1	A1	TS01	0.9070	0.6862	-1.3881	15	17.4432	3.6151	13.0690	0.9982	0.2073
12	3804	1	2	BA*	BS**	0.9657	0.5709	-0.2772	15	19.2490	3.2761	10.7328	0.9991	0.1702
12	3811	1	1	BA*	BS**	1.2626	0.2499	0.0000	15	15.9368	10.9476	119.8507	0.9937	0.6869
12	3811	1	2	A2	TS03	1.0453	0.3358	-0.8567	15	12.0285	6.0151	36.1813	0.9964	0.5001
12	3811	2	1	BA*	BG**	0.8395	0.6029	-0.2223	15	51.1611	3.7397	13.9853	0.9995	0.0731
12	3811	2	2	BA*	BG**	0.5468	0.6922	0.0000	15	49.2982	6.4105	41.0949	0.9976	0.1300
12	3995	1	1	A1	TS01	0.6758	0.6123	-0.3224	15	14.8891	3.4067	11.6056	0.9980	0.2288
12	3995	1	2	TP1	BS55	0.8587	0.4460	0.0000	15	14.8411	4.6674	21.7851	0.9977	0.3145
12	3995	2	2	TP1	BG56	0.8732	0.5308	0.0000	15	51.7569	3.2508	10.5679	0.9996	0.0628
12	3995	3	1	BA*	BG**	0.5862	0.7820	0.0000	15	66.3438	22.8761	523.3177	0.9800	0.3448
12	3995	3	2	TP1	BG55	1.0498	0.6834	0.0000	15	93.5001	14.8367	220.1285	0.9965	0.1587
12	3996	1	1	BA*	BS**	1.1853	0.5631	-0.3406	15	22.7466	3.7254	13.8786	0.9992	0.1638
12	3996	1	2	A2	TS03	0.7946	0.6264	-0.6460	15	16.2255	3.5180	12.3766	0.9982	0.2168
12	3996	2	1	BA*	BG**	1.2738	0.5697	-0.2774	15	66.8735	7.1835	51.6032	0.9990	0.1074
12	3996	2	2	TP1	BG56	1.1808	0.6139	-0.1975	15	75.3561	5.1741	26.7718	0.9995	0.0687
12	3996	3	2	TP1	BG55	1.2266	0.5697	-0.2059	15	68.3164	10.4957	110.1605	0.9979	0.1536
12	3997	1	1	BA*	BS**	0.9690	0.4790	-0.2001	15	16.4152	3.3933	11.5143	0.9990	0.2067
12	3997	1	2	A2	TS02	0.5257	0.7256	-1.0220	15	11.7866	1.6129	2.6014	0.9991	0.1368

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
12	3997	2	1	BA*	BG**	0.6290	0.8039	-0.3322	15	58.9405	4.6904	21.9994	0.9990	0.0796
12	3997	2	2	TP1	BG56	0.6511	0.7805	-0.2947	15	59.1027	4.8368	23.3942	0.9990	0.0818
12	3997	3	1	BA*	BG**	0.9810	0.6149	0.0000	15	87.3458	56.1647	3154.4790	0.9313	0.6430
12	3997	3	2	TP1	BG55	1.8166	0.6821	-0.3972	15	119.9431	11.8271	139.8806	0.9989	0.0986
12	4000	1	1	A1	TS01	0.7079	0.1281	0.0000	15	13.2043	12.7528	162.6327	0.9723	0.9658
12	4000	1	2	A2	TS04	0.6955	0.5877	-0.3577	15	14.1808	2.9421	8.6558	0.9985	0.2075
12	4057	1	1	A1	TS01	1.0015	0.6071	-0.2501	15	22.2544	7.1691	51.3967	0.9959	0.3221
12	4057	1	2	A2	TS03	1.1368	0.7373	-0.6570	15	28.9109	8.2250	67.6514	0.9956	0.2845
12	4057	2	1	BA*	BG**	1.1329	0.5996	-0.1200	15	73.9796	3.5863	12.8614	0.9998	0.0485
12	4057	2	2	BA*	BG**	1.1356	0.5978	-0.1918	15	70.0804	5.2201	27.2492	0.9994	0.0745
12	4059	1	1	A1	TS01	0.7213	0.5814	0.0000	15	17.4465	7.2319	52.3008	0.9926	0.4145
12	4059	1	2	BA*	BS**	0.8018	0.3872	-0.3412	15	11.6937	6.1376	37.6695	0.9948	0.5249
12	4059	2	1	BA*	BG**	1.6715	0.5319	-0.4455	15	68.3669	12.1150	146.7725	0.9979	0.1772
12	4059	2	2	BA*	BG**	1.5439	0.5875	-0.3898	15	77.7682	7.6240	58.1253	0.9992	0.0980
12	4096	1	1	A1	TS01	0.5874	0.6335	0.0000	15	14.8558	4.6186	21.3318	0.9956	0.3109
12	4096	1	2	A2	TS03	0.6756	0.8444	-0.6089	15	19.4696	4.5569	20.7655	0.9964	0.2341
12	4096	2	1	BA*	BG**	0.8613	0.5729	-0.1239	15	52.0244	3.7153	13.8037	0.9995	0.0714
12	4096	2	2	TP1	BG55	0.5867	0.7227	-0.1420	15	51.8209	1.8257	3.3332	0.9998	0.0352
12	4097	1	1	A1	TS01	0.8105	0.4330	-0.4685	15	11.8615	3.5622	12.6895	0.9982	0.3003
12	4097	1	2	A2	TS03	1.1159	0.5017	-1.1770	15	16.3963	4.1717	17.4031	0.9984	0.2544
12	4099	1	1	BA*	BS**	0.9644	0.5428	0.0000	15	20.0649	4.5685	20.8710	0.9983	0.2277
12	4099	1	2	TP1	BS55	1.0681	0.5000	0.0000	13	21.3952	3.1893	10.1714	0.9993	0.1491
12	4099	2	1	BA*	BG**	0.9989	0.6266	-0.1209	15	69.0869	3.5593	12.6688	0.9997	0.0515
12	4099	2	2	TP1	BG56	1.0873	0.5745	-0.0372	15	71.0889	3.6850	13.5794	0.9997	0.0518
12	4099	3	1	BA*	BG**	1.0777	0.5905	-0.1316	15	67.4197	7.5809	57.4708	0.9987	0.1124
12	4100	1	1	A1	TS01	0.5159	0.5230	0.0000	15	10.5456	3.3422	11.1702	0.9968	0.3169
12	4100	1	2	A2	TS03	0.5491	0.5933	0.0000	15	12.4663	2.5676	6.5927	0.9984	0.2060
12	4100	2	1	BA*	BG**	0.8429	0.6516	-0.3325	15	53.9442	4.1538	17.2545	0.9994	0.0770
12	4100	2	2	TP1	BG55	0.8432	0.5865	-0.0964	15	53.9411	2.6795	7.1797	0.9997	0.0497
12	4101	1	1	A1	TS01	0.4948	0.6069	-0.6083	15	9.7897	1.1690	1.3665	0.9995	0.1194
12	4101	1	2	A2	TS03	0.5166	0.5130	-0.4348	15	9.1641	3.1218	9.7458	0.9968	0.3407
12	4101	2	1	BA*	BG**	1.0272	0.6928	-0.3993	15	69.2829	6.7941	46.1596	0.9989	0.0981
12	4101	2	2	TP1	BG56	0.7937	0.7175	-0.2933	15	62.0190	3.8732	15.0015	0.9995	0.0625
12	4101	3	1	BA*	BG**	1.4702	0.4829	-0.2496	15	60.6487	9.7178	94.4349	0.9984	0.1602
12	4101	3	2	TP1	BG55	1.0903	0.5542	-0.0534	15	66.7345	9.8639	97.2973	0.9979	0.1478
12	4102	1	1	A1	TS02	0.5231	0.4857	0.0000	15	13.8822	10.2642	105.3530	0.9713	0.7394
12	4102	1	2	A2	TS03	0.4947	0.7199	-0.6812	15	11.7526	2.8602	8.1807	0.9971	0.2434
12	4102	2	1	BA*	BG**	0.9817	0.6666	-0.1654	15	73.8272	3.6918	13.6293	0.9997	0.0500
12	4102	2	2	TP1	BG56	0.9340	0.6579	-0.1694	15	69.4508	6.6583	44.3335	0.9989	0.0959
12	4102	3	1	BA*	BG**	1.0586	0.6259	-0.1294	15	73.0574	8.9601	80.2832	0.9983	0.1226
12	4102	3	2	TP1	BG55	1.0933	0.5949	0.0000	15	77.8220	11.9144	141.9525	0.9974	0.1531
12	4103	1	1	BA*	BS**	0.6491	0.6565	0.0000	15	33.0970	29.0194	842.1244	0.8766	0.8768
12	4103	1	2	TP1	BS55	0.8813	0.6075	-0.3588	14	18.7143	2.0665	4.2704	0.9996	0.1104
12	4103	2	1	BA*	BG**	1.3077	0.6478	0.0000	15	107.1725	12.7980	163.7882	0.9981	0.1194
12	4103	2	2	BA*	BG**	1.3077	0.6478	0.0000	15	107.1725	12.7980	163.7882	0.9981	0.1194
12	4103	2	2	TP1	BG56	1.4307	0.5687	-0.2639	15	75.8032	16.7789	281.5308	0.9958	0.2213
12	4103	3	1	BA*	BG**	0.2985	1.0083	0.0000	15	55.7031	7.1588	51.2488	0.9960	0.1285
12	4103	3	2	TP1	BG55	0.3982	1.0622	0.0000	15	84.1613	5.0229	25.2297	0.9991	0.0597
12	4105	1	1	BA*	BS**	0.9902	0.5251	-0.3831	15	17.5494	3.3652	11.3245	0.9990	0.1918
12	4105	1	2	BA*	BS**	0.8644	0.6456	-0.3097	15	19.2942	2.9455	8.6757	0.9991	0.1527
12	4105	2	1	BA*	BG**	0.9147	0.6413	-0.1892	15	63.5754	2.7306	7.4561	0.9998	0.0430
12	4105	2	2	BA*	BG**	0.9363	0.5835	-0.1520	15	57.1025	3.0922	9.5615	0.9997	0.0542
12	4105	3	1	BA*	BG**	1.1295	0.6654	-0.2417	15	79.3272	10.5297	110.8754	0.9980	0.1327
12	4105	3	2	BA*	BG**	1.2034	0.5859	0.0000	15	83.1151	16.2179	263.0190	0.9958	0.1951
12	4106	1	1	A1	TS01	0.7348	0.7280	-0.4088	15	18.9957	4.8558	23.5786	0.9965	0.2556
12	4106	1	2	A2	TS03	0.8087	0.6480	-0.2570	15	18.8068	4.1161	16.9422	0.9980	0.2189

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
12	4106	2	1	BA*	BG**	0.7192	0.8682	0.0000	15	108.7992	58.5846	3432.1540	0.9310	0.5385
12	4106	2	2	TP1	BG56	0.9003	0.6710	-0.2002	15	66.7200	3.0393	9.2374	0.9997	0.0456
12	4106	3	1	BA*	BG**	1.1197	0.5430	0.0000	15	95.5868	69.3999	4816.3440	0.9070	0.7260
12	4106	3	2	TP1	BG55	1.1762	0.7253	-0.1736	15	102.0559	6.7128	45.0612	0.9994	0.0658
12	4107	1	1	A1	TS01	0.6872	0.5268	0.0000	15	14.7283	5.9662	35.5950	0.9943	0.4051
12	4107	2	1	BA*	BG**	1.1597	0.7404	-0.1617	15	106.3249	9.6466	93.0578	0.9988	0.0907
12	4108	2	1	BA*	BG**	0.8199	0.6055	-0.0285	15	58.4847	2.6824	7.1953	0.9998	0.0459
12	4108	2	2	TP1	BG55	0.8789	0.6536	-0.3168	15	56.9647	3.7440	14.0179	0.9995	0.0657
12	4136	1	2	TP1	BS55	0.8085	0.4982	0.0000	15	15.1585	1.1706	1.3704	0.9998	0.0772
12	4153	2	1	BA*	BG**	1.2416	0.7259	-0.2695	15	100.7053	8.0287	64.4608	0.9992	0.0797
12	4153	2	2	TP1	BG55	1.2721	0.6403	-0.2794	15	82.4839	6.7410	45.4406	0.9993	0.0817
12	4154	2	1	BA*	BG**	1.1643	0.4996	0.0000	15	62.6633	9.4596	89.4846	0.9981	0.1510
12	4154	2	2	TP1	BG55	1.1360	0.4973	-0.0894	15	56.3619	7.5011	56.2666	0.9986	0.1331
12	9054	3	2	TP1	BG55	0.5994	1.0198	-0.1789	15	102.6889	8.1423	66.2965	0.9985	0.0793
13	0507	1	1	BA*	BS**	0.9499	0.3930	-1.8450	15	11.4068	3.0205	9.1235	0.9985	0.2648
13	0507	2	1	BA*	BG**	1.0362	0.6794	-0.2521	14	77.5624	5.6562	31.9925	0.9993	0.0729
13	0509	2	2	BA*	BG**	1.0046	0.6334	-0.1394	15	70.8226	3.8759	15.0225	0.9997	0.0547
13	1001	2	1	BA*	BG**	0.6046	0.8342	-0.1435	15	69.6931	2.4606	6.0544	0.9998	0.0353
13	1001	2	2	TP1	BG55	0.8146	0.7086	-0.1135	15	70.9952	3.9226	15.3864	0.9996	0.0553
13	1004	2	1	BA*	BG**	0.8050	0.8342	-0.3270	15	80.9104	6.9782	48.6952	0.9988	0.0862
13	1004	2	2	TP1	BG55	0.7927	0.5838	-0.0444	15	52.7293	3.6009	12.9665	0.9995	0.0683
13	1005	2	2	TP1	BG55	0.9928	0.5953	-0.2068	15	59.5105	5.7688	33.2787	0.9991	0.0969
13	1031	2	1	BA*	BG**	0.8214	0.5996	-0.4204	15	42.0999	8.9091	79.3714	0.9962	0.2116
13	1031	2	2	TP1	BG55	0.3498	1.0213	-0.6299	15	43.9569	4.9407	24.4102	0.9976	0.1124
13	3007	2	1	BA*	BG**	0.9088	0.7512	-0.0006	15	94.9349	9.6074	92.3022	0.9984	0.1012
13	3007	2	2	TP1	BG55	0.9234	0.7572	0.0000	15	99.2485	3.7725	14.2316	0.9998	0.0380
13	3016	2	1	BA3	BG03	0.9990	0.6250	-0.0824	15	72.5807	7.0308	49.4323	0.9989	0.0969
13	3016	2	2	BA*	BG**	0.6669	0.7000	-0.0929	15	57.7468	5.5427	30.7210	0.9987	0.0960
13	3019	2	1	BA*	BG**	0.4957	0.6388	0.0000	15	40.1800	4.8493	23.5156	0.9981	0.1207
13	3019	2	2	BA*	BG**	0.6419	0.6839	-0.0113	15	57.4828	4.1381	17.1239	0.9993	0.0720
13	4111	2	1	BA*	BG**	0.4531	0.9688	-0.3873	15	60.2849	7.0552	49.7762	0.9973	0.1170
13	4111	2	2	TP1	BG55	1.2044	0.5349	-0.1181	15	65.0076	10.4045	108.2534	0.9978	0.1601
13	4119	2	1	BA*	BG**	0.6039	0.6786	-0.0545	15	51.9033	4.9568	24.5703	0.9987	0.0955
13	4119	2	2	BA*	BG**	1.0735	0.6537	-0.1402	15	79.4028	5.7009	32.4999	0.9994	0.0718
15	1003	1	1	BA*	BS**	1.1801	0.2744	0.0000	15	14.2170	7.7635	60.2712	0.9964	0.5461
15	1003	1	2	TP1	BS93	0.8037	0.2713	-1.9778	15	8.4386	1.6830	2.8324	0.9993	0.1994
15	1006	1	2	TP1	BS93	0.8282	0.2533	-1.5392	15	7.6364	2.0750	4.3055	0.9991	0.2717
16	1005	1	1	BA*	BS**	0.8133	0.1709	-0.8203	15	5.0351	1.8550	3.4410	0.9994	0.3684
16	1005	1	2	TP1	BS92	0.5412	0.4771	-1.4878	15	7.4495	2.3277	5.4183	0.9977	0.3125
16	1005	2	1	BA*	BG**	0.4444	0.6073	-0.0347	15	31.3161	3.0125	9.0752	0.9990	0.0962
16	1009	1	1	BA*	BS**	0.6956	0.3369	-1.2859	15	7.1661	2.1588	4.6603	0.9988	0.3013
16	1009	1	2	TP1	BS92	0.5343	0.5533	-2.0868	15	8.0575	2.0946	4.3874	0.9978	0.2600
16	1010	1	1	BA*	BS**	0.4761	0.7369	-0.7215	15	10.9948	1.4424	2.0805	0.9992	0.1312
16	1010	1	2	TP1	BS92	0.4972	0.6362	-0.8064	15	9.7003	1.8796	3.5330	0.9987	0.1938
16	1020	1	1	BA*	BS**	0.6778	0.2134	-0.4236	15	4.8472	2.0117	4.0467	0.9991	0.4150
16	1020	1	2	TP1	BS93	0.5297	0.5317	-2.4055	15	7.8619	2.0733	4.2987	0.9975	0.2637
16	3017	1	1	BA*	BS**	0.6379	0.4009	-1.4634	15	7.6108	2.4823	6.1619	0.9981	0.3262
16	3017	1	2	BA*	BS**	0.5082	0.5484	-1.0714	15	8.1807	2.2643	5.1271	0.9979	0.2768
16	3023	1	1	BA*	BS**	0.6797	0.2082	-1.0948	15	5.0972	1.7088	2.9202	0.9992	0.3353
16	3023	1	2	BA*	BS**	0.5490	0.5495	-1.2113	15	8.6421	2.2628	5.1203	0.9981	0.2618
16	3023	2	1	BA*	BG**	0.8836	0.2666	-0.1515	15	16.9276	3.1961	10.2148	0.9992	0.1888
16	5025	1	2	BA*	BS**	0.8766	0.2593	-0.9251	15	7.1760	2.3484	5.5150	0.9992	0.3273
16	6027	1	2	TP1	BS93	1.4416	0.2028	0.0000	15	16.3454	12.3673	152.9498	0.9937	0.7566
16	9032	1	2	TP1	BS92	0.4390	0.1143	-4.2765	15	7.0326	2.1370	4.5666	0.9933	0.3039
16	9034	1	2	TP1	BS91	0.5695	0.7125	-1.7816	15	10.8869	2.3033	5.3054	0.9980	0.2116
17	1002	1	1	A1	TS01	1.3479	0.2225	-1.7115	15	12.2467	1.5635	2.4446	0.9998	0.1277

