Evaluation of Louisiana Experimental Base Project with VESYS

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Since the early 1900s, many empirical methods have been developed for the structural design of pavements. The empirical nature of these methods was necessary because of a limited knowledge of material behavior as well as limitations in the ability to solve boundary value problems. Empirical methods may be adequate for a range of established conditions; however, it is difficult to extrapolate such methods beyond the conditions for which they were developed. The desirability of extending the range of pavement design methods to include new materials, widely varying environmental conditions, and changing loading conditions requires a more fundamental and analytical approach to the design of pavement structural systems. The method should probably be based on a rational (theoretical) basis, with the capability to predict the performance of a pavement over its useful (i.e., design) life. One of the latest rational methods proposed is the VESYS IIIA computer-based approach developed through FHWA. The VESYS IIIA computer program was used to predict pavement performance in terms of rutting, fatigue cracking, and a present serviceability index (PSI) for the Louisiana Experimental Base Project. It was found that the VESYS IIIA mechanistic analysis package, in combination with material characterization information developed from resilient indirect tensile tests, can adequately predict rut depths over a short period of time but inadequately predicts fatigue cracking. Comparisons between measured and predicted PSI values indicated that the VESYS IIIA model may be adequate for short periods of evaluation.

Since the early 1900s, many empirical pavement design methods have been developed. The empirical nature of these methods was necessary because of a limited knowledge of material behavior as well as limitations in the ability to solve boundary value problems (*1*). In general, empirical methods yield satisfactory results when used within the limits for which they were derived, as evidenced by the good performance of many existing pavement structures. Empirical methods may be adequate for a range of established conditions; however, it is difficult to extrapolate such methods beyond the conditions for which they were developed.

The desirability of extending the range of pavement design methods to include new materials, widely varying environmental conditions, and changing loading conditions in an era of growing shortages of existing pavement materials requires that a new approach to the analysis and design of pavement structural systems be undertaken.

BACKGROUND

In recognition of this problem, the FHWA Office of Research initiated a project entitled New Methodology for Flexible Pavements. This project was aimed at developing a rationally based pavement design procedure with the capability to predict the performance of pavement over its useful life. As an initial step, a pavement design system was developed under an FHWA contract with the Massachusetts Institute of Technology (*2–4*). This work resulted in the creation of a computer program called VESYS IIM, which performed a structural analysis of a three-layer pavement system on a probabilistic basis. Subsequent improvements by FHWA resulted in an improved version of the computer program called VESYS III, which was developed to incorporate the best features of several existing versions of the VESYS IIM computer program and is capable of handling eight-layer pavements (*5*). One of the latest versions, VESYS IIIA, uses an elastic rather than a viscoelastic pavement evaluation approach.

The VESYS computer program predicts the performance of a pavement in terms of a present serviceability index (PSI), derived from the AASHTO road test procedures. The PSI is related to the fundamental structural conditions of integrity, continuity, and deformation of the pavement system. In the VESYS IIIA program, these fundamental entities are expressed as cracking, rutting, and pavement roughness. The magnitude and relative quantities of these responses are dependent upon input of materials properties of the pavement layers, the geometry of the pavement section, traffic data, and environmental conditions.

RESEARCH APPROACH

An essential element in a comprehensive evaluation of the effectiveness of mechanistic analysis and design packages in predicting pavement distress and performance is a comparison of the estimated results with actual results from in-service pavement sections. A group of 18 pavement sections constructed in conjunction with the Louisiana Experimental Base Project (*6*) was selected for this purpose. This selection was made because the following information was available for each of the pavement sections (*7,8*):

- The original construction parameters, including layer thicknesses, temperature conditions, asphalt content, and gradation;
- Sufficient field performance data, including PSI, rutting, and cracking; and
- General field conditions, including moisture contents, temperature conditions, and traffic loadings.

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LITERATURE SURVEY

A number of research projects have been conducted to validate the practicability of the VESYS pavement design system. A design method for flexible pavements based on the VESYS IIM structural subsystem was evaluated by Kenis (*9*). All components of the design procedures were formulated to ensure inclusion of the inherent variabilities in traffic estimates, material properties, and environmental conditions. Estimates of the performance were produced and considered to be reasonable for the time measured.

An evaluation of flexible pavement design methodology based on field observations was conducted by Sharma et al. (*10*). In this study, field observations of distress and performance of flexible pavement test sections under accelerated traffic loading at the Pennsylvania State University Test Track facility were presented and correlated with corresponding values predicted by the VESYS IIM program. Results indicated that it was possible to predict the relative magnitudes of these distress and performance indicators.

LOUISIANA EXPERIMENTAL BASE PROJECT

The necessary requirements for this study were met by using the 18 different test sections constructed by the Louisiana Department of Transportation and Development (LADOTD) at LeCompte, Louisiana, for the Louisiana Experimental Base Project (*6*).

The test sections are located on US-167 and LA-71 between Meeker and Chambers in the central portion of the state of Louisiana. The location of the facility represents a compromise between the low wetlands of South Louisiana and the slight hills in the northern part of the state (*6*). The terrain at the test site is flat and affords poor drainage. Subgrade material is relatively uniform, basically fine-grained soil. In 1977 the mean variation in air temperature at the test site ranged from 39°F to 84°F, and the annual rainfall was typically 55.6 in. The roadway was opened to traffic in August 1976.

The main elements of the experimental design are presented in Table 1. The design includes asphaltic concrete surface thickness at two nominal levels (3.5 and 5.5 in.), base course materials at three levels (asphaltic concrete or black base, cement-stabilized soils, and cement-stabilized sand-clay-gravel), and design life at three levels (5, 10, and 15 years). The levels of thickness for each base course material were determined using AASHTO design procedures and the following Louisiana coefficients for material components:

- Surface course—0.44; and
- Base course—0.34 for asphaltic concrete, 0.15 for cement-stabilized soil, and 0.18 for cement-stabilized sand-clay gravel.

The 14 basic experimental test sections were supplemented with four control sections for reference, one at each end of the project and two within the experimental area. These control sections were composed nominally of 5.5 in. of asphaltic surface course over 7 in. of asphaltic concrete base course and 6 in. of soil cement. The design profiles of the various test sections are shown in Figure 1. Each test section is approximately 550 ft long, with a transition of 50 ft between each section. The 10- and 15-year design sections were placed in random order. However, the 5-year design sections (Sections 9–14) were grouped together to allow an overlay of this portion of the entire segment should early manifestation of distress become evident in any or all of the sections.

