Field Analysis of Rutting in Overlays of Concrete Interstate Pavements in Illinois

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Thirty-two overlay projects placed over portland cement concrete pavements were surveyed for the initial development of a comprehensive statewide pavement data base of which these overlay projects would be part. Ninety-two different uniform sections were visually surveyed to obtain performance data on the overlay projects. Design and construction data were collected for inclusion in the data base. The data were analyzed to develop regression relations between rutting and mixture properties of the asphalt concrete overlays. The analysis clearly shows the importance of material properties to the development of rutting, particularly the gradation parameters. Eleven of the projects were cored for structural testing in the laboratory. The structural tests clearly show that the resilient modulus and indirect tensile strength bear a strong relationship to the rutting that develops in the overlay during its life. The analysis in this paper clearly shows how a statistically sound examination of pavement performance can furnish data for an analysis that provides information that can be used to alter mix design and construction practices to address a specific problem. In this paper it is shown that permanent deformation can be controlled through proper material control; further, if the allowable limits on variability of the mixture coming out of the plant can be altered, performance can be altered. A judicious selection of median values and tighter plant control can reduce rutting potential.

The goal of the research project, part of which is presented here, is to examine the structural characterization of bituminous mixes used as overlays on concrete pavements subjected to heavy traffic. To develop a full and true characterization of material performance it is necessary to be able to detail the actual performance of that material in service. Theoretical considerations, which show that asphalt concrete mixtures used as overlays of concrete pavements can be subjected to more severe shear deformation than the same mixture placed over a flexible pavement, were presented previously (*1*). The initial report indicates that some simple material properties determined in the laboratory could possibly be used to indicate the potential for rutting if the tests were performed properly to simulate actual pavement conditions. For these laboratory tests to be meaningful, they must be related to the actual performance of the material on the pavement.

The ability of pavement survey data to establish statistically valid relationships among performance, pavement conditions, and material properties has been established in several recent studies, most effectively in the COPES study (*2*). The COPES project also developed requirements for data collection and preparation that produce a data base with statistically valid data capable of furnishing reliable relationships that can be used to study design changes.

HISTORICAL BACKGROUND

At the time this project was being prepared for the Federal Highway Administration in 1981, the Illinois Department of Transportation was considering a survey of their overlaid Interstate pavements because of premature deformation problems. It was decided at that time to coordinate the two studies in order that the data developed would be of benefit to both organizations. Work began to develop the framework for a comprehensive data schema, collection procedure, and analysis procedures. This initial study developed into a comprehensive data base for the state known as the Illinois Pavement Feedback Information System (IPFS). The data collected for this FHWA study formed the basis for the information contained in that study for the initial overlay sections.

SCOPE

The data contained in the data base can be analyzed with suitable statistical procedures to develop relationships among material properties of the bituminous mixtures, the design properties of the overlay, possible construction differences, and the performance of the pavement as detailed by the distress parameters collected during condition surveys of the pavement. Because the focus of this study is on the stability of mixes used as overlays, the performance predictions presented here will concentrate principally on permanent deformation.

Statistical relationships between the permanent deformation developing in any particular mixture and the properties recorded in the data base should relate to properties obtained in a laboratory analysis. Laboratory tests conducted on cores taken from representative overlay sections around the state will also be discussed. It is essential to have laboratory procedures, used to predict the performance potential of a mixture, that logically relate to performance and the mechanism causing the deterioration in the field.

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DEVELOPMENT OF DATA BASE

Data Base

A data base is a computerized storage area containing all of the variables used to describe the pavements of interest. The data base used in this study was taken from that used in the NCHRP COPES study (*2*) for rigid pavements that has proven successful throughout the United States and has been adopted for implementation by several states (Pennsylvania, Illinois, and Minnesota). Modifications were made to the data base structure for this project to include the overlay over the existing concrete pavement and its properties. This new section allows separate data on the binder and surface courses to be input to determine the influence of different materials on overall performance.

There are 32 overlay projects and 92 cases in this study. This means that there are approximately 3 cases, or uniform sections, per overlay project. Some had more or fewer uniform sections, depending on the overall length of the project. Material on each case in a project is placed in a separate file folder that is labeled with the identifying project identification and uniform section code.

Design Data Sheets

The design sheets contain all of the information about the case that should be obtainable from the state or district headquarters or from other sources of information about the design and construction of the pavement. This information should not require any revisions once it has been collected and stored in the computer.

Field Data Sheets

The field data sheets contain information that the survey team gathers at each project site.

The section added to the collection sheets, which is significantly different from the COPES collection sheets, is the Bituminous Overlay Design Data. These sheets contain all of the information about the overlay design, mix properties, and asphalt cement properties. Subsequent overlays can be added to the data base through the use of this section.

Data Collection

The data in this study were gathered by the Illinois Department of Transportation. The data were submitted to the project researchers on standard data sheets. Previous studies have indicated that 3 percent sampling can provide a statistically valid indication of the condition of the pavements in a state (*3*). For this study, the pavements under analysis were restricted to Interstate concrete pavements with asphalt concrete overlays. The selection process produced 92 cases across the state of Illinois that are shown in Figure 1. These cases are the "uniform sections" of each pavement.

When any characteristic of a pavement changes, a new uniform section should be selected for inclusion in the data base. The average uniform section length in this study is 3.5 mi. Each uniform section is divided into sample units 600 ft in length. In general, one sample unit is selected for data collection for each mile of the uniform section. The location of the sample units within the uniform section is randomly selected.

The design data from the original pavement construction were obtained from the headquarters office of the Illinois Department of Transportation in Springfield. The information from their historical records is recorded on the design data sheets and referred to as the historical data.