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
17	1002	1	2	TP*	BS**	0.7694	0.7533	-4.0159	15	14.2552	3.3959	11.5320	0.9956	0.2382
17	1003	1	1	BA*	BS**	0.8986	0.2605	-1.6956	15	8.4724	0.9582	0.9182	0.9998	0.1131
17	1003	1	2	TP*	BS**	0.3314	0.7253	-4.3621	15	6.2427	2.3750	5.6405	0.9872	0.3804
17	4074	1	1	BA*	BS**	0.6099	0.2265	-0.5543	15	4.4508	1.7885	3.1987	0.9991	0.4018
17	4074	1	2	BA*	BS**	1.6972	0.3568	-0.8437	15	17.5860	1.9087	3.6430	0.9999	0.1085
17	4082	1	1	A1	TS01	0.9277	0.0669	-1.7470	15	8.4504	0.8743	0.7644	0.9999	0.1035
17	4082	1	2	A2	TS03	0.8998	0.2462	-3.5207	15	12.6540	1.6305	2.6587	0.9992	0.1289
17	5020	1	1	A1	TS01	0.4670	0.1470	-3.8974	15	6.9946	0.9860	0.9722	0.9988	0.1410
17	5020	1	2	A2	TS03	1.1749	0.2575	-2.7268	15	14.3371	1.2611	1.5903	0.9998	0.0880
17	5151	1	1	BA*	BS**	0.6819	0.7680	-0.7372	15	16.5946	2.5366	6.4344	0.9988	0.1529
17	5151	1	2	BA*	BS**	0.7360	0.7417	-1.1850	15	15.6336	2.3824	5.6759	0.9990	0.1524
17	5217	1	1	A1	TS01	0.6774	0.1698	-3.3220	15	9.2644	1.1282	1.2728	0.9994	0.1218
17	5217	2	1	BA*	BG**	0.8709	0.6651	-0.0736	15	69.5484	3.1945	10.2050	0.9997	0.0459
17	5217	2	2	BA*	BG**	0.7451	0.6239	0.0000	15	56.5062	4.3643	19.0473	0.9993	0.0772
17	5423	1	1	A1	TS01	1.0361	0.1443	-1.6573	15	8.9427	1.3387	1.7921	0.9998	0.1497
17	5423	1	2	A2	TS03	1.4215	0.3107	-1.6122	15	14.0604	1.9613	3.8465	0.9997	0.1395
17	5453	1	1	A1	TS01	0.8921	0.3810	-4.5791	15	14.6102	3.1721	10.0621	0.9963	0.2171
17	5453	1	2	A2	TS03	1.2888	0.1400	-2.6957	15	15.7843	1.1936	1.4247	0.9998	0.0756
17	5843	1	1	A1	TS01	0.9798	0.1512	-1.9692	15	9.4602	1.0294	1.0596	0.9998	0.1088
17	5843	1	2	A2	TS03	1.3123	0.1087	-1.4823	15	10.4129	1.3978	1.9538	0.9998	0.1342
17	5849	1	1	BA*	BS**	1.5837	0.3030	-1.2764	15	14.5645	2.2465	5.0468	0.9997	0.1542
17	5849	1	2	TP*	BS**	1.3882	0.3634	-2.2505	15	16.5394	3.1663	10.0255	0.9992	0.1914
17	5854	1	1	BA*	BS**	0.2378	0.0231	-2.0798	15	3.3094	2.2278	4.9629	0.9856	0.6732
17	5854	1	2	A2	TS03	1.1069	0.1574	-2.2795	15	11.9754	1.0224	1.0453	0.9999	0.0854
17	5869	1	1	BA*	BS**	0.9555	0.5101	-2.8228	14	14.1501	3.1949	10.2077	0.9979	0.2258
17	5908	1	1	BA*	BS**	1.2271	0.3164	-1.8914	15	12.7384	0.9803	0.9609	0.9999	0.0770
17	5908	1	2	A2	TS03	1.1184	0.2961	-3.5981	15	16.0926	1.8435	3.3986	0.9994	0.1146
17	6050	1	1	BA*	BS**	0.5312	0.4764	-5.0924	15	8.9320	1.4586	2.1276	0.9975	0.1633
17	6050	1	2	TP1	BS**	1.3150	0.2621	-0.9935	14	9.3291	1.0072	1.0144	0.9999	0.1080
17	6050	2	1	BA*	BG**	0.8542	0.6403	0.0000	15	67.3355	6.1253	37.5189	0.9990	0.0910
17	6050	2	2	TP*	BG**	1.0270	0.5903	0.0000	15	71.1082	5.7426	32.9779	0.9993	0.0808
17	6050	3	1	BA*	BG**	1.0193	0.7123	-0.0121	15	96.3697	5.9577	35.4946	0.9994	0.0618
17	6050	3	2	TP*	BG**	1.2085	0.5660	0.0000	14	74.4341	6.2652	39.2524	0.9994	0.0842
17	7937	1	1	BA*	BS**	0.7524	0.3875	-2.9406	15	10.3680	2.7066	7.3259	0.9975	0.2611
17	7937	1	2	A2	TS03	0.4952	0.4619	-4.4102	15	8.3478	2.7544	7.5866	0.9914	0.3300
17	7937	2	1	BA*	BG**	0.6658	0.5978	-0.0450	15	45.4803	8.8611	78.5189	0.9959	0.1948
17	7937	2	2	TP*	BG**	0.5436	0.7482	-0.0841	15	52.4847	8.8776	78.8126	0.9957	0.1691
17	9267	1	2	BA*	BS**	0.6401	0.6992	-0.5095	15	14.7535	1.3112	1.7193	0.9997	0.0889
17	9327	1	1	A2	TS03	0.7987	0.2157	-3.6060	15	11.3381	0.8968	0.8042	0.9997	0.0791
17	9327	1	1	BA*	BS**	0.3284	0.2792	-3.6669	14	5.5589	3.1555	9.9571	0.9787	0.5676
17	9327	2	1	BA*	BG**	0.9241	0.5903	0.0000	15	64.0460	2.9739	8.8442	0.9998	0.0464
17	9327	2	2	TP*	BG**	0.8682	0.5603	-0.0696	15	52.2651	7.1054	50.4874	0.9982	0.1360
18	1028	1	1	A1	TS01	1.0185	0.2041	-3.9905	15	15.4858	3.0842	9.5120	0.9976	0.1992
18	1028	1	2	A2	TS03	1.4511	0.2260	-0.8881	15	10.0773	1.0247	1.0499	0.9999	0.1017
18	1037	1	1	BA*	BS**	0.2130	0.4021	0.0000	15	4.3622	3.0453	9.2739	0.9839	0.6981
18	1037	1	2	TP*	BS**	0.3652	0.3284	-2.6868	15	5.9362	4.0843	16.6813	0.9775	0.6880
18	2008	1	2	A2	TS03	2.2960	0.3122	-2.1867	14	21.8729	2.7116	7.3526	0.9998	0.1240
18	2009	2	1	BA1	BG01	1.3611	0.4370	-0.5682	14	37.4322	13.9977	195.9342	0.9941	0.3739
18	2009	2	2	TP*	BG**	2.3228	0.3086	-1.1605	13	36.0690	22.8971	524.2750	0.9892	0.6348
18	3002	1	1	A1	TS01	1.2879	0.3377	-1.7600	15	13.6057	1.6677	2.7812	0.9998	0.1226
18	3002	1	2	A2	TS03	0.9382	0.2318	-2.0386	15	9.5444	1.0347	1.0707	0.9998	0.1084
18	3002	2	1	BA*	BG**	0.9557	0.6382	0.0000	14	69.4903	3.1152	9.7045	0.9998	0.0448
18	3002	2	2	TP*	BG**	1.0218	0.6626	-0.0370	14	76.4659	4.3353	18.7947	0.9996	0.0567
18	3003	1	1	BA*	BS**	0.3717	0.7565	-1.5394	15	8.9240	4.9152	24.1593	0.9807	0.5508
18	3003	1	2	TP*	BS**	0.4990	0.8898	-0.9009	15	14.0401	2.2433	5.0324	0.9983	0.1598
18	3030	1	1	A1	TS01	1.9430	0.3907	-1.6994	15	22.5046	5.3663	28.7969	0.9990	0.2385

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
18	3030	1	2	TP*	BS**	1.1469	0.3549	-4.5930	15	18.2983	2.5840	6.6769	0.9985	0.1412
18	3031	1	1	A1	TS01	1.3715	0.1639	-1.9271	15	13.1501	1.3828	1.9121	0.9998	0.1052
18	3031	1	2	A2	TS03	0.8333	0.2519	-4.4471	15	13.0738	1.6140	2.6049	0.9989	0.1235
18	4021	1	1	A1	TS01	1.0102	0.5087	-5.5454	15	17.6751	4.9346	24.3500	0.9914	0.2792
18	4021	1	2	TP*	BS**	1.3495	0.3534	-4.1962	15	20.7422	2.4830	6.1655	0.9991	0.1197
18	4042	1	1	BA*	BS**	1.2089	0.3601	-1.8826	15	13.8914	2.8705	8.2395	0.9992	0.2066
18	4042	1	2	BA*	BS**	0.6107	0.6534	-1.3516	15	11.2059	2.3325	5.4403	0.9984	0.2081
18	5022	1	1	BA*	BS**	0.7935	0.6230	-2.7372	13	11.2278	2.9441	8.6679	0.9974	0.2622
18	5022	1	2	A2	TS04	1.5391	0.2834	-1.3788	15	13.8058	1.8257	3.3333	0.9998	0.1322
18	5043	1	1	BA*	BS**	1.1261	0.2032	-2.3606	15	12.4491	1.2976	1.6838	0.9998	0.1042
18	5043	1	2	BA*	BS**	0.8842	0.3176	-4.2421	15	13.7885	2.8014	7.8476	0.9972	0.2032
18	5043	2	1	BA*	BG**	0.6851	0.7196	-0.2192	15	56.5018	3.3685	11.3468	0.9995	0.0596
18	5043	2	2	BA*	BG**	0.5903	0.7128	-0.1781	15	49.1084	5.7173	32.6873	0.9982	0.1164
18	5518	1	1	BA*	BS**	0.6409	0.7795	-0.9907	15	15.1877	3.1805	10.1157	0.9977	0.2094
18	5518	1	2	BA*	BS**	0.5421	0.8955	-2.2834	15	12.2338	1.6973	2.8807	0.9987	0.1387
18	5518	2	1	BA*	BG**	0.8349	0.6897	-0.1683	14	61.7587	4.0735	16.5930	0.9995	0.0660
18	5518	2	2	BA*	BG**	1.0768	0.4659	0.0000	15	52.0478	8.0773	65.2426	0.9982	0.1552
18	5528	1	1	BA*	BS**	0.5961	1.3450	-5.0231	15	15.8556	5.7838	33.4519	0.9792	0.3648
18	5528	2	1	BA*	BG**	0.5415	0.7558	-0.2264	14	46.4155	2.8352	8.0383	0.9995	0.0611
18	5528	2	2	BA*	BG**	0.5918	0.7527	-0.2666	15	51.4652	3.1689	10.0419	0.9995	0.0616
18	5538	1	1	BA*	BS**	0.6547	0.7629	-0.8125	15	15.6929	3.5963	12.9334	0.9974	0.2292
18	5538	1	2	BA*	BS**	0.6262	0.7890	-0.8639	15	15.3877	2.2576	5.0969	0.9989	0.1467
18	5538	2	1	BA*	BG**	0.6834	0.5664	-0.1700	15	38.8131	6.4711	41.8752	0.9975	0.1667
18	5538	2	2	BA*	BG**	0.7562	0.4858	-0.1272	15	35.0845	6.5490	42.8899	0.9975	0.1867
18	6012	1	1	A1	TS01	1.4520	0.1806	-2.2634	15	15.7662	1.1087	1.2292	0.9999	0.0703
18	6012	1	2	A2	TS03	1.3473	0.2058	-3.0076	15	17.5070	1.3145	1.7279	0.9998	0.0751
18	9020	1	1	A1	TS02	1.8770	0.3469	-0.7316	15	19.4777	3.0350	9.2112	0.9997	0.1558
18	9020	1	2	A2	TS04	1.5309	0.1642	-1.3203	15	11.3356	1.6831	2.8328	0.9998	0.1485
18	9020	2	1	BA*	BG**	0.8442	0.5724	-0.0204	15	54.5464	6.2601	39.1891	0.9987	0.1148
18	9020	2	2	BA*	BG**	0.6308	0.7969	-0.1728	15	64.1682	4.6479	21.6026	0.9992	0.0724
19	0102	1	3	A5	TS10	1.4885	0.2082	-0.7352	14	9.2961	0.7045	0.4963	1.0000	0.0758
19	0103	1	3	A1	TS02	2.1248	0.2735	0.0000	15	21.6801	3.3727	11.3749	0.9998	0.1556
19	0106	1	3	A13	TS26	0.8838	0.1107	-3.3215	15	12.2909	1.2949	1.6768	0.9995	0.1054
19	0110	1	3	A10	TS20	1.2411	0.1176	-1.4465	15	9.7311	1.8654	3.4797	0.9997	0.1917
19	0110	1	3	A11	TS22	1.3405	0.1687	-1.1501	15	9.0827	1.5498	2.4019	0.9998	0.1706
19	0112	1	3	A9	TS18	1.6401	0.1607	-0.4726	15	8.2393	1.6502	2.7231	0.9999	0.2003
19	1044	1	1	BA*	BS**	1.6966	0.2525	-1.3993	12	12.4633	1.4705	2.1623	0.9999	0.1180
19	1044	1	2	A2	TS03	2.0502	0.2428	-0.8598	15	15.2075	2.8095	7.8932	0.9998	0.1847
19	3006	1	1	A1	TS01	0.9369	0.1784	-3.9041	15	13.9932	1.9829	3.9321	0.9988	0.1417
19	3006	1	2	A2	TS03	1.4405	0.2547	-2.2705	15	15.9696	1.7289	2.9892	0.9998	0.1083
19	3009	1	1	BA*	BS**	0.7151	0.7334	-1.4018	15	14.5448	2.0739	4.3010	0.9991	0.1426
19	3009	1	2	BA*	BS**	0.8679	0.4185	-1.8791	14	10.7663	2.3589	5.5645	0.9989	0.2191
19	3009	2	2	BA*	BG**	0.9315	0.4114	-0.5268	15	24.1217	7.9768	63.6300	0.9959	0.3307
19	3009	2	1	BA*	BG**	2.1712	0.3023	-0.3806	15	38.1122	4.4926	20.1835	0.9997	0.1179
19	3028	1	1	BA*	BS**	1.1183	0.2181	-2.5405	15	12.9861	1.2676	1.6069	0.9998	0.0976
19	3028	1	2	BA*	BS**	0.8075	0.2894	-3.0993	15	10.5754	1.2393	1.5358	0.9995	0.1172
19	3033	1	1	A1	TS01	1.2537	0.2884	-2.1453	15	13.4837	2.4316	5.9129	0.9994	0.1803
19	3033	1	2	A2	TS03	1.4562	0.2610	-1.8767	15	14.4529	2.0627	4.2547	0.9997	0.1427
19	3055	1	1	A1	TS01	0.7844	0.1595	-2.7298	15	9.4542	0.7456	0.5560	0.9998	0.0789
19	3055	1	2	TP*	BS**	1.6817	0.2754	-1.7494	15	16.1413	1.5473	2.3941	0.9999	0.0959
19	3055	2	1	BA*	BG**	0.8248	0.7487	-0.1108	15	80.6146	7.5650	57.2297	0.9986	0.0938
19	3055	2	2	TP*	BG**	0.6546	0.7635	-0.0902	15	65.5517	4.1582	17.2907	0.9994	0.0634
19	5042	1	2	BA*	BS**	0.9288	0.5303	-2.7635	15	13.7502	2.3804	5.6664	0.9988	0.1731
19	5042	1	1	BA*	BS**	1.2637	0.3349	-1.3799	15	12.7373	2.2182	4.9203	0.9996	0.1741
19	5046	1	1	BA*	BS**	0.9709	0.6113	-1.9458	15	15.6701	2.9761	8.8572	0.9987	0.1899
19	5046	1	2	TP*	BS**	1.0231	0.5057	-1.7480	15	14.2972	3.2284	10.4228	0.9987	0.2258

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
19	6049	1	1	A1	TS01	0.8254	0.1955	-3.3212	15	11.3103	2.1609	4.6693	0.9985	0.1911
19	6049	1	2	TP*	BS**	1.0164	0.1962	-3.3031	15	13.8351	1.5015	2.2546	0.9995	0.1085
19	6150	1	1	BA*	BS*	1.2065	0.2198	-1.2748	15	9.2849	0.4994	0.2494	1.0000	0.0538
19	6150	1	2	A2	TS03	0.4963	0.6050	-4.1992	15	8.4976	1.7196	2.9569	0.9970	0.2024
19	6150	2	1	BA*	BG**	1.5332	0.3766	-0.5671	14	33.7438	13.8003	190.4490	0.9948	0.4090
19	6150	2	2	BA*	BG**	1.6464	0.4173	-0.5915	14	40.4489	12.1557	147.7598	0.9967	0.3005
19	9126	1	1	A1	TS01	1.2189	0.3434	-2.9238	15	16.0036	2.5706	6.6081	0.9991	0.1606
19	9126	1	2	A2	TS03	0.8953	0.3317	-4.0784	15	13.3944	1.6416	2.6948	0.9991	0.1226
19	9126	3	1	BA*	BG**	0.7340	0.8203	-0.1035	15	83.6418	8.1848	66.9905	0.9984	0.0979
19	9126	3	2	TP*	BG**	0.8565	0.5750	0.0000	15	56.6504	11.3103	127.9232	0.9958	0.1997
20	0101	1	3	A5	TS12	0.9228	0.2176	-2.1077	14	9.1198	1.1220	1.2589	0.9998	0.1230
20	0110	1	3	A23	TS53	1.0282	0.3089	-2.0891	15	11.2622	2.2341	4.9913	0.9993	0.1984
20	0203	1	2	B1	BS01	1.1307	0.2483	-1.0144	15	8.7788	1.4964	2.2392	0.9998	0.1705
20	1005	1	1	A1	TS01	0.9171	0.0998	-2.8131	15	11.7648	0.8882	0.7888	0.9998	0.0755
20	1005	1	2	A2	TS03	1.0058	0.2793	-3.0416	15	13.2970	1.2214	1.4917	0.9997	0.0919
20	1006	1	1	BA*	BS*	1.0688	0.3618	-2.5638	15	13.5425	2.8128	7.9117	0.9988	0.2077
20	1006	1	2	TP*	BS**	0.5343	0.3354	-2.1834	15	6.4991	2.5681	6.5950	0.9963	0.3951
20	1009	1	2	TP*	BS**	1.4287	0.2558	-2.7932	15	17.8480	2.7120	7.3549	0.9993	0.1519
20	1009	1	1	BA*	BS**	0.5444	0.7363	-1.9292	15	10.6355	2.4440	5.9731	0.9974	0.2298
20	1010	1	1	A1	TS01	0.8326	0.3336	-2.3971	15	9.9990	1.6626	2.7641	0.9993	0.1663
20	1010	1	2	A2	TS03	0.9594	0.3163	-2.9697	15	12.6818	2.0378	4.1528	0.9991	0.1607
20	3013	1	1	A1	TS01	1.1909	0.1432	-1.1052	15	7.6014	0.8713	0.7592	0.9999	0.1146
20	3013	1	2	BA*	BS**	1.0051	0.1964	-1.7240	15	9.1026	1.4938	2.2315	0.9997	0.1641
20	3015	1	1	A1	TS01	1.1866	0.1883	-1.1641	15	8.3484	1.1655	1.3584	0.9999	0.1396
20	3015	1	2	BA*	BS**	0.9001	0.2254	-1.3863	15	7.3082	0.8490	0.7207	0.9999	0.1162
20	3060	1	1	BA*	BS**	1.0383	0.3049	-1.9478	15	10.9510	1.4304	2.0462	0.9997	0.1306
20	3060	1	2	A2	TS03	0.8682	0.2030	-2.7581	15	10.6802	0.8186	0.6701	0.9998	0.0766
20	4016	1	1	BA*	BS**	1.3182	0.1903	-0.9351	15	8.4555	1.0999	1.2099	0.9999	0.1301
20	4016	1	2	A2	TS03	0.8293	0.2439	-3.0881	15	10.9427	1.0727	1.1506	0.9996	0.0980
20	4016	2	1	BA*	BG**	0.9342	0.5967	0.0000	15	65.9965	4.3712	19.1073	0.9995	0.0662
20	4052	1	1	BA*	BS**	0.6744	0.5186	-1.9799	13	9.6190	1.3937	1.9425	0.9994	0.1449
20	4052	1	2	BA*	BS**	0.6321	0.6997	-0.7172	15	13.8640	2.4230	5.8709	0.9987	0.1748
20	4053	1	1	BA*	BS**	0.8396	0.4462	-3.5158	15	12.6201	3.0494	9.2991	0.9971	0.2416
20	4053	1	2	A2	TS03	0.8677	0.2452	-5.5103	15	14.7351	2.5128	6.3142	0.9969	0.1705
20	4054	1	1	A1	TS01	1.0542	0.1421	-1.7260	15	9.2772	0.8409	0.7071	0.9999	0.0906
20	4054	1	2	BA*	BS**	0.9615	0.2514	-0.9968	15	7.5498	1.5755	2.4823	0.9997	0.2087
20	4063	1	1	A1	TS02	0.6180	0.3951	-4.0257	15	9.5802	2.1407	4.5824	0.9969	0.2234
20	4063	1	2	BA*	BS**	0.8238	0.6084	-2.3082	15	13.1022	2.1113	4.4577	0.9990	0.1611
20	4067	1	1	BA*	BS**	0.5004	0.1924	-5.4471	15	8.3854	0.8444	0.7131	0.9989	0.1007
20	4067	1	2	A2	TS04	1.4136	0.1418	-1.2489	15	9.9226	1.7860	3.1896	0.9998	0.1800
20	4067	3	1	BA*	BG**	0.5290	0.8166	-0.2554	13	47.7971	3.0617	9.3741	0.9995	0.0641
20	4067	3	2	TP*	BG**	0.7695	0.6528	-0.0573	14	56.2055	2.8450	8.0940	0.9997	0.0506
20	6026	1	1	A1	TS01	1.3415	0.1781	-1.0188	15	8.7244	1.9034	3.6229	0.9998	0.2182
20	6026	1	2	A2	TS04	1.4843	0.2690	-0.5641	15	12.1988	1.9063	3.6340	0.9998	0.1563
20	7073	1	1	BA*	BS**	0.7014	0.6221	-0.6926	15	13.5394	1.8848	3.5526	0.9993	0.1392
20	7073	1	2	BA*	BS**	0.6359	0.7141	-0.7743	15	14.1462	1.2418	1.5421	0.9997	0.0878
20	7073	2	2	BA*	BG**	1.0509	0.4321	0.0000	15	45.7356	4.2702	18.2344	0.9994	0.0934
20	7073	2	1	BA*	BG**	0.6247	0.7330	-0.2781	15	51.2025	2.2313	4.9787	0.9997	0.0436
20	7085	1	1	A1	TS01	0.6522	0.2634	-3.6317	15	9.2618	0.8985	0.8073	0.9995	0.0970
20	7085	1	2	A2	TS03	1.0001	0.1866	-2.0313	15	9.9657	0.8299	0.6887	0.9999	0.0833
20	7085	2	2	BA*	BG**	0.9166	0.6488	-0.2080	15	62.9350	5.1951	26.9889	0.9992	0.0825
20	7085	2	1	BA*	BG**	1.1409	0.5790	-0.4235	15	54.8568	7.9566	63.3077	0.9983	0.1450
20	9037	1	1	A1	TS02	0.6495	0.4006	-3.3312	15	9.2880	1.9667	3.8678	0.9980	0.2117
20	9037	1	2	A2	TS03	0.8944	0.4029	-3.3992	15	12.8256	2.0650	4.2644	0.9988	0.1610
20	9037	2	1	BA*	BG**	0.7377	0.7179	0.0000	15	70.8941	5.5094	30.3536	0.9991	0.0777
20	9037	2	2	BA*	BG**	1.5178	0.3971	0.0000	15	58.9320	4.4759	20.0333	0.9997	0.0759