TABLE 1 EXPERIMENTAL DESIGN—LOUISIANA EXPERIMENTAL BASE PROJECT

Nominal Design Life (years)	Base Type (in.) by Surface Thickness					
	3.5 in.			5.5 in.		
	Black Base	Soil-Cement	Stab. SCG	Black Base	Soil-Cement	Stab. SCG
5	6	12	10	3	6	6
10	7.5	15		4.5	9	
15	11	20		8	16	

For this study, the 18 pavement sections were separated into five categories with a separate analysis completed for each category.

In some of the pavement test sections, soil cement layers were placed in two lifts. Core borings from these sections have indicated poor bonding between the lifts. As a consequence, those sections with the two-lift construction procedure were assumed to be a distinct type of pavement section containing two separate soil-cement base layers.

The following five types of pavement sections were considered:

1. Control sections,
2. Black-base sections,
3. Two-lift soil-cement sections,
4. Single-lift soil-cement sections, and
5. Cement-stabilized sand-clay-gravel sections.

For all five types of pavement sections, the wearing course and the binder course were treated as a single asphalt course. Each test section was constructed with a plant mix seal (PMS) covering the entire surface.

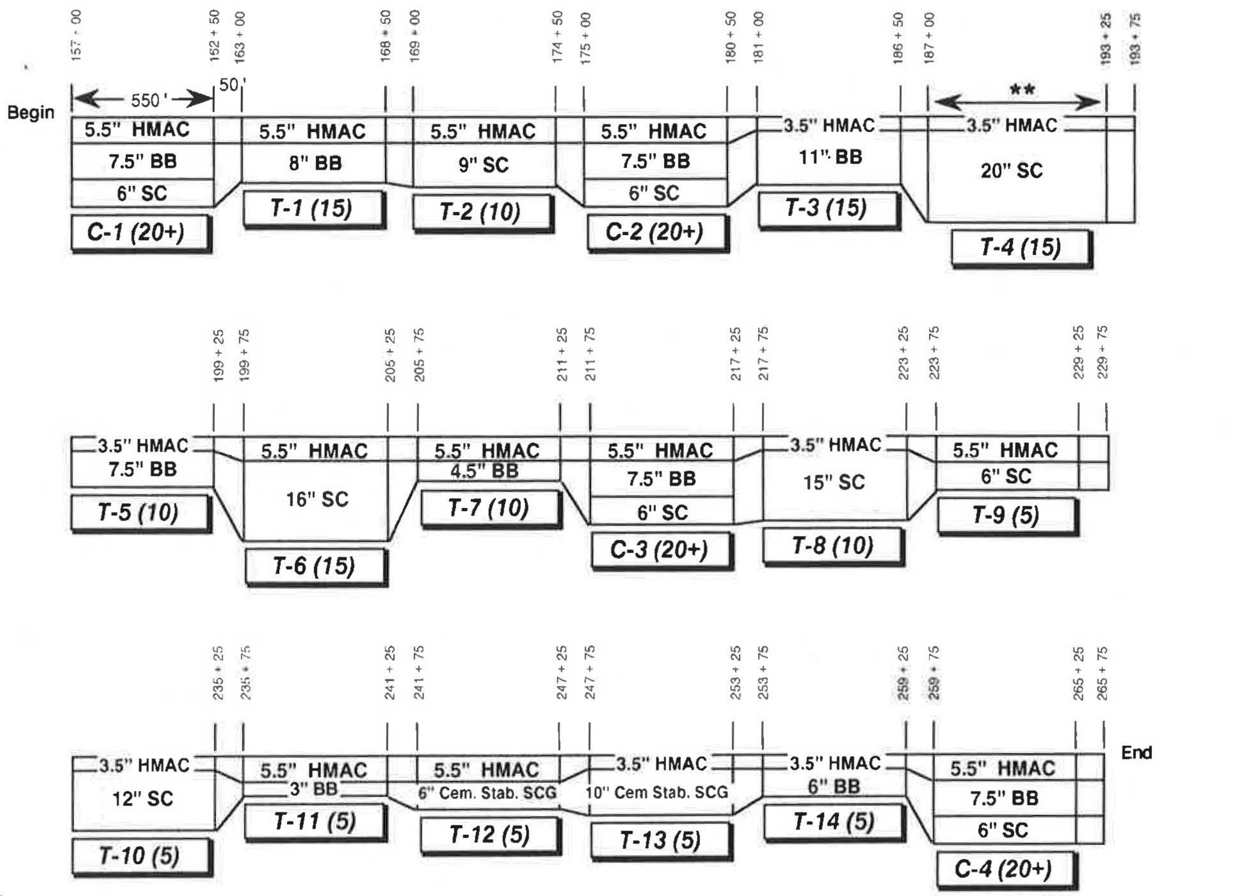
PROJECT INPUT VARIABLES

The development of performance results from the analysis packages required that certain input variables be specified. These variables were divided into the following four categories:

1. System geometry,
2. Environmental variables,
3. Traffic loadings, and
4. Mechanical properties of materials.

System Geometry

In VESYS IIIA models the system geometry is defined by the thickness of the various pavement structural layers and a subgrade considered to be semi-infinite in thickness. In this study the wearing and binder courses were combined to form a single layer. The average as-constructed layer thicknesses for each test section are presented in Table 2. These thickness



NOTES:
-- ( ) designates AASHTO design life in years
-- Test section lengths = 550' except for ** which = 625'
-- Transition section lengths = 50'

C	--	Control Section
T	--	Test Section
HMAC	--	Hot Mix Asph. Conc.
BB	--	Black Base
SC	--	Soil Cement
SCG	--	Sand Clay Gravel

FIGURE 1 Experimental base project layout.

values were used to define the pavement structural sections for the test sections. The PMS was not considered a structural layer and, hence, was not included in the models. Because the average as-constructed layer thicknesses (Table 2) exceed the design thicknesses (Table 1), the actual pavement design life would be expected to exceed the nominal design life.

Environmental Variable

Temperature and moisture contents are two major environmental conditions that can influence overall pavement response. The effect of moisture content on the engineering properties of subgrade, embankment, and select materials is usually reflected in the variability of material properties (*11*). Temperature effects on the properties of asphalt-bound layers can be inferred by using mean monthly ambient temperatures to establish representative moduli for each pavement section. Representative temperatures were obtained from the Weather Bureau, whereas in-situ moisture contents were obtained from LADOTD (*6*).