ANALYSIS OF DATA BASE INFORMATION

Preparing the Collected Data

Although most of the raw data could be transcribed directly from the collection sheets to the computer, other data required manipulation. Some data required calculations and estimations to be made by the research group before final entries in the data base could be made. One area that required outside input was the environmental data. The temperature and precipitation values were taken from standard climatic charts. The Freezing Index was obtained from a standard map. The temperature and precipitation values were taken from data for the U.S. Geological Survey weather station nearest each pavement. The other area that required computations by the research staff was Sheet 21, Traffic Volume Data. The traffic values [average daily traffic and average daily truck traffic (ADT and ADTT)] were taken from Illinois DOT traffic maps. The left and right lane distributions for trucks were obtained from relationships derived in previous studies (*2*).

Traffic had to be estimated for the opening of a route if no maps were published that year. It also had to be estimated for 1982, the year the distress surveys were made. Because of changes in recording total commercial traffic, estimates were made for the years 1977-1979 when necessary.

Inventory of Overlaid Interstate Pavements

A major function of the data base is to produce reports that indicate the condition of the pavements in the data base and the types of pavements that are available for analysis. This form of investigation should be done before any statistical analysis to show any distinct groupings of data that should be analyzed separately before being combined into one complete analysis. Examples of this would be thickness; traffic levels; climatic area in the state; and construction differences such as two or three layers of different materials in level binders, binders, and surface mixtures.

Another reason for the inventory study is to establish the range of variables present in the pavement network being examined. Much information can be gained from a study of the average, maximum, and minimum values that can be

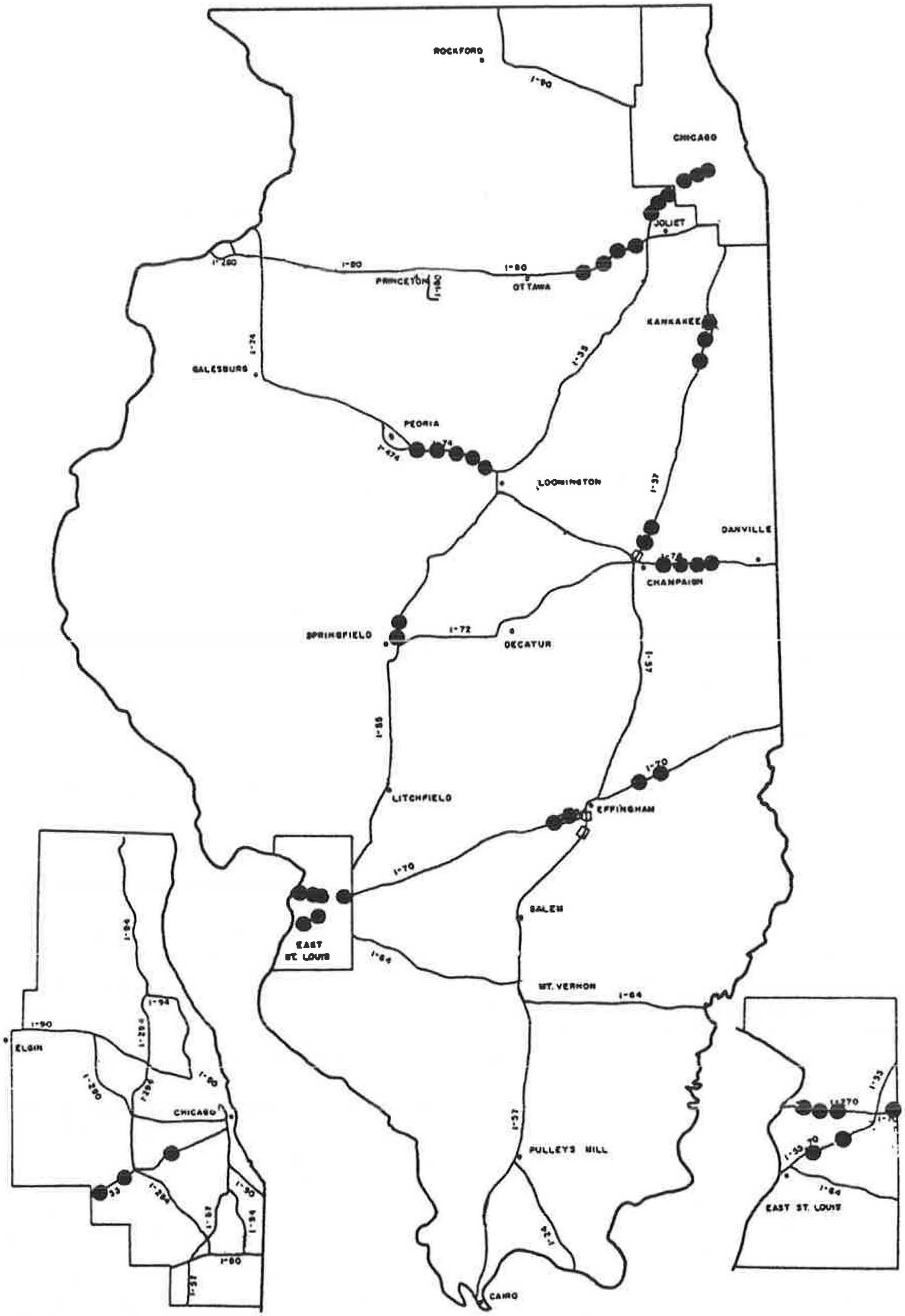

FIGURE 1 Locations of overlay surveys.

found in a state. This analysis shows what variables exist in the field and the variability associated with each factor. Extreme minimum or maximum values should indicate where potential problems may exist. The values of some important variables extracted from the overlay data base are given in Table 1.

