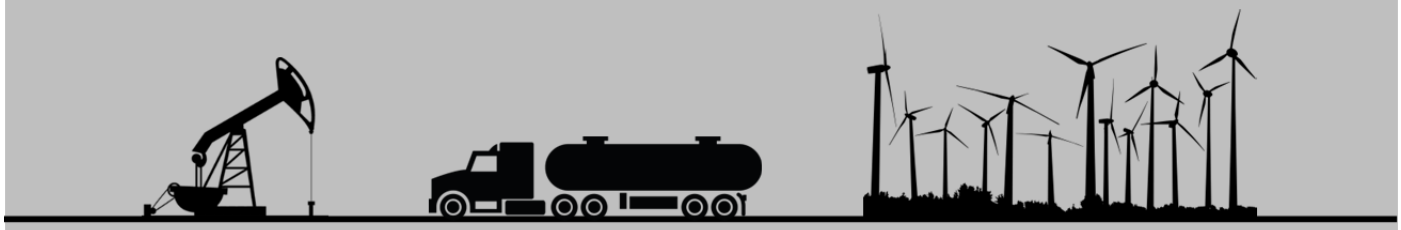
Evaluation of the Structural Strength of Pavements Repaired in the West Texas Energy Sector SH 349 in Martin County

Technical Memorandum TM-14-05



Prepared for Texas Department of Transportation
Maintenance Division

Prepared by
Texas A&M Transportation Institute

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TxDOT Contract No. 47-4PV1A007

TTI Contract No. 409186

Texas A&M Transportation Institute

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INTRODUCTION

The Odessa District uses a repair strategy for its roadways damaged by energy development traffic, which includes the following construction steps:

- Pulverization of existing flexible base and asphalt bound surfacing materials.
- Spreading the pulverized materials (without stabilization) over a widened subgrade.
- Placement of new flexible base material.
- Application of a three-course surface treatment or chip seal.

This type of technique is widely used in the energy sector for roadway repair. Many districts pulverize the existing pavement and add a stabilizer.

The District requested that the Texas A&M Transportation Institute perform field investigations and analyses to determine the structural load carrying ability of pavements repaired using this design and construction methodology. The District is considering using this cost effective repair approach to convert rural two-lane highways to a widened Super 2 highway (alternating sections of a highway with two lanes in one direction and one lane in the other direction, after approximately 2 miles the directional lanes are reversed and the two-lane direction becomes a one-lane direction and the one-lane direction becomes a two-lane direction). The load carrying ability of the base course materials was of interest.

State Highway (SH) 349 in Martin County was selected for study. Falling weight deflectometer (FWD) measurements were made in the study area between Reference Marker (RM) 298 to 300. Figure 1 shows the area selected for study.

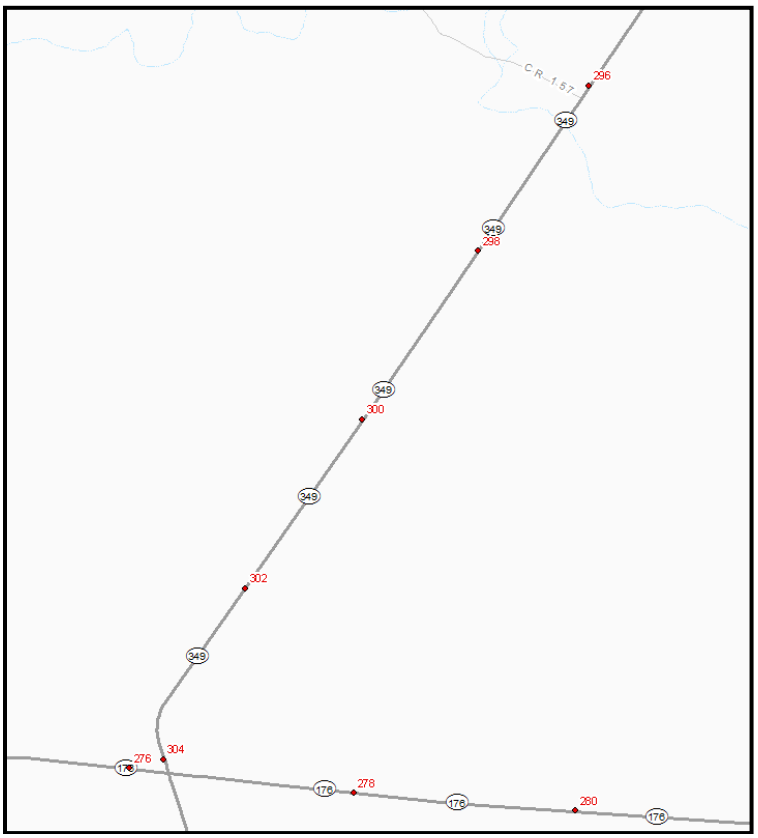

Figure 1. SH 349 Investigation Limits from RM 298 to 300.

This technical memorandum summarizes the analysis performed.

INFORMATION COLLECTED

The following information was collected and testing performed:

- Pavement layer thicknesses.
- Structural strength assumptions of pavement layers.
- Flexible pavement system (FPS) analysis.
- Ground penetrating radar (GPR).
- FWD.