Traffic Loading

Previous attempts to validate the AASHTO design procedure in Louisiana were unsuccessful because of an inadequate traffic evaluation (*6*). To avoid a recurrence of this situation, periodic traffic counts and accurate truck weight measurements were taken at the project site. Traffic counts were taken yearly to establish growth patterns and to randomly measure large seasonal variation. A weigh-in-motion (WIM) device was used to make periodic truck weight studies in the outer lane of the roadway (*12*). Some difficulties were encountered in the calibration of the WIM system, and a complete record was not available for axle loads applied during each weighing period.

Serviceability Bounds

The system serviceability bounds are accounted for by such restraints as tolerance, terminal serviceability index, and the mean and standard deviation of the serviceability index at time zero. The tolerance is defined as the minimum accep-

TABLE 2 AS-CONSTRUCTED LAYER THICKNESSES, IN INCHES

Pavement Section	Layers WC/BC	BB	SC-1	SC-2	SCG	Sel.
C-1	6.97	6.31	6.63	—	—	9.00[1]
C-2	5.94	8.50	5.38	—	—	9.00[1]
C-3	5.88	7.01	6.75	—	—	9.00[1]
C-4	5.81	6.15	6.75	—	—	9.00[1]
T-1	7.03	7.75	—	—	—	15.00[2]
T-3	4.38	11.00	—	—	—	15.00[2]
T-5	3.51	9.25	—	—	—	15.00[2]
T-7	6.34	5.94	—	—	—	15.00[2]
T-11	5.94	4.70	—	—	—	15.00[2]
T-14	4.31	6.25	—	—	—	15.00[2]
T-4	3.72	—	11.78	7.85	—	6.00[3]
T-6	5.76	—	9.15	6.10	—	6.00[3]
T-8	3.88	—	8.10	7.78	—	6.00[3]
T-10	5.26	—	7.67	5.33	—	6.00[3]
T-2	6.16	—	8.13	—	—	9.25[4]
T-9	5.94	—	6.50	—	—	14.00[4]
T-12	5.82	—	—	—	8.375	12.00[4]
T-13	4.82	—	—	—	9.375	14.25[4]

NOTES: WC/BC = wearing and binder course layers combined; BB = black base layer; SC-1 = single-life soil cement layer; SC-2 = two-life soil cement layer; SCG = cement stabilized sand-clay-gravel layer; Sel = select layer; and — = no layer.
[1]Average thickness for C1–C4.
[2]Average for all black base sections.
[3]Thickness required because of thickness limitation of VESYS IIIA.
[4]Average thickness for section.

tance reliability of the pavement expressed as a percentile (*13*). A value of 50 percent (or mean value) was used. The terminal serviceability is that rating that can just be tolerated before overlay (*13*). A value of 2.5 was used because the sections under study are part of a primary highway. Initial serviceability indexes for each of the sections correspond to the Mays measurements obtained from the Louisiana Experimental Base Project before the sections were opened to traffic.

Mechanical Properties of Materials

The rutting and fatigue responses predicted by the VESYS IIIA program depend not only on the analytical technique but also on the material properties selected as input values for the computer program. Information developed from a resilient indirect tensile testing program (*7*) was used in calculating the modulus of elasticity, Poisson's ratio, permanent deformation, and fatigue input data for the asphalt, soil-cement, and cement-stabilized sand-clay-gravel layers. The ranges in the mechanical properties of the pavement materials modeled in this study are presented in Table 3.

The material properties of the select and embankment materials were obtained from the results of repeated-load triaxial compression tests conducted by the Asphalt Institute (*10*) on materials extracted from the pavement sections.

The permanent deformation variables, GNU and alpha, for the asphalt and soil-cement materials were obtained from the Materials Research Laboratory of Louisiana Tech University (*14*). The fatigue coefficients for VESYS IIIA were generated from previous test results (*1,7,14,15*).

The GNU and alpha values for the select and embankment materials were not determined directly but were correlated with values obtained by others (*16*) for similar materials.

FIELD VERIFICATION

Each of the 18 pavement sections was evaluated. The VESYS IIIA results were generated for each pavement section, including damage and performance parameters. From these results, it was possible to compare the predicted and measured responses for both the damage and performance model, thereby evaluating the accuracy of each model.

Rut Depths—Predicted Versus Measured

The ranges in rut depths are presented in Table 4 along with median estimates of rutting. The measured and predicted

TABLE 3 ESTIMATES OF MECHANICAL PROPERTIES OF MATERIALS

Layer	Modulus 10^5 psi	Poisson's Ratio	Permanent Deformation Parameters Alpha	GNU	Fatigue Parameter F_1	F_2
WC/BC	1.3 - 11.3[1]	.37-.39	.47	.025	$9x10^{-7}$ to .1[3]	2.5-4.2[3]
BB	1.9 - 13.0[1]	.33-.36	.43	.021	$9x10^{-7}$ to .1[3]	2.5-4.2[3]
SC	5.577	.25	1.0	0	---	---
SCG	3.979	.25	1.0	0	---	---
SEL	0.75-.200[2]	.35	.89	.068	---	---
EMBK	.067-.071[2]	.35	.735	.048	---	---

[1] Corresponding to mean monthly ambient temperatures (MMAT)

[2] Corresponding to location along test road

[3] F_1 and F_2 values related to MMAT and particular test section

TABLE 4 MEASURED RUT DEPTHS WITH TIME IN YEARS

Design Life*	Test Sections		1.67	2.25	2.67	3.0	3.25	3.5	5.33	6.08	6.5	COMMENT
20y	C1-C4	low	0	0	0	0	0	0	0	.2	.2	black base
		high	.1	.1	.2	.3	.2	.3	.3	.4	.4	with
		median	.05	.05	.10	.15	.10	.15	.15	.30	.30	soil cement
15y	T1,3	low	0	0	0	0	.1	.1	0	.3	.2	
		high	.1	.1	.2	.3	.2	.3	.3	.5	.4	black base
		median	.05	.05	.10	.15	.15	.20	.15	.40	.30	sections
15y	T4,6	low	0	0	0	0	0	0	0	.1	.2	
		high	0	.1	.1	.2	.1	.2	.2	.3	.3	soil cement
		median	0	.05	.05	.10	.05	.10	.10	.15	.25	sections
10y	T5,T7	low	0	0	0	.1	.1	.2	.2	.2	.3	
		high	.1	0	.2	.4	.3	.4	.5	.6	.6	black base
		median	.05	0	.10	.25	.20	.30	.3	.40	.45	sections
10y	T2,8	low	0	0	0	.1	0	.1	-	.2	.2	
		high	.1	0	.2	.2	.2	.3	-	.5	.4	soil cement
		median	.05	0	.20	.15	.10	.20	-	.35	.30	sections
5y	T11,14	low	0	0	.1	.1	0	.1	.1	.2	.2	
		high	.1	0	.3	.3	.2	.3	.3	.4	.4	black base
		median	.05	0	.20	.20	.10	.20	.20	.30	.30	sections
5y	T9,10	low	0	0	0	.1	0	.1	.1	.2	.2	
		high	.1	.1	.1	.2	.1	.3	.5	.6	.4	black base
		median	.05	.05	.05	.15	.05	.20	.30	.40	.30	sections
5y	T12,13	low	0	0	0	.1	0	.1	.1	.1	.2	cement
		high	.1	0	.2	.2	.1	.2	.3	.3	.4	stabilized
		median	.05	0	.10	.15	.05	.15	.20	.20	.30	sand-clay-gravel

* Originally established nominal design life

(VESYS IIIA) median rut depths were plotted as a function of time for each pavement section in Figures 2–5.

