EVALUATION OF FULL DEPTH ASPHALTIC CONCRETE PAVEMENTS

FINAL REPORT

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ABSTRACT

The aim of this study was to evaluate the full depth asphaltic concrete pavement design concept by observing the performance characteristics of two 13-inch pavements constructed in 1970. Pavement performance measurements, over an 11-year period, included Dynaflect deflections, Mays Ride Meter serviceability measurements, as well as documentation of rutting, cracking, and patching.

At five years of age one of the pavements (Interstate I - 20) had experienced surface raveling and intermittent wheelpath cracking. By 1977 the raveling and cracking had intensified to the extent that the pavement required resurfacing to restore surface continuity and to seal out surface water. During the same period the full depth pavement on Interstate 12 developed longitudinal and transverse cracking along with surface raveling, but has not required resurfacing. Both pavements are beginning to require spot patching in the wheelpaths and have carried approximately 35% of their designed traffic loads.

Roadway cores indicated a fatigue failure of the wearing and binder course layers. Rapid oxidation of the AC-40 wearing course and an unstable binder course layer are cited as contributing to the early failures. A change in asphalt type (AC-40 to AC-30) along with the addition of antistrip additives is expected to enhance performance of subsequent full depth pavements beyond the level observed in this study.

INTRODUCTION

The relatively new section design concept of full depth asphaltic concrete pavement was implemented in Louisiana on Interstate Highway 12 near Slidell (project control number 454-04-09) and on Interstate Highway 20 near Holly Ridge (project control number 451-07-08) in the early 1970's. At that time anticipated increased traffic necessitated thicker asphaltic concrete section design; however, it was thought desirable to periodically investigate these projects from a performance viewpoint since this design concept was new to Louisiana. The specific aim of this project was to evaluate the project was to evaluate the full depth asphaltic concrete pavement design concept by observing the performance and structural characteristics of such a section over an extended period of time. This report presents the results of 11 years of evaluation of the two full depth asphaltic pavement projects in Louisiana.

SCOPE

The evaluation and performance of the two full depth pavements as presented in this report are reflective of the materials used in 1970 in Louisiana. Paving materials have been modified since that time to include the substitution of softer asphalts (AC-30 for AC-40) as well as the addition of antistrip compounds. It is expected that full depth asphaltic concrete pavements built with the improved materials will out perform the pavements evaluated in this report.

METHODOLOGY

At the outset of this performance evaluation, two 1000-foot test sections were selected to represent each of the four-mile paving projects. As cracking and other signs of distress developed, it became apparent that the test sections did not adequately represent the overall performance of the pavements. As a result of this variation in performance, deflection tests, crack surveys, rutting measurements, and serviceability measurements were expanded to better reflect all areas of the projects.

Deflection measurements were obtained using the Dynaflect device by testing in alternate wheelpaths of the outside lanes. Use of the Dynaflect and interpretation of the deflection data is explained in the Appendix.

Pavement serviceability measurements were obtained by measuring the response of an automobile to road roughness. The instrumentation and roughness recording system used is the Mays Ride Meter, also described in the Appendix.

The typical pavement section consists of 13 inches of asphaltic concrete as follows: 3 inches of wearing course, 4 inches of binder course, and 6 inches of base course on a 9-inch sand-clay-gravel subbase. The asphalt used in the mix was an AC-40 grade.

INVESTIGATION OF PERFORMANCE

I-20 Holly Ridge-Dunn

Approximately four years after construction (in 1970) the asphaltic concrete wearing course on this project began to lose surface aggregate. This condition, also termed raveling, was found primarily in the wheelpaths of the outside lanes for a majority of the project length. Within a year longitudinal cracking began to develop, occurring primarily in the inside wheelpaths of the outside lanes.

The rate of aggregate loss accelerated during the next three years (1974 - 1977) and a series of cracks resembling wheelpath cracking began to surface in the outside lane as indicated in Figures 1 and 2. Roadway cores of the 13-inch pavement were taken to examine the asphalt in the laboratory. Tests indicated that the AC-40 asphaltic concrete wearing and binder course layers were heavily oxidized and brittle. Asphalt viscosity tests ranged from 40,000 to 85,000 poises for the wearing course and from 40,000 to 200,000 poises for the binder course. Laboratory tests run on the asphalt sampled prior to construction indicated viscosities in the range of 4000 - 5000 poises. In several instances the four-inch binder course crumbled upon coring, resembling a small pile of aggregate as depicted in Figure 3.

A decision was made in 1977 to resurface the pavement by adding a 3/4-inch asphaltic concrete friction course (A.C.F.C.). Since that time (1977 - 1982) the wheelpath cracking has reflected through the resurfacing as indicated in Figure 4 and 5. Spot patching has begun in the wheelpaths where small segments of the fatigued asphalt concrete have broken loose, Figures 6 and 7.

Field measurements of the AASHTO Structural number (SN) have been computed since construction using Dynaflect data. The SN value is an expression of the load carrying ability of the pavement layers (in this case, 13 inches of asphaltic concrete over nine inches of sand-clay-gravel subbase) irrespective of the subgrade strength.

Figure 8 depicts the SN measurements for a ten year period following construction (1972 - 1982). Pavement strength increased, initially, upon aging and densification of the asphalt mix in the wheelpaths. A gradual decrease in strength followed until 1976 when the raveling and cracking problem accelerated and the section began to lose strength rapidly.