Project Background and Pavement Design

The section evaluated on SH 349 was part of CSJ 0380-07-021. District-provided core log and FWD data showed the existing section (prior to repair) consisted of:

- 5 in. hot mix asphalt with a modulus of 231 ksi.
- 6.75 in. of flexible base with a modulus of 107 ksi.
- Subgrade modulus of 10 ksi.

Based on the existing pavement and the planned FDR strategy, Table 1 summarizes the input parameters used in the FPS design of the new pavement section. Note the relatively low value for

the ACP or asphalt concrete pavement modulus.

Table 1. Key FPS Inputs Used for SH 349 Pavement Design.

Basic Design Criteria	Length of analysis period (yr.)	20.0
	Minimum time to first overlay (yr.)	8.0
	Minimum time between overlays (yr.)	8.0
	Minimum Serviceability Index	3.0
	Design confidence level	C
Traffic Data	Beginning ADT (vehicles/day)	2600
	Ending ADT (vehicles/day at end of 20 yr.)	3600
	One-direction 20-yr ESALs (millions)	1.775
	Percent trucks in ADT	19.3
	Average Heaviest Wheel Loads Daily (ATHWLD, lb)	10,500
	Percentage of tandem axles	70.0
Materials Properties	ACP modulus (ksi)	70.0
	Flexible base modulus (ksi)	70.0
	Subgrade modulus (ksi)	10.0
	Subgrade triaxial class	3.0

Figure 2 and Figure 3 show the pavement design summary and the typical existing and proposed sections developed by the District. The contractor completed full depth recycling (FDR) on this project in June 2013.

PAVEMENT DESIGN INFORMATION

PROJECT INFORMATION

HIGHWAY: SH 349 CSJ: 0380-07-021 COUNTY: Martin
LIMITS: From: SH 176
To: Dawson County Line
LENGTH OF PROJECT: 16.309 MILES
FROM REFERENCE MARKER: 288 DISPLACEMENT: 0.000 MILES
TO REFERENCE MARKER: 304 DISPLACEMENT: 0.145 MILES

TRAFFIC DATA

ADT, BEGINNING (VEH/DAY): 2600 ATHWLD = 10500
ADT, END 20 YEAR (VEH/DAY): 3600 PERCENT TRUCKS IN ADT: 19.3
18 KSA, 20 YEAR (ONE DIRECTION): 1.775 % TANDEMS IN ATHWLD = 70.0

PAVEMENT DESIGN RESULTS

LAYER	MATERIAL	THICKNESS (IN.)	MODULUS (KSI)
SURFACE	ASPH CONC PAV	0.5	~~500~~ 70
BASE	FLEX BASE	~~14.0~~ 15	70
SUB-BASE	____	____	____
SUB-GRADE	SUBGRADE(200)	200	~~15~~ 10

INPUTS
DESIGN CONFIDENCE LEVEL: C
SUB-GRADE TRIAXIAL CLASS = 3.8

Please refer to the attached design report for more detailed information.

LIFE OF PAVEMENT STRUCTURE

TIME TO FIRST OVERLAY: 9 YEARS TOTAL LIFE: 21 YEARS

PAVEMENT DESIGN ENGINEERING REPORT DATE AND SIGNATURE

NOT INTENDED FOR CONSTRUCTION, BIDDING, OR PERMIT PURPOSES

Name: HEATHER C. SINCLAIR, P.E. Release Date: July 9, 2007
Professional Engineering License Serial Number: 90297

Signature: Heather C. Sinclair PE 8/3/07

Approved by Committee
Mike McAnulty, Lauren Garduño
Stephen Smith & Matt Carr

Figure 2. Summary of SH 349 Pavement Design.