In all the pavement sections, greater rut depths were predicted by VESYS IIIA during the first 2 years. As time progressed, rutting predictions comparable to the measured values were obtained.

Figure 2 shows that there was generally good agreement between the predicted and measured rutting depths for the control sections, particularly through the first 6 years. Although the measured rut depths are slightly greater after 6 years, the rate of rutting depicted by the VESYS IIIA predictions is considered reasonable.

Good agreement is also seen for the 15- and 10-year black-base sections between measured and predicted rut depths (see Figures 2 and 3, respectively). In Figure 3, the predicted rut depths are generally greater than the measured values for the 5-year design pavements. The agreement, however, is well within the expected measurement variation.

Similar good agreement between predicted (VESYS IIIA) rut depths and measured rut depths is shown in Figures 4 and 5 for the soil-cement and cement-stabilized sand-clay-gravel base sections.

In comparing the results for the control, black-base, and soil-cement and sand-clay-gravel sections, it is obvious that the amount of rutting is greater for the black-base sections than for the other sections. On the basis of measured data, the rate of rutting is greater than the predicted rate of rutting (VESYS IIIA) within the time frame of 3 to 7 years. However,

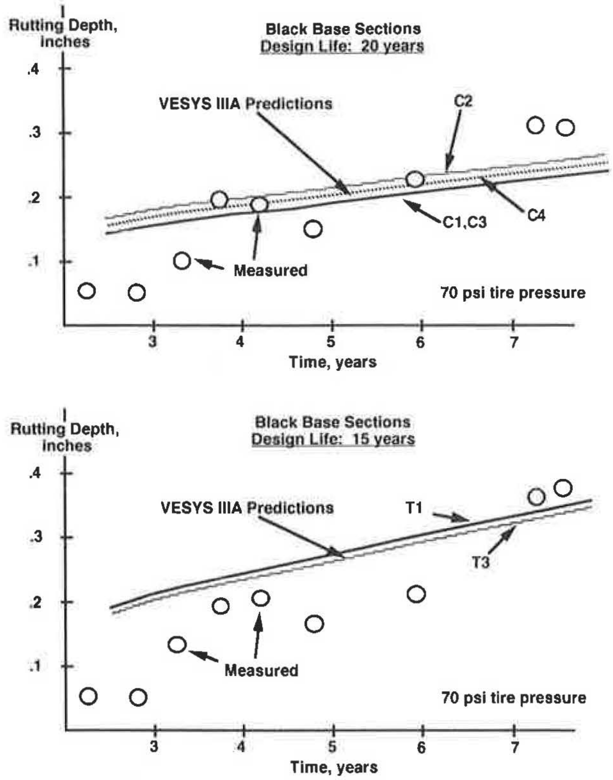


FIGURE 2 Predicted versus measured rutting depth: Control Sections 1–4 and Test Sections 1 and 3.

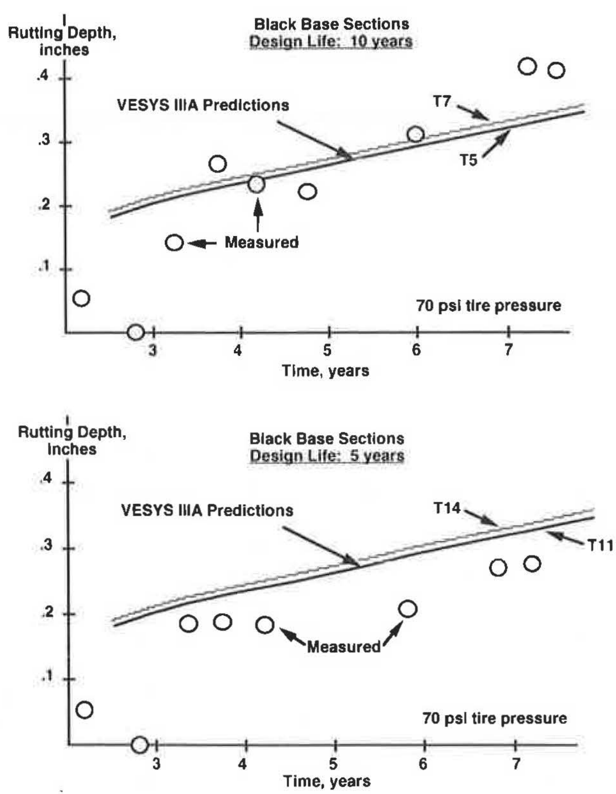


FIGURE 3 Predicted versus measured rutting depth: Test Sections 5, 7, 11, and 14.

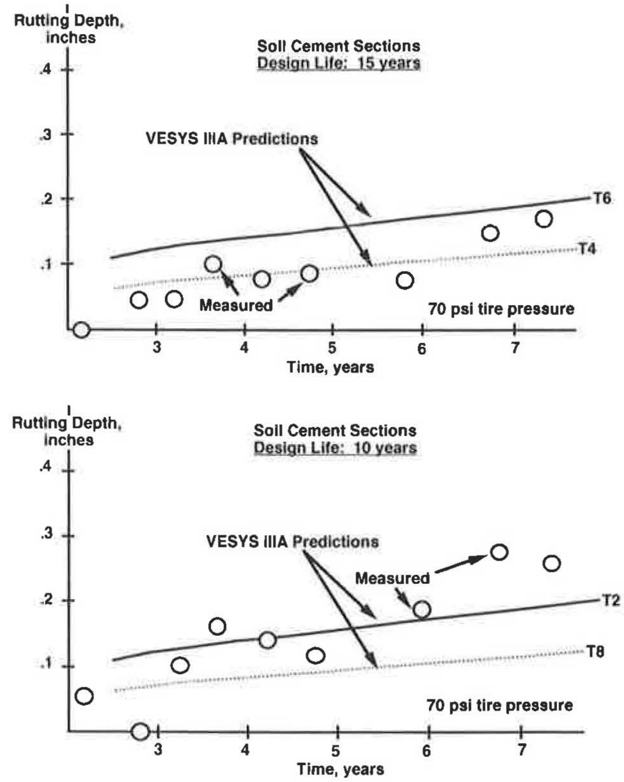


FIGURE 4 Predicted versus measured rutting depth: Test Sections 2, 4, 6, and 8.