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
21	1010	1	1	BA*	BS**	1.3140	0.3828	-1.5136	14	14.3787	1.6804	2.8238	0.9998	0.1169
21	1010	1	2	TP*	BS**	1.5693	0.2436	-1.3492	15	13.1105	1.7836	3.1812	0.9998	0.1360
21	1010	2	1	BA*	BG**	0.9395	0.7345	0.0000	15	93.9695	6.0900	37.0880	0.9994	0.0648
21	1010	2	2	TP*	BG**	1.0459	0.6707	0.0000	15	89.6545	10.0747	101.5000	0.9983	0.1124
21	1034	1	1	BA*	BS**	1.2691	0.1488	-1.4909	15	10.5483	2.9698	8.8194	0.9992	0.2815
21	1034	1	2	TP*	BS**	1.5143	0.2963	-0.8791	15	13.4625	2.5721	6.6158	0.9997	0.1911
21	3016	1	1	BA*	BS**	1.2755	0.3655	-3.9170	15	19.1833	1.5922	2.5350	0.9996	0.0830
21	3016	1	2	BA*	BS**	1.4503	0.2515	-2.0894	15	15.4633	2.7497	7.5611	0.9994	0.1778
21	3016	3	1	BA*	BG**	1.2765	0.6587	-0.2201	14	85.0612	5.2495	27.5576	0.9996	0.0617
21	4025	2	1	BA*	BG**	1.8262	0.5918	-0.8477	14	68.0482	21.4827	461.5070	0.9933	0.3157
21	4025	2	2	BA*	BG**	1.0295	0.5355	0.0000	15	61.0209	10.5917	112.1837	0.9972	0.1736
21	6040	1	1	BA*	BS**	1.8454	0.1822	0.0000	15	17.9828	13.0745	170.9435	0.9957	0.7271
21	6040	1	2	TP*	BS**	1.7626	0.3400	-0.1478	12	21.5062	3.0622	9.3770	0.9997	0.1424
21	6040	2	1	BA*	BG**	0.7885	0.7352	-0.0396	15	76.3275	5.6096	31.4680	0.9992	0.0735
21	6040	2	2	TP*	BG**	0.9805	0.6050	0.0000	15	70.4505	6.2345	38.8694	0.9991	0.0885
21	6043	1	2	TP1	BS**	1.1778	0.2814	-1.5852	15	11.1283	2.1033	4.4240	0.9996	0.1890
21	6043	2	1	BA*	BG**	0.8953	0.7648	0.0000	15	95.9820	6.9636	48.4916	0.9991	0.0726
21	6043	2	2	TP*	BG**	0.7641	0.7552	-0.0122	15	78.9523	7.0479	49.6732	0.9987	0.0893
22	0113	1	1	B6	BS06	1.0059	0.1915	0.0000	15	9.4617	6.2752	39.3779	0.9966	0.6632
22	0113	3	2	B12	BG12	0.7163	0.2062	-0.6477	15	4.8137	1.7752	3.1514	0.9994	0.3688
22	0117	1	2	B5	BS05	0.7686	0.1458	0.0000	15	4.8028	2.5121	6.3109	0.9991	0.5231
22	0118	1	2	B4	BS04	0.8679	0.1866	0.0000	15	7.4066	4.4189	19.5269	0.9978	0.5966
22	0118	2	1	B10	BG10	0.6805	0.3283	-1.0674	15	6.6490	1.6997	2.8890	0.9993	0.2556
22	0119	1	2	B1	BS01	0.6042	0.2110	-0.2100	15	4.4753	1.6793	2.8201	0.9993	0.3752
22	0119	2	1	B7	BG07	0.4108	0.5374	-0.7097	15	6.8020	1.1648	1.3567	0.9992	0.1712
22	0121	1	2	B2	BS02	0.4437	0.4391	-0.4960	15	6.3456	1.7877	3.1957	0.9985	0.2817
22	0124	1	1	B3	BS03	0.8404	0.1335	0.0000	15	5.1390	3.0860	9.5235	0.9988	0.6005
22	4001	1	1	BA*	BS**	1.4944	0.8507	-2.3484	15	32.2921	11.1757	124.8952	0.9923	0.3461
22	4001	1	2	BA*	BS**	1.3809	0.3573	-0.5343	15	15.8033	4.5453	20.6596	0.9990	0.2876
22	4001	2	1	BA*	BG**	0.6173	0.6772	-0.3508	15	41.1482	6.8960	47.5550	0.9969	0.1676
23	0506	1	2	TP1	BS55	0.5087	0.5699	-0.0732	15	10.6158	1.2952	1.6776	0.9995	0.1220
23	0506	2	2	TP1	BG56	0.4848	0.5852	-0.0566	15	31.7366	1.3996	1.9590	0.9998	0.0441
23	1012	1	1	BA*	BS**	0.6022	0.5781	0.0000	15	13.3442	2.7335	7.4722	0.9985	0.2048
23	1012	1	2	TP	BS55	0.6974	0.6371	-1.5406	15	12.6867	4.1763	17.4412	0.9958	0.3292
23	1012	2	1	BA*	BG**	0.5464	0.7491	-0.2655	14	48.4540	3.9740	15.7924	0.9990	0.0820
23	1026	1	2	TP	BS55	0.8330	0.6087	-0.9905	15	14.8574	1.8059	3.2613	0.9995	0.1215
23	3013	1	2	BA*	BS**	0.6755	0.6278	-0.4215	15	14.2368	1.9750	3.9005	0.9993	0.1387
23	3013	2	1	BA*	BG**	0.6736	0.6746	-0.1825	15	51.0720	3.2040	10.2659	0.9995	0.0627
23	3014	1	1	BA*	BS**	0.7205	0.7498	-0.9058	15	16.4056	2.2938	5.2613	0.9991	0.1398
23	7023	1	1	BA**	BS**	0.6913	0.6144	0.0000	14	16.4290	3.1704	10.0515	0.9985	0.1930
23	7023	1	2	BA*	BS**	0.7092	0.6402	0.0000	15	17.3940	4.0928	16.7511	0.9976	0.2353
24	1632	2	1	BA*	BG**	0.5811	0.6991	-0.0579	15	52.1860	2.9777	8.8666	0.9995	0.0571
24	1632	2	2	TP	BG55	0.7274	0.6283	-0.2507	15	46.4612	4.1235	17.0034	0.9992	0.0888
24	1634	1	2	TP	BS55	0.8622	0.6097	-0.6792	15	16.6796	3.7889	14.3557	0.9982	0.2272
24	1634	2	1	BA1	BG03	1.2617	0.5666	-0.4912	15	55.4963	11.5692	133.8464	0.9969	0.2085
24	2401	3	1	BA2	BG02	1.1044	0.4425	-0.0430	15	48.3967	11.6601	135.9578	0.9961	0.2409
24	2401	3	2	TP	BG55	1.3128	0.5367	-0.4288	15	55.4645	13.6206	185.5200	0.9959	0.2456
24	2805	2	1	BA*	BG**	0.8228	0.5139	-0.1333	15	41.6713	3.4960	12.2221	0.9994	0.0839
24	5807	2	1	BA*	BG**	0.8824	0.5890	-0.2614	15	49.5448	7.9898	63.8367	0.9976	0.1613
24	5807	2	2	BA5	BG05	0.8888	0.5661	-0.0848	15	54.0839	8.5424	72.9731	0.9976	0.1579
25	1002	1	2	TP	BS55	0.7155	0.6381	-0.8656	15	14.1209	3.4568	11.9492	0.9978	0.2448
25	1004	1	1	BA3	BS03	0.6026	0.6496	0.0000	14	15.8268	4.9782	24.7828	0.9953	0.3145
26	0120	1	2	B1	BS01	1.4818	0.3113	-2.9054	13	18.9804	1.3988	1.9567	0.9998	0.0737
26	0121	2	1	B9	BG01	1.0702	0.7188	-0.0101	14	94.1332	18.6328	347.1815	0.9945	0.1979
26	0122	1	1	B4	BS04	1.4366	0.2674	-1.4395	15	12.6822	1.5319	2.3466	0.9998	0.1208
26	0218	1	2	B6	BS06	1.4717	0.2640	-1.5980	15	13.6706	2.1813	4.7582	0.9997	0.1596

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
26	0219	1	1	B7	BS07	1.3374	0.3864	-2.0730	13	16.3868	1.8866	3.5591	0.9997	0.1151
26	0219	2	2	B14	BG14	1.4301	0.3172	-2.8978	15	18.5673	1.8217	3.3184	0.9997	0.0981
26	0220	1	1	B3	BS03	1.3238	0.2598	-3.4381	14	18.7605	1.3376	1.7890	0.9998	0.0713
26	0222	1	2	B5	BS05	1.0187	0.4008	-4.7503	14	16.9487	2.5285	6.3933	0.9981	0.1492
26	0224	1	2	B2	BS02	1.1615	0.2411	-3.9661	15	17.3543	1.8745	3.5138	0.9993	0.1080
26	0224	2	2	B9	BG09	1.4414	0.3682	-2.1885	14	14.3291	0.8665	0.7509	0.9999	0.0605
26	1001	1	1	BA*	BS**	0.7635	0.6178	-0.6505	15	15.6683	5.5531	30.8369	0.9952	0.3544
26	1001	2	1	BA*	BG**	1.2137	0.5162	0.0000	15	68.2490	8.0786	65.2642	0.9988	0.1184
26	1001	2	2	TP*	BG**	0.9975	0.6751	-0.0387	15	84.1689	3.2104	10.3066	0.9998	0.0381
26	1004	1	1	BA*	BS**	0.9051	0.6812	-1.0068	14	18.9593	4.0895	16.7237	0.9980	0.2157
26	1004	1	2	TP*	BS**	0.8749	0.6533	-0.9488	15	18.2227	6.8059	46.3206	0.9941	0.3735
26	1004	2	2	TP*	BG**	0.6441	0.7193	-0.0274	15	61.1261	3.4596	11.9692	0.9995	0.0566
26	1010	1	1	BA*	BS**	0.2186	0.7104	0.0000	15	7.3937	4.4017	19.3749	0.9726	0.5953
26	1010	1	2	TP*	BS**	0.2849	0.1893	-0.9044	15	4.5930	4.2497	18.0598	0.9752	0.9253
26	1010	2	1	BA*	BG**	0.6960	0.6713	-0.1122	15	54.7890	2.8313	8.0163	0.9997	0.0517
26	1010	2	2	TP*	BG**	0.5464	0.8224	-0.4050	13	46.1708	2.4887	6.1938	0.9996	0.0539
26	1010	3	1	BA*	BG**	1.0904	0.5005	0.0000	15	58.7963	5.2456	27.5165	0.9993	0.0892
26	1010	3	2	TP*	BG**	0.8491	0.7005	0.0000	15	78.0328	5.7623	33.2042	0.9992	0.0738
26	1012	1	1	BA*	BS**	0.7369	0.7053	-0.7929	15	16.5840	4.7026	22.1141	0.9963	0.2836
26	1012	1	2	A2	TS04	1.2862	0.1626	-1.5326	15	10.3473	0.7875	0.6201	0.9999	0.0761
26	1012	2	1	BA*	BG**	0.7927	0.5511	-0.1813	15	42.9293	6.8693	47.1871	0.9978	0.1600
26	1012	2	2	TP*	BG**	0.6790	0.8114	-0.4863	15	57.6894	6.7627	45.7343	0.9981	0.1172
26	1012	3	2	TP*	BG**	0.8505	0.6235	-0.2292	15	54.2979	6.9024	47.6425	0.9983	0.1271
26	1013	1	1	BA*	BS**	0.7225	0.7486	-0.6051	15	17.5857	1.6345	2.6716	0.9996	0.0929
26	1013	2	1	BA*	BG**	0.5853	0.7240	-0.1627	15	50.5296	5.9401	35.2853	0.9981	0.1176
26	1013	2	2	TP*	BG**	0.6525	0.6243	-0.0706	15	46.6640	5.2572	27.6385	0.9986	0.1127
26	1013	3	1	BA*	BG**	0.5752	0.6509	0.0000	15	46.6444	7.1070	50.5094	0.9970	0.1524
26	1013	3	2	TP*	BG**	0.6082	0.7773	-0.2590	15	55.6492	4.4721	19.9998	0.9991	0.0804
26	3069	1	1	BA*	BS**	0.7556	0.7524	-0.6701	14	18.7552	1.8128	3.2862	0.9995	0.0967
26	3069	1	2	TP*	BS**	0.7152	0.7789	-0.7880	13	16.3911	1.1601	1.3459	0.9998	0.0708
26	4015	1	1	BA*	BS**	1.2632	0.3423	-3.0715	15	17.2530	3.4649	12.0054	0.9985	0.2008
26	4015	1	2	TP*	BS**	1.0766	0.4109	-3.9369	15	16.3745	1.6421	2.6964	0.9994	0.1003
26	4015	2	1	BA*	BG**	0.6861	0.6778	-0.0540	15	57.0374	5.6369	31.7743	0.9987	0.0988
26	4015	2	2	TP*	BG**	0.9150	0.5608	-0.0688	15	55.2729	5.8685	34.4389	0.9989	0.1062
26	5363	2	1	BA*	BG**	0.9378	0.4957	0.0000	15	49.7299	4.4243	19.5743	0.9993	0.0890
26	5363	2	2	TP*	BG**	0.7150	0.6980	-0.0108	15	64.8101	3.5763	12.7899	0.9996	0.0552
26	5363	3	1	BA*	BG**	0.8545	0.6235	-0.1165	15	58.9102	8.5503	73.1082	0.9977	0.1451
26	5363	3	2	TP*	BG**	0.5204	0.6969	0.0000	15	47.1990	6.1308	37.5861	0.9976	0.1299
26	6016	1	1	BA*	BS**	0.6990	0.6532	-0.5370	15	14.8837	2.0780	4.3179	0.9992	0.1396
26	6016	2	2	TP*	BG**	1.2267	0.4050	-0.0344	15	47.4821	9.3367	87.1732	0.9978	0.1966
26	6016	2	1	BA*	BG**	0.7111	0.7467	-0.3196	15	58.7317	2.7828	7.7439	0.9997	0.0474
26	6016	3	1	BA*	BG**	0.6625	0.6839	-0.1188	15	53.2955	7.4471	55.4593	0.9975	0.1397
26	6016	3	2	TP*	BG**	0.7712	0.7104	-0.1748	14	59.9572	3.6474	13.3032	0.9995	0.0608
26	7072	1	1	BA*	BS**	0.6671	0.8126	-1.0981	14	15.5712	1.8731	3.5084	0.9992	0.1203
26	7072	1	2	TP*	BS**	2.3352	0.2824	-0.8111	14	18.2108	1.3008	1.6921	1.0000	0.0714
26	7072	2	1	BA*	BG**	0.7257	0.7702	-0.3289	15	62.3880	4.9261	24.2666	0.9991	0.0790
26	7072	2	2	TP*	BG**	0.5510	0.8236	-0.0397	15	65.5310	5.3964	29.1217	0.9988	0.0824
26	7072	3	1	BA*	BG**	1.3205	0.4923	0.0000	15	69.2262	9.2379	85.3392	0.9985	0.1334
26	7072	3	2	TP*	BG**	0.8766	0.7457	0.0000	15	89.4937	7.4010	54.7755	0.9989	0.0827
26	9029	2	1	BA*	BG**	0.5808	0.7716	-0.2813	15	51.7133	3.0769	9.4670	0.9995	0.0595
26	9029	3	1	BA*	BG**	0.7054	0.6211	0.0000	15	52.7891	6.2922	39.5924	0.9983	0.1192
26	9029	3	2	BA*	BG**	0.7859	0.5949	0.0000	15	55.0050	6.3423	40.2248	0.9985	0.1153
27	1016	1	1	BA*	BS**	0.7571	0.6718	-0.7353	15	15.7782	1.5184	2.3057	0.9996	0.0962
27	1016	1	2	TP*	BS**	0.6648	0.7455	-0.7598	15	15.4873	1.7236	2.9706	0.9994	0.1113
27	1016	2	1	BA*	BG**	0.7940	0.6779	0.0000	15	68.8309	5.3381	28.4953	0.9992	0.0776
27	1016	2	2	TP*	BG**	0.6633	0.6964	0.0000	15	60.3926	3.9359	15.4914	0.9994	0.0652