TABLE 1 EXAMPLE OF PROPERTIES AND THEIR STATEWIDE VARIABILITY

Property	Average	Maximum	Minimum
Thickness	4.04	8.00	2.6
Level Binder Thickness	1.82	5.0	1.0
Binder Thickness	0.96	2.0	0.0
Surface Thickness	1.27	1.7	0.6
Binder Stability	2154	2908	1567
Binder Flow	11.3	20.4	3.4
Binder Air Voids	2.2	2.4	0.2
Surface Stability	2292	3210	1515
Surface Flow	9.7	13.2	5.1
Surface Air Voids	2.5	4.1	1.1
18k ESALx10^6	3.1	9.5	0.0
Average Rut Depth	0.2	0.48	0.03
Gradation Hump No. 40 Sieve	3.3	13.0	-2.7

Although these values show some significant variation throughout the state, they cannot show the total picture of the influence of the individual variables on the development of rut depth. The numbers in Table 1 do not indicate any influence geographic location may exert on the individual overlay or show whether there may be a pattern of thicknesses that varies from one part of the state to another. Nor does this simple presentation show any climatic influence. Further breakdown of these data is required to show these relationships. This breakdown is typically done with statistical regression techniques.

Examination of the numbers in Table 1 poses some interesting questions, which cannot be answered from a visual analysis, to be investigated later. One question that can be asked is, does rutting occur more when air voids are lower or are air voids even important? There is potential for some quite low air voids in the mixtures used in Illinois during the period being studied. Does more rutting occur in mixes the flow of which is higher, or is there a corresponding change in another mix parameter that reduces total rutting? Does the hump in the gradation curve on the No. 40 sieve as plotted on the FHWA 0.45 power curve really produce increased rutting as is surmised in the literature (*4*)?

These questions can only be answered through a comprehensive statistical regression analysis of the entire data base.

Regression Analysis

To examine the interaction of the variables, a stepwise multiple linear regression was performed on the data base using the Statistical Package for the Social Sciences (*5*). The data base file contained 163 independent variables. Preliminary regression runs were performed to examine correlations between the variables and rut depth. This preliminary analysis indicated the variables that had no relationship with rut depth and could be eliminated. Other variables were eliminated because they contained a significant number of missing values, which reduced the number of cases for the final comparison. There were 95 to 100 variables in the final group used for the general regression, which resulted in 52 out of a possible 80 cases being included in the general analysis.

As anticipated, the rutting in the right lane wheelpaths showed better correlation (higher R^2-values) with the material properties. This is due to the higher traffic in the right lane, which produces more rutting and activates more of the mixture's internal properties that influence rutting. Regression equations were developed initially from a linear regression analysis and later from a nonlinear procedure that takes into account any curvilinear relationship with material properties.

The regression package does not preselect the variables to relate to rutting. The variable that has the highest correlation with the rut depth in the travel lane is automatically selected first by the program. The program subsequently selects the variable that shows the next highest correlation with rut depth. This selection process continues until there is no further improvement in the goodness of fit between the equation and the data. The initial linear equation is

$$\begin{aligned} RUTR \quad & -0.004671(40 + 80) - 0.0002597(SSTAB) \\ & + 0.1032(DIFFS40) \\ & + 0.1125(AVEHOT) \end{aligned}$$

where

$RUTR$ = average rutting for the travel lane (in.);
$40 + 80$ = percentage passing the No. 40 sieve and retained on the No. 80 sieve for the surface mixture;
$SSTAB$ = Marshall stability (lb) of the surface mixture;
$DIFFS40$ = hump in the gradation on the No. 40 sieve when plotted on the FHWA 0.45 power gradation curve for the surface mixture (%); and
$AVEHOT$ = average monthly temperature for June, July, and August at the location of the overlay.

The R^2 correlation coefficient for this equation was 0.82 based on 52 cases. The standard error of estimate of the equation was 0.3. These statistics are quite good for equations derived from field data (previous studies have typically developed R^2-values on the order of 0.5 for pavement studies).

Although this relationship by itself is not bad, the linear analyses of the variables in the data base do not accurately indicate such variables as thickness, traffic, and age of the overlay. In addition, better representations of rut depth and traffic could be developed. A thick pavement surface will develop more rutting than a thin surface, but the amount of permanent strain may be the same in both. An overlay that gets a large amount of traffic in 1 year may have a substantial amount of loadings placed on the overlay during the colder periods of the year and will develop less rutting than a similar overlay that receives the same traffic over a 3- to 4-year period during which there are a greater number of months with high temperatures.

To better include the nonlinear relationships in the data, the data were transformed with the best-fit nonlinear function for that data element. The transformed variables were placed in the data base along with the standard linear variables, and another regression was performed. The resulting equation includes variables that give a truer picture of how they interact to alter rutting development. The nonlinear analysis of the entire data base allowing modified variables provided the following relationship:

$$
\begin{aligned}
RUT = & - 0.040930187(40 + 80)^{1.0849} \\
& - 0.0002569715\,(STAB) + 0.083705(DIFFS40) \\
& + 0.0523817(AVEHOT) \\
& + 0.313578(TCUMRR)^{0.045565} \\
& - 1.127458(-200)^{-1.24927} + .00041937(D) \\
& + 0.0106828(RDen)
\end{aligned}
$$

where

RUT = rut depth (in.);
$40 + 80$ = percentage passing the No. 40 sieve and retained on the No. 80 sieve in the surface mixture;
$STAB$ = Marshall stability of the surface mixture;
$DIFFS40$ = hump in the FHWA 0.45 power gradation curve on the No. 40 sieve in the surface;
$AVEHOT$ = average of the maximum monthly temperatures during June, July, and August;
$TCUMRR$ = total 18-kip equivalent standard axle loads (ESALs) applied to the overlay in the right lane;
-200 = minus No. 200 material in the binder;
D = maximum theoretical density (lb/ft^3) of the surface mixture; and
$RDen$ = relative density of the surface mixture (%).