Surface continuity was restored by the resurfacing in 1977 bringing the SN back near the 5.0 level. A restoration of load spreadability from 68% to 81% was the most influential factor in the SN increase. Load spreadability has decreased during the five years following resurfacing to the extent that the current SN is back to the pre-resurfacing level of 3.8 It is interesting to note that the pavement never reached its design SN of 5.8 even though the proper thickness of asphaltic concrete was provided. The rate of SN decrease measured is far greater than theoretically would have been expected considering the rate of load applications as depicted in Figure 8.

Rutting measurements have increased from an average of 0.10 inches in 1976 to 0.20 inches in 1982. Areas of the project with heavy wheelpath cracking contain rutting in the range of 0.30 to 0.50 inches. Pavement rideability remains very good with a serviceability index of 4.5. This pavement has never developed transverse cracks, waves, or corrugations which detract from a smooth ride.

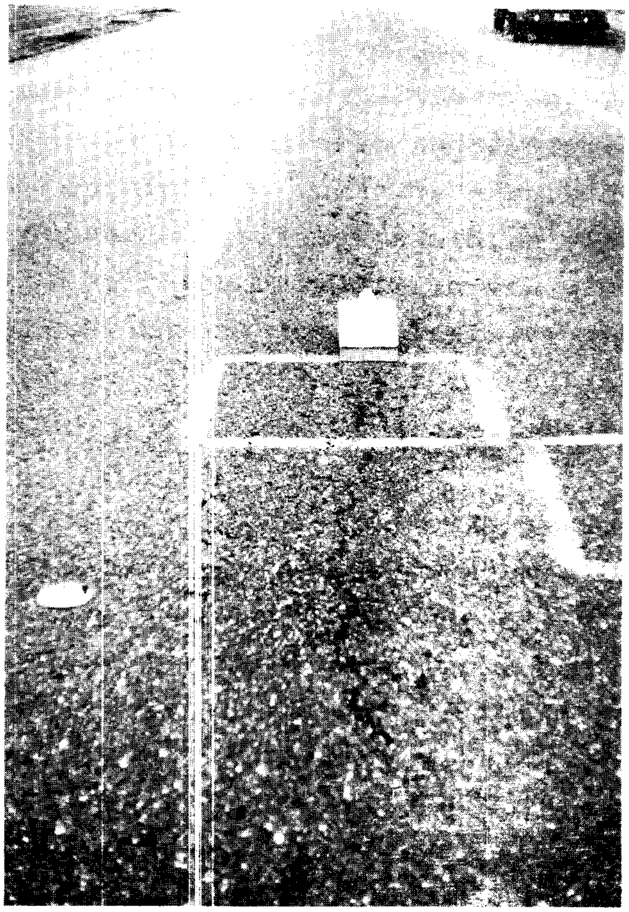
The data listed in Table 1 includes traffic volume, traffic load, deflection parameters, field measured SN and embankment strength (modulus of elasticity, E_s), as well as rutting and serviceability (roughness) measurements.

I - 12 Slidell

The performance of the full-depth asphalt concrete on I - 12 was very good for the first seven years of service (1971 - 1978), with the exception of minor raveling and the development of several longitudinal cracks. Traffic volume approximately doubled in 1977 due to completion of several Interstate projects west of the Slidell area. After the increase in traffic volume the raveling and cracking problem began to accelerate. Roadway cores were taken over several raveled areas containing the longitudinal wheelpath cracking as depicted in Figure 9. The cores contained heavily oxidized wearing and binder course material. The asphalt concrete was brittle and appeared to have aged prematurely. Longitudinal cracking did not extend through the asphaltic concrete base course on any of the cores, suggesting fatigue of the wearing and binder layers.

Since 1978 a series of transverse cracks have surfaced, primarily on the western portion of the project in both roadways as indicated in Figures 10 and 11. Small potholes are developing along these cracks, especially where transverse and longitudinal cracks intersect, Figures 12 and 13. Spot patching and 24-foot wide roadway patching have been required in some areas, as shown in Figures 14 and 15. The field measured strength of the 13-inch pavement section, as indicated in Figure 16, has diminished from an SN of around 6.0 to an SN level of 4.6 after 11 years of service. The as built pavement section achieved its design structural number of 5.8, unlike the full-depth section on I - 20. The strength of the I - 12 pavement has decreased at a premature rate, but less rapidly than the project on I - 20. Tests in areas of the project with the heaviest cracking have resulted in field measured SN values in the 3.5 to 4.0 range.

Rutting measurements average 0.10 inch in the better performing areas of the project and 0.20 - 0.30 inches in areas with the heaviest cracking. Pavement rideability has decreased from 4.50 to a current serviceability level of 3.70. The influence of patching and the transverse cracking has contributed to the increase in roughness. The variation in performance in the eastern and western sections of the project is again indicated by averaging PSI values in the four successive miles from east to west as follows: 4.1, 4.2, 3.4, 2.9. Table 2 contains a listing of the field performance and traffic data.