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
27	1018	1	1	BA*	BS**	0.7145	0.6922	-0.7367	15	15.3431	1.6328	2.6662	0.9995	0.1064
27	1018	1	2	TP*	BS**	0.5661	0.8358	-0.8654	15	14.7254	1.3619	1.8547	0.9995	0.0925
27	1018	2	1	BA*	BG**	0.7521	0.6316	-0.2637	15	47.3867	7.7311	59.7703	0.9973	0.1632
27	1018	2	2	TP*	BG**	0.4830	0.8376	-0.3472	14	45.5099	4.0817	16.6607	0.9987	0.0897
27	1019	2	1	BA*	BG**	0.7410	0.6698	-0.0688	15	60.1734	3.5661	12.7168	0.9995	0.0593
27	1019	2	2	TP*	BG**	0.9804	0.5447	0.0000	15	59.7106	7.0383	49.5374	0.9987	0.1179
27	1028	1	1	BA*	BS**	0.7300	0.7753	-1.1021	15	16.7724	2.1937	4.8124	0.9991	0.1308
27	1028	1	2	TP*	BS**	0.7891	0.8533	-1.4552	15	18.7266	2.1106	4.4548	0.9993	0.1127
27	1029	1	1	BA*	BS**	0.7796	0.5804	-1.1021	15	12.9773	2.0276	4.1110	0.9993	0.1562
27	1029	1	2	TP*	BS**	0.7419	0.6791	-0.9346	15	15.0403	1.8658	3.4814	0.9994	0.1241
27	1085	1	1	BA*	BS**	1.7532	0.2988	-2.2666	15	19.7383	2.2788	5.1930	0.9997	0.1155
27	1085	1	2	A2	TS03	1.5602	0.3192	-1.0676	15	14.9418	3.3932	11.5138	0.9995	0.2271
27	3003	1	1	A1	TS01	1.4477	0.2800	-1.1707	15	12.5463	2.1119	4.4602	0.9997	0.1683
27	3003	1	2	A2	TS03	1.5063	0.2453	-1.3728	15	12.5982	1.2990	1.6875	0.9999	0.1031
27	3003	2	1	BA*	BG**	0.8425	0.6046	-0.2097	14	48.8306	4.1211	16.9831	0.9993	0.0844
27	3003	2	2	TP*	BG**	0.5108	0.8536	-0.0885	15	63.0153	4.2206	17.8133	0.9992	0.0670
27	3013	1	2	TP*	BS**	0.6015	0.7370	-1.1199	12	12.5224	1.0219	1.0442	0.9997	0.0816
27	4033	1	1	C6	BS01	0.5412	0.7300	-1.0006	13	12.1560	1.7003	2.8911	0.9990	0.1399
27	4033	1	2	TP*	BS**	0.6682	0.7574	-1.5541	15	13.8753	2.4022	5.7707	0.9985	0.1731
27	4034	1	1	TP*	BS**	0.7241	0.6873	-0.7904	15	15.0627	1.7392	3.0247	0.9995	0.1155
27	4034	1	2	TP*	BS**	0.6477	0.5919	-0.9236	15	11.6202	2.5074	6.2868	0.9985	0.2158
27	4034	2	1	TP*	BG**	0.7621	0.6335	-0.0142	15	58.7706	4.4924	20.1821	0.9993	0.0764
27	4034	2	2	TP*	BG**	0.6644	0.7182	-0.0591	15	60.9059	6.7047	44.9524	0.9983	0.1101
27	4037	1	1	C6	BS01	0.8953	0.6661	-1.5409	15	16.1770	2.9636	8.7830	0.9987	0.1832
27	4037	1	2	TP*	BS**	0.4114	0.7488	0.0000	15	11.9312	1.6108	2.5947	0.9990	0.1350
27	4037	2	2	TP*	BG**	0.9164	0.6053	0.0000	15	66.4647	5.3933	29.0877	0.9992	0.0811
27	4040	1	1	A1	TS01	0.9116	0.1902	-2.5367	15	10.5348	0.8562	0.7330	0.9998	0.0813
27	4040	1	2	A2	TS03	0.8461	0.1965	-3.2454	15	11.3921	1.2857	1.6531	0.9995	0.1129
27	4040	2	1	BA*	BG**	0.4578	0.8095	-0.0486	15	52.3923	4.5158	20.3924	0.9987	0.0862
27	4040	2	2	TP*	BG**	0.5690	0.7350	-0.0515	15	54.5549	5.2740	27.8148	0.9986	0.0967
27	4054	1	1	BA*	BS**	0.6709	0.7337	-0.9679	15	14.7367	1.7097	2.9232	0.9994	0.1160
27	4054	1	2	BA*	BS**	0.7898	0.8614	-1.4658	14	17.7177	1.6678	2.7817	0.9996	0.0941
27	4054	2	1	BA*	BG**	1.0646	0.5307	0.0000	15	62.4086	6.8673	47.1599	0.9989	0.1100
27	4054	2	2	BA*	BG**	0.7552	0.6763	0.0000	15	64.9811	7.9268	62.8338	0.9980	0.1220
27	4055	1	1	BA*	BS**	0.8370	0.6106	-1.0765	15	14.8269	2.7212	7.4048	0.9989	0.1835
27	4055	1	2	TP*	BS**	0.6854	0.5817	-0.8830	15	11.9929	2.2371	5.0048	0.9989	0.1865
27	4055	2	2	TP*	BG**	0.6695	0.7695	-0.2960	15	58.3902	7.7278	59.7194	0.9976	0.1323
27	4082	1	1	A1	TS01	0.9684	0.2068	-2.6811	15	11.5540	1.1560	1.3364	0.9997	0.1001
27	4082	1	2	TP*	BS**	0.3577	0.9497	-1.4417	14	10.0952	5.0992	26.0017	0.9814	0.5051
27	5076	1	1	BA*	BS**	1.1417	0.3884	-2.1105	15	13.7096	2.4614	6.0586	0.9993	0.1795
27	5076	1	2	BA*	BS**	1.3797	0.2945	-1.8713	15	14.0601	1.3203	1.7431	0.9999	0.0939
27	5076	2	1	BA*	BG**	0.7697	0.5864	-0.0996	15	48.7001	6.3801	40.7062	0.9983	0.1310
27	5076	2	2	BA*	BG**	0.3297	0.9073	-0.1510	15	43.6744	4.0163	16.1309	0.9984	0.0920
27	6251	1	1	BA*	BS**	0.7261	0.6619	-0.8628	15	14.4888	1.7593	3.0952	0.9994	0.1214
27	6251	1	2	TP*	BS**	0.6138	0.8872	-1.7640	15	14.5455	1.8369	3.3740	0.9990	0.1263
27	6251	2	2	TP*	BG**	0.7751	0.6919	0.0000	15	70.1171	4.1232	17.0004	0.9995	0.0588
27	6300	1	1	A1	TS01	1.1684	0.2273	-3.1249	15	15.4081	1.7242	2.9730	0.9995	0.1119
27	6300	1	2	TP*	BS**	1.4667	0.3651	-2.4260	15	17.8144	2.3072	5.3234	0.9996	0.1295
27	7090	1	1	BA*	BS**	0.6077	0.3404	-3.8486	15	9.0333	1.6799	2.8222	0.9981	0.1860
27	7090	2	1	BA*	BG**	0.6938	0.5582	-0.0688	15	41.7675	5.5503	30.8056	0.9983	0.1329
27	7090	2	2	TP*	BG**	0.7152	0.6393	-0.2359	15	47.8012	4.7170	22.2499	0.9989	0.0987
27	7090	3	1	BA*	BG**	0.6122	0.6561	-0.5419	14	31.8438	4.4535	19.8337	0.9985	0.1399
27	7090	3	2	TP*	BG**	0.4889	0.7558	-0.3140	15	40.9719	7.1768	51.5069	0.9958	0.1752
27	9075	1	1	BA*	BS**	0.8421	0.2536	-0.8485	15	6.3636	0.7034	0.4947	0.9999	0.1105
27	9075	1	2	BA*	BS**	1.1881	0.2096	-1.2414	15	8.8678	0.6159	0.3793	1.0000	0.0695
28	0501	1	1	A1	TS01	0.4296	0.7504	-0.4600	15	10.9965	1.7604	3.0991	0.9987	0.1601

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
28	0501	1	2	A2	TS04	0.2136	0.4305	-1.7715	15	2.9488	1.3894	1.9306	0.9943	0.4712
28	0503	1	1	A7	TS01	0.5346	0.5908	0.0000	15	12.8612	4.6447	21.5732	0.9945	0.3611
28	0504	1	2	BA*	BS**	1.3927	0.1484	-1.3025	15	10.1278	2.0865	4.3534	0.9997	0.2060
28	0506	1	1	A5	TS01	0.5916	0.5060	-1.2199	15	8.4808	2.1701	4.7095	0.9985	0.2559
28	0507	1	1	A3	TS01	1.1560	0.6145	-0.7763	15	21.9812	6.6461	44.1702	0.9969	0.3024
28	0508	1	1	A8	TS01	0.6763	0.5245	-3.0140	15	10.1980	2.5687	6.5980	0.9973	0.2519
28	0508	1	2	A9	TS03	0.6411	0.1921	-0.2812	15	4.7929	2.7593	7.6139	0.9983	0.5757
28	0509	1	1	A6	TS01	0.9214	0.3365	-4.0909	15	13.5794	2.9234	8.5465	0.9975	0.2153
28	1001	1	1	A1	TS01	0.4830	0.4098	-4.9710	15	7.4909	1.7125	2.9327	0.9961	0.2286
28	1001	1	2	A2	TS03	0.6843	0.0033	-3.7063	15	10.3694	2.0291	4.1173	0.9977	0.1957
28	1001	2	1	BA*	BG**	1.2394	0.4378	-0.3516	15	40.4610	11.0430	121.9489	0.9964	0.2729
28	1001	2	2	BA4	BG**	0.6769	0.7374	-0.2764	15	55.9691	4.4790	20.0615	0.9991	0.0800
28	1016	1	1	A1	TS01	0.5635	0.8344	-1.4185	15	15.1789	5.8728	34.4901	0.9887	0.3869
28	1016	1	2	A2	TS03	0.9632	0.4011	-1.9807	15	14.5104	8.4931	72.1324	0.9887	0.5853
28	1016	2	1	BA*	BG**	0.7199	0.6171	-0.1429	15	48.1306	4.3071	18.5509	0.9991	0.0895
28	1016	2	2	TP1	BG55	0.7488	0.5864	-0.1679	15	45.5534	2.7471	7.5464	0.9996	0.0603
28	1802	1	1	BA*	BS**	0.8968	0.3915	-0.4663	15	11.5882	3.4637	11.9969	0.9986	0.2989
28	1802	1	2	A2	TS03	0.7525	0.3040	-0.0600	15	9.2941	4.4133	19.4774	0.9971	0.4749
28	1802	2	1	BA*	BG**	1.2030	0.4672	-0.1977	15	49.0857	7.2767	52.9502	0.9986	0.1482
28	1802	2	2	TP1	BG55	0.9001	0.6394	-0.1210	15	65.0943	6.6476	44.1907	0.9988	0.1021
28	2807	1	1	A1	TS01	0.3856	0.6519	-3.2137	15	6.5407	1.7095	2.9225	0.9964	0.2614
28	2807	1	2	A2	TS03	0.9370	0.2147	-2.8659	15	11.2559	1.9621	3.8497	0.9992	0.1743
28	3018	1	1	A1	TS01	0.7536	0.4199	-1.3997	15	9.0963	2.0228	4.0918	0.9991	0.2224
28	3018	1	2	A2	TS03	0.9323	0.2198	-1.7576	15	9.8522	4.9390	24.3937	0.9959	0.5013
28	3081	1	1	A1	TS01	0.7610	0.1258	-1.0848	15	7.3569	5.7537	33.1050	0.9931	0.7821
28	3081	1	2	A2	TS03	0.7022	0.5815	-1.3703	15	11.4155	1.8482	3.4158	0.9992	0.1619
28	3082	1	1	A1	TS01	0.9479	0.5542	0.0000	15	19.7653	2.3317	5.4368	0.9995	0.1180
28	3082	1	2	A2	TS03	0.8337	0.4984	0.0000	15	16.2211	5.4201	29.3771	0.9967	0.3341
28	3083	1	1	A1	TS01	0.6474	0.4511	0.0000	15	11.0247	2.2784	5.1912	0.9990	0.2067
28	3083	1	2	A2	TS03	0.6062	0.5550	-0.1346	15	12.3327	1.5799	2.4960	0.9995	0.1281
28	3085	1	1	BA*	BS**	1.4489	0.2148	-0.9126	15	10.5546	3.7374	13.9683	0.9992	0.3541
28	3087	1	1	BA3	BS03	0.8903	0.6372	-0.8657	14	17.5893	2.3582	5.5609	0.9993	0.1341
28	3087	1	2	BA*	BS**	0.7258	0.3482	0.0000	13	10.4311	2.9281	8.5736	0.9987	0.2807
28	3089	1	1	A1	TS01	0.7743	0.4456	-2.3509	15	10.3427	2.4650	6.0764	0.9984	0.2383
28	3089	1	2	A2	TS03	0.7370	0.3363	-0.9617	15	8.6839	4.9681	24.6817	0.9950	0.5721
28	3090	1	1	A1	TS01	0.6065	0.2834	-1.8594	15	8.2271	5.3669	28.8039	0.9885	0.6523
28	3090	1	2	A2	TS02	0.7514	0.4839	-2.0114	15	10.2794	2.3089	5.3308	0.9986	0.2246
28	3090	2	1	BA*	BG**	0.9484	0.5388	0.0000	15	58.3285	9.8922	97.8550	0.9972	0.1696
28	3090	2	2	BA*	BG**	1.2587	0.6058	-0.4254	15	65.0352	10.5074	110.4063	0.9978	0.1616
28	3090	3	1	BA*	BG**	0.7073	0.9193	-0.0673	15	106.5282	7.6451	58.4479	0.9989	0.0718
28	3090	3	2	BA*	BG**	0.8222	0.6158	0.0000	15	81.5996	56.1786	3156.0310	0.9075	0.6885
28	3091	1	1	A1	TS01	0.9539	0.4315	-0.7337	15	13.7137	6.0720	36.8695	0.9960	0.4428
28	3091	1	2	A2	TS03	0.6823	0.4351	0.0000	14	11.8952	2.9579	8.7491	0.9985	0.2487
28	3093	1	1	BS*	BS**	0.7523	0.5735	-0.4220	15	14.3968	1.9019	3.6171	0.9995	0.1321
28	3093	1	2	BA*	BS**	0.8434	0.3937	-0.8469	15	10.2153	3.1608	9.9909	0.9985	0.3094
28	3094	1	1	A1	TS01	1.5502	0.6160	-4.2283	15	27.2839	9.6517	93.1548	0.9905	0.3538
28	3094	1	2	A2	TS02	0.7404	0.4200	0.0000	15	12.8719	5.7306	32.8400	0.9953	0.4452
28	3097	1	1	A1	TS01	0.5048	0.0000	-0.0175	15	9.3960	9.3958	88.2817	0.9693	1.0000
28	3097	1	2	A2	TS03	0.5593	0.6087	-3.1221	15	9.0685	1.9423	3.7724	0.9978	0.2142
28	3097	3	1	BA*	BG**	0.9806	0.7369	-0.2088	15	86.7918	8.8876	78.9887	0.9985	0.1024
28	3097	3	2	BA*	BG**	0.9068	0.7638	-0.1300	15	91.3346	7.5634	57.2049	0.9989	0.0828
28	3099	1	1	A1	TS01	0.5174	0.1286	-0.4072	15	3.9182	3.2914	10.8335	0.9960	0.8400
28	3099	1	2	A2	TS03	0.5807	0.2052	-2.6455	15	7.3937	3.0364	9.2196	0.9949	0.4107
28	4024	1	1	BA*	BS**	0.7762	0.1760	0.0000	15	9.6051	8.2256	67.6604	0.9904	0.8564
28	4024	1	2	A2	TS03	0.5100	0.3021	-2.2208	15	6.0765	2.2798	5.1975	0.9967	0.3752
28	5006	1	1	A1	TS01	1.0949	0.2238	-2.6408	15	12.9780	3.0408	9.2464	0.9986	0.2343

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
28	5006	1	2	A2	TS03	0.8565	0.2252	-3.6845	15	11.8816	2.4900	6.2003	0.9980	0.2096
28	5025	1	1	BA*	BS**	0.9304	0.4181	-0.5371	15	12.6144	3.1695	10.0460	0.9989	0.2513
28	5025	1	2	BA*	BS**	0.9196	0.2927	-0.5659	15	8.9272	3.9180	15.3509	0.9982	0.4389
28	5025	2	1	BA*	BG**	1.2468	0.5861	0.0000	15	87.0926	6.7758	45.9121	0.9993	0.0778
28	5025	2	2	BA*	BG**	1.1200	0.6862	-0.1840	15	88.7097	9.4346	89.0116	0.9985	0.1064
28	5803	1	2	BA*	BS**	0.7222	0.3697	0.0000	15	11.3984	5.4634	29.8484	0.9954	0.4793
28	5805	1	1	BA*	BS**	0.6256	0.5485	0.0000	15	13.5636	4.3057	18.5387	0.9965	0.3174
28	5805	1	2	BA*	BS**	0.8535	0.2995	-1.7143	15	9.4375	4.0607	16.4892	0.9968	0.4303
28	5805	2	1	BA*	BG**	0.7525	0.6732	-0.2135	15	55.6776	3.6392	13.2441	0.9995	0.0654
28	5805	2	2	BA*	BG**	0.6319	0.7589	-0.2775	15	55.0203	3.4368	11.8119	0.9995	0.0625
28	7012	1	1	BA2	BS02	0.9665	0.3616	-1.6515	15	10.7051	2.7175	7.3847	0.9989	0.2538
28	7012	1	2	A2	TS03	0.4493	0.4766	0.0000	15	8.6674	3.8543	14.8555	0.9944	0.4447
28	7012	2	1	BA*	BG**	0.7754	0.5459	0.0000	15	48.1845	6.9962	48.9466	0.9979	0.1452
28	7012	2	2	BA*	BG**	0.6465	0.5989	0.0000	15	46.2632	3.2678	10.6787	0.9994	0.0706
28	7012	3	1	BA*	BG**	1.0775	0.6422	-0.1267	15	79.6098	8.1694	66.7398	0.9987	0.1026
28	7012	3	2	BA*	BG**	0.6694	0.5714	-0.0622	15	42.1163	5.1458	26.4788	0.9985	0.1222
28	9030	1	1	A1	TS01	0.5855	0.5830	-1.6244	15	9.6100	3.0490	9.2965	0.9966	0.3173
28	9030	1	2	A2	TS03	0.9572	1.0500	-2.5503	15	25.9545	11.6392	135.4719	0.9807	0.4484
29	0603	1	2	TP7	BS07	0.7049	0.4336	-2.0065	15	8.8544	1.9018	3.6168	0.9989	0.2148
29	0605	1	2	TP5	BS05	1.1613	0.1806	-1.9226	15	11.1343	1.4382	2.0683	0.9998	0.1292
29	0607	1	2	TP1	BS01	1.2712	0.1479	-1.2551	15	8.9719	1.7118	2.9304	0.9998	0.1908
29	0608	1	2	TP3	BS03	0.9406	0.1876	-1.5575	15	7.7907	1.0183	1.0369	0.9998	0.1307
29	0608	2	2	TP3	BG03	0.8897	0.4855	0.0000	14	45.7283	16.6274	276.4708	0.9888	0.3636
29	1002	1	1	BA*	BS**	2.2555	0.3205	-1.0017	13	19.8262	2.5669	6.5889	0.9998	0.1295
29	1002	2	1	BA*	BG**	0.6787	0.7076	0.0000	15	63.1432	7.7860	60.6218	0.9978	0.1233
29	1002	2	2	TP*	BG**	0.6757	0.6406	0.0000	15	53.1658	6.9456	48.2409	0.9979	0.1306
29	1005	2	1	BA*	BG**	0.8208	0.6707	0.0000	15	69.5521	7.4657	55.7371	0.9985	0.1073
29	1005	2	2	TP*	BG**	0.6483	0.8938	-0.0367	15	90.5061	8.1123	65.8088	0.9984	0.0896
29	1008	1	1	A1	TS02	1.2151	0.4634	-3.2285	15	17.8213	2.9713	8.8286	0.9988	0.1667
29	1008	1	2	A2	TS04	1.3415	0.2402	-2.4097	15	15.2300	1.5926	2.5363	0.9998	0.1046
29	1008	2	1	BA*	BG**	1.3623	0.4655	0.0000	15	66.4470	16.0703	258.2561	0.9956	0.2419
29	1010	1	1	BA*	BS**	2.3257	0.3104	-0.4505	13	24.1425	5.5821	31.1604	0.9994	0.2312
29	1010	2	2	TP*	BG**	0.6512	0.7504	0.0000	15	67.2327	7.9067	62.5153	0.9979	0.1176
29	4036	1	1	A1	TS01	1.0374	0.2343	-2.6844	15	12.4835	1.7344	3.0082	0.9995	0.1389
29	4036	1	2	BA*	BS**	1.3092	0.2385	-1.1929	15	10.0560	0.7493	0.5614	1.0000	0.0745
29	4036	2	1	BA*	BG**	0.8372	0.6580	0.0000	15	69.4966	5.3582	28.7099	0.9992	0.0771
29	4036	2	2	BA*	BG**	0.9379	0.6573	-0.1898	15	66.8932	4.0826	16.6680	0.9996	0.0610
29	4069	1	1	BA*	BS**	0.7065	0.6609	-0.4527	15	15.5970	3.0304	9.1836	0.9985	0.1943
29	4069	1	2	BA*	BS**	0.6859	0.8918	-0.9959	12	18.2657	3.5880	12.8736	0.9977	0.1964
29	4069	2	1	BA*	BG**	0.7332	0.6173	-0.2456	15	44.9813	6.5533	42.9457	0.9979	0.1457
29	5000	1	1	A1	TS01	0.9256	0.1323	-2.3526	15	10.3150	0.9680	0.9370	0.9998	0.0938
29	5000	2	1	BA*	BG**	0.8774	0.6656	-0.0273	15	72.5356	5.8178	33.8464	0.9992	0.0802
29	5000	2	2	BA*	BG**	0.8525	0.7155	0.0000	15	81.5036	5.3840	28.9875	0.9994	0.0661
29	5047	1	1	BA*	BS**	0.6935	0.3517	-1.9299	15	7.7724	1.3191	1.7402	0.9995	0.1697
29	5047	1	2	BA*	BS**	0.9456	0.3450	-2.4405	15	11.3356	1.0444	1.0907	0.9998	0.0921
29	5058	1	2	BA*	BS**	0.7524	0.2320	-2.9214	15	9.4557	0.9426	0.8886	0.9997	0.0997
29	5081	1	2	A2	TS04	1.1171	0.0606	-0.9467	15	6.0906	0.7289	0.5312	0.9999	0.1197
29	5081	1	1	BA*	BS**	0.9644	0.1864	-1.9737	15	9.4299	1.2547	1.5743	0.9997	0.1331
29	5091	1	1	A1	TS02	0.7057	0.1451	-3.2496	15	9.6125	1.0902	1.1884	0.9995	0.1134
29	5091	1	2	A2	TS03	0.8396	0.2428	-2.9690	15	10.6695	1.1016	1.2135	0.9996	0.1032
29	5393	1	1	A1	TS02	1.4920	0.2024	-2.0448	15	15.0593	1.6159	2.6112	0.9998	0.1073
29	5393	2	1	BA*	BG**	0.7257	0.7392	-0.3216	15	57.9131	6.7310	45.3067	0.9982	0.1162
29	5393	2	2	TP*	BG**	0.8813	0.6496	-0.4566	15	50.5395	8.2776	68.5194	0.9974	0.1638
29	5403	1	1	BA*	BS**	0.3236	0.8099	-1.1268	15	8.5646	3.8331	14.6930	0.9867	0.4476
29	5403	1	2	TP*	BS**	0.4875	0.8351	-1.8453	15	10.8921	2.6887	7.2290	0.9964	0.2468
29	5413	1	1	BA*	BS**	0.1583	0.6566	0.0000	14	5.6276	4.3697	19.0940	0.9506	0.7765