The R^2-value for this regression equation is 0.89, the standard deviation is 0.04, and the coefficient of variation is 16.1 percent.

When a regression equation is developed, the variables in the equation must first be examined to determine if they relate to the dependent variable in a logical manner. The influence of the variables entering into the prediction equation is shown in Figure 2. The variable relationships tend to support commonly held beliefs about their influence on rutting. As stability increases, rutting decreases. As summer temperatures increase, rutting increases. Although the relationship with relative density may be contrary to current thinking, as relative density increases rutting increases, the average relative density may already be at the level desirable for minimal rutting. Thus the variability seen in the survey data could justify a decrease in air voids producing a minor increase in rutting as shown in the figures. By far the most influential variable in the equation appears to be the hump in the gradation on the No. 40 sieve in the FHWA 0.45 power gradation chart, which shows a dramatic influence on rutting. This variable has been pointed out by many engineers as a prime contributor to an unstable mixture. This value is determined on a plot of the gradation on 0.45 power paper. A line is extended from the origin to the No. 4 sieve data point. The difference between this straight line and the gradation at the No. 40 sieve is the hump value.

Mix Variability

An important use of any regression equation developed to describe behavior of a pavement is the examination of material properties and how they affect the development of distress in the pavement. The ability to study individual materials provides the opportunity to study variability throughout the state and quantify the impact of specific material properties and their variability on pavement life as well as quantify what certain agencies could do to reduce the potential for distress. Table 2 gives the statewide averages and standard deviations for the variables in the regression equation.

In the equation developed here the influence of gradation on the mixture's ability to resist rutting is evident. Although stability and temperature have a definite effect, as does the relative density of the surface, the gradation parameters show the largest influence, given the variability of the parameters across the state. If a complete survey of the state were made, a

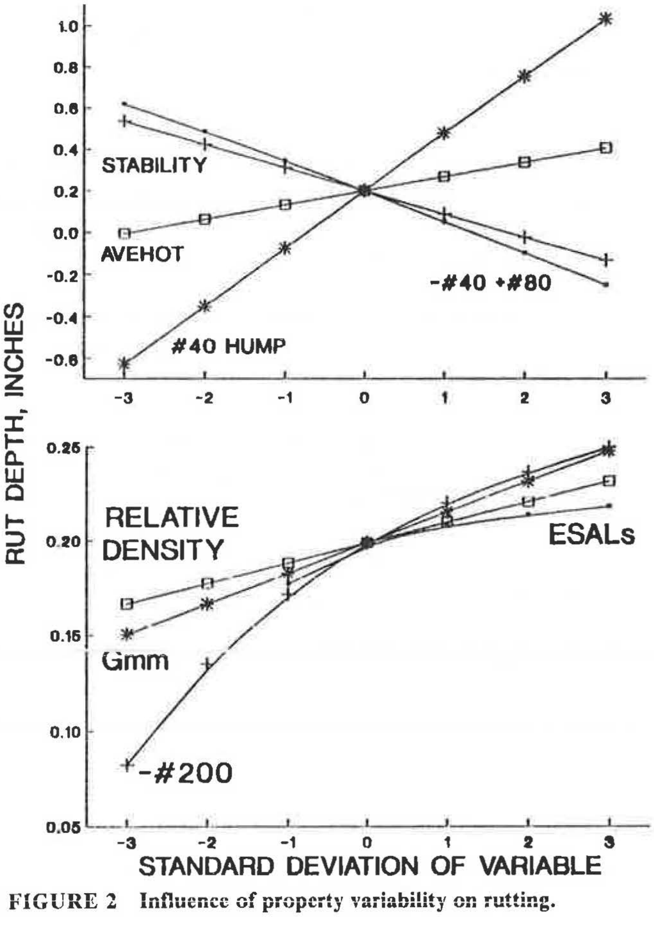

FIGURE 2 Influence of property variability on rutting.

TABLE 2 STATEWIDE VALUES FOR PARAMETERS IN THE REGRESSION EQUATION

Variable	Average	Standard Deviation
40+80	10.6	2.7
SSTAB	2292	435
DIFFS40	3.3	3.3
AVEHOT	22.2	1.3
TCUMRR	3.1	2.4
-200	4.8	0.57
D	143.1	38.4
RDen	96.8	1.0
Rut Depth	0.20	0.11

more detailed analysis could be performed to develop individual regression relationships for each district in the state. This would reflect the construction practices and materials used in the individual districts, which may be highly variable. Because of the limited number of projects in this survey it is more appropriate to examine only the magnitude of each parameter and the variability of that parameter within the district for comparison between districts. This analysis can provide insight into reasons for rutting being higher or lower in any particular district. The mean and standard deviations of the variables in the regression equation for each district in the survey are given in Table 3.

The data in Table 3 indicate which districts have the potential to reduce rutting by altering the mean value of a specific parameter. For example, District 1 could reduce the mean value of the *DIFFS*40 variable and reduce the potential for rutting. Likewise, a material variable with a high standard deviation is a candidate for improvement through more control. By lowering the variability, the number of projects constructed with a high potential for rutting will be reduced.

Figures 3-6 show the differences in rutting in each district as a function of the variability about the mean for several of the variables. Variables such as temperature cannot be altered, but the regression equation shows where more stringent gradation controls can reduce the potential for rutting. Certain increased expenses for extra gradation or mixture control may be justified by prolonged overlay life.