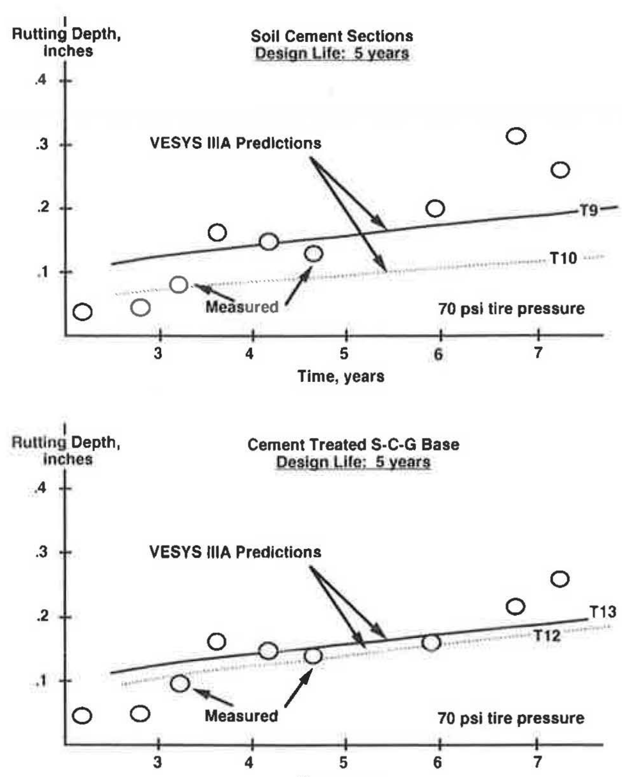


FIGURE 5 Predicted versus measured rutting depth: Test Sections 9, 10, 12, and 13.

the initial rate of predicted rutting was higher during the initial years of service and leveled off. It is expected that additional rut depth information will correspond reasonably well with predicted values. Because the correlation between measured and predicted rut depths is reasonable through 7 years, VESYS IIIA can be expected to effectively predict short-term rutting in flexible as well as composite pavement sections.

Cracking

Introduction

Pavement cracking can be separated into several categories. The category selected for this study was fatigue cracking. Fatigue cracking develops if excessive tensile strains (either in magnitude of load or number of applications) are produced in the bottom of a pavement layer. The rupture or cracking in the bottom of the layer eventually extends upward through the overlying layers to the pavement surface. Fatigue cracking is expected to occur both laterally and longitudinally along the inner edge of the individual tire of a dual set. The advanced stage of fatigue cracking is generally known as alligator cracking.

Measured and Projected Cracking

For the control and black-base sections (see Figure 6), fatigue cracking is projected to begin within the wearing course and binder layer in Year 9 and be 100 percent cracked by Year 19. On the other hand, VESYS IIIA analysis projected instantaneous fatigue cracking in the black-base layer for most of the black-base sections (see Figure 7). Because there is no evidence of this condition, the fatigue cracking models may be suspect. However, fatigue cracks may have developed in the black-base layer, but are not yet reflected through the wearing course and binder layer.

PSI

The PSI is a measure of the user's satisfaction with the level of service provided by the pavement system at a given time. The VESYS IIIA model predicts the PSI for each pavement section using the following relationship developed for the AASHTO road test (*11*):

$$PSI = PSI_i - 1.91 \log(1 + SV) - 0.01 (c + p) - 1.38R^2$$

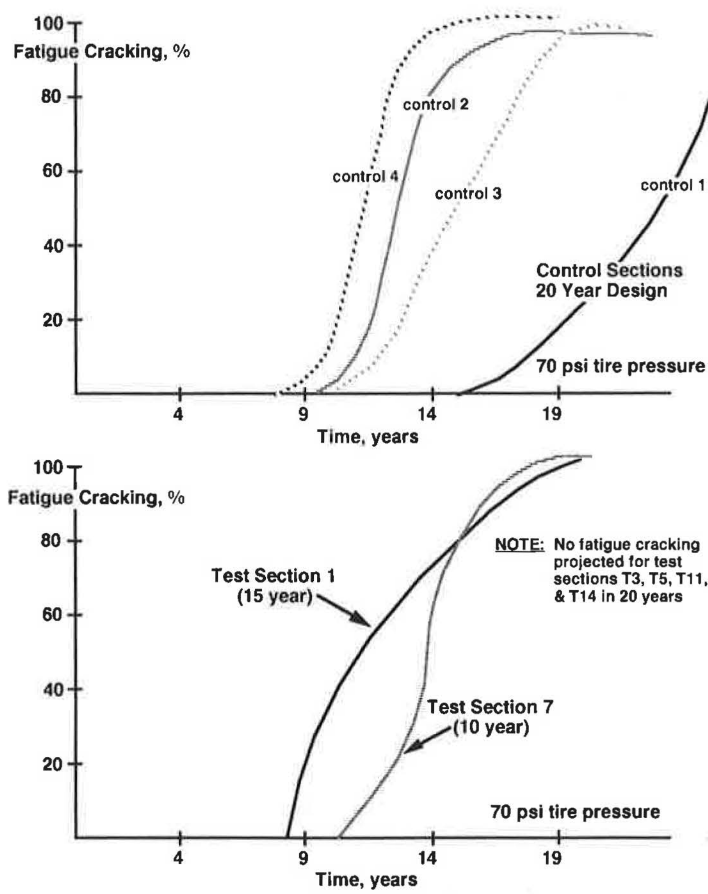


FIGURE 6 Projected fatigue cracking in wearing and binder layer with time: Control Sections 1–4 and Test Sections 1 and 7.