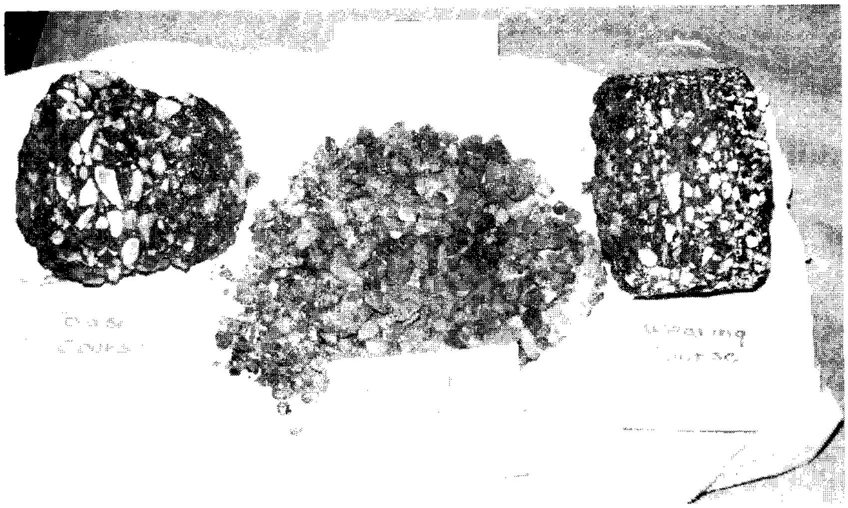


Wheelpath Cracking

Figure 1

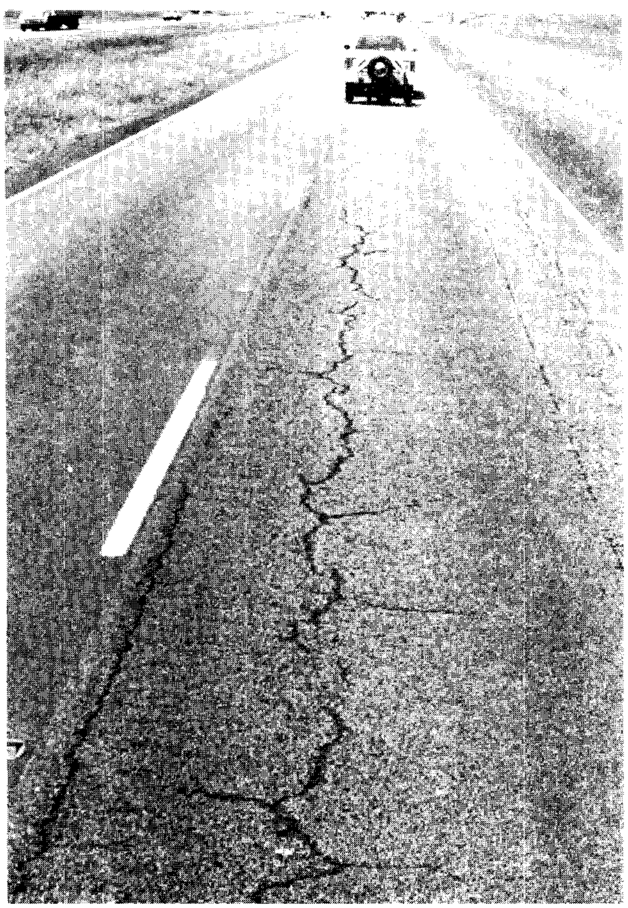
Loss of Surface A[illegible]