Regression analyses such as this also provide performance data that can be used to evaluate specific mix design properties to show where specific improvements can be made. As part of its new Interstate overlay mix, IDOT eliminated the hump in the gradation on the No. 40 sieve, which, from this analysis, indicates that an improvement in rutting resistance should be realized.

LABORATORY ANALYSIS

Cores were taken from 11 of the 32 overlay projects surveyed. These cores were brought to the laboratory for further analysis to verify any correlation between structural testing and rutting performance. The projects that were sampled are given in Table 4. Six cores were taken between the wheelpaths at each location for testing. Each core was composed of several layers of surface and binder, depending on the construction history of the project. The thicknesses obtained from direct measurement are given in Table 5.

These pavements represent different designs and come from different climatic zones within Illinois, as shown in Figure 7. Table 6 gives the survey data from the data base for each sample unit from which a core was taken and the predicted rutting from the regression equation. Several cores were taken from new construction and therefore do not have data in the data base.

The cores were separated into surface and binder layers for structural testing of the individual layers. Resilient modulus testing was conducted at 40° F, 72° F, and 100° F. Indirect tensile testing was conducted at 72° F under standard conditions. Three cores were tested at each temperature. For the diametral resilient modulus, each core was tested twice. The results for indirect tensile strength are given in Table 7. The diametral resilient modulus values obtained from the testing are given in Table 8.

Stiffness and tensile strength can be related directly to rut depth in the pavement using the rut depth measurements from the data base, but a more suitable parameter to indicate the development of rutting, including the effect of traffic, would be percentage of permanent strain per level of axle load application (rut/thickness/ESAL). This can account, to some extent, for the different ages of the overlay mixtures and the different levels of traffic that have been placed on the

TABLE 3 DISTRICT AVERAGES AND STANDARD DEVIATIONS OF VARIABLES IN THE REGRESSION EQUATION

Variable	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev
	District 1		District 3		District 5		District 8	
40+80	12.5	1.6	12.03	1.73	10.8	0.31	7.27	1.08
SSTAB	2289	354	2268	389	1999	138	2343	641
DIFFS40	5.54	1.65	4.35	1.25	2.91	1.05	-0.62	1.2
AVEHOT	22.3	1.22	22.8	0.34	23.3	0.52	25.7	0.0
TCUMRR	5.69	1.71	3.02	1.96	1.85	0.24	2.65	1.76
-200	4.65	0.47	4.35	0.41	4.57	0.10	4.72	0.71
D	154.3	2.2	153.4	2.14	-	-	150.9	4.5
RDen	96.79	1.10	96.68	0.97	97.47	0.41	96.19	0.79
Rut	0.29	0.10	0.22	0.08	0.26	0.11	0.18	0.08

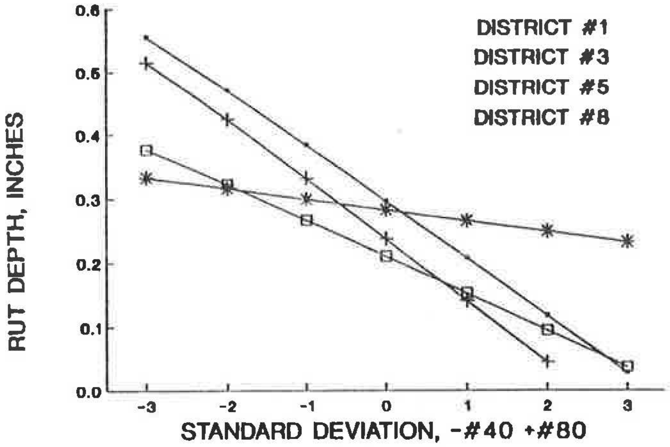

FIGURE 3 Influence of variability in the amount passing the No. 40 and retained on the No. 80 sieve for each district.

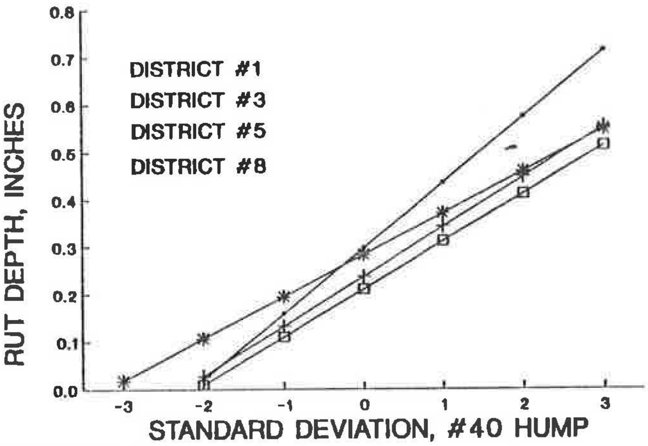

FIGURE 5 Influence of variability in the 0.45 power curve hump on the No. 40 sieve on rutting in each district.

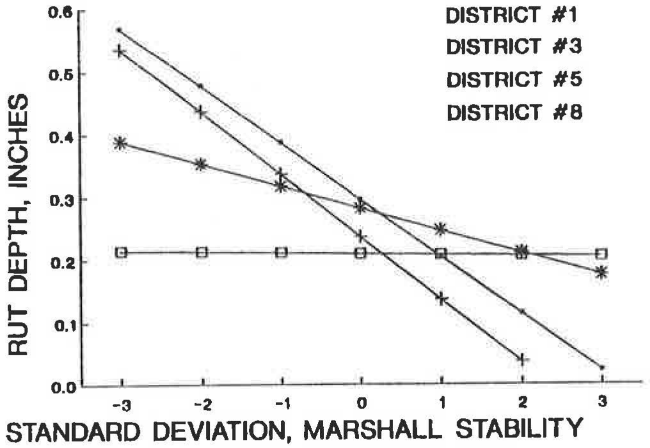

FIGURE 4 Influence of variability in the Marshall stability of the surface layer on rutting in each district.