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
29	5413	1	2	BA*	BS**	0.5343	0.7912	-1.9114	15	11.0121	2.1423	4.5896	0.9980	0.1945
29	6067	1	1	BA*	BS**	0.8896	0.7517	-3.5453	15	16.3716	4.8038	23.0761	0.9942	0.2934
29	6067	1	2	TP*	BS**	0.8678	0.7015	-3.6541	15	15.3058	4.0251	16.2016	0.9955	0.2630
29	6067	2	1	BA*	BG**	0.8021	0.7135	0.0000	15	75.9444	5.1494	26.5163	0.9993	0.0678
29	6067	2	2	TP*	BS**	0.7277	0.7680	0.0000	15	78.0581	7.4258	55.1421	0.9985	0.0951
29	7054	1	1	BA*	BS**	1.4209	0.3180	-2.1790	12	13.0802	0.7556	0.5709	1.0000	0.0578
29	7054	1	2	BA*	BS**	1.6696	0.2102	-1.3860	15	13.3442	1.5837	2.5081	0.9999	0.1187
29	7054	2	2	BA*	BG**	1.0058	0.5377	0.0000	15	60.0267	10.1294	102.6042	0.9973	0.1687
29	7073	1	1	A1	TS01	0.7707	0.3347	-5.1748	15	12.9541	1.3913	1.9359	0.9989	0.1074
29	7073	1	2	A2	TS03	1.1225	0.1654	-2.2798	15	12.1784	1.3835	1.9142	0.9997	0.1136
29	7073	3	2	BA*	BG**	1.4402	0.4837	-0.1764	15	63.3902	14.0779	198.1872	0.9966	0.2221
30	1001	1	1	BA*	BS**	0.8632	0.1528	-0.9899	15	5.6627	2.2048	4.8611	0.9992	0.3894
30	6004	1	1	BA*	BS**	0.6669	0.2432	-2.4667	15	7.7226	1.3104	1.7172	0.9993	0.1697
30	6004	1	2	TP1	BS93	0.8320	0.1334	-1.6088	15	7.1760	1.4691	2.1583	0.9996	0.2047
30	6004	2	2	TP1	BG92	0.5146	0.5290	-0.2255	15	24.9023	4.2754	18.2788	0.9977	0.1717
30	7066	1	1	BA*	BS**	0.6669	0.2432	-2.4667	15	7.7226	1.3104	1.7172	0.9993	0.1697
30	7075	1	2	TP1	BS93	0.6023	0.2563	-2.7520	15	7.4514	1.4447	2.0873	0.9989	0.1939
30	7076	2	1	BA*	BG**	0.4187	0.6012	-0.4023	15	21.7755	4.3598	19.0076	0.9966	0.2002
30	7076	2	2	TP1	BG93	0.2809	0.8542	-0.3448	15	29.2977	1.4241	2.0281	0.9996	0.0486
30	7088	1	1	BA*	BS**	0.7415	0.1513	-1.2324	15	5.4493	1.7719	3.1395	0.9993	0.3252
30	7088	1	2	TP1	BS93	0.9762	0.1447	-0.3559	15	4.9694	2.3714	5.6234	0.9994	0.4772
30	8129	1	1	BA*	BS**	1.0897	0.1394	0.0000	15	6.5625	3.5179	12.3759	0.9991	0.5361
31	0113	1	3	A17	TS33	0.9527	0.2803	-1.0314	15	7.9180	0.6568	0.4314	0.9999	0.0830
31	0115	1	3	A8	TS16	0.7421	0.4491	-2.4975	13	10.2100	1.2588	1.5846	0.9995	0.1233
31	0115	1	2	B3	BS03	0.9652	0.3697	-0.8094	15	10.5198	1.2057	1.4537	0.9998	0.1146
31	0116	1	1	B5	BS05	1.0765	0.1833	-0.8971	12	5.8672	0.6441	0.4148	1.0000	0.1098
31	0120	1	3	A11	TS22	0.7922	0.2468	-1.8877	15	7.7078	0.9509	0.9043	0.9998	0.1234
31	0124	1	2	B1	BS01	0.7360	0.3377	-2.7693	14	9.6077	0.7949	0.6319	0.9998	0.0827
31	3018	1	1	BA*	BS**	0.6827	0.8523	-1.1184	15	17.2605	2.4041	5.7798	0.9988	0.1393
31	3018	1	2	TP*	BS**	0.7840	0.8169	-1.2018	15	18.5336	2.1622	4.6752	0.9993	0.1167
31	3023	1	1	BA*	BS**	0.7441	0.7108	-0.9261	15	15.6880	1.7926	3.2133	0.9995	0.1143
31	3023	1	2	TP*	BS**	0.6779	0.7220	-0.4899	13	15.1514	1.2281	1.5081	0.9997	0.0811
31	3023	2	2	TP*	BG**	0.6834	0.6123	-0.1004	15	46.9521	4.2287	17.8815	0.9991	0.0901
31	3024	1	1	BA*	BS**	1.1275	0.3020	-1.5126	15	10.7282	1.6009	2.5629	0.9997	0.1492
31	3024	1	2	TP*	BS**	0.6338	0.4853	-2.8514	15	9.1610	2.0618	4.2508	0.9981	0.2251
31	3028	1	1	BA*	BS**	1.0009	0.1676	-2.2151	15	10.5388	1.1265	1.2690	0.9998	0.1069
31	3028	1	2	A2	TS03	0.9545	0.1654	-2.4789	15	11.1995	0.7506	0.5634	0.9999	0.0670
31	3033	1	1	BA*	BS**	0.9545	0.5284	-1.7917	12	12.3469	0.9881	0.9764	0.9999	0.0800
31	3033	1	2	TP*	BS**	0.6171	0.7665	-1.1180	15	13.7834	2.8737	8.2582	0.9979	0.2085
31	4019	1	1	A1	TS01	0.9180	0.1886	-1.7982	15	8.4177	0.7255	0.5263	0.9999	0.0862
31	4019	1	2	A2	TS04	0.5789	0.2259	-3.1061	15	7.5423	0.8853	0.7837	0.9995	0.1174
31	5052	1	1	A1	TS02	1.2649	0.2288	-1.3382	15	10.1099	0.9002	0.8103	0.9999	0.0890
31	5052	1	2	TP1	BS55	0.9413	0.2472	-1.7577	15	8.8759	1.4139	1.9992	0.9997	0.1593
31	6700	1	1	BA*	BS**	0.5489	0.4015	-2.4837	15	7.1214	1.6574	2.7470	0.9984	0.2327
31	6700	1	2	TP1	BS**	0.3902	0.4593	-2.7419	15	5.6543	1.7948	3.2212	0.9962	0.3174
31	6701	1	1	BA*	BS**	0.5232	1.0135	-3.1041	15	12.3211	1.9729	3.8923	0.9977	0.1601
31	6701	1	2	TP1	BS55	0.7962	0.6268	-0.6755	15	15.6783	1.5852	2.5127	0.9996	0.1011
31	6702	1	1	BA*	BS**	0.7452	0.7673	-2.3411	15	14.4677	2.5028	6.2641	0.9984	0.1730
31	6702	1	2	TP*	BS**	0.6271	0.7658	-2.2391	15	12.1624	2.3043	5.3097	0.9981	0.1895
31	7005	1	1	BA*	BS**	0.5740	0.5377	-1.9149	15	8.5010	1.9488	3.7978	0.9984	0.2292
31	7005	1	2	BA*	BS**	0.6827	0.5896	-1.8517	15	10.8422	2.0928	4.3798	0.9987	0.1930
31	7005	2	1	BA*	BG**	0.7557	0.7040	-0.1716	15	61.9387	3.7489	14.0542	0.9995	0.0605
31	7005	2	2	BA*	BG**	0.6823	0.7349	-0.2183	15	58.1916	3.5337	12.4867	0.9995	0.0607
31	7017	1	1	BA*	BS**	1.0963	0.2533	-1.7314	15	10.3150	1.3966	1.9506	0.9998	0.1354
31	7017	1	2	TP*	BS**	0.8180	0.2451	-2.8582	15	10.2167	0.9774	0.9553	0.9997	0.0957
31	7017	2	2	TP*	BG**	0.7653	0.5134	-0.1536	15	37.8804	5.5099	30.3590	0.9983	0.1455

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
31	7040	1	1	A1	TS02	0.6558	0.1907	-2.1733	15	6.7844	0.5449	0.2969	0.9999	0.0803
31	7040	1	2	TP1	BS**	0.6510	0.1307	-1.0998	13	4.0997	0.6884	0.4740	0.9999	0.1679
31	7040	2	1	BA*	BG**	0.7887	0.6180	-0.0098	15	58.3264	4.4061	19.4138	0.9993	0.0755
31	7040	2	2	TP*	BG**	0.8222	0.5398	-0.0242	15	48.6055	4.3531	18.9496	0.9992	0.0896
31	7050	1	1	BA*	BS**	0.6882	0.2449	-2.8732	15	8.6509	1.3074	1.7092	0.9993	0.1511
31	7050	1	2	TP*	BS**	0.7362	0.1835	-2.8416	15	9.1298	0.8446	0.7134	0.9997	0.0925
31	7050	2	2	TP*	BG**	0.5955	0.6446	-0.2215	15	40.3730	5.9077	34.9003	0.9976	0.1463
32	0101	1	2	B26	BS01	0.5965	0.7717	-1.9526	15	12.0147	2.5560	6.5330	0.9977	0.2127
32	0105	1	2	B31	BS06	0.5774	0.7375	-1.9775	15	11.2470	2.2511	5.0675	0.9980	0.2002
32	0106	1	2	B27	BS02	1.2794	0.2343	-1.5824	15	11.3339	1.7717	3.1388	0.9997	0.1563
32	0109	1	2	B28	BS03	0.7370	0.5980	-2.1861	15	11.8912	3.1952	10.2093	0.9972	0.2687
32	0111	1	2	B30	BS05	1.2431	0.2367	-1.4671	15	10.5573	1.3104	1.7171	0.9999	0.1241
32	1020	1	1	BA*	BS**	0.5320	0.6989	-0.6981	15	11.7400	1.3112	1.7191	0.9995	0.1117
32	1020	1	2	TP1	BS92	0.6278	0.6056	-1.2972	15	10.7296	2.3186	5.3759	0.9985	0.2161
32	1021	1	1	BA*	BS**	0.8756	0.1361	-0.3087	15	4.2404	2.0614	4.2493	0.9995	0.4861
32	1021	1	2	TP1	BS93	0.4802	0.3284	-2.1831	15	5.5222	1.3584	1.8452	0.9987	0.2460
32	1021	2	1	BA*	BG**	0.5125	0.5064	-0.3604	15	20.9655	6.0519	36.6260	0.9946	0.2887
32	1030	1	1	BA*	BS**	1.1115	0.1956	-0.0890	15	7.9144	2.4045	5.7818	0.9996	0.3038
32	1030	1	2	TP1	BS71	1.0128	0.2753	-0.4842	15	9.0143	2.8766	8.2746	0.9992	0.3191
32	2027	1	1	BA*	BS**	0.6036	0.4453	-1.6384	15	7.8090	2.3743	5.6373	0.9980	0.3040
32	2027	1	2	TP1	BS93	0.4681	0.5335	-1.6621	15	7.0495	1.9534	3.8157	0.9978	0.2771
32	3010	1	2	BA*	BS**	0.4898	0.3852	-1.1293	15	5.3940	0.8337	0.6951	0.9997	0.1546
32	7084	2	1	BA*	BG**	0.6450	0.4418	-0.2098	15	23.9131	4.1919	17.5716	0.9983	0.1753
34	0503	1	2	TP2	BS56	0.7614	0.2402	-0.5386	15	6.0828	2.5897	6.7068	0.9988	0.4258
34	0505	1	2	TP1	BS55	0.5751	0.5115	-0.8372	15	8.9618	2.3731	5.6316	0.9983	0.2648
34	0505	2	2	TP1	BG55	0.9100	0.7671	-0.3020	15	79.3859	4.7504	22.5663	0.9995	0.0598
34	0801	1	2	B1	BS01	0.4990	0.6526	-0.4719	15	11.0871	3.0075	9.0452	0.9970	0.2713
34	0802	1	1	B2	BS02	0.5312	0.5392	-0.1860	15	10.1831	1.8512	3.4268	0.9990	0.1818
34	1011	1	2	TP	BS55	0.7084	0.5922	-0.6944	15	13.0464	1.9333	3.7376	0.9993	0.1482
34	1031	1	1	BA*	BS**	0.7516	0.6361	-1.0440	15	13.9755	1.9745	3.8986	0.9993	0.1413
34	1031	1	2	TP	BS55	0.6511	0.4797	-0.4137	15	10.4845	2.2398	5.0168	0.9990	0.2136
34	1033	1	1	BA*	BS**	0.8907	0.2220	-0.3252	13	6.3063	3.3177	11.0073	0.9987	0.5261
34	1033	1	2	TP	BS55	1.0464	0.2820	-1.2799	15	10.7814	5.5022	30.2746	0.9965	0.5103
34	4042	2	1	BA*	BG**	0.6578	0.6752	-0.1177	15	52.5478	4.1776	17.4526	0.9992	0.0795
35	0101	1	2	B1	BS01	0.8437	0.1740	0.0000	15	7.9791	5.8879	34.6669	0.9958	0.7379
35	0102	1	3	A2	TS03	0.5317	0.2421	0.0000	15	4.9971	1.7731	3.1439	0.9991	0.3548
35	0103	1	2	B2	BS02	0.7778	0.3042	0.0000	15	5.6753	3.8139	14.5455	0.9975	0.6720
35	0105	1	2	B3	BS03	0.7277	0.1732	0.0000	15	6.5538	4.6474	21.5980	0.9965	0.7091
35	0106	1	3	A9	TS17	0.3991	0.2297	-1.2502	15	3.2704	1.0192	1.0388	0.9992	0.3116
35	0107	1	2	B4	BS04	0.6822	0.2334	0.0000	15	6.3042	2.3610	5.5744	0.9990	0.3745
35	0108	1	3	A11	TS21	0.4910	0.1442	-1.0136	15	3.0907	0.9621	0.9256	0.9995	0.3113
35	0109	1	2	B5	BS05	0.6704	0.1364	0.0000	15	3.7696	1.7358	3.0130	0.9994	0.4605
35	0110	1	3	A14	TS27	0.7783	0.3229	0.0000	15	10.1957	4.3493	18.9161	0.9974	0.4266
35	0111	1	2	B6	BS06	0.6016	0.3769	-0.6062	15	7.0933	1.8948	3.5904	0.9990	0.2671
35	0112	1	3	A17	TS33	0.5187	0.2317	-0.7539	15	3.8545	1.3528	1.8300	0.9993	0.3510
35	1002	1	2	TP1	BS55	0.9051	0.4221	-0.8276	15	11.2834	2.2779	5.1888	0.9993	0.2019
35	1002	2	2	TP1	BG55	0.9707	0.6487	-0.0935	15	73.9881	5.9341	35.2135	0.9992	0.0802
35	1003	1	1	BA*	BS**	1.2015	0.4417	-0.0646	15	19.8538	3.8564	14.8721	0.9992	0.1942
35	1003	2	1	BA*	BG**	0.7762	0.7697	-0.1357	15	78.3228	4.2805	18.3231	0.9995	0.0547
35	1003	2	2	TP1	BG55	1.3095	0.3860	0.0000	15	49.8529	12.8881	166.1037	0.9963	0.2585
35	1005	1	2	TP1	BS55	1.0627	0.2438	-1.0162	15	8.1912	1.7384	3.0222	0.9997	0.2122
35	1005	2	1	BA*	BG**	0.7366	0.7375	0.0000	15	75.4685	8.2614	68.2504	0.9981	0.1095
35	1005	2	2	TP1	BG55	0.8802	0.6531	-0.0940	15	67.7448	5.1798	26.8300	0.9993	0.0765
35	1022	1	1	A1	TS01	0.9878	0.4068	-2.2316	15	13.5446	5.9267	35.1262	0.9943	0.4376
35	1022	1	2	A2	TS03	0.8339	0.4387	-1.8656	15	10.4348	2.3617	5.5776	0.9989	0.2263
35	1022	2	1	BA*	BG**	0.6392	0.8025	0.0000	15	77.4217	10.4941	110.1256	0.9966	0.1355