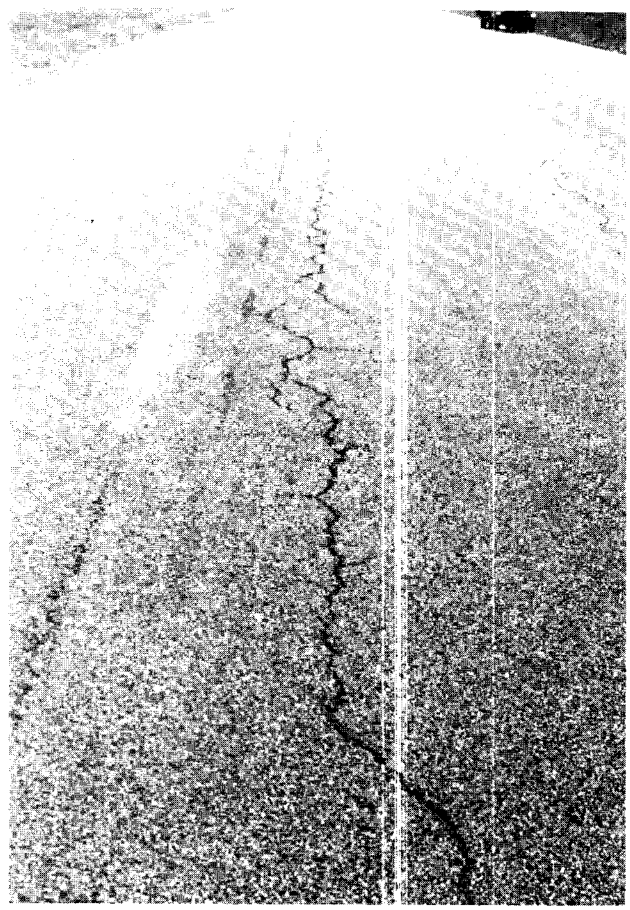
Figure 2



Roadway Core With Crumbled Binder Course Layer

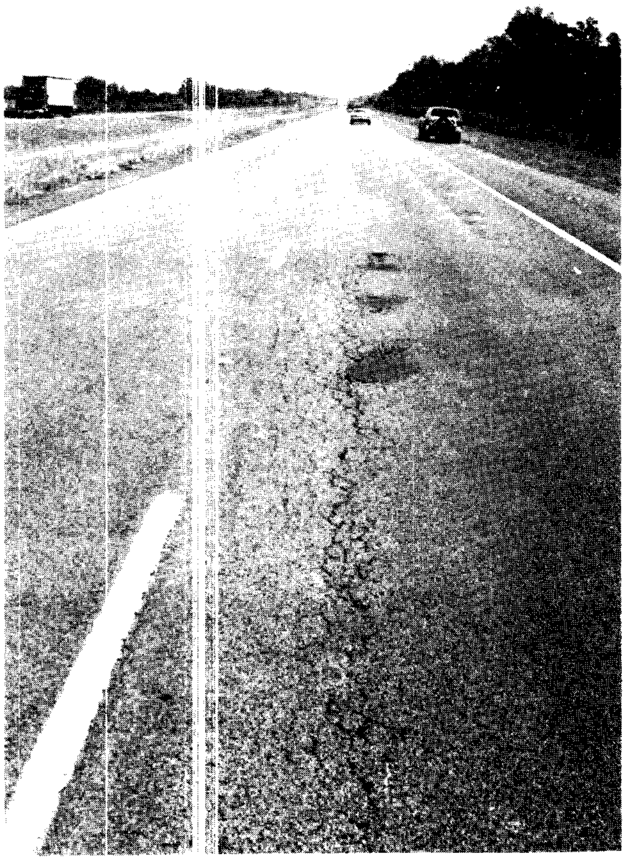
Figure 3





Wheelpath Cracking Reflecting Through Friction Course

Figure 4 *Figure 5*