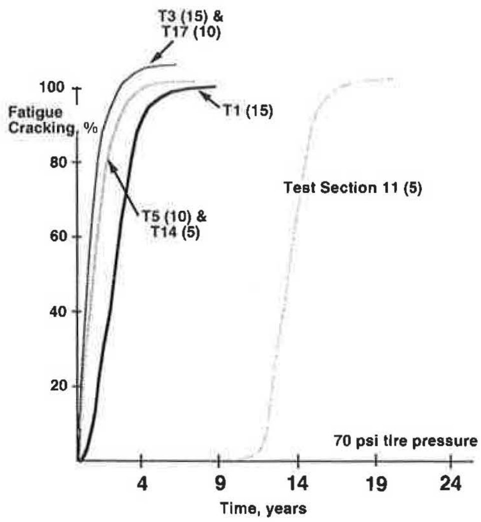


FIGURE 7 Projected fatigue cracking in black-base layer with time: black-base sections.

where

PSI_i = initial serviceability input,
SV = slope variance (roughness),
c = cracking ($yd^2/1,000\ yd^2$),
p = patching ($yd^2/1,000\ yd^2$), and
R = rut depth (in.).

LADOTD measured the initial PSIs in the field using the CHLOE Profilometer and the Mays Ride Meter (MRM). Subsequently, the MRM was used exclusively to measure the road roughness, or slope variance, of each of the 18 test sections.

The measured and predicted PSI values for the first 7 years are presented in Figures 8–12. From the results for the four control sections (see Figure 8), it is evident that there is good correlation between the measured and predicted PSI values. For these sections the VESYS IIIA program adequately predicted the PSI values. The initial PSI value can have a direct effect on the correlation between the measured and predicted

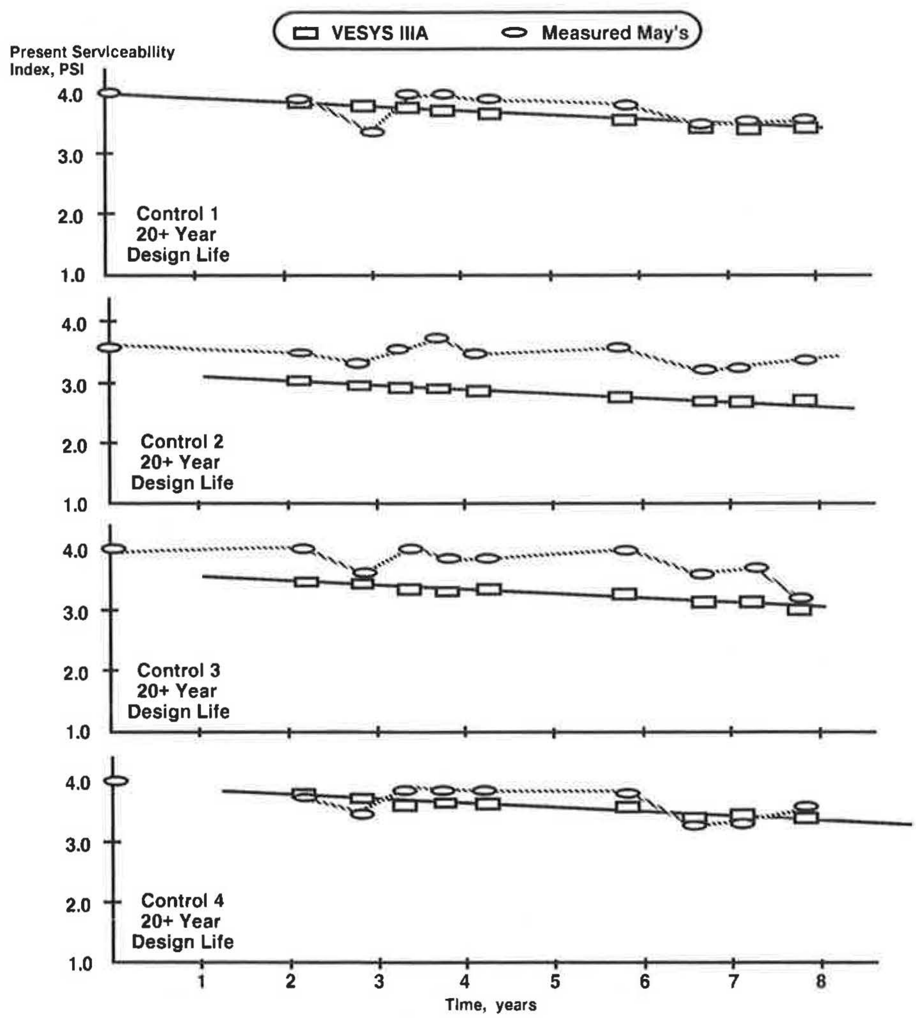


FIGURE 8 Comparisons of predicted (VESYS IIIA) and measured serviceability indexes: control sections.

values. For instance, PSI values in Year 3 for Control Sections 2 and 3 are greater than the initial PSI value. Obviously, a higher initial PSI value would have resulted in greater predicted values and an even better correlation between the measured and predicted ratings.

The PSI comparisons for the 15-year design section are presented in Figure 9. The plots show that there is better agreement between the measured and predicted PSI values for the soil-cement sections (i.e., T4 and T6) than for the black-base sections (i.e., T1 and T3). For these latter sections predicted (VESYS IIIA) values are quite a bit lower than the measured (MRM) values due primarily to the prediction of early fatigue cracking in the black-base layers (see Figure 7).

The PSI results for the 10-year design section are presented in Figure 10. In this case there is excellent agreement between the predicted (VESYS IIIA) and measured (MRM) values for Test Sections 2 and 5. For Test Sections 7 and 8, there was good agreement between predicted and measured values through Year 5. After that time the measured ratings were substantially decreased. These two test sections are, of course, adjacent to one another. It was expected that Test Section 8 would not perform as expected because of localized construction problems. The increase in measured rutting in Years 6 and 7 (see Figures 3 and 4) apparently contributed to the decrease in serviceability for Test Sections 7 and 8.

The serviceability results for the 5-year design sections are presented in Figures 11 and 12. There is good agreement between the measured and predicted PSI values for the two black-base sections (i.e., T11 and T14). In fact, in Year 7 both sections have very good serviceability ratings (3.0 or above) and exceeded their nominal design lives by 2 years (at least on the basis of a terminal PSI of 2.5).