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
35	1022	2	2	TP1	BG55	0.7352	0.7532	0.0000	15	78.5264	5.2192	27.2399	0.9993	0.0665
35	1112	1	1	BA*	BS**	0.8417	0.4699	0.0000	15	15.2222	4.4575	19.8690	0.9978	0.2928
35	1112	1	2	TP1	BS55	0.8456	0.5132	-0.1217	15	15.7918	2.8769	8.2768	0.9991	0.1822
35	1112	2	1	BA*	BG**	0.9479	0.8044	-0.5377	15	76.7049	4.8738	23.7542	0.9995	0.0635
35	1112	2	2	TP1	BG55	1.0553	0.6409	-0.5854	15	54.3913	12.5249	156.8721	0.9953	0.2303
35	2006	1	1	A1	TS01	0.5038	0.6525	-0.5448	15	10.9666	1.4940	2.2320	0.9992	0.1362
35	2006	1	2	A2	TS03	0.6805	0.6776	-1.4607	15	12.8656	2.5914	6.7151	0.9983	0.2014
35	2006	2	1	BA*	BG**	0.5394	0.7011	-0.2255	15	42.2135	3.7086	13.7537	0.9990	0.0879
35	2006	2	2	TP1	BG55	0.5955	0.6705	-0.2082	15	43.6172	3.9785	15.8286	0.9990	0.0912
35	2007	2	1	BA*	BS**	0.8077	0.3957	-1.6296	15	9.6288	2.7639	7.6391	0.9984	0.2870
35	2007	2	2	TP1	BS55	0.6662	0.4153	-1.0251	15	8.5245	3.2107	10.3085	0.9974	0.3766
35	2118	1	1	A1	TS01	0.2731	0.1298	0.0000	15	2.5598	2.1970	4.8269	0.9944	0.8583
35	2118	1	2	TP1	BS55	0.5064	0.2923	-0.2238	15	5.5136	2.4358	5.9334	0.9979	0.4418
35	2118	2	1	BA*	BG**	0.6992	0.6753	-0.2370	15	51.0614	3.8876	15.1132	0.9993	0.0761
35	2118	2	2	TP1	BG56	0.6065	0.6786	-0.1466	15	47.8181	2.3394	5.4728	0.9997	0.0489
35	2118	3	1	BA*	BG**	0.8368	0.6790	0.0000	15	74.9557	5.2642	27.7122	0.9993	0.0702
35	2118	3	2	TP1	BG55	0.9554	0.6672	-0.1183	15	75.1762	4.7487	22.5504	0.9995	0.0632
35	3010	1	1	A1	TS01	0.7204	0.4099	0.0000	15	13.4100	7.8390	61.4499	0.9907	0.5846
35	3010	1	2	A2	TS03	0.6200	0.5703	-1.0452	15	10.6650	3.9780	15.8242	0.9957	0.3730
35	3010	2	1	BA*	BG**	0.9575	0.6966	-0.0228	15	87.5216	7.6745	58.8976	0.9989	0.0877
35	3010	2	2	BA*	BG**	0.6851	0.7610	0.0000	15	74.5450	12.4774	155.6846	0.9953	0.1674
35	6033	1	1	BA*	BS**	0.9073	0.3140	-0.8156	15	9.0543	3.4644	12.0018	0.9984	0.3826
35	6033	1	2	A2	TS03	0.7294	0.8171	-1.3477	15	17.4512	3.7982	14.4267	0.9972	0.2177
35	6033	2	1	BA*	BG**	0.6598	0.6857	0.0000	15	59.8510	8.0811	65.3044	0.9974	0.1350
35	6033	2	2	TP1	BG55	0.4777	0.7270	0.0000	15	47.3977	2.8824	8.3081	0.9994	0.0608
35	6035	1	1	A1	TS01	0.7396	0.1481	-2.0998	15	8.3569	3.8169	14.5685	0.9956	0.4567
35	6035	1	2	TP1	BS55	1.0431	0.2668	-1.5392	15	10.0157	3.3195	11.0192	0.9986	0.3314
35	6035	3	1	BA3	BG03	0.8740	0.5158	-0.0205	15	48.6443	4.9770	24.7702	0.9991	0.1023
35	6035	3	2	TP1	BG55	0.3365	0.8375	0.0000	15	43.2443	6.3093	39.8069	0.9960	0.1459
35	6401	1	1	A1	TS01	1.0291	0.5537	-2.8297	15	15.2862	3.4135	11.6521	0.9981	0.2233
35	6401	1	2	A2	TS03	0.8011	0.6618	-1.5567	15	14.1495	0.9985	0.9970	0.9998	0.0706
35	6401	3	1	BA*	BG**	0.9800	0.6441	0.0000	15	80.7271	15.9003	252.8196	0.9948	0.1970
35	6401	3	2	TP1	BG**	0.9800	0.6441	0.0000	15	80.7271	15.9003	252.8196	0.9948	0.1970
36	0801	1	2	B1	BS01	0.4623	0.5655	-0.1668	15	9.3412	1.6278	2.6499	0.9990	0.1743
36	0802	1	2	B2	BS02	0.4891	0.6660	-0.6244	15	10.5343	2.4175	5.8445	0.9979	0.2295
36	1008	1	1	BA*	BS**	0.8533	0.5917	-1.5578	15	13.8609	3.4739	12.0682	0.9980	0.2506
36	1008	1	2	TP	BS55	0.6464	0.4130	-1.2083	15	8.2883	3.4294	11.7609	0.9967	0.4138
36	1011	1	1	BA*	BS**	1.2531	0.2721	-1.8965	15	14.2170	6.1444	37.7537	0.9964	0.4322
36	1011	1	2	TP	BS55	0.3868	0.0434	-0.5088	14	5.0715	4.9699	24.6996	0.9828	0.9800
36	1644	1	1	BA*	BS**	0.7869	0.7098	-1.1339	15	16.3051	2.3951	5.7367	0.9991	0.1469
36	4018	1	1	BA*	BS**	1.2293	0.4279	-1.1935	15	15.2980	4.0828	16.6694	0.9987	0.2669
37	0201	1	3	A2	TS02	0.4533	0.3225	-1.3388	15	4.9924	2.3729	5.6306	0.9966	0.4753
37	0206	1	3	A8	TS08	0.5075	0.2494	-2.1239	15	5.5917	1.6271	2.6475	0.9983	0.2910
37	0207	1	3	A11	TS11	0.3071	0.5937	-1.8885	15	4.9981	1.4187	2.0128	0.9971	0.2839
37	0210	1	3	A5	TS05	0.5609	0.2707	-0.9501	15	5.0398	2.1611	4.6702	0.9983	0.4288
37	0212	1	1	B5	BS05	0.7789	0.1193	0.0000	15	4.3337	2.6932	7.2531	0.9989	0.6214
37	0212	1	3	A14	TS14	0.4674	0.2894	-2.4036	15	5.6044	1.7037	2.9026	0.9977	0.3040
37	0801	1	2	B1	BS01	0.7232	0.6717	-0.5640	15	15.8361	2.0406	4.1641	0.9993	0.1289
37	0802	1	2	B2	BS02	0.6942	0.7289	-1.1240	15	15.0513	3.4940	12.2078	0.9975	0.2321
37	1006	1	1	BA2	BS02	0.9164	0.3319	-3.1837	15	12.7709	4.0516	16.4157	0.9960	0.3173
37	1006	1	2	TP	BS55	0.8226	0.2487	-2.5525	15	10.6225	4.7713	22.7656	0.9939	0.4492
37	1006	2	1	BA1	BG01	0.9826	0.6171	-0.1741	15	63.9775	9.1950	84.5476	0.9978	0.1437
37	1006	2	2	TP1	BG55	1.0125	0.6169	-0.1279	15	69.1116	4.5007	20.2563	0.9995	0.0651
37	1024	1	2	TP	BS55	0.3320	0.2857	-3.2671	14	4.9725	2.5609	6.5584	0.9874	0.5150
37	1024	2	1	BA*	BG**	0.7243	0.7045	-0.2415	15	56.4088	7.4521	55.5338	0.9978	0.1321
37	1028	1	2	TP	BS55	0.5957	0.5871	0.0000	14	13.8604	2.8360	8.0429	0.9984	0.2046

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
37	1030	1	2	TP	BS55	0.5776	0.5130	0.0000	15	11.7039	4.0470	16.3786	0.9963	0.3458
37	1040	2	1	BA*	BG**	0.6688	0.6185	-0.0045	15	50.1581	5.3333	28.4436	0.9987	0.1063
37	1040	2	2	TP	BG55	0.8254	0.6915	-0.2682	15	60.5673	8.3977	70.5219	0.9977	0.1387
37	1352	1	2	TP	BS55	0.6910	0.0000	0.0000	15	6.2336	6.2335	38.8571	0.9927	1.0000
37	1801	1	2	TP	BS55	0.8054	0.2202	-2.9237	15	10.5320	3.3995	11.5569	0.9964	0.3228
37	1803	1	2	TP	BS55	0.8492	0.2879	-1.4407	15	9.1823	4.7054	22.1410	0.9960	0.5124
37	1803	2	1	BA*	BG**	0.6012	0.6739	0.0000	15	52.1425	12.4341	154.6067	0.9923	0.2385
37	1803	2	2	TP	BG55	0.7949	0.7390	-0.4169	15	59.3161	7.6911	59.1527	0.9979	0.1297
37	1817	1	1	BA*	BS**	0.9124	0.3333	-3.4651	15	13.2190	4.0068	16.0547	0.9956	0.3031
37	1817	1	2	TP	BS55	0.9654	0.1769	-2.5638	15	11.9084	4.0678	16.5471	0.9967	0.3416
37	1992	1	1	BA*	BS**	0.8120	0.2192	-0.9444	15	6.5814	3.3311	11.0965	0.9981	0.5061
37	2819	1	1	BA*	BS**	0.5632	0.2011	-2.2567	15	6.3456	1.9793	3.9177	0.9979	0.3119
37	2819	1	2	TP	BS55	0.7508	0.0614	-1.7706	15	7.5939	3.4340	11.7925	0.9968	0.4522
37	2825	1	2	TP	BS55	0.5958	0.1375	-0.2998	15	4.4379	3.6210	13.1116	0.9964	0.8159
37	3008	1	1	BA*	BS**	0.6223	0.3402	-2.8894	15	8.7603	3.6009	12.9661	0.9935	0.4110
37	3008	1	2	BA*	BS**	0.6704	0.4799	-2.2577	15	9.8624	3.8740	15.0077	0.9948	0.3928
37	3011	1	1	BA*	BS**	0.9754	0.2170	-0.4908	15	8.8436	6.0037	36.0446	0.9962	0.6789
37	3011	1	2	TP	BS55	1.2689	0.2668	-1.9342	15	13.4837	4.6206	21.3501	0.9980	0.3427
37	3044	2	1	BA*	BG**	0.7047	0.5818	-0.3382	15	36.6513	8.7532	76.6182	0.9952	0.2388
37	3044	2	2	BA*	BG**	0.8331	0.5646	-0.3174	15	41.5713	7.4481	55.4742	0.9974	0.1792
37	3807	1	1	BA*	BS**	0.7188	0.4839	-2.9830	15	11.3129	4.6917	22.0120	0.9919	0.4147
37	3807	1	2	TP	BS55	0.7263	0.4405	-3.2208	15	10.9731	3.9086	15.2769	0.9940	0.3562
37	5037	1	1	BA*	BS**	0.6293	0.3403	-2.3543	15	9.3646	5.6625	32.0642	0.9865	0.6047
37	5037	1	2	BA*	BS**	0.8095	0.1422	-2.6958	15	10.5456	4.1501	17.2232	0.9949	0.3935
37	5827	1	1	BA*	BS**	0.6703	0.4708	-2.8276	15	10.0631	3.8618	14.9137	0.9938	0.3838
37	5827	1	2	TP	BS55	0.6923	0.2928	-2.4503	15	9.2849	4.4524	19.8240	0.9928	0.4795
38	0219	1	3	A14	TS27	0.7657	0.1591	-1.6992	15	6.5843	0.5169	0.2671	0.9999	0.0785
38	0219	1	3	A14	TS28	0.5685	0.1507	-2.8057	13	6.5594	0.4256	0.1811	0.9999	0.0649
38	0221	1	3	A20	TS40	0.7199	0.1386	-1.8029	13	5.1078	0.5500	0.3025	0.9999	0.1077
38	0221	1	3	A21	TS42	0.7785	0.2271	-2.2288	15	8.2173	0.4454	0.1983	0.9999	0.0542
38	0221	3	3	B13	BG12	1.0296	0.5450	0.0000	14	59.1369	6.0983	37.1893	0.9990	0.1031
38	0223	3	3	B12	BG11	1.0719	0.6569	-0.0664	14	78.4702	4.4137	19.4806	0.9996	0.0562
38	3005	2	1	BA*	BG**	0.9006	0.3575	-0.7161	15	16.3261	6.2887	39.5482	0.9964	0.3852
38	3006	1	1	BA*	BS**	0.6977	0.6230	-3.1469	15	11.4280	2.4777	6.1392	0.9976	0.2168
38	3006	1	2	TP*	BS**	0.6985	0.5303	-2.2198	15	10.0854	1.7994	3.2379	0.9990	0.1784
38	3006	2	1	BA*	BG**	0.6527	0.6024	-0.0942	15	43.1805	6.8477	46.8905	0.9973	0.1586
38	3006	2	2	TP*	BG**	0.3656	0.8232	-0.0286	15	43.6899	5.1463	26.4848	0.9976	0.1178
39	0101	2	2	B16	BG16	1.3235	0.6547	0.0000	14	101.9413	9.9099	98.2065	0.9988	0.0972
39	0102	2	2	B18	BG18	1.3342	0.6330	0.0000	14	95.7167	5.3768	28.9097	0.9996	0.0562
39	0106	1	2	B2	BS02	1.5063	0.3014	-0.9646	14	12.3440	1.8809	3.5379	0.9998	0.1524
39	0107	1	1	B3	BS03	1.1437	0.2312	-2.5223	15	13.2773	1.6224	2.6320	0.9996	0.1222
39	0108	1	1	B5	BS05	1.0460	0.2559	-1.6620	15	9.7165	1.2973	1.6829	0.9998	0.1335
39	0108	2	2	B19	BG19	0.9477	0.5841	-0.0283	14	58.5248	4.9704	24.7051	0.9993	0.0849
39	0203	2	2	B23	BG23	1.3221	0.5554	-0.0436	14	76.0211	5.9199	35.0458	0.9994	0.0779
39	0204	3	1	B19	BG19	1.2464	0.5372	0.0000	14	70.0611	5.6160	31.5398	0.9994	0.0802
39	0209	2	1	B22	BG22	1.2262	0.6116	0.0000	13	78.9295	5.7591	33.1673	0.9995	0.0730
39	0210	2	1	B20	BG20	0.7285	0.8353	0.0000	14	83.3119	4.4737	20.0137	0.9995	0.0537
39	0211	1	2	B6	BS06	1.3626	0.3090	-0.2987	15	13.9226	2.9887	8.9323	0.9996	0.2147
39	0803	1	3	A4	TS07	1.8490	0.2425	-1.3345	15	15.1620	1.7963	3.2267	0.9999	0.1185
39	0804	1	3	A1	TS13	1.3505	0.2300	-1.9049	15	13.1974	1.9383	3.7568	0.9997	0.1469
39	0804	3	1	B6	BG06	1.0810	0.6542	-0.0182	13	76.6177	4.2136	17.7548	0.9997	0.0550
39	0809	3	2	B7	BG07	1.1805	0.5990	0.0000	14	78.2695	4.3249	18.7047	0.9997	0.0553
39	0810	1	2	B4	BS04	1.0565	0.2802	-3.9932	15	15.7864	2.1498	4.6215	0.9989	0.1362
39	0810	3	2	B8	BG08	1.0751	0.6261	-0.0474	14	73.1927	6.4980	42.2246	0.9991	0.0888
39	3013	1	1	A1	TS02	0.5991	0.3751	-4.0511	15	9.6988	4.1732	17.4159	0.9876	0.4303
39	3013	1	2	A2	TS03	0.8795	0.3858	-5.8718	15	15.3849	3.1500	9.9227	0.9949	0.2047

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
39	3801	1	1	BA*	BS**	1.5905	0.2845	-2.3499	15	18.1764	1.4295	2.0435	0.9999	0.0786
39	3801	1	2	BA*	BS**	1.3816	0.4328	-1.4045	14	15.2036	1.2717	1.6172	0.9999	0.0836
39	4031	1	1	BA*	BS**	1.8391	0.2655	-2.0338	15	19.1379	1.7028	2.8994	0.9999	0.0890
39	4031	1	2	B*	BS**	1.5370	0.3557	-1.6368	14	14.1414	1.3570	1.8416	0.9999	0.0960
39	4031	2	1	BA*	BG**	0.9639	0.5048	-0.1818	15	45.3001	10.8097	116.8488	0.9958	0.2386
39	4031	2	2	BA*	BG**	0.7575	0.6792	0.0000	15	65.7124	6.2888	39.5489	0.9988	0.0957
39	5003	1	1	BA*	BS**	1.2735	0.2940	-3.2631	14	14.7829	1.5177	2.3035	0.9997	0.1027
39	5003	1	2	BA*	BG**	1.3413	0.2548	-2.8297	15	16.8755	1.7787	3.1639	0.9997	0.1054
39	5003	2	1	BA*	BG**	1.1465	0.4724	0.0000	15	56.8831	8.3130	69.1059	0.9984	0.1461
39	5003	2	2	BA*	BG**	0.7158	0.7927	-0.1822	15	72.2603	3.7138	13.7924	0.9996	0.0514
39	5010	1	2	BA*	BS**	0.9527	0.4270	-2.8889	15	13.4263	3.7567	14.1131	0.9970	0.2798
39	7021	1	1	BA*	BS**	1.0532	0.4167	-4.3618	15	16.5995	1.2925	1.6707	0.9996	0.0779
39	7021	1	2	BA*	BS**	1.2614	0.1805	-2.4099	15	14.3301	1.8556	3.4432	0.9996	0.1295
39	7021	2	1	BA*	BG**	0.7853	0.5365	0.0000	15	46.8231	6.0738	36.8907	0.9984	0.1297
39	7021	2	2	BA*	BG**	0.6546	0.7917	-0.2778	15	61.4396	3.4390	11.8264	0.9995	0.0560
39	9006	1	1	A1	TS02	0.7979	0.1969	-4.7725	15	12.9144	1.5188	2.3068	0.9988	0.1176
39	9006	1	2	BA*	BS**	1.1796	0.2895	-1.3390	14	10.6948	1.0943	1.1974	0.9999	0.1023
39	9006	2	1	BA*	BG**	0.6696	0.7168	-0.1912	15	55.2714	5.6925	32.4043	0.9986	0.1030
39	9006	2	2	BA*	BG**	0.7314	0.6309	-0.0579	15	53.6655	5.3642	28.7742	0.9988	0.1000
39	9022	1	1	BA*	BS**	0.9700	0.2885	-2.2142	15	10.7029	1.6258	2.6431	0.9995	0.1519
39	9022	1	2	BA*	BS**	1.2538	0.2363	-1.3040	14	8.8109	1.5731	2.4748	0.9998	0.1785
40	0114	1	2	B1	BS01	0.6288	0.2585	-0.3183	15	5.6036	2.1666	4.6943	0.9989	0.3867
40	0116	1	2	B2	BS02	0.7489	0.1739	0.0000	15	5.5532	2.8508	8.1271	0.9987	0.5134
40	0117	1	2	B3	BS03	0.8804	0.2326	0.0000	15	9.4557	5.7176	32.6911	0.9964	0.6047
40	0120	1	2	B5	BS05	0.8234	0.2199	0.0000	15	8.2045	4.8307	23.3353	0.9971	0.5888
40	0121	1	3	A14	TS27	0.5877	0.0915	-1.7329	15	5.5403	1.8775	3.5251	0.9985	0.3389
40	0122	1	2	B4	BS04	0.7352	0.2144	-0.0206	15	6.2618	2.5809	6.6610	0.9989	0.4122
40	0123	1	2	B6	BS06	1.0303	0.2341	0.0000	15	13.1087	9.6699	93.5063	0.9926	0.7377
40	0124	1	3	A17	TS33	0.5897	0.0185	-1.1002	15	4.3894	2.0908	4.3715	0.9984	0.4763
40	1015	1	1	A1	TS01	1.0432	0.1972	-1.7187	15	9.2633	1.3513	1.8261	0.9998	0.1459
40	1015	1	2	A2	TS03	0.5881	0.3653	-0.1026	15	8.6658	4.0718	16.5793	0.9960	0.4699
40	1017	1	1	A1	TS01	1.7708	0.4159	-1.3840	15	23.2895	11.2262	126.0274	0.9951	0.4820
40	1017	1	2	A2	TS03	0.7012	0.6516	-1.5159	15	12.5003	2.0748	4.3050	0.9990	0.1660
40	3018	1	1	A1	TS01	0.5833	0.5169	-4.2692	15	9.3121	2.2222	4.9381	0.9963	0.2386
40	3018	1	2	A2	TS03	0.2960	0.0000	-2.1828	15	3.5950	1.9737	3.8954	0.9928	0.5490
40	4086	1	1	A1	TS01	0.5422	0.6520	-4.0088	15	8.9576	2.6429	6.9847	0.9946	0.2950
40	4086	1	2	A2	TS03	0.5464	0.5555	-2.6984	15	8.3427	1.9925	3.9701	0.9978	0.2388
40	4087	1	1	A1	TS01	1.7265	0.2555	-0.6188	15	13.4423	1.6242	2.6379	0.9999	0.1208
40	4087	1	2	BA*	BS**	0.5161	0.2697	0.0000	15	16.0911	15.2534	232.6666	0.9319	0.9479
40	4088	1	2	BA*	BS**	0.5991	0.2581	-1.9140	15	6.3004	2.2542	5.0814	0.9978	0.3578
40	4155	1	1	A1	TS01	0.7895	0.5631	-3.6829	15	12.2987	2.4675	6.0887	0.9980	0.2006
40	4155	1	2	BA*	BS**	0.9793	0.4536	-2.3316	15	13.0311	3.0449	9.2715	0.9985	0.2337
40	4157	1	1	BA*	BS**	0.6765	0.5117	-0.6596	15	11.3167	3.7357	13.9554	0.9971	0.3301
40	4157	1	2	BA*	BS**	0.6748	0.6605	-1.3037	15	12.5993	2.2571	5.0945	0.9988	0.1791
40	4158	1	1	BA*	BS**	0.6912	0.5342	-1.9908	15	10.6815	3.6615	13.4066	0.9961	0.3428
40	4158	1	2	BA*	BS**	0.6080	0.3899	-1.3724	15	7.5637	3.3252	11.0572	0.9963	0.4396
40	4160	1	1	A1	TS01	0.5848	0.3835	-5.9611	15	9.3646	3.3566	11.2667	0.9885	0.3584
40	4160	1	2	A2	TS02	1.0501	0.4262	-1.7440	15	13.0136	3.2212	10.3762	0.9987	0.2475
40	4160	2	1	BA*	BG**	0.9827	0.3492	-0.0154	15	32.0665	7.2453	52.4938	0.9977	0.2259
40	4160	2	2	BA*	BG**	0.9216	0.5836	-0.0393	15	61.3965	9.6157	92.4612	0.9973	0.1566
40	4161	1	1	A1	TS01	0.6876	0.1714	0.0000	15	11.0000	10.1482	102.9855	0.9814	0.9226
40	4161	1	2	A2	TS03	0.5642	0.1977	-0.0065	15	8.8452	7.8870	62.2048	0.9833	0.8917
40	4162	1	1	A1	TS01	1.2183	0.5652	-1.8572	15	18.4623	2.9331	8.6030	0.9992	0.1589
40	4162	1	2	A2	TS03	0.7156	0.2577	-1.8255	15	7.3988	2.8343	8.0331	0.9977	0.3831
40	4164	1	1	BA*	BS**	0.7598	0.5080	-0.8089	15	12.1212	3.8623	14.9177	0.9974	0.3186
40	4164	1	2	A2	TS03	0.7977	0.6125	-1.1781	15	14.0655	2.1484	4.6156	0.9992	0.1527