Wheelpath Cracking and Patching
Figure 6

Patching in Wheelpath
Figure 7

HOLLY RIDGE - DUNN I - 20

ST. PROJECT No. 451-07-08

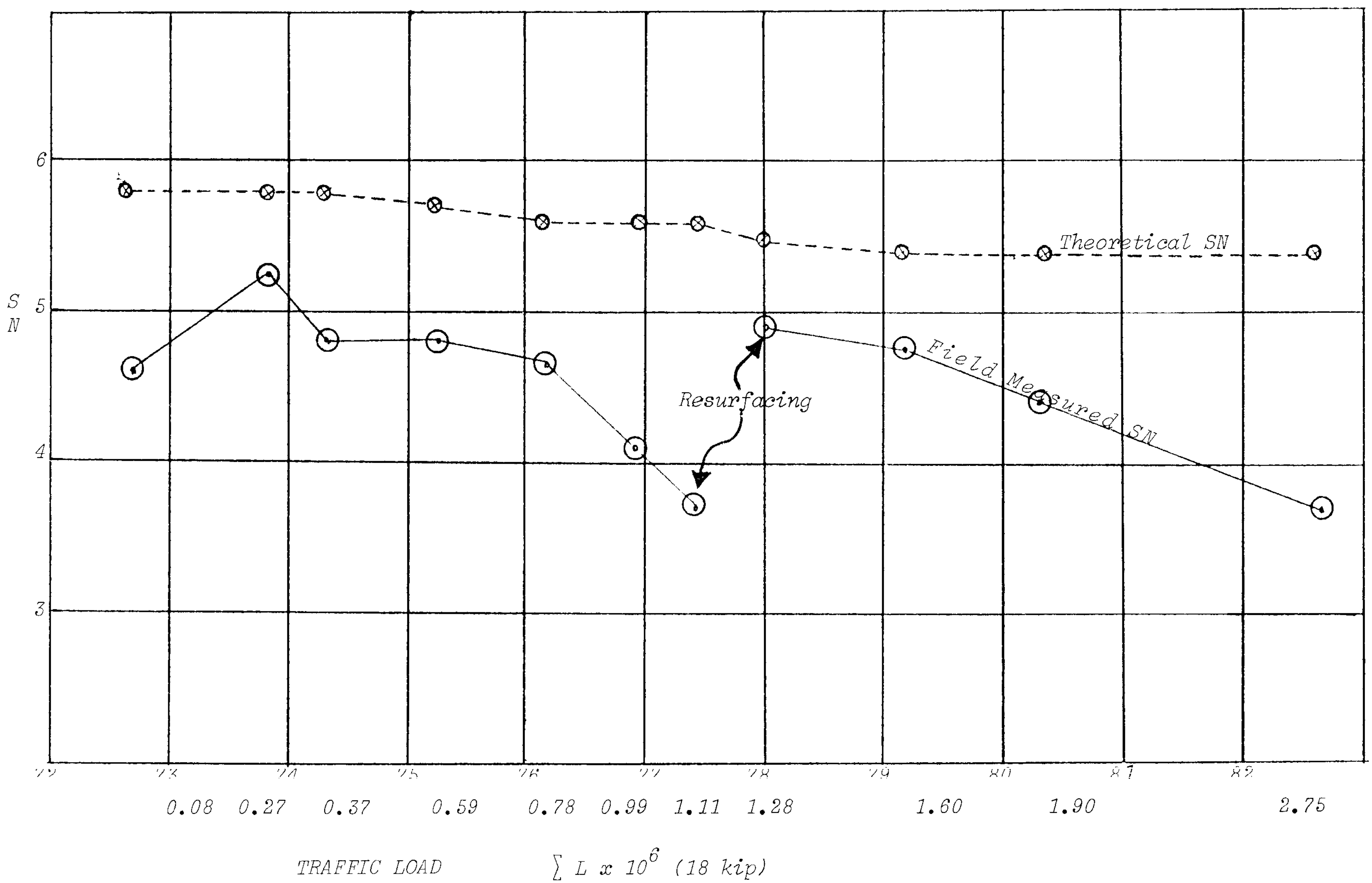
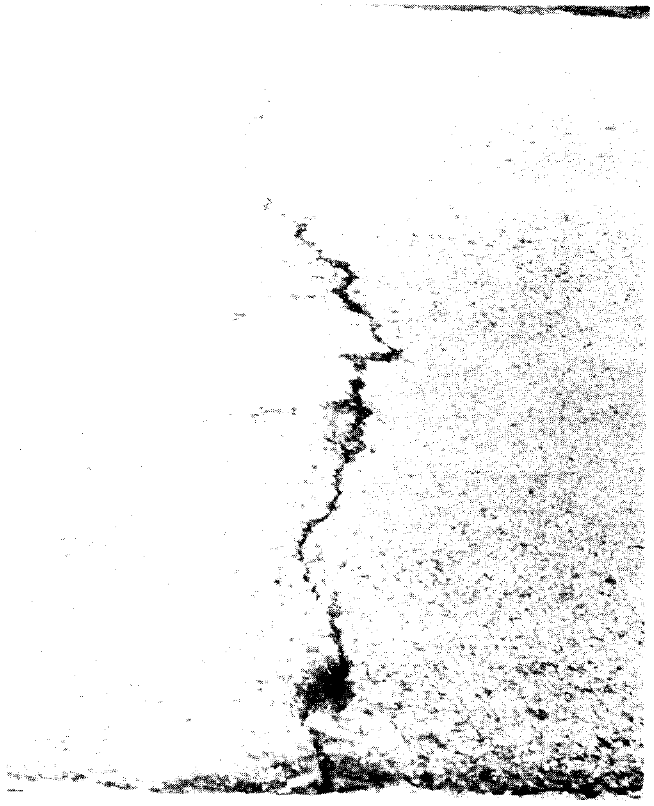
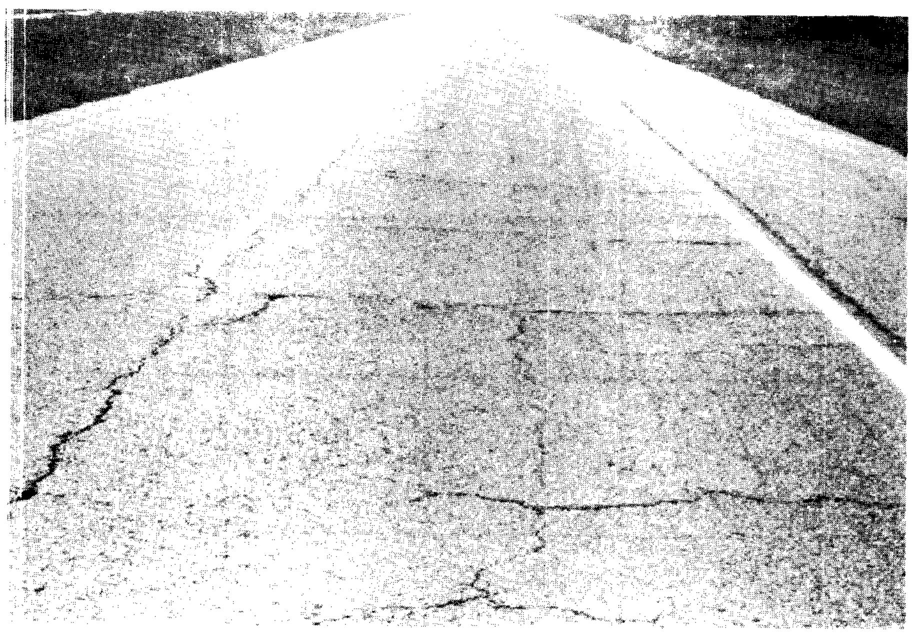