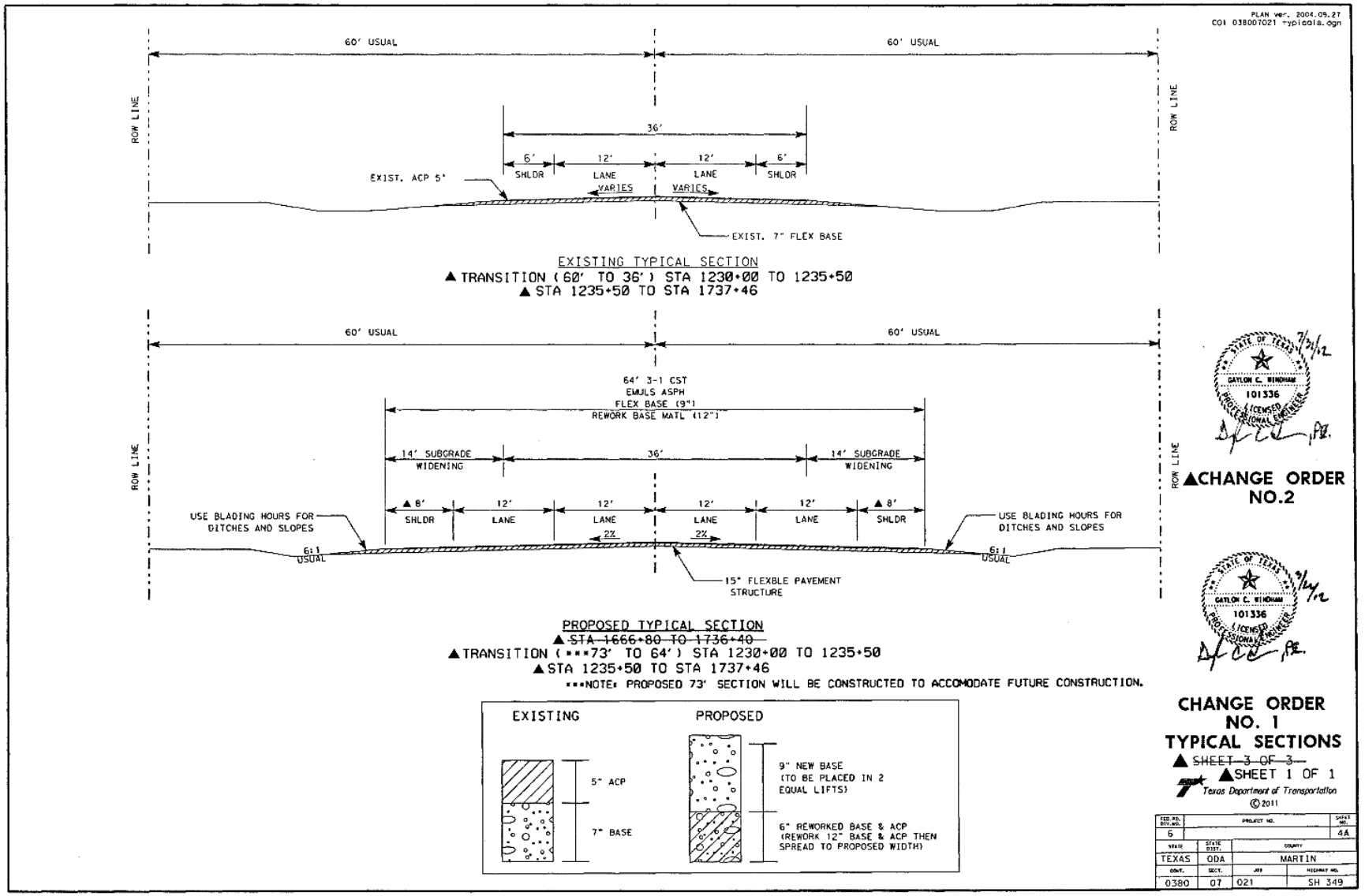

Figure 3. Typical Existing and Proposed Sections on SH 349.

Ground Penetrating Radar Results

GPR was conducted on the north and southbound outside lanes over the entire ~ 9.6 mi. project in 2014 when the project was approximately one year old. The only interface detected with confidence by the GPR was between the surface treatment and the base. Figure 4 illustrates representative GPR data.