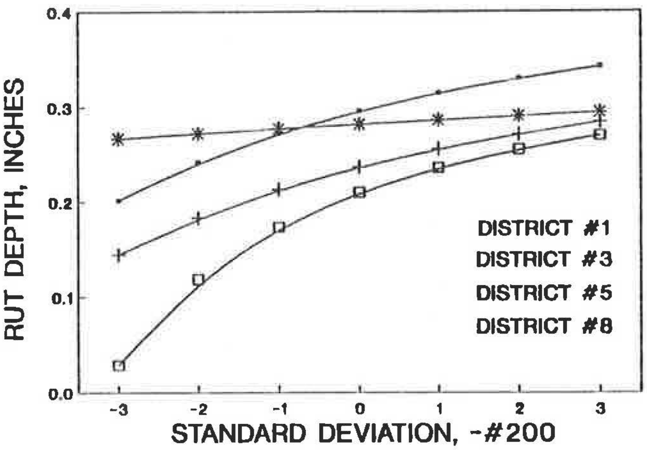

FIGURE 6 Influence of variability of the percentage of the binder mix passing the No. 200 sieve on rutting in each district.

TABLE 4 CORES TAKEN FROM OVERLAY PROJECTS FOR LABORATORY ANALYSIS

Core Sequence	District	Highway	Contract No.
1	1	I 55	30861
4	8	I 270	33348
5	8	I 70	33347
7	7	I 70	26040
10	5	I 57	33123
11	1	I 80	34444
13	3	I 80	34187
16	1	I 55	29437
17*	5	I 70	34174
20*	5	I 70	35824
21*	5	I 70	35824

* = data not in data base, just constructed.

TABLE 5 LAYER THICKNESSES OF OVERLAY CORES

Core Sequence	Surface	Binder	Age, years
1	2.5	3.0	11
4	0.75	2.25	1
5	1.0	1.0	2
7 Combo*	1.0, 1.0	4.0, 3.5	1, 13
10	1.0	4.2	2
11	1.6	2.7	4
13	1.5	3.2	1
16	1.5	4.0	6
17	1.0	3.9	0
20	1.3	2.0	0
21	1.0	2.7	0

* = two overlays, respectively.

overlay. This parameter is the permanent strain (rut depth/thickness) divided by the 18-kip ESALs, in millions, that have trafficked the overlay since placement. This conversion produces the rutting variable, permanent strain/ESAL, given in Table 9.

The laboratory structural tests show a clear relationship to the development of rutting in an overlay of a concrete pavement. Figure 8 shows average tensile strength of the surface-binder combination versus rate of rutting. Below an average tensile strength of approximately 150 psi, the rate of rut development increases dramatically. The two extreme points with high strengths and high rutting levels are also the oldest pavements. This shows the influence of age on the stiffening of the asphalt mixture and also hints at problems in testing pavement materials placed at different times with possibly different mix criteria. The older mixes may have been constructed with materials that produce low tensile strengths, which over the years have reached the high value shown in Figure 8. The relationship of age and tensile strength is seen in Figure 9, which clearly shows an influence of age on structural properties of the mix.

A similar relationship exists between the diametral resilient modulus and the rate of rutting. This is shown in Figure 10 for