Figure 8

Longitudinal Crack With Raveling
Figure 9



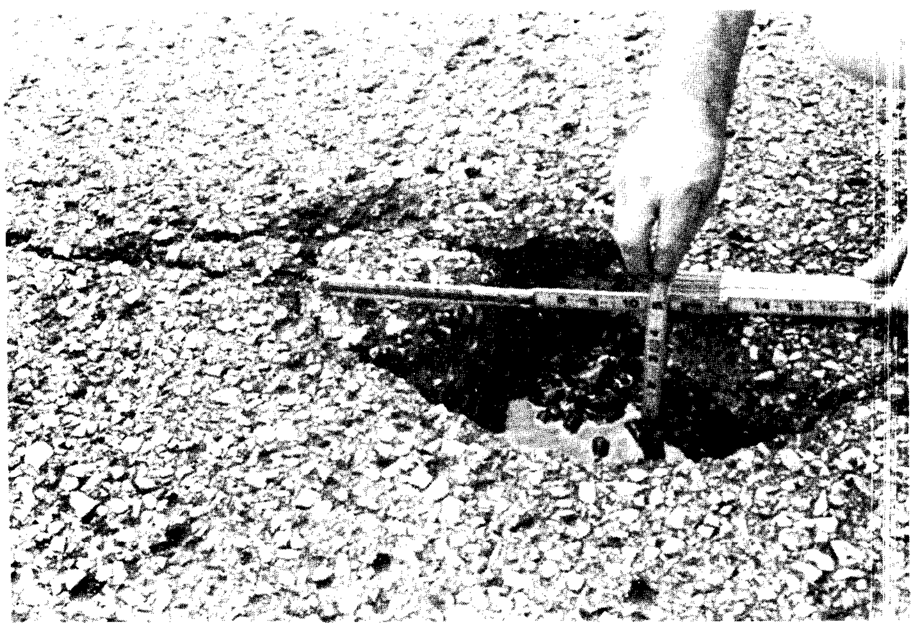
Transverse Cracking
Figure 10



Series of Transverse Cracks
Figure 11

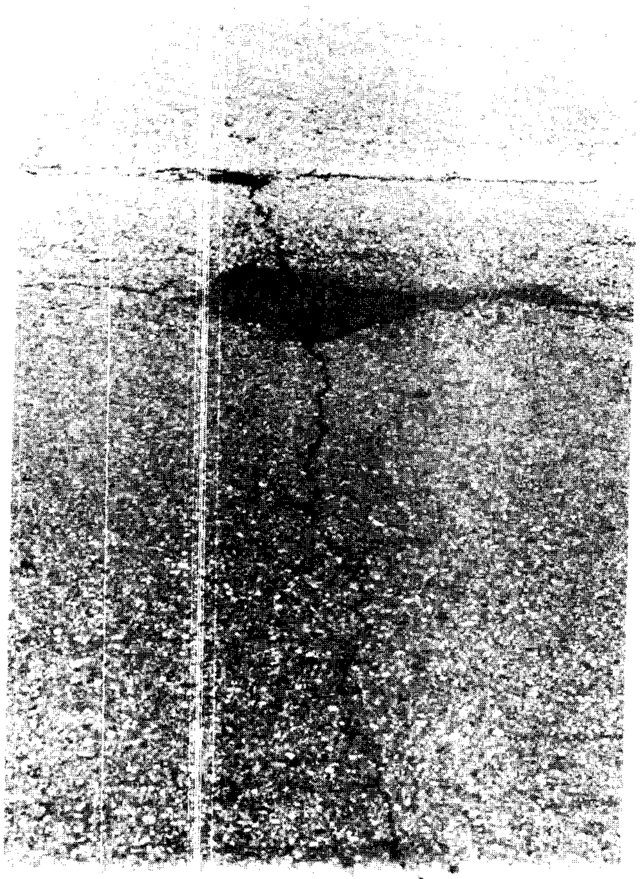
Potholes Develop Where Cracks Intersect

Figure 12



Pothole Where Wearing and Binder Course Have Broken Out

Figure 13

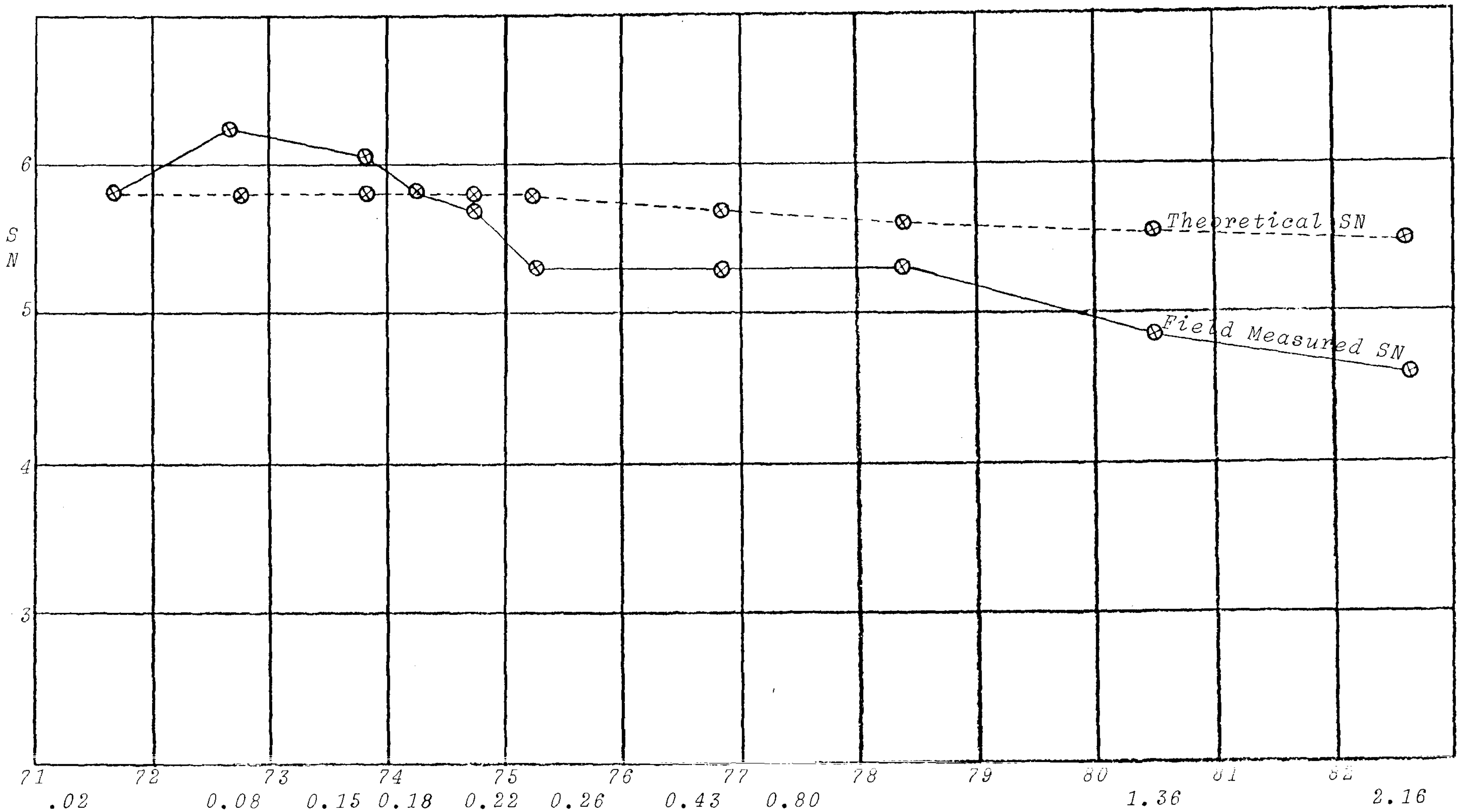


Spot Patching of Potholes
Figure 14

Full Width Patching
Figure 15

SLIDELL - I - 12

ST. PROJECT 454-04-09



TRAFFIC LOAD $\sum L \times 10^6$ (18 kip)