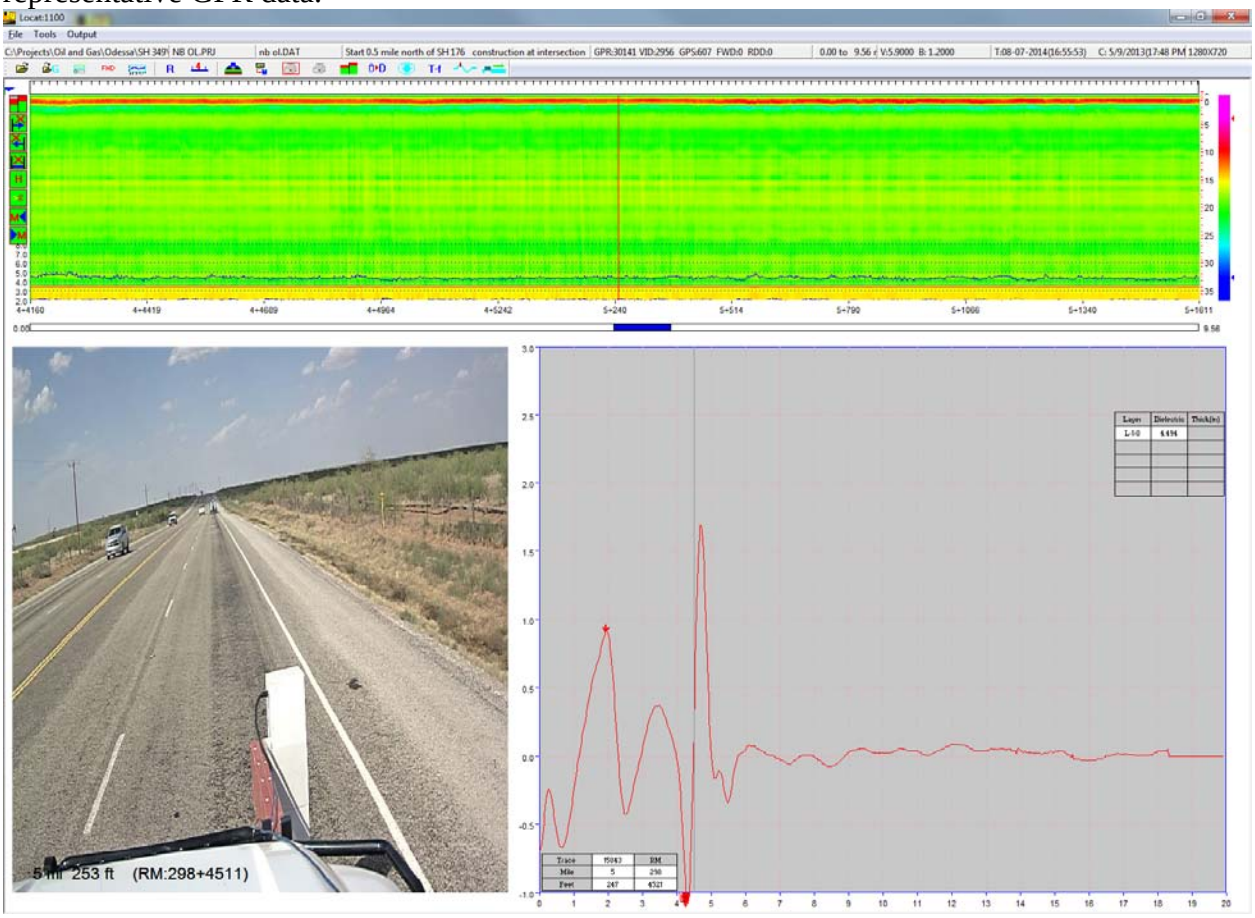

Figure 4. Example GPR data from SH 349.

FWD Results

FWD data were collected at 0.05-mi. intervals in the southbound outside lane. Table 2 presents the backcalculated results, which show on average the base modulus did exceed the 70 ksi assumed in design. The data in Table 2 also suggest a much higher subgrade modulus and asphalt concrete pavement modulus than used in design. While the design used 10 ksi for the subgrade modulus, the data collected on the approximately 1-year old pavement show a subgrade modulus of 32 ksi. The asphalt concrete pavement modulus used for design was 70 ksi, and the assumed value was 225 ksi in the backcalculation analysis.

Table 2. FWD Results from SH 349.

TTI MODULUS ANALYSIS SYSTEM (SUMMARY REPORT) (Version 6.1)

District:
County :
Highway/Road:

	Thickness(in)	MODULI RANGE(psi) Minimum	Maximum	Poisson Ratio Values
Pavement:	0.75	225,000	225,000	H1: v = 0.35
Base:	15.00	10,000	150,000	H2: v = 0.35
Subbase:	0.00			H3: v = 0.00
Subgrade:	215.04(by DB)	10,000		H4: v = 0.40