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
40	4166	1	1	BA*	BS**	0.6403	0.1545	0.0000	15	7.2230	6.2647	39.2470	0.9917	0.8673
40	4166	1	2	A2	TS03	0.7740	0.1165	-2.2322	15	8.4046	4.0599	16.4826	0.9957	0.4831
40	5021	1	2	A2	TS01	0.5350	0.0000	-0.6667	15	6.6961	6.3165	39.8978	0.9848	0.9433
40	6010	1	1	BA*	BS**	1.1617	0.2813	-1.0623	15	10.2850	3.1847	10.1424	0.9991	0.3096
40	6010	1	2	BA*	BS**	1.0072	0.2751	-0.6287	15	9.8899	5.3661	28.7954	0.9971	0.5426
40	7024	1	1	A1	TS01	0.6482	0.4314	-2.7779	15	9.1781	3.3174	11.0053	0.9953	0.3614
40	7024	1	2	A2	TS03	0.7882	0.1866	-1.5423	15	9.4466	6.8567	47.0143	0.9897	0.7258
41	2002	1	1	A1	TS01	0.1994	0.5385	-2.2799	15	3.1045	1.3327	1.7760	0.9932	0.4293
41	2002	1	2	A2	TS03	0.3939	0.4940	-2.0941	15	5.5609	1.7347	3.0092	0.9971	0.3119
41	5005	1	1	A1	TS01	0.4772	0.2917	-2.2655	15	5.3426	1.1851	1.4045	0.9990	0.2218
41	5005	1	2	A2	TS03	0.5785	0.1770	-2.9179	15	7.1401	0.9754	0.9513	0.9994	0.1366
41	5006	1	1	A1	TS01	0.5503	0.2553	-2.4153	15	6.2731	1.1852	1.4048	0.9992	0.1889
41	5006	1	1	BA*	BS**	0.6064	0.1979	-0.8382	15	3.9976	1.2551	1.5752	0.9995	0.3140
41	5006	1	2	BA*	BS**	0.2850	0.7409	-2.7081	15	5.3247	1.4871	2.2114	0.9956	0.2793
41	5006	2	1	BA*	BG**	1.0135	0.1741	0.0000	15	14.1320	1.6635	2.7673	0.9998	0.1177
41	5006	2	2	BA*	BG**	1.0411	0.1936	0.0000	15	16.4050	1.2461	1.5528	0.9999	0.0760
41	5006	3	2	BA*	BG**	0.5314	0.5185	-0.1905	15	25.6261	4.5654	20.8425	0.9976	0.1782
41	5008	1	1	BA*	BS**	0.8025	0.2465	-0.8242	15	6.1389	1.6796	2.8210	0.9995	0.2736
41	5008	1	2	BA*	BS**	1.0517	0.1759	-0.1054	15	6.4417	1.1887	1.4129	0.9999	0.1845
41	5022	1	2	BA6	BS16	0.9010	0.2600	-1.0831	15	7.3860	1.5785	2.4915	0.9996	0.2137
41	6011	1	1	A1	TS01	0.5741	0.2144	-1.1075	15	4.1952	0.7865	0.6185	0.9998	0.1875
41	6011	1	2	A2	TS03	0.4429	0.2012	-2.0200	15	4.3665	0.6748	0.4554	0.9996	0.1545
41	7018	1	1	BA*	BS**	0.6390	0.1580	-2.3917	15	7.1201	0.7665	0.5875	0.9997	0.1076
41	7018	1	2	BA*	BS**	0.9140	0.1529	-0.0717	15	5.1195	1.5882	2.5225	0.9997	0.3102
41	7019	1	1	BA*	BS**	0.8883	0.1998	0.0000	15	8.9560	6.1635	37.9882	0.9959	0.6882
41	7019	1	2	BA*	BS**	1.0430	0.2763	0.0000	15	11.7100	4.9578	24.5801	0.9981	0.4234
41	7025	1	2	A2	TS05	0.7142	0.2945	-4.7190	15	11.2517	2.2405	5.0198	0.9970	0.1991
42	0603	1	2	B5	BS05	0.8429	0.2252	0.0000	15	7.9144	3.8112	14.5250	0.9983	0.4815
42	0608	1	2	BA6	BS06	0.7779	0.2264	-0.5420	15	5.8285	2.4156	5.8350	0.9990	0.4144
42	1597	1	1	BA1	BS01	1.2179	0.2240	-1.3571	15	11.1283	5.2052	27.0944	0.9976	0.4677
42	1597	1	2	TP	BS55	0.9290	0.2135	0.0000	15	16.1797	14.4547	208.9396	0.9797	0.8934
42	1598	1	2	BA6	BS06	0.8814	0.2810	0.0000	15	30.5068	29.1444	849.3943	0.9162	0.9553
42	1599	1	1	BA*	BS**	1.1976	0.2726	-1.4671	15	11.2610	3.5947	12.9217	0.9988	0.3192
42	1599	1	2	TP	BS55	0.8779	0.3119	-1.6200	15	9.2788	3.2764	10.7350	0.9981	0.3531
42	1605	1	1	BA2	BS02	1.1296	0.2423	-2.7411	15	14.5193	4.8309	23.3378	0.9965	0.3327
42	1605	1	2	TP	BS55	0.7416	0.1876	-3.6869	14	11.3205	4.9672	24.6734	0.9889	0.4388
42	1606	1	1	BA2	BS02	1.0593	0.0861	-0.1187	15	8.2531	7.7058	59.3792	0.9951	0.9337
42	1606	1	2	BA5	BS04	1.3631	0.2563	0.0000	15	13.9993	5.7341	32.8805	0.9985	0.4096
42	1608	1	1	BA1	BS01	1.1241	0.2083	-0.5573	15	8.1766	4.0561	16.4521	0.9987	0.4961
42	1613	1	1	BA*	BS**	0.6696	0.6107	-2.6245	15	11.0678	3.2580	10.6148	0.9961	0.2944
42	1613	1	2	BA*	BS**	0.7219	0.4706	-2.2170	14	10.8923	4.4822	20.0902	0.9940	0.4115
42	1613	2	1	BA1	BG01	0.8608	0.7675	-0.4527	15	67.4814	8.4253	70.9859	0.9980	0.1249
42	1614	1	1	BA*	BS**	1.1678	0.3567	-1.9054	14	14.4923	5.3291	28.3991	0.9970	0.3677
42	1614	1	2	BA*	BS**	1.4264	0.2147	-1.4519	15	12.0917	3.1325	9.8123	0.9993	0.2591
42	1614	2	1	BA*	BG**	0.6597	0.6437	-0.2470	15	43.8404	3.1860	10.1506	0.9994	0.0727
42	1617	1	1	BA*	BS**	1.7221	0.4466	-2.7154	15	24.0327	4.9292	24.2971	0.9985	0.2051
42	1617	1	2	BA*	BS**	1.0380	0.3248	-3.0124	15	14.5857	5.1336	26.3537	0.9950	0.3520
42	1618	1	1	BA*	BS**	0.8466	0.0940	0.0000	15	15.7954	15.5357	241.3591	0.9710	0.9836
42	1618	2	1	BA*	BG**	0.7340	0.7223	-0.4796	14	51.9994	6.8455	46.8612	0.9979	0.1316
42	1623	1	1	BA*	BS**	1.1494	0.3166	-1.3721	15	11.2787	2.9156	8.5008	0.9992	0.2585
42	1623	1	2	BA5	BS05	0.8315	0.4185	-2.4920	15	11.2998	3.8210	14.5999	0.9964	0.3381
42	1627	1	1	BA*	BS**	1.1344	0.2458	-0.7043	15	9.5244	4.5863	21.0340	0.9983	0.4815
42	1627	1	2	BA*	BS**	1.0536	0.4409	-2.0805	15	14.1108	4.6979	22.0705	0.9970	0.3329
42	1690	1	1	BA*	BS**	1.1688	0.2724	0.0000	15	14.9389	9.5433	91.0754	0.9944	0.6388
42	1690	1	2	BA*	BS**	0.7380	0.3412	-0.9247	15	7.9361	3.3480	11.2092	0.9977	0.4219
42	3044	1	1	BA1	BS01	1.4695	0.4205	-3.1776	15	21.3035	4.6973	22.0645	0.9979	0.2205

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
42	5020	1	2	BA5	BS04	0.8639	0.5063	-1.0841	15	12.5725	2.1072	4.4404	0.9994	0.1676
42	7025	1	1	BA*	BS**	0.8528	0.4199	-2.2559	15	12.2311	5.5955	31.3100	0.9931	0.4575
42	7025	1	2	BA*	BS**	0.8620	0.6210	-2.3223	15	14.6346	5.3154	28.2534	0.9942	0.3632
42	7025	2	2	BA*	BG**	1.2372	0.5122	-0.4399	15	47.7571	9.7326	94.7229	0.9975	0.2038
42	7037	1	1	BA*	BS**	1.2869	0.2822	-1.3211	15	12.1342	4.1306	17.0618	0.9987	0.3404
42	7037	1	2	BA*	BS**	1.0692	0.2131	-0.8617	15	8.6850	4.8633	23.6512	0.9977	0.5600
42	7037	2	1	BA3	BG03	0.8159	0.5241	0.0000	15	47.6005	7.7802	60.5310	0.9975	0.1634
42	7037	2	2	BA5	BG05	1.3511	0.4294	-0.4827	15	38.1261	10.7165	114.8433	0.9967	0.2811
42	9027	1	2	BA*	BS**	1.1214	0.1738	-0.7099	15	7.8782	4.8097	23.1334	0.9980	0.6105
45	1008	1	1	A1	TS01	0.9584	0.5623	-2.6292	15	14.5498	2.1731	4.7222	0.9991	0.1494
45	1008	1	2	A2	TS03	0.6119	0.2568	0.0000	15	10.4462	8.7071	75.8142	0.9829	0.8335
45	1008	2	1	BA*	BG**	0.5487	0.7521	-0.1001	15	53.7453	3.4792	12.1046	0.9994	0.0647
45	1008	2	2	TP1	BG55	0.8435	0.7367	-0.2961	15	69.2724	4.6863	21.9612	0.9994	0.0677
45	1011	1	1	BA*	BS**	0.8791	0.5004	-0.7119	15	13.6214	2.7876	7.7706	0.9990	0.2046
45	1011	1	2	BA*	BS**	0.8041	0.4662	-0.4398	15	12.4319	2.7275	7.4393	0.9990	0.2194
45	1011	2	1	BA*	BG**	0.8686	0.6486	0.0000	15	74.1676	23.4012	547.6161	0.9862	0.3155
45	1011	2	2	BA*	BG**	1.2357	0.5509	0.0000	15	77.7528	15.0246	225.7375	0.9963	0.1932
45	1024	1	1	A1	TS01	0.9860	0.3844	-2.0542	15	12.5254	4.7007	22.0968	0.9966	0.3753
45	1024	1	2	TP1	BS55	1.0778	0.2189	-2.2483	15	12.5007	5.0386	25.3870	0.9963	0.4031
45	1024	2	1	BA*	BG**	0.5058	0.7978	-0.0066	15	59.2241	4.5845	21.0178	0.9989	0.0774
45	1024	2	2	TP1	BG55	0.4304	0.8535	-0.0496	15	56.2340	2.7222	7.4102	0.9995	0.0484
45	1025	1	1	A1	TS01	0.6298	0.4025	0.0000	15	9.8305	3.0734	9.4456	0.9981	0.3126
45	1025	1	2	A2	TS03	0.8716	0.4924	-5.2213	15	14.2812	3.3376	11.1398	0.9954	0.2337
45	1025	2	1	BA*	BG**	0.6765	0.6035	-0.0609	15	46.7493	2.7040	7.3115	0.9996	0.0578
45	1025	2	2	TP1	BG**	0.8929	0.6805	-0.1293	15	71.4322	4.1134	16.9201	0.9996	0.0576
45	3012	1	1	A1	TS01	0.5775	0.3749	-3.0666	15	8.2779	2.7739	7.6948	0.9953	0.3351
45	3012	1	2	A2	TS03	0.5603	0.4095	-4.3981	15	9.0701	3.0086	9.0518	0.9921	0.3317
45	5017	1	1	A1	TS01	0.8494	0.4346	-0.7402	15	11.7830	3.8878	15.1153	0.9979	0.3300
45	5017	1	2	BA*	BS**	0.7194	0.5896	0.0000	14	16.9997	5.2463	27.5236	0.9961	0.3086
45	5034	1	1	A1	TS01	0.9504	0.5001	-1.5595	15	13.9786	5.3898	29.0500	0.9959	0.3856
45	5034	1	2	A2	TS03	0.7599	0.4244	-1.8524	15	9.7174	2.9941	8.9644	0.9978	0.3081
45	5035	1	1	A1	TS01	0.6324	0.7250	-1.3138	15	13.1283	2.5475	6.4899	0.9983	0.1940
45	5035	1	2	A2	TS03	0.8516	0.3949	-0.4930	15	11.6157	4.5648	20.8377	0.9973	0.3930
45	7019	1	1	A1	TS01	0.8309	0.3925	-1.7864	15	10.6064	4.5556	20.7534	0.9958	0.4295
45	7019	1	2	A2	TS03	0.4102	0.6064	-1.0110	15	7.4814	1.8731	3.5086	0.9979	0.2504
46	0804	1	3	A5	TS10	1.0014	0.1792	-0.5826	15	5.6290	1.2340	1.5228	0.9998	0.2192
46	0804	1	3	A6	TS12	1.0125	0.2113	-1.1664	14	7.4543	1.4291	2.0425	0.9998	0.1917
46	3009	1	1	A1	TS02	1.5606	0.2006	-1.1031	15	10.9052	1.2399	1.5373	0.9999	0.1137
46	3009	2	1	BA*	BG**	0.8673	0.5690	-0.2010	15	49.3638	16.8450	283.7539	0.9892	0.3412
46	3009	2	2	TP*	BG**	0.6031	0.7497	-0.0289	15	60.9481	5.8817	34.5944	0.9986	0.0965
46	3010	1	1	BA*	BS**	0.9322	0.3758	-2.7217	15	12.0752	2.3515	5.5293	0.9988	0.1947
46	3010	1	2	TP*	BS**	1.0380	0.4275	-3.1172	15	14.6385	2.8377	8.0523	0.9985	0.1938
46	3010	2	1	BA*	BG**	0.5338	0.7779	-0.1845	15	51.6920	5.5391	30.6814	0.9983	0.1072
46	3010	2	2	TP*	BG**	0.5876	0.6184	-0.0587	15	41.9237	8.9799	80.6390	0.9948	0.2142
46	3012	1	2	TP*	BS**	1.2348	0.2422	-2.5427	15	14.5183	1.8950	3.5911	0.9996	0.1305
46	3012	2	2	TP*	BG**	0.8957	0.5861	0.0000	15	61.4029	8.3851	70.3101	0.9980	0.1366
46	3013	1	1	BA*	BS**	0.8050	0.4527	-2.8605	15	11.3293	2.3970	5.7457	0.9983	0.2116
46	3013	1	2	TP*	BS**	0.4566	0.9315	-2.9497	15	10.2363	3.2072	10.2859	0.9923	0.3133
46	3013	2	1	BA*	BG**	0.8500	0.5165	0.0000	15	48.3228	9.9216	98.4390	0.9962	0.2053
46	3013	2	2	TP*	BG**	0.8512	0.5507	-0.0674	15	50.3168	11.1993	125.4248	0.9954	0.2226
46	3052	1	1	A1	TS01	0.8446	0.1040	-1.6726	15	7.2552	0.3888	0.1512	1.0000	0.0536
46	3052	1	2	A2	TS03	0.9241	0.2112	-1.8830	15	8.9443	1.6171	2.6149	0.9995	0.1808
46	3052	2	1	BA*	BG**	0.7146	0.7893	-0.4298	15	59.4961	12.6767	160.6987	0.9939	0.2131
46	3052	2	2	TP*	BG**	0.6374	0.8206	-0.3821	15	59.1952	11.2968	127.6171	0.9946	0.1908
46	3053	1	1	TP*	BS56	1.7962	0.3681	0.0000	15	25.0367	6.0484	36.5830	0.9991	0.2416
46	3053	1	2	TP*	BS55	1.2268	0.4501	-2.1052	14	15.7522	1.4936	2.2308	0.9998	0.0948