Figure 16

TABLE 1

I - 20 HOLLY RIDGE - DUNN

STATE PROJECT 451-07-08

TEST DATE	ADT	ADL (18 kip)	$\sum$ LOAD (18 kip) (x 10^6)	SERVICEABILITY INDEX	W_1 (in. x 10^{-3})	W_1 (in. x 10^{-3}) (Corrected Temperature)	PERCENT SPREAD	SURFACE CURVATURE INDEX	PAVEMENT STRENGTH SN	SUBGRADE STRENGTH E_s (x 10^3)	RUTTING (inches)
08/24/72	6400	628	0.08	4.50	0.70	0.37	70	0.08	4.6	20	0.00
10/18/73	6656	653	0.27	----	0.49	0.35	75	0.04	5.2	17	0.00
04/02/74	6291	617	0.37	----	0.65	0.38	72	0.08	4.8	17	0.00
03/24/75	5922	581	0.59	4.40	0.59	0.44	75	0.05	4.8	12	0.00
02/11/76	7703	756	0.78	4.20	0.50	0.53	78	0.05	4.6	8	0.10
11/17/76	7703	756	0.99	4.30	0.61	0.67	76	0.04	4.1	8	0.14
05/05/77	7810	766	1.11	----	0.78	0.56	68	0.13	3.7	11	0.15
06/22/77	PAVEMENT RESURFACED, Asphaltic Concrete Friction Course										
12/07/77	7810	766	1.28	4.60	1.18	0.55	81	0.05	4.8	7	0.10
02/13/79	7792	764	1.60	4.50	0.48	0.70	83	0.02	4.7	6	0.10
04/01/80	6360	624	1.90	4.40	0.62	0.53	77	0.06	4.4	9	0.10
08/24/82	11827	1161	2.75	4.50	0.70	0.52	67	0.11	3.7	14	0.20

TABLE 2

I - 12 SLIDELL

STATE PROJECT 454-04-09

TEST DATE	ADT	ADL (18 kip)	$\sum$ LOAD (18 kip) (x 10^6)	SERVICEABILITY INDEX	W_1 (in. x 10^{-3})	W_1 (in. x 10^{-3}) (Corrected Temperature)	PERCENT SPREAD	SURFACE CURVATURE INDEX	PAVEMENT STRENGTH SN	SUBGRADE STRENGTH E_s (x 10^3)	RUTTING (inches)
08/24/71	2070	146	0.02	4.40	0.41	0.23	73	0.06	5.8	26	0.00
08/21/72	2270	160	0.08	----	0.43	0.22	79	0.04	6.2	24	0.00
10/09/73	2470	175	0.15	4.20	0.45	0.26	78	0.04	6.1	21	0.00
03/29/74	3185	225	0.18	----	0.48	0.37	81	0.04	5.8	13	0.00
09/23/74	3185	225	0.22	4.10	0.56	0.34	79	0.06	5.7	16	0.00
03/31/75	2815	199	0.26	4.20	0.48	0.42	78	0.05	5.3	11	0.00
10/18/76	5590	395	0.43	----	0.57	0.41	79	0.05	5.3	12	0.05
05/02/78	10870	769	0.80	4.20	0.51	0.44	81	0.03	5.3	9	0.05
06/11/80	11700	827	1.36	4.40	0.68	0.38	73	0.07	4.9	14	0.10
08/09/82	15400	1088	2.16	3.70	0.79	0.45	74	0.07	4.6	13	0.10

SUMMARY OF RESULTS

The findings of this report indicate the following:

1. The two full-depth asphaltic concrete pavements evaluated in this study have experienced surface raveling and have developed intermittent wheelpath cracking. The distress was first observed after the 11-year old pavements had been under traffic for approximately five years.

2. Roadway cores from both projects contained AC-40 type wearing and binder course material which was oxidized and brittle. Cracking appeared to have begun in the binder course layer and progressed up through the wearing course. Subgrade support and subbase support remain very good.

3. Asphalt viscosity measurements at five years of age were typically in the range of 40,000 to 80,000 poises. One viscosity test on the binder course material was in excess of 200,000 poises. Viscosity values of this magnitude suggest that some of the asphalt concrete may have been overheated prior to paving.

4. Wheelpath rutting was less than 0.1 inch for approximately 10 years on the two projects. Recently, however, the average rutting has increased to 0.2 inches as the wheelpath cracking accelerates, with isolated measurements in the 0.3 to 0.5-inch range.

5. Serviceability (ride) measurements on the Interstate 20 project remain very good with a P.S.I. of 4.5. This pavement was resurfaced in 1977 to restore surface continuity and to seal out surface water. The ride of the Interstate 12 project, which was not resurfaced has decreased from 4.5 to 3.7 P.S.I. on the average. The roughest one mile section on this project contains an average P.S.I. of 2.9.

6. Deflection measurements indicate that both projects are decreasing in strength at a fairly rapid rate. The pavements are losing their ability to transfer load as cracking in the wheelpaths accelerates.

SUMMARY OF RESULTS (CONTINUED)

7. Traffic load was slow to accumulate on the full depth pavements but has recently increased to a more normal load level for rural interstate. The pavements have carried approximately 35% of their designed load after 11 years of service.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this study it is concluded that:

1. The early strength loss of the two full depth asphaltic concrete pavements is related to a materials problem which resulted in rapid aging and early fatigue of the wearing and binder course layers. The pavements have carried approximately 35% of their designed load after 11 years of service.