Station	Load (lbs)	Measured Deflection (mils): R1	R2	R3	R4	R5	R6	R7	Calculated Moduli values (ksi): SURF(E1)	BASE(E2)	SUBB(E3)	SUBG(E4)	Absolute ERR/Sens	Dpth to Bedrock
3.746	10,364	18.33	5.37	2.94	2.06	1.64	1.23	0.94	225.0	63.4	0.0	31.8	18.41	300.0
0.000	10,276	18.00	5.37	3.02	2.11	1.61	1.20	0.91	225.0	65.3	0.0	31.0	17.22	255.5
0.050	9,816	13.45	4.56	2.26	1.62	1.23	0.92	0.71	225.0	86.8	0.0	35.9	15.59	300.0
0.100	9,684	15.11	4.46	2.20	1.62	1.20	0.88	0.73	225.0	69.3	0.0	38.0	18.70	300.0
0.150	9,695	13.75	5.09	3.16	2.30	1.78	1.31	1.00	225.0	101.0	0.0	27.1	13.32	260.9
0.201	11,021	9.89	3.59	2.02	1.41	1.09	0.83	0.67	225.0	150.0	0.0	44.7	13.95	300.0 *
0.250	9,717	12.00	4.05	1.98	1.44	1.11	0.83	0.67	225.0	97.6	0.0	39.3	16.85	300.0
0.300	9,630	12.57	5.43	3.07	2.17	1.65	1.26	0.96	225.0	112.1	0.0	27.4	9.37	264.2
0.351	9,980	16.43	5.71	2.97	2.17	1.60	1.17	0.91	225.0	73.0	0.0	28.6	13.89	300.0
0.400	10,451	11.85	4.22	2.29	1.67	1.34	1.10	0.83	225.0	124.0	0.0	36.4	16.39	300.0
0.452	10,353	14.10	5.30	2.62	1.94	1.53	1.15	0.92	225.0	96.5	0.0	30.9	14.63	300.0
0.501	9,761	13.88	5.17	2.61	1.93	1.46	1.08	0.80	225.0	91.3	0.0	29.8	13.30	300.0
0.550	9,783	11.59	4.44	2.46	1.82	1.36	1.00	0.80	225.0	118.4	0.0	33.2	12.04	300.0
0.600	9,849	23.60	7.81	3.31	2.31	1.77	1.24	1.02	225.0	42.3	0.0	26.3	12.34	104.6
0.650	10,013	14.27	4.42	2.27	1.64	1.33	0.98	0.76	225.0	81.8	0.0	36.9	19.11	300.0
0.701	10,780	20.78	7.34	2.63	1.89	1.67	1.12	0.69	225.0	52.0	0.0	32.6	18.51	57.6
0.751	10,386	19.98	6.99	2.99	2.15	1.74	1.39	1.06	225.0	56.6	0.0	28.8	15.36	110.5
0.800	10,561	15.43	5.92	3.05	2.12	1.59	1.22	0.94	225.0	88.6	0.0	28.6	11.90	300.0
0.852	10,276	14.31	5.82	3.43	2.42	2.15	1.37	0.96	225.0	104.5	0.0	26.2	12.44	300.0
0.901	9,914	8.98	3.07	1.56	1.13	0.90	0.69	0.55	225.0	150.0	0.0	47.3	17.83	300.0 *
0.951	9,695	13.05	3.88	1.63	1.31	1.05	0.80	0.61	225.0	76.9	0.0	46.4	23.03	97.2
1.000	9,893	10.32	4.05	2.09	1.50	1.17	0.90	0.72	225.0	134.5	0.0	38.1	12.96	300.0
1.051	10,265	14.43	4.23	1.82	1.48	1.22	0.98	0.80	225.0	74.1	0.0	44.3	24.07	113.3
1.093	9,936	11.30	4.68	2.36	1.65	1.27	0.93	0.72	225.0	120.4	0.0	34.6	10.78	300.0
1.150	10,747	18.15	6.44	2.69	1.91	1.46	1.15	0.91	225.0	64.3	0.0	32.9	14.87	95.0
1.199	9,958	20.28	7.75	3.32	2.50	2.16	1.44	1.13	225.0	56.4	0.0	24.0	15.19	111.7
1.251	10,495	15.69	6.43	2.50	1.62	1.38	1.04	0.84	225.0	75.3	0.0	33.6	18.10	69.8
1.301	10,627	16.57	5.92	2.65	1.91	1.51	1.11	0.86	225.0	73.6	0.0	32.6	14.78	159.5
1.351	9,980	15.35	6.54	3.64	2.76	2.07	1.45	1.21	225.0	92.8	0.0	23.6	9.95	300.0
1.400	10,407	39.16	4.46	2.44	1.87	1.51	1.17	1.00	225.0	27.9	0.0	27.9	29.29	300.0 *
1.452	10,002	11.18	4.30	2.37	1.63	1.24	0.94	0.73	225.0	124.4	0.0	35.6	11.67	295.6
1.501	10,123	20.08	6.98	3.29	2.29	1.73	1.28	1.06	225.0	56.1	0.0	26.9	11.97	288.1
1.551	9,553	13.35	5.80	3.03	1.98	1.45	1.10	0.87	225.0	95.7	0.0	27.7	9.75	300.0
1.599	10,079	14.44	4.72	2.19	1.71	1.33	1.04	0.79	225.0	80.8	0.0	36.4	19.50	230.9
1.651	9,695	15.87	6.25	3.06	2.25	1.69	1.32	1.03	225.0	77.8	0.0	25.5	12.04	300.0
1.700	9,717	15.03	5.64	2.65	2.33	1.71	1.43	1.27	225.0	85.0	0.0	27.1	17.86	263.8
1.751	9,652	16.59	6.59	3.71	2.64	2.02	1.57	1.24	225.0	78.7	0.0	22.6	11.12	300.0
1.802	9,564	12.71	4.87	2.94	2.17	1.67	1.28	1.02	225.0	110.1	0.0	28.3	13.06	300.0
1.850	9,728	11.60	5.42	3.36	2.43	1.87	1.42	1.11	225.0	139.5	0.0	25.7	8.29	300.0
1.900	9,904	11.68	4.90	3.04	2.02	1.45	1.05	0.76	225.0	123.9	0.0	30.5	6.35	200.8
1.950	9,805	13.14	5.01	2.93	2.00	1.47	1.05	0.79	225.0	101.6	0.0	29.7	9.67	212.6
2.057	9,487	18.67	7.24	3.78	2.59	1.99	1.60	1.24	225.0	62.8	0.0	21.3	11.16	300.0
2.057	9,465	18.50	7.21	3.75	2.58	1.98	1.55	1.20	225.0	63.2	0.0	21.4	10.80	300.0
Mean:		15.48	5.43	2.75	1.98	1.54	1.15	0.90	225.0	88.8	0.0	31.6	14.59	230.8
Std. Dev:		4.92	1.18	0.57	0.39	0.31	0.22	0.18	0.0	28.8	0.0	6.5	4.45	144.8
Var Coeff(%):		31.82	21.68	20.61	19.67	19.94	19.16	20.26	0.0	32.4	0.0	20.5	30.47	64.6

In addition to the layer backcalculations, the FWD data can check the structure by first setting a maximum deflection (based on design assumptions and predictions) and then analyzing whether the actual deflection stays below the maximum. Figure 5 illustrates that, for this pavement design, the expected R1 deflection for a 9,000 lb FWD load is 23.7 mils. Thus, if the structural design assumptions were met, the actual R1 deflection should not exceed 23.7 mils.