For the soil-cement sections (i.e., T9 and T10) there was good agreement between the measured and predicted values for a period equal to their nominal design lives (i.e., 5-year design). After Year 6 there has been a noticeable drop in the measured PSI values below a terminal 2.5. However, it is believed that the measured PSI values have been biased by a disintegrating PMS, resulting in low slope variance values as measured by the MRM. On the basis of VESYS IIIA

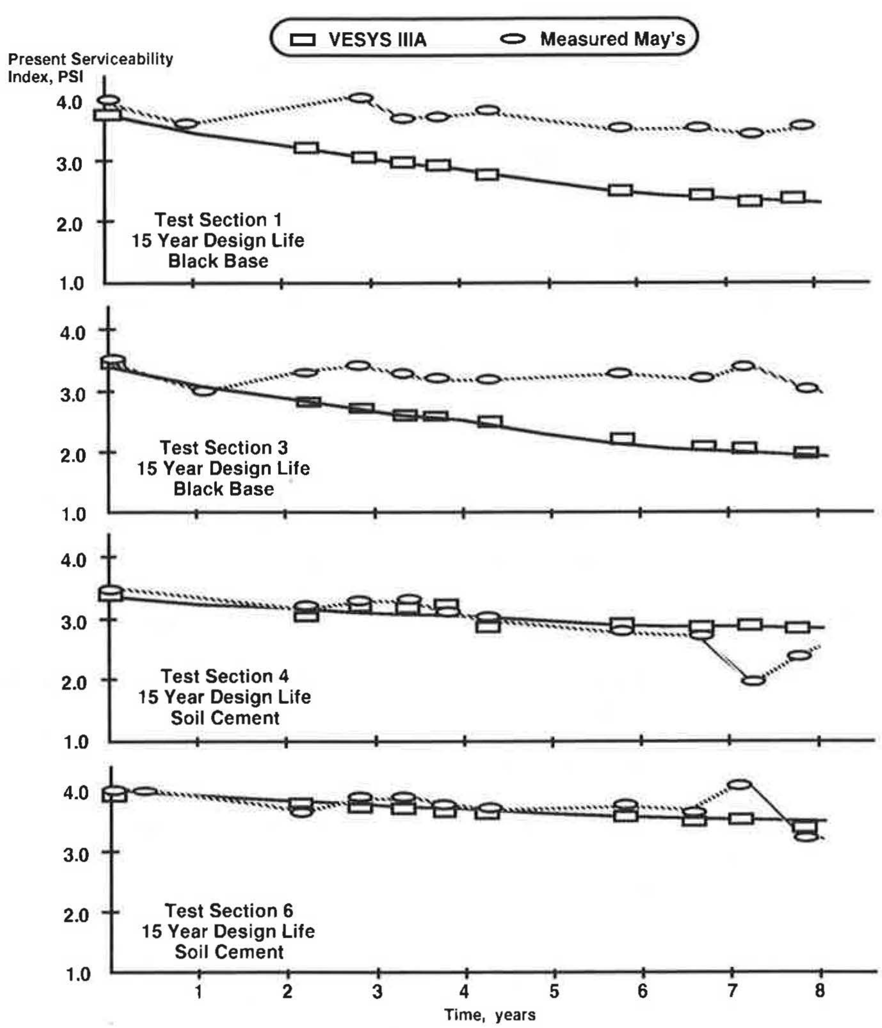


FIGURE 9 Comparisons of predicted (VESYS IIIA) and measured serviceability indexes: Test Sections 1, 3, 4, and 6.

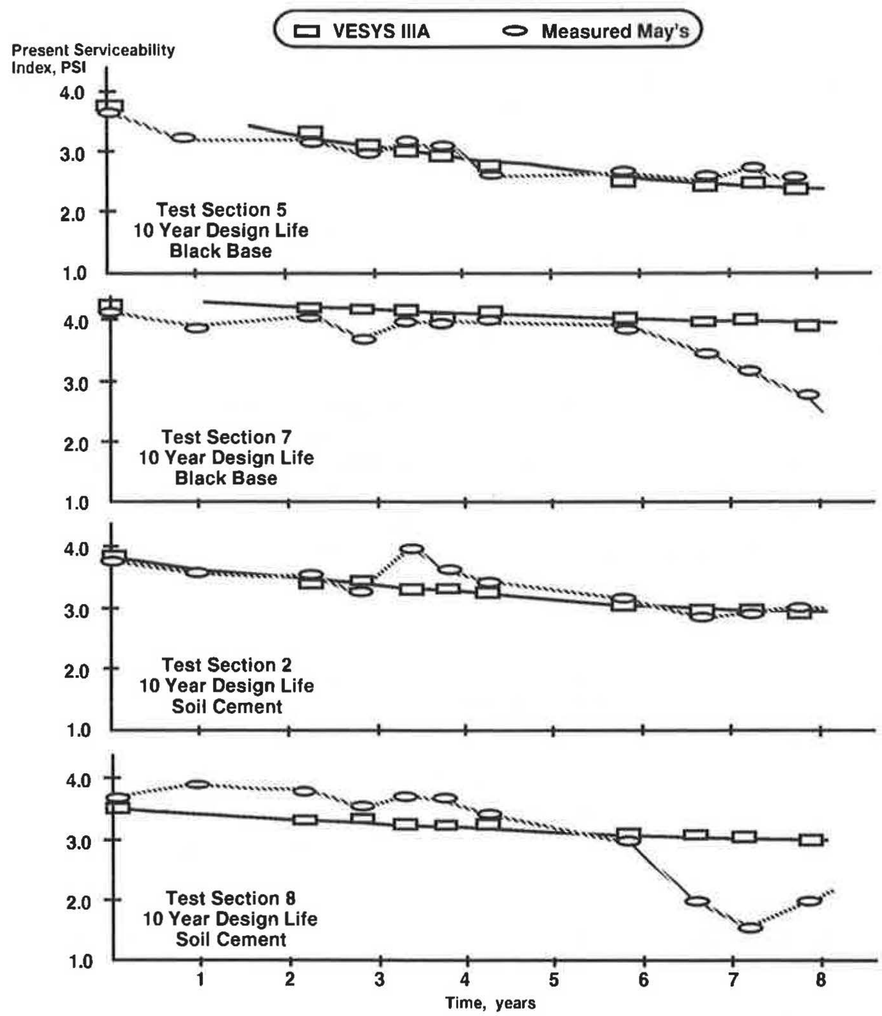


FIGURE 10 Comparisons of predicted (VESYS IIIA) and measured serviceability indexes: Test Sections 2, 5, 7, and 8.

predictions, these two sections should still be performing adequately.

Similar results are presented in Figure 12 for the cement-stabilized sand-clay-gravel sections (i.e., T12 and T13). There is excellent agreement between the predicted (VESYS IIIA) and measured (MRM) PSI values for a 6-year period. After the 6th year the measured PSI values dropped drastically, but they recovered slightly in Year 7. These two sections were also plagued by a disintegrating PMS, which could have resulted in lower MRM ratings as compared with VESYS IIIA predictions.