2. An increase in traffic volume along with an increase in the rate of strength loss indicates a need for some type of structural rehabilitation within the next five years on these projects. Due to the existing thickness of asphaltic concrete it is recommended that the pavements be reconstructed by recycling the seven inches of wearing and binder course material.

CITED BIBLIOGRAPHY

1. Southgate, H. F. An Evaluation of Temperature Distribution Within Asphalt Pavements and Its Relationship to Pavement Deflections. Commonwealth of Kentucky, Department of Transportation, Bureau of Highways, Division of Research, April, 1968.

2. Kinchen, R. W. and W. H. Temple, Asphaltic Concrete Overlays of Rigid and Flexible Pavement. Research Report No. 109, Louisiana Department of Transportation and Development, 1977, 73 pp.

APPENDIX

PAVEMENT PERFORMANCE MEASUREMENTS

PAVEMENT PERFORMANCE MEASUREMENTS

Structural Evaluation by Means of Dynamic Deflection Determination System (Dynaflect)

The Dynaflect is a trailer-mounted device which induces a 1000-pound dynamic load on the pavement. It then measures the resulting slab deflections by use of five geophones spaced under the trailer at approximately one-foot intervals from the application of the load. The 1000-pound dynamic load is generated at a frequency of eight cycles per second by the counter-rotation of two unbalanced fly-wheels. This cyclic force is transmitted vertically to the pavement through two steel wheels spaced 20 inches center to center. The horizontal reaction forces cancel themselves due to the opposing rotations. The dynamic force varies in sine wave fashion from 500 pounds upward to 500 pounds downward during each rotation. The entire force transmitted to the pavement, however, consists of the weight of the trailer (approximately 1600 pounds) and the dynamic force which alternately adds to and subtracts from the static weight. Thus, the vertical force during each rotation of the flywheels at the proper speed varies from 1100 to 2100 pounds. The deflections induced by this system are expressed in terms of milli-inches (thousandths of an inch). The Dynaflect actually measures the extent of only one-half of a deflection basin, with the other half assumed to be a mirror image of the measured portion. The measurement W_1 is the maximum depth of the deflection bowl and occurs near the force wheels. The terms W_2, W_3, W_4, and W_5 are the deflections related by geophones 2 through 5, respectively.

The maximum (first sensor) deflection W_1 provides an indication of the relative strength of the total road section. The Surface Curvature Index, S.C.I. (W_1-W_2), provides an indication of the relative strength of the upper (pavement) layers of the road section. A parameter termed spreadability or percent spread, $\% \ SP = (W_1 + W_3 + W_4 + W_5 \ / \ 5W_1)100$, relates the response of the pavement distributing load applied thereon. The Base Curvature

Index, B.C.I. (W_4-W_5), and the fifth sensor value W_5 provide a measure of the relative strength of the foundation. For the four parameters W_1, S.C.I., B.C.I., and W_5, smaller deflections values indicate greater strength. Percent spread increases as pavement strength increases.

Analysis of Dynaflect deflections on flexible pavements must consider pavement temperature. A procedure for determining temperature-deflection correction factors, developed by H. F. Southgate (1)* has produced excellent results in Louisiana. The applicability of this procedure to the conditions and construction materials used in the state has been verified by using a digital probe thermometer. All Dynaflect deflections reported have been adjusted to a standard temperature of 60° F. A comparison of as-built strengths and design strengths can be accomplished by translating measured Dynaflect deflections into structural numbers, SN, a strength parameter used in the AASHO Flexible Pavement Design system.

This method of deflection analysis was developed through a combination of two-layer linear elastic theory and AASHO-Louisiana flexible pavement design theory. Layered theory provided the ability to individually characterize the strengths of the embankment layer (E_s) and the pavement layer (E_1). A recent Louisiana Department of Transportation and Development research study provided an E_s-SN relationship in a pavement evaluation chart which was used to evaluate the strength contribution of each layer upon construction. An example of the pavement evaluation chart used to calculate the strength contributions of individual pavement layers is presented in Figure (16).

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*Underlined numbers in parentheses refer to Bibliography.

Functional Evaluation by Means of the Mays Ride Meter (M.R.M.)

The M.R.M. operates from within a standard size car and records road roughness as reflected by movement of the vehicle's axle with respect to its chassis. A transmitter attached to the differential collects this movement information and feeds it forward to a portable recorder located on the front seat. Quantitative and qualitative roughness measurements are presented on a strip chart produced by the recorder. The base speed for the M.R.M. is 50 miles per hour, and correlation curves for each M.R.M. convert test data obtained at other speeds to that at the base speed.

M.R.M. measurements are reported in terms of Present Serviceability Index (P.S.I.) P.S.I. has been defined as a "numerical index (ranging from 0.0 to 5.0) of the ability of a pavement in its present condition to serve traffic." Perfectly smooth pavement would have a P.S.I. of 5.0. Pavement so rough as to be impassable would have a P.S.I. of 0.0.

More specifically, a numerical-adjective description of P.S.I. is as follows:

4.1 - 5.0	Very Good
3.1 - 4.0	Good
2.1 - 3.0	Fair
1.1 - 2.0	Poor
0.0 - 1.0	Very Poor

Mays Ride Meter P.S.I. reported herein is based on a correlation with the University of Texas (General Motors) Surface Dynamics Profilometer, which, in turn, relates to actual panel ratings.

Figure 17

DATE ______________

RESEARCH PROJECT NO. ______________
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