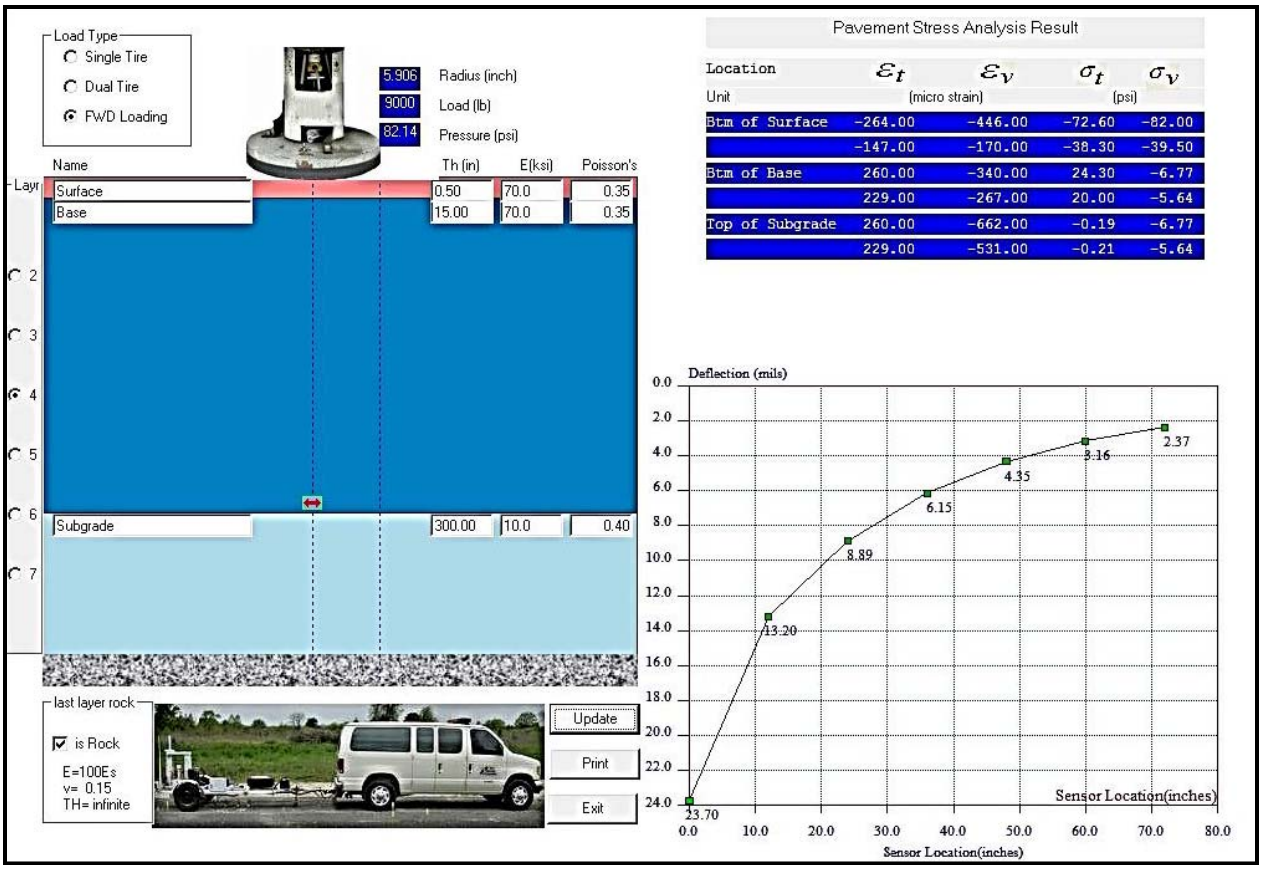

Figure 5. Expected FWD Deflection Based on Design Assumptions.

Figure 6 illustrates that, in the actual FWD data, all locations except one met the expected deflection criteria. Further analysis of the deflection bowl at 1.40 mi. reveals that although R1 significantly increased, R2 deflection remained virtually unchanged from surrounding test locations. This suggests sensor 1 probably was not well seated on the seal coat at this test location, and the high R1 deflection at that test spot likely is an erroneous reading.

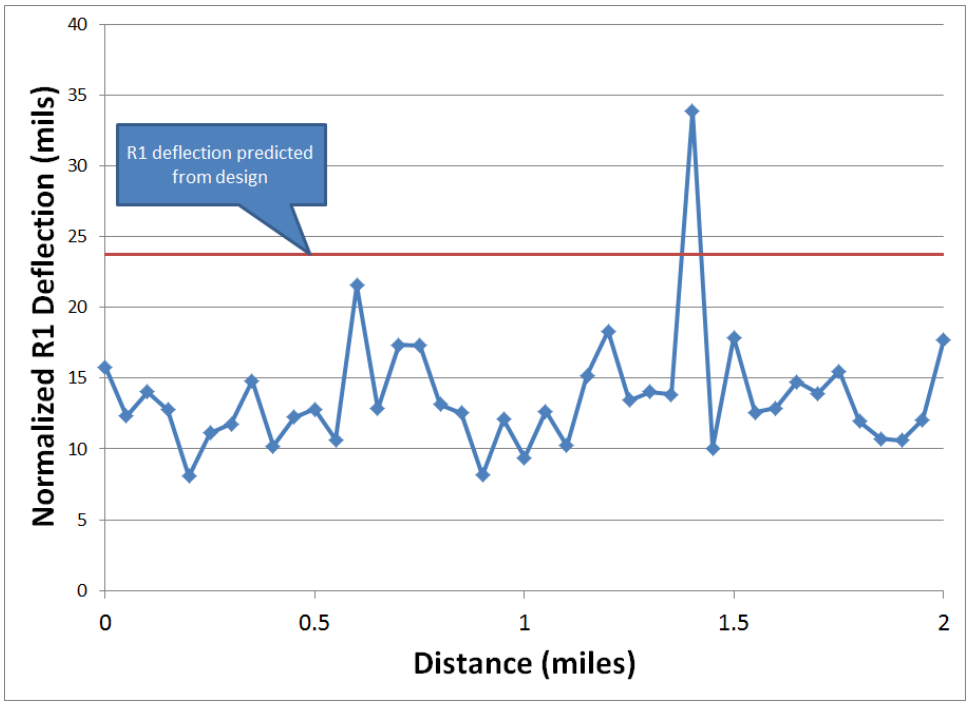

Figure 6. Comparison of FWD R1 to Expected Deflection for 9,000 lb FWD Load.