From the comparisons presented in Figures 8–12, it is apparent that VESYS IIIA can adequately predict pavement performance over a 5- to 7-year period of time.

CONCLUSIONS

The following conclusions were developed:

1. The VESYS IIIA mechanistic analysis package can adequately predict rut depths over a short period of time.

2. The indirect tensile test can produce material characterization information (both static and resilient models) that yields VESYS IIIA rutting predictions compatible with measured results.

3. VESYS IIIA cracking predictions using the indirect tensile characterization information predicted early fatigue cracking in most sections, but no actual significant amount of fatigue cracking developed. The combination of the VESYS fatigue algorithm and temperature-moduli-fatigue characterization information is suspect because reasonable predictions were not obtained. VESYS IIIA uses a single-wheel load of constant pressure rather than multiple-wheel loads, which probably produced a more critical condition in the upper layers of the pavement sections resulting in prediction of early and severe fatigue cracking.

4. Comparisons between measured and predicted PSI values showed the VESYS IIIA model to be adequate for short periods of evaluation even though the fatigue algorithm results are unrealistic. As a result the accuracy of the PSI predictions over long time periods may be questionable because the effects of other types of cracking (e.g., shrinkage and rut distortion cracking) are not considered.

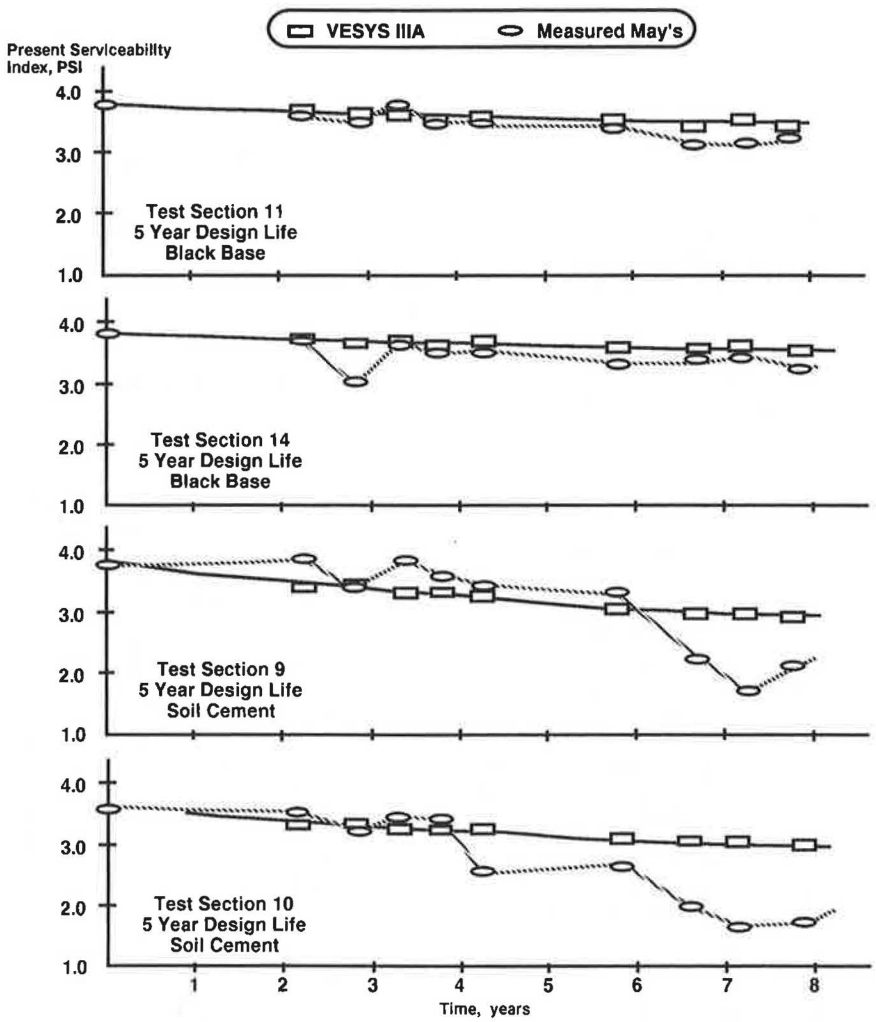


FIGURE 11 Comparisons of predicted (VESYS IIIA) and measured serviceability indexes: Test Sections 9, 10, 11, and 14.

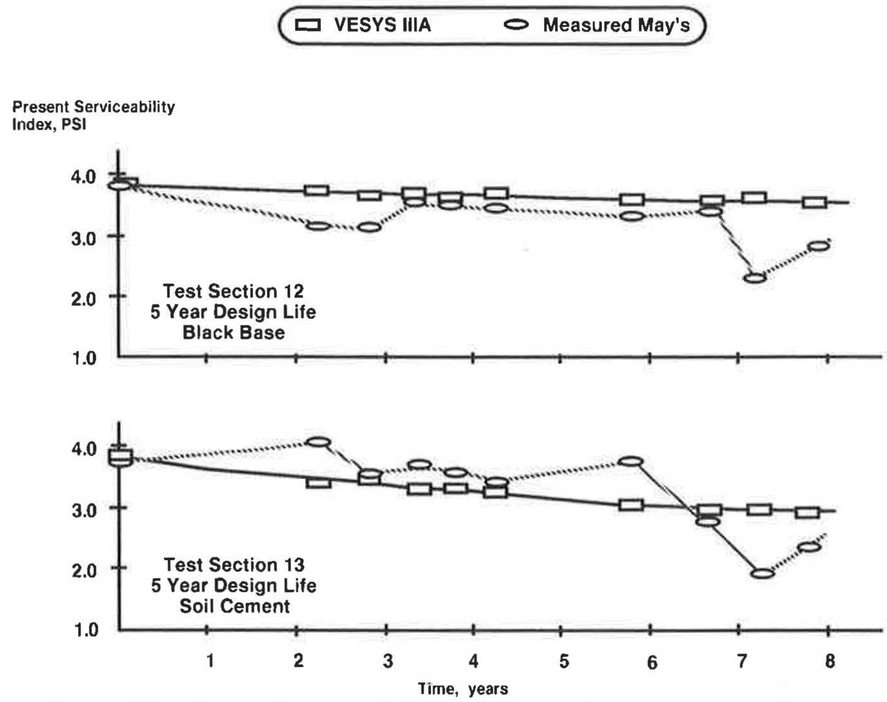


FIGURE 12 Comparisons of predicted (VESYS IIIA) and measured serviceability indexes: Test Sections 12 and 13.

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