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
46	3053	2	1	TP*	BG**	0.8185	0.7113	0.0000	15	77.8152	3.4433	11.8566	0.9997	0.0443
46	3053	2	2	TP*	BG55	1.1884	0.5823	-0.2036	14	64.9293	6.3667	40.5343	0.9991	0.0981
46	5020	1	1	BA*	BS**	2.7055	0.4640	-0.8565	12	35.1499	3.1575	9.9701	0.9999	0.0898
46	5020	1	2	TP*	BS**	1.5206	0.6009	-1.0997	12	23.2240	3.4530	11.9230	0.9995	0.1487
46	5025	1	1	A1	TS01	0.8830	0.1689	-2.5597	15	10.2432	0.6086	0.3704	0.9999	0.0594
46	5025	1	2	A2	TS03	0.5766	0.1952	-1.9920	15	5.6501	0.7813	0.6104	0.9997	0.1383
46	5025	2	1	BA*	BG**	0.9986	0.5352	-0.1822	14	48.4778	5.0833	25.8399	0.9991	0.1049
46	5025	2	2	TP*	BG**	0.5190	0.7112	-0.1280	15	44.2861	6.6796	44.6170	0.9969	0.1508
46	5040	1	1	A1	TS01	0.7909	0.2828	-3.0264	15	10.2181	0.8014	0.6423	0.9998	0.0784
46	5040	1	2	TP*	BS**	0.7266	0.3868	-2.9324	15	9.8406	1.8869	3.5602	0.9987	0.1917
46	5040	2	1	BA*	BG**	0.6632	0.6993	0.0000	15	60.6216	5.1603	26.6284	0.9990	0.0851
46	5040	2	2	TP*	BG**	0.5935	0.7513	-0.0979	15	57.3438	4.4212	19.5467	0.9991	0.0771
46	5040	3	1	BA*	BG**	0.6328	0.7042	0.0000	15	58.7378	3.1279	9.7837	0.9996	0.0533
46	5040	3	2	TP*	BG**	0.5499	0.7878	-0.2430	14	48.8398	5.3293	28.4011	0.9983	0.1091
46	6600	1	1	TP1	BS55	1.1863	0.2317	-0.5790	15	8.3740	0.9404	0.8844	0.9999	0.1123
46	6600	1	2	TP2	BS56	1.0023	0.1514	-1.3986	14	7.8296	1.0442	1.0904	0.9999	0.1334
46	7049	1	1	A1	TS01	1.5136	0.1861	-1.2292	15	10.9340	1.3506	1.8242	0.9999	0.1235
46	7049	1	2	TP1	BS**	0.8353	0.1960	-1.7720	15	7.5593	0.7829	0.6129	0.9999	0.1036
46	7049	2	1	BA*	BG**	0.5622	0.6946	-0.1306	15	45.9112	8.3765	70.1656	0.9957	0.1825
46	7049	2	2	TP*	BG**	0.6955	0.6255	-0.3226	15	41.5335	7.9110	62.5833	0.9964	0.1905
46	9106	1	1	BA*	BS**	1.1870	0.2524	-0.6165	15	9.0984	1.9959	3.9837	0.9997	0.2194
46	9106	1	2	A2	TS04	1.0458	0.1937	-1.6813	15	9.1558	0.9413	0.8860	0.9999	0.1028
46	9106	2	2	TP*	BG**	0.5238	0.7802	-0.1904	14	51.4747	6.8047	46.3046	0.9974	0.1322
46	9106	2	1	BA*	BG**	1.8358	0.3683	-0.5697	15	36.7206	4.5272	20.4955	0.9996	0.1233
46	9197	1	1	BA*	BS**	1.4855	0.2598	-0.7724	15	11.5107	1.0718	1.1488	0.9999	0.0931
46	9197	2	1	BA*	BG**	0.7879	0.6616	-0.0875	15	61.4780	4.2921	18.4225	0.9994	0.0698
46	9197	2	2	TP*	BG**	1.0141	0.5245	-0.1141	15	53.3287	3.6552	13.3603	0.9996	0.0685
46	9197	3	1	BA*	BG**	0.9735	0.5689	-0.2246	15	53.2131	5.0722	25.7276	0.9992	0.0953
46	9197	3	2	TP*	BG**	0.8925	0.5091	0.0000	15	49.3730	4.7788	22.8370	0.9992	0.0968
47	1023	1	1	A1	TS01	1.0786	0.2218	-3.0252	15	13.8537	2.1721	4.7179	0.9992	0.1568
47	1023	1	2	A2	TS03	1.2949	0.3683	-3.3139	15	18.9807	6.8685	47.1759	0.9939	0.3619
47	1023	2	2	BA*	BG**	0.8648	0.6731	0.0000	15	77.8210	24.1529	583.3605	0.9860	0.3104
47	1028	1	1	A1	TS01	1.2481	0.2578	-1.5370	15	12.3083	5.3024	28.1152	0.9976	0.4308
47	1028	1	2	A2	TS03	0.8043	0.0949	-2.3105	15	9.0333	2.7403	7.5091	0.9980	0.3034
47	1028	2	1	BA*	BG**	1.1137	0.6494	0.0000	15	91.8633	10.7345	115.2304	0.9982	0.1169
47	1028	2	2	TP1	BG55	0.9327	0.7073	0.0000	15	88.5205	6.8098	46.3732	0.9991	0.0769
47	1029	1	1	BA*	BS**	0.8849	0.4230	-2.1874	15	11.8374	4.9107	24.1146	0.9952	0.4148
47	1029	1	2	TP1	BS55	1.4501	0.2150	-1.2842	15	14.3676	8.7824	77.1311	0.9953	0.6113
47	1029	2	1	BA*	BG**	0.7273	0.8019	-0.0465	15	84.0687	5.7557	33.1284	0.9992	0.0685
47	1029	2	2	TP1	BG55	1.0711	0.5600	-0.0865	15	63.9161	10.5702	111.7286	0.9974	0.1654
47	2001	1	1	A1	TS01	0.7135	0.3533	-3.6649	15	10.2850	1.9889	3.9558	0.9982	0.1934
47	2001	1	2	A2	TS03	0.9409	0.3478	-3.0080	15	12.7809	3.8818	15.0685	0.9966	0.3037
47	2008	1	1	A1	TS01	0.8779	0.5949	-3.0326	15	14.5350	4.7821	22.8686	0.9945	0.3290
47	2008	1	2	A2	TS03	0.7039	0.1426	-1.4181	15	7.5574	5.3151	28.2505	0.9924	0.7033
47	3075	1	2	TP1	BS55	0.8884	0.3764	-1.6948	15	10.2725	2.9924	8.9542	0.9984	0.2913
47	3075	2	2	TP1	BG55	0.6575	0.8543	0.0000	15	87.4282	6.0281	36.3380	0.9991	0.0689
47	3101	1	1	A1	TS01	0.7853	0.1677	0.0000	15	12.8767	11.9530	142.8747	0.9803	0.9283
47	3101	1	2	A2	TS03	0.9733	0.0706	-3.1421	15	14.5104	5.9779	35.7349	0.9917	0.4120
47	3101	2	1	BA*	BG**	1.2076	0.5647	-0.1090	15	71.6649	7.9968	63.9488	0.9988	0.1116
47	3101	2	2	TP1	BG55	1.8474	0.5231	-0.2039	15	90.9057	24.5441	602.4151	0.9943	0.2700
47	3104	1	1	A1	TS01	0.8583	0.3951	-2.5626	15	11.4247	3.5042	12.2792	0.9971	0.3067
47	3104	1	2	A2	TS03	1.0671	0.7672	-3.6486	15	19.6622	3.4665	12.0164	0.9979	0.1763
47	3104	2	1	BA*	BG**	1.0306	0.6849	0.0000	15	118.1427	78.0074	6085.1500	0.9052	0.6603
47	3104	2	2	TP1	BG55	0.7363	0.7146	0.0000	15	70.9373	10.2498	105.0592	0.9969	0.1445
47	3108	1	1	A1	TS01	0.6470	0.4496	-2.0586	15	8.7325	2.7688	7.6660	0.9973	0.3171
47	3108	1	2	TP1	BS55	0.7829	0.0000	-3.3939	15	12.4377	5.1447	26.4681	0.9899	0.4136

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
47	3108	2	1	BA*	BG**	0.7518	0.8033	-0.1174	15	82.3921	3.3388	11.1474	0.9997	0.0405
47	3108	2	2	TP1	BG**	1.1590	0.6200	0.0000	15	87.5784	8.8720	78.7129	0.9988	0.1013
47	3109	1	1	A1	TS01	0.8278	0.3696	-3.5625	15	11.8201	2.9844	8.9068	0.9971	0.2525
47	3109	1	2	TP1	BS55	0.8609	0.0000	-1.9870	15	11.6292	7.3989	54.7442	0.9880	0.6362
47	3109	2	2	TP1	BG55	0.7034	0.9260	-0.1367	15	100.6816	3.0394	9.2379	0.9998	0.0302
47	3110	1	1	A1	TS01	1.0502	0.1794	-3.1042	15	14.4364	5.4579	29.7884	0.9943	0.3781
47	3110	2	2	TP1	BG55	0.9401	0.7373	-0.0074	15	95.8770	6.5525	42.9347	0.9993	0.0683
47	6015	1	1	A1	TS01	0.6318	0.5032	-3.4845	15	9.6273	2.6672	7.1137	0.9963	0.2770
47	6015	1	2	A2	TS03	0.5653	0.4175	-2.0241	15	7.4948	2.9248	8.5545	0.9960	0.3902
47	6015	2	1	BA*	BG**	0.8159	0.7663	-0.1549	15	79.6900	5.2476	27.5375	0.9993	0.0659
47	6015	2	2	TP1	BG55	1.1750	0.5796	0.0000	15	81.5816	8.9494	80.0916	0.9986	0.1097
47	6022	1	1	A1	TS01	0.8717	0.3258	-1.6146	15	10.0830	4.8007	23.0465	0.9959	0.4761
47	6022	1	2	A2	TS03	0.7641	0.4143	-2.3112	15	10.0105	3.2069	10.2841	0.9971	0.3204
47	6022	2	2	TP1	BG55	1.1636	0.6405	0.0000	15	93.6808	8.1064	65.7136	0.9990	0.0865
47	9024	1	1	BA*	BG**	0.7471	0.9837	-0.3424	15	107.1057	7.8765	62.0396	0.9988	0.0735
47	9024	1	2	TP1	BG55	1.1186	0.5635	0.0000	15	73.0364	6.8620	47.0864	0.9991	0.0940
47	9025	2	1	BA*	BG**	0.6103	0.6752	0.0000	15	54.4923	14.4041	207.4771	0.9900	0.2643
47	9025	2	2	TP1	BG55	1.2069	0.5885	-0.0494	15	81.7582	9.9364	98.7320	0.9984	0.1215
48	0001	1	1	BA*	BS**	1.1825	0.1390	-0.7944	15	6.3343	1.8259	3.3341	0.9997	0.2883
48	0001	1	2	TP1	BS55	2.4171	0.4522	-2.1555	15	36.0592	18.5955	345.7918	0.9909	0.5157
48	0001	2	1	BA*	BG**	1.2829	0.5166	0.0000	15	73.5065	13.5510	183.6289	0.9969	0.1844
48	0001	2	2	TP1	BG55	1.5222	0.6143	-0.1842	15	97.9238	14.9166	222.5048	0.9976	0.1523
48	0113	1	2	B7	BS07	0.5169	0.5114	0.0000	15	10.0631	2.6437	6.9890	0.9980	0.2627
48	0116	1	2	B10	BS10	0.5240	0.5196	0.0000	15	10.4722	3.0734	9.4456	0.9974	0.2935
48	0117	1	2	B8	BS08	0.5169	0.5384	0.0000	15	10.5978	2.4509	6.0069	0.9983	0.2313
48	0119	1	2	B3	BS03	0.5116	0.5199	0.0000	15	10.1840	2.6951	7.2636	0.9979	0.2646
48	0121	1	2	B4	BS04	0.4944	0.5622	0.0000	15	10.6762	2.8146	7.9218	0.9976	0.2636
48	0123	1	2	B9	BS09	0.5120	0.4813	0.0000	15	9.2633	1.7556	3.0822	0.9991	0.1895
48	0801	1	1	B2	BS02	0.8722	0.1827	0.0000	15	6.9158	3.6900	13.6163	0.9985	0.5336
48	0801	1	2	B3	BS03	0.7152	0.1898	-0.1431	15	5.1111	2.3524	5.5338	0.9990	0.4603
48	0801	1	3	A5	TS09	0.6076	0.1794	-0.4282	15	4.1610	2.4970	6.2349	0.9983	0.6001
48	0801	3	2	B5	BG02	0.7867	0.2624	-0.5323	15	6.6812	2.4791	6.1460	0.9990	0.3711
48	0801	3	3	B6	BG03	0.8143	0.2526	-0.5981	15	6.6102	2.4686	6.0938	0.9991	0.3734
48	0802	1	1	B1	BS01	0.9765	0.2118	0.0000	15	10.5884	7.4231	55.1028	0.9951	0.7011
48	0802	1	3	A1	TS01	0.5835	0.1785	-0.9326	15	4.0036	1.7313	2.9974	0.9990	0.4324
48	0802	3	2	B4	BG01	0.7746	0.0000	0.0000	15	7.1301	7.1301	50.8381	0.9924	1.0000
48	1039	1	1	BA*	BS**	0.6196	0.2150	-1.8082	15	5.7130	1.1450	1.3111	0.9995	0.2004
48	1039	1	2	A2	TS03	0.8759	0.3008	-1.4755	15	8.3049	1.6820	2.8292	0.9995	0.2025
48	1039	3	1	BA*	BG**	0.8631	0.5002	-0.3710	15	33.7749	4.9935	24.9346	0.9987	0.1478
48	1046	1	1	A1	TS01	0.2690	0.4162	0.0000	15	4.7580	2.3261	5.4108	0.9941	0.4889
48	1046	1	2	TP1	BS55	0.9175	0.1621	-1.5803	15	7.5706	1.1793	1.3908	0.9998	0.1558
48	1046	2	1	BA*	BG**	0.5926	0.6244	0.0000	13	42.0988	16.6814	278.2681	0.9832	0.3962
48	1046	2	2	TP1	BG56	0.9471	0.4889	-0.8175	15	26.5594	10.2416	104.8895	0.9931	0.3856
48	1046	3	2	TP1	BG55	0.9946	0.6148	0.0000	15	75.0062	8.4506	71.4128	0.9985	0.1127
48	1047	1	1	A1	TS01	0.1957	0.5812	-1.0967	15	3.9545	2.3003	5.2916	0.9855	0.5817
48	1047	1	2	A2	TS03	0.7547	0.0755	-1.0669	15	5.6753	3.4096	11.6253	0.9975	0.6008
48	1048	1	1	A1	TS01	0.5724	0.3698	-1.4262	15	6.2640	1.4335	2.0549	0.9992	0.2288
48	1048	1	2	A2	TS03	0.5912	0.1241	-1.3962	15	4.7759	2.1736	4.7244	0.9982	0.4551
48	1049	1	1	A1	TS01	1.0273	0.1630	-1.6539	15	8.9400	2.2006	4.8426	0.9993	0.2462
48	1049	1	2	BA*	BS**	0.9918	0.2778	0.0000	15	11.1612	4.5471	20.6765	0.9982	0.4074
48	1050	1	1	A1	TS01	1.5581	0.2048	-1.6032	15	13.8254	2.5861	6.6878	0.9996	0.1871
48	1050	1	2	A2	TS04	1.4249	0.2317	-1.3411	15	11.8615	3.3286	11.0797	0.9993	0.2806
48	1050	3	2	TP1	BG55	1.1191	0.6722	0.0000	15	97.1308	10.5492	111.2865	0.9984	0.1086
48	1056	1	1	A1	TS02	0.7251	0.1003	-0.6057	15	3.6029	2.2711	5.1577	0.9990	0.6303
48	1056	1	2	A2	TS03	0.6485	0.1412	-2.2270	15	5.9666	1.6549	2.7388	0.9990	0.2774
48	1056	2	1	BA*	BG**	0.4747	0.7532	0.0000	15	50.1248	6.6977	44.8590	0.9971	0.1336

Table 16. k-values determined from nonlinear regression analyses of LTPP resilient modulus test of unbound materials (continued).

State Code	SHRP ID	Layer No.	Test No.	Loc. No.	Sample No.	k1	k2	k3	No. Points	Std Dev(M_R)	RMSE	MSE	R^2	S_e/S_y
48	1056	2	2	TP1	BG55	0.8513	0.4880	-0.4002	15	35.8626	15.4161	237.6548	0.9863	0.4299
48	1056	2	2	TP1	BG56	0.7956	0.4463	-0.6084	15	23.5245	11.2791	127.2175	0.9890	0.4795
48	1060	1	1	A1	TS01	0.6443	0.3365	-2.3882	15	7.7133	2.0621	4.2522	0.9983	0.2673
48	1060	1	2	A2	TS03	0.7981	0.1751	0.0000	15	5.6172	2.3073	5.3238	0.9993	0.4108
48	1060	3	1	BA*	BG**	0.4672	0.9551	-0.0712	15	74.4472	4.3246	18.7024	0.9993	0.0581
48	1061	1	1	A1	TS02	0.8909	0.4123	-1.3360	15	10.8153	2.6377	6.9574	0.9989	0.2439
48	1061	1	2	A2	TS04	0.8356	0.1845	-1.0435	15	6.4016	3.3320	11.1023	0.9981	0.5205
48	1061	2	1	BA*	BG**	0.8527	0.5775	0.0000	15	57.9665	7.5989	57.7437	0.9981	0.1311
48	1061	2	2	TP1	BG55	1.0719	0.5824	-0.4320	15	51.7045	10.9626	120.1779	0.9964	0.2120
48	1065	1	1	A1	TS01	0.5213	0.5976	-1.6932	15	8.5312	1.6362	2.6770	0.9988	0.1918
48	1065	1	2	A2	TS03	0.4962	0.2820	-2.2360	15	5.7801	1.8836	3.5480	0.9977	0.3259
48	1065	2	1	BA*	BG**	0.7229	0.7348	-0.5081	15	50.2397	7.6681	58.7990	0.9973	0.1526
48	1068	1	1	BA2	BS02	0.8729	0.1775	-1.6186	15	7.3374	1.2804	1.6394	0.9997	0.1745
48	1068	1	2	TP1	BS55	0.6051	0.0593	-1.8845	15	5.6804	1.0365	1.0744	0.9995	0.1825
48	1068	3	1	BA*	BG**	0.6203	0.6740	-0.0205	15	53.5868	3.6333	13.2006	0.9994	0.0678
48	1068	3	2	TP1	BG55	0.5156	0.8304	-0.0221	15	64.2182	5.0362	25.3634	0.9989	0.0784
48	1069	1	1	BA*	BS**	0.7532	0.0771	0.0000	15	3.0000	2.1279	4.5279	0.9993	0.7093
48	1069	1	2	A2	TS03	0.4375	0.1681	-0.2736	15	2.9681	1.8376	3.3768	0.9983	0.6191
48	1069	1	2	TP1	BS55	1.0704	0.1992	-0.9432	15	7.2355	1.9804	3.9220	0.9996	0.2737
48	1070	1	1	BA*	BS**	0.8122	0.1334	-0.9318	15	4.5743	0.8297	0.6885	0.9999	0.1814
48	1070	1	2	A2	TS03	0.5886	0.1441	-2.6538	15	7.5826	2.9387	8.6362	0.9952	0.3876
48	1076	1	1	A1	TS01	0.8602	0.4952	-1.1453	15	12.4281	3.8649	14.9375	0.9978	0.3110
48	1076	1	2	A2	TS03	0.8243	0.5250	-1.6402	15	12.0704	2.5359	6.4308	0.9988	0.2101
48	1077	1	1	A1	TS03	0.7623	0.4403	-1.0167	15	10.6064	4.7174	22.2535	0.9958	0.4448
48	1077	1	2	TP1	BS55	0.6875	0.4037	-0.8742	15	8.4515	2.6379	6.9586	0.9984	0.3121
48	1077	2	2	TP1	BG55	1.1532	0.6336	-0.0656	15	86.5221	5.9036	34.8525	0.9994	0.0682
48	1087	1	1	A1	TS02	1.0534	0.5543	-2.1209	15	16.5135	5.2940	28.0269	0.9963	0.3206
48	1087	1	2	A2	TS04	0.9902	0.4640	-1.8606	15	12.9144	2.5636	6.5719	0.9991	0.1985
48	1087	2	1	BA*	BG**	1.0699	0.4313	-0.0371	15	45.4053	9.7455	94.9744	0.9971	0.2146
48	1087	2	2	TP1	BG55	0.8091	0.6580	-0.1574	15	60.5297	5.1602	26.6275	0.9991	0.0853
48	1092	1	1	BA*	BS**	0.6858	0.0000	0.0000	15	6.8958	6.8958	47.5524	0.9909	1.0000
48	1092	1	2	A2	TS03	0.5586	0.1308	-1.3361	15	4.4110	2.1759	4.7348	0.9980	0.4933
48	1092	2	1	BA*	BG**	1.2075	0.6778	-0.1562	15	95.8562	11.6279	135.2075	0.9981	0.1213
48	1092	2	2	TP1	BG56	1.0069	0.7279	-0.1513	15	90.0656	7.9083	62.5408	0.9989	0.0878
48	1092	3	2	TP1	BG55	0.8162	0.9196	-0.1491	15	113.9006	5.2890	27.9736	0.9996	0.0464
48	1093	1	1	BA*	BS**	0.8755	0.5979	-1.6241	15	14.1202	2.5389	6.4461	0.9990	0.1798
48	1093	1	2	A2	TS03	0.8456	0.2368	-2.8365	15	9.9976	1.2405	1.5390	0.9996	0.1241
48	1093	2	1	BA*	BG**	0.4777	0.8992	0.0000	15	70.9626	3.8067	14.4906	0.9994	0.0536
48	1094	1	1	BA*	BS**	1.6352	0.1700	-1.2629	15	12.5691	4.8236	23.2669	0.9989	0.3838
48	1094	1	2	TP1	BS55	1.3982	0.3655	0.0000	15	23.0356	13.1342	172.5080	0.9929	0.5702
48	1094	2	1	BA*	BG**	1.5853	0.6592	-0.2348	15	110.3281	11.0771	122.7017	0.9989	0.1004
48	1094	2	2	TP1	BG55	1.4927	0.7425	-0.5738	15	101.3282	21.6068	466.8531	0.9947	0.2132
48	1096	1	1	A1	TS01	0.6131	0.3404	-2.4188	15	7.3179	1.8548	3.4402	0.9985	0.2535
48	1096	1	2	A2	TS03	0.7918	0.1782	0.0000	15	5.6172	2.2089	4.8791	0.9993	0.3932
48	1096	2	1	BA*	BG**	1.1299	0.6115	-0.0809	15	78.6232	9.6798	93.6992	0.9983	0.1231
48	1096	2	2	TP1	BG55	1.4170	0.6724	0.0000	15	131.5498	47.2433	2231.9330	0.9802	0.3591
48	1109	1	1	A1	TS01	0.8706	0.0230	-2.1721	15	9.5529	1.7616	3.1032	0.9993	0.1844
48	1109	1	2	A2	TS03	0.7174	0.2844	-2.2452	15	7.7410	1.5772	2.4875	0.9992	0.2037
48	1111	1	1	A1	TS01	0.5797	0.0165	-0.1335	15	5.7046	5.6809	32.2726	0.9910	0.9958
48	1111	1	2	A2	TS03	0.5305	0.1816	0.0000	15	8.1504	7.3507	54.0324	0.9837	0.9019
48	1111	2	1	BA*	BG**	0.8135	0.6991	-0.6209	15	47.2577	6.7876	46.0711	0.9979	0.1436
48	1111	2	2	TP1	BG55	0.9247	0.6744	-0.5227	15	54.4180	5.4616	29.8294	0.9990	0.1004
48	1113	1	1	A1	TS01	1.4862	0.5646	-0.4100	15	27.9782	2.8598	8.1783	0.9997	0.1022
48	1113	1	2	A2	TS03	0.6508	0.0979	0.0000	15	15.7788	15.6134	243.7787	0.9513	0.9895
48	1113	2	1	BA*	BG**	0.6822	0.6823	-0.0883	15	56.8836	3.4954	12.2182	0.9995	0.0614
48	1113	2	2	BA*	BG**	0.5870	0.6988	-0.3355	15	42.5607	4.2733	18.2612	0.9988	0.1004