Flexible Pavement System Analysis

For the SH 349 project, the design assumptions led to an estimated first performance period of 9 years and a total life of 21 years. One disconnect exists between the design assumptions and post-construction analysis in the subgrade modulus. The assumed subgrade modulus in design was 10 ksi; post-construction testing showed the subgrade modulus to average 32 ksi.

Keeping other design assumptions identical and only changing the subgrade modulus value to 32 ksi results in a predicted first performance period of 17 years as opposed to 9 years. Appendix A shows this FPS output. Alternatively, with the higher subgrade modulus, it is estimated the base thickness could be reduced to 9 in. while still achieving a 9 year time to first overlay as shown in Appendix B.

CONCLUSIONS

The data show the structural assumptions for SH 349 were met. The design should serve well under the assumed traffic loadings.

The project analysis revealed conflicting subgrade modulus values between design and post-construction. The measured post-construction subgrade modulus was substantially higher than the 10 ksi used in design. If the higher value measured after construction is more accurate, the design is quite conservative. However, especially in the energy sector where substantial uncertainty over future traffic loads generally exists, conservatism in the design is probably prudent.

APPENDIX A. - FPS OUTPUT WITH POST-CONSTRUCTION MEASURED SUBGRADE MODULUS

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                        TEXAS DEPARTMENT OF TRANSPORTATION
FPS21 -1.3                 FLEXIBLE PAVEMENT SYSTEM                 Release:6-1-2012

--------------------------------------------------------------------------------
PAVEMENT DESIGN TYPE # 1 -- SURFACE TREATED + FLEX BASE OVER SUBGRADE

PROB    DIST.- 6    COUNTY-156    CONT.   SECT.   JOB      HIGHWAY        DATE     PAGE

002      Odessa        MARTIN       NA       NA     NA      SH 349      12/18/2014  1
--------------------------------------------------------------------------------
                          COMMENTS ABOUT THIS PROBLEM

SH 176 to 9.592 mi. N of SH 176



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BASIC DESIGN CRITERIA
**********************

  LENGTH OF THE ANALYSIS PERIOD (YEARS)                                    20.0
  MINIMUM TIME TO FIRST OVERLAY (YEARS)                                     8.0
  MINIMUM TIME BETWEEN OVERLAYS (YEARS)                                     8.0
  DESIGN CONFIDENCE LEVEL ( 95.0%)                                          C
  SERVICEABILITY INDEX OF THE INITIAL STRUCTURE                             4.2
  FINAL SERVICEABILITY INDEX P2                                             3.0
  SERVICEABILITY INDEX P1 AFTER AN OVERLAY                                  4.2
  DISTRICT TEMPERATURE CONSTANT                                            31.0
  SUBGRADE ELASTIC MODULUS by COUNTY (ksi)                                 32.00
  INTEREST RATE OR TIME VALUE OF MONEY (PERCENT)                            6.0

PROGRAM CONTROLS AND CONSTRAINTS
**********************************

  NUMBER OF SUMMARY OUTPUT PAGES DESIRED ( 8 DESIGNS/PAGE)                    3
  MAX FUNDS AVAILABLE PER SQ.YD. FOR INITIAL DESIGN (DOLLARS)              99.00
  MAXIMUM ALLOWED THICKNESS OF INITIAL CONSTRUCTION (INCHES)               69.0
  ACCUMULATED MAX DEPTH OF ALL OVERLAYS (INCHES) (EXCLUDING LEVEL-UP)       2.0

TRAFFIC DATA
*************

  ADT AT BEGINNING OF ANALYSIS PERIOD (VEHICLES/DAY)                      2600.
  ADT AT END OF TWENTY YEARS (VEHICLES/DAY)                               3600.
  ONE-DIRECTION 20YEAR 18 kip ESAL (millions)                             1.775
  AVERAGE APPROACH SPEED TO THE OVERLAY ZONE(MPH)                          70.0
  AVERAGE SPEED THROUGH OVERLAY ZONE (OVERLAY DIRECTION)(MPH)              60.0
  AVERAGE SPEED THROUGH OVERLAY ZONE (NON-OVERLAY DIRECTION) (MPH)         70.0
  PROPORTION OF ADT ARRIVING EACH HOUR OF CONSTRUCTION (PERCENT)            6.0
  PERCENT TRUCKS IN ADT                                                    19.3
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TEXAS DEPARTMENT OF TRANSPORTATION
FPS21 -1.3 FLEXIBLE PAVEMENT SYSTEM Release:6-1-2012