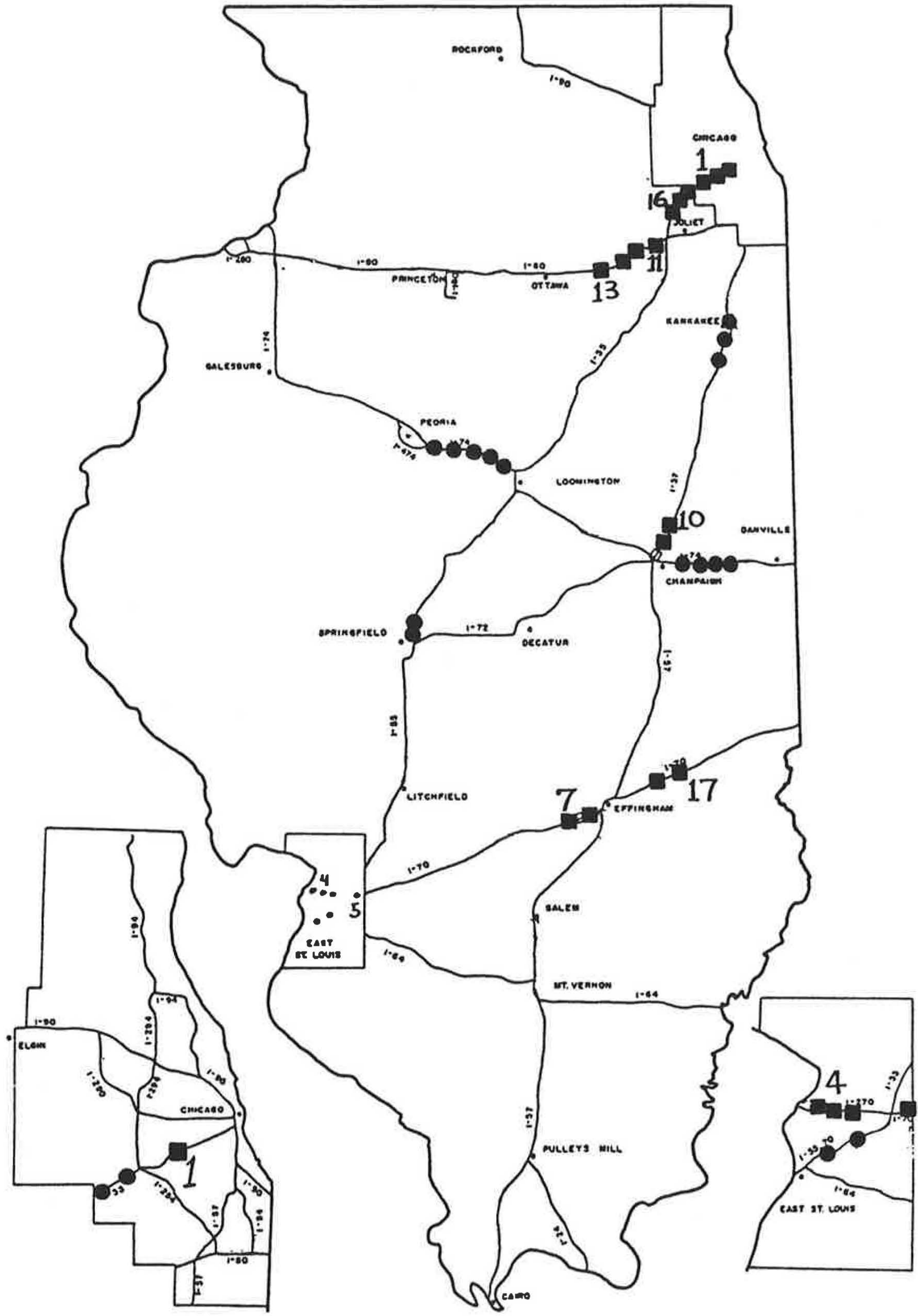

FIGURE 7 Location of overlay projects with the core sequence numbers indicated by squares.

the average diametral resilient modulus of the surface and binder mixtures.

The relationships among these structural parameters, rutting, and age are important because rutting is most likely to develop during the initial years of the life of mixes. When the problem is premature deformation, the initial years are

TABLE 6 MIXTURE PARAMETERS FROM THE DATA BASE

Core Sequence	CASE-NO	AGE	-200	40+80	SSTAB	D	RDen	TCUMRR	RUTR
1	14	10.5	4.9	11.9	2036.	152.3	95.5	7.93	.23
16	15	6.0	4.5	13.8	2386.	155.4	97.6	5.65	.31
11	24	1.67	4.3	10.2	3210.	149.8	95.0	1.77	.03
	25	4.67	4.9	14.7	-0	-0	-0	2.89	.19
13	44	.92	5.7	-0	-0	-0	-0	.49	.07
10	50	1.67	-0	-0	2830.	-0	-0	2.23	.13
	51	1.67	-0	-0	2830.	-0	-0	2.21	.25
7	70	.92	3.9	8.6	1819.	155.4	96.4	4.43	.32
5	82	1.83	5.5	-0	-0	-0	-0	2.30	.10
4	87	0.92	5.6	6.0	2847.	147.3	94.9	1.20	.14
	89	0.92	5.6	6.0	2847.	147.3	94.9	1.20	.09

Where the variables are as defined previously.

TABLE 7 INDIRECT TENSILE STRENGTH FOR OVERLAY CORES

Core Sequence		Surface	Binder
1		284	205
4		136	130
5		124	121
7	new	210	164
	old	186	176
10		207	241
11		192	224
13		127	201
16		285	300

TABLE 8 DIAMETRAL RESILIENT MODULUS OF OVERLAY CORES

Core Sequence		Layer	Stiffness, psi x 10^6		
			40°F	72°F	100°F
1		Surf	3.21	1.01	.274
		Binder	2.93	1.14	.38
4		Surf	1.62	.797	.178
		binder	2.09	.723	.143
5		Surf	1.73	.822	.198
		Binder	1.65	.89	.25
7	New	Surf	3.84	1.99	.80
	Old	Surf	3.99	1.51	.308
	New	Binder	2.96	.902	.166
	Old	Binder	3.18	1.71	.445
10		Surf	2.73	1.15	.196
		Binder	2.9	1.15	
11		Surf	3.42	1.46	.652
		Binder		1.09	.262
13		Surf	2.43	.847	.686
		Binder		.919	.116
16		Surf	3.34	1.38	.392
		binder	2.87	1.33	.319
20		Surf	2.94	1.25	.346
		Binder	2.95	1.3	.357

TABLE 9 RUTTING PARAMETER FOR COMPARISON WITH STRUCTURAL PROPERTIES

Core Sequence	Strain/ESAL x10-08	Rut Depth
1	0.58	0.23
4	3.30	0.12
5	2.17	0.10
7	0.76	0.32
10	1.64	0.19
11	1.10	0.11
13	3.04	0.07
16	1.00	0.31

even more critical to the performance of the overlay. The relationships clearly show that, during the first 2 to 3 years, stiffness and tensile strength are direct indicators of the rate at which rutting may be expected to develop. To determine the precise relationship between rutting and stiffness or tensile strength over longer times it will be necessary to collect more data in the future from these same sections and repeat the analysis to determine the exact influence of age on changes in material properties.

RESULTS AND CONCLUSIONS

The work presented here is part of a study to establish field and laboratory data indicating factors that may be crucial to the development of rutting or premature deformation, or both, in asphalt concrete overlays of portland cement concrete pavements. Although this study of materials was confined to Illinois, the methodology used to establish these relationships can be implemented without a great deal of expenditure and actually represents the concept behind the long-term pavement performance studies now being initiated as part of the Strategic Highway Research Program. The results indicate that a state can survey its pavements and study material properties that contribute to a specific problem. The field survey and data base development have been implemented in Illinois with the development of the Illinois Pavement Feedback System, which will contain a comprehensive data base of the entire system of pavements in the state (*6*).

Analysis of the field data indicates that the majority of problems in Illinois can be attributed to material properties in the gradation of the mixture. Although temperature and traffic have an impact on rutting, as expected, the properties of the component materials demonstrated the most critical relationship with rutting. The impact of these material parameters is not unexpected. The "tender mix" phenomenon associated with the hump in the 0.45 power gradation chart has long been recognized as contributing to rutting. The predominant influence of the percentage passing the No. 40 sieve and retained on the No. 80 sieve on rutting is a result that, although not contrary to experience, was not expected to come out as strongly as it did.

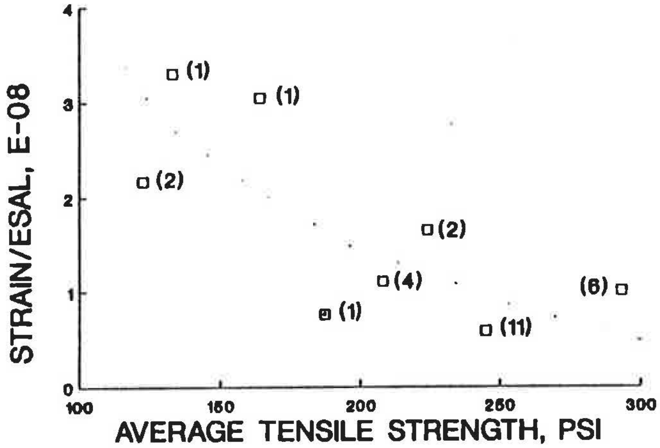

FIGURE 8 Average tensile strength of overlay related to rutting (age in parentheses).

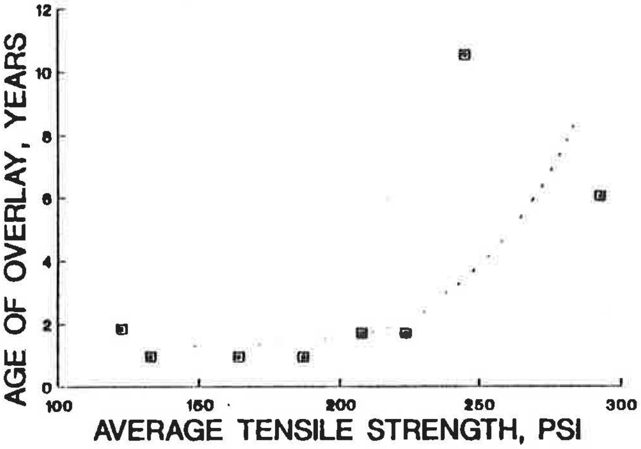

FIGURE 9 Relationship between tensile strength and age of overlay.

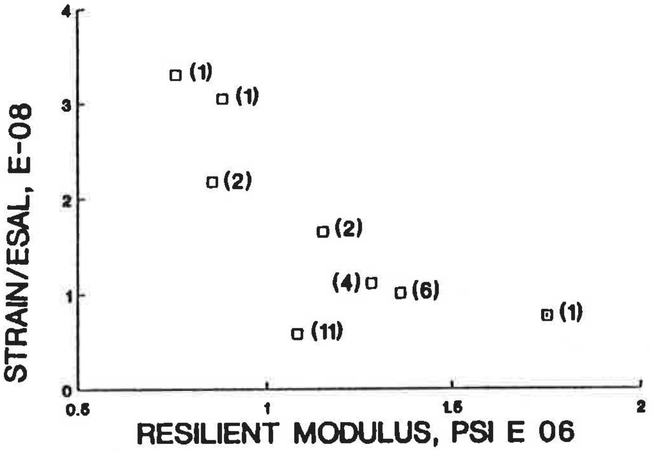

FIGURE 10 Relationship of resilient modulus to rutting.

An important factor that emerges from the analysis is that normal variability in gradation occurring across a state can produce a significant change in the rutting that develops in the overlay. Studies such as this one can show where changing one variable or exercising extra control during construction can reduce the occurrence of distress. Data such as these will have future use in establishing life values for quality assurance specifications, which must be based on material variability. Laboratory testing has shown only inconsistent tendencies relating laboratory structural tests of material properties to rutting or other distress that decreases the life of a pavement. Field testing of actual pavements with samples taken for laboratory analysis provides a better indication of performance. The data developed in this study clearly indicate where variability can be controlled to alter the rutting life of an overlay.

The close relationship between a structural property of individual lifts and age may indicate that aging does indeed alter more than the surface layer of the mix. Whether this is "aging" wherein chemical alterations are taking place or a thixotropic hardening over time is an academic question. That changes occur, over time in all layers, and provide an increased resistance to rutting is the important consideration. It is important to develop a historical time sequence to establish a minimum tensile strength in the mix at the time of construction that may be required to resist rutting in the initial years of the life of the overlay until the hardening develops sufficiently to provide significant strength to resist rutting. This must be balanced against cracking and other distress that may increase as a mix becomes harder.

The problem of premature deformation in overlays of Interstate concrete pavements in Illinois led to the formation of a Task Force on Rutting and Durability to address and recommend changes to eliminate premature deformation. The relationships established in this study were presented to the task force and served to reinforce the recommendations the task force was formulating. Gradations were altered to ensure that the hump in the gradation was not allowed to occur again. The amount of material in the No. 40 to No. 80 sieve range was also changed by this alteration to further reduce the potential for rutting. Additional recommendations addressed control on density and air voids and voids in mineral aggregate during construction.

This study clearly demonstrates the usefulness of field distress surveys for establishing relationships between material properties and mixture performance. Such surveys can be accomplished without great expense and can provide a source of information for future use in evaluating pavement performance when unforeseen problems arise.

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