PAVEMENT DESIGN TYPE # 1 -- SURFACE TREATED + FLEX BASE OVER SUBGRADE

PROB	DIST.- 6	COUNTY-156	CONT.	SECT.	JOB	HIGHWAY	DATE	PAGE
002	Odessa	MARTIN	NA	NA	NA	SH 349	12/18/2014	2

INPUT DATA CONTINUED

CONSTRUCTION AND MAINTENANCE DATA
****

MINIMUM OVERLAY THICKNESS (INCHES)	1.5
OVERLAY CONSTRUCTION TIME (HOURS/DAY)	10.0
ASPHALTIC CONCRETE COMPACTED DENSITY (TONS/C.Y.)	1.98
ASPHALTIC CONCRETE PRODUCTION RATE (TONS/HOUR)	150.0
WIDTH OF EACH LANE (FEET)	12.0
FIRST YEAR COST OF ROUTINE MAINTENANCE (DOLLARS/LANE-MILE)	100.00
ANNUAL INCREMENTAL INCREASE IN MAINTENANCE COST (DOLLARS/LANE-MILE)	10.00

DETOUR DESIGN FOR OVERLAYS
****

TRAFFIC MODEL USED DURING OVERLAYING	1
TOTAL NUMBER OF LANES OF THE FACILITY	2
NUMBER OF OPEN LANES IN RESTRICTED ZONE (OVERLAY DIRECTION)	1
NUMBER OF OPEN LANES IN RESTRICTED ZONE (NON-OVERLAY DIRECTION)	1
DISTANCE TRAFFIC IS SLOWED (OVERLAY DIRECTION) (MILES)	0.60
DISTANCE TRAFFIC IS SLOWED (NON-OVERLAY DIRECTION) (MILES)	0.60
DETOUR DISTANCE AROUND THE OVERLAY ZONE (MILES)	0.00

PAVING MATERIALS INFORMATION
****

LAYER	MATERIALS CODE	NAME	COST PER CY	E MODULUS	POISSON RATIO	MIN. DEPTH	MAX. DEPTH	SALVAGE PCT.
1	A	SURFACE TREATMENT	70.00	70000.	0.35	0.50	0.50	30.00
2	B	FLEXIBLE BASE	28.00	70000.	0.35	15.00	15.00	75.00
3	C	SUBGRADE(200)	2.00	32000.	0.40	200.00	200.00	90.00

NOTE -- THE CALCULATED BASE VALUE WAS OVER-WRITTEN BY THE USER FOR PAVEMENT DESIGN TYPE #1

NOTE -- THE CALCULATED BASE VALUE WAS OVER-WRITTEN BY THE USER FOR PAVEMENT DESIGN TYPE #1

TEXAS DEPARTMENT OF TRANSPORTATION

FPS21 -1.3 FLEXIBLE PAVEMENT SYSTEM Release:6-1-2012

PAVEMENT DESIGN TYPE # 1 -- SURFACE TREATED + FLEX BASE OVER SUBGRADE

PROB	DIST.- 6	COUNTY-156	CONT.	SECT.	JOB	HIGHWAY	DATE	PAGE
002	Odessa	MARTIN	NA	NA	NA	SH 349	12/18/2014	3

C. LEVEL C SUMMARY OF THE BEST DESIGN STRATEGIES IN ORDER OF INCREASING TOTAL COST

	1
MATERIAL ARRANGEMENT	AB
INIT. CONST. COST	12.64
OVERLAY CONST. COST	1.44
USER COST	0.00
ROUTINE MAINT. COST	0.28
SALVAGE VALUE	-3.09
TOTAL COST	11.27
NUMBER OF LAYERS	2
LAYER DEPTH (INCHES)	
D(1)	0.50
D(2)	15.00
NO.OF PERF.PERIODS	2
PERF. TIME (YEARS)	
T(1)	17.
T(2)	38.
OVERLAY POLICY(INCH) (INCLUDING LEVEL-UP)	
O(1)	2.0

THE TOTAL NUMBER OF FEASIBLE DESIGNS CONSIDERED WAS 1

APPENDIX B. - FPS OUTPUT SHOWING BASE THICKNESS REDUCTION

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                    TEXAS DEPARTMENT OF TRANSPORTATION
FPS21 -1.3             FLEXIBLE PAVEMENT SYSTEM              Release:6-1-2012

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PAVEMENT DESIGN TYPE # 1 -- SURFACE TREATED + FLEX BASE OVER SUBGRADE

PROB   DIST.- 6   COUNTY-156   CONT.  SECT.  JOB     HIGHWAY       DATE     PAGE

002     Odessa       MARTIN      NA      NA    NA     SH 349     12/18/2014  1
--------------------------------------------------------------------------------
                         COMMENTS ABOUT THIS PROBLEM

Sh 176 to 9.592 mi. N of SH 176



--------------------------------------------------------------------------------

BASIC DESIGN CRITERIA
**********************

  LENGTH OF THE ANALYSIS PERIOD (YEARS)                                  20.0
  MINIMUM TIME TO FIRST OVERLAY (YEARS)                                   8.0
  MINIMUM TIME BETWEEN OVERLAYS (YEARS)                                   8.0
  DESIGN CONFIDENCE LEVEL ( 95.0%)                                        C
  SERVICEABILITY INDEX OF THE INITIAL STRUCTURE                           4.2
  FINAL SERVICEABILITY INDEX P2                                           3.0
  SERVICEABILITY INDEX P1 AFTER AN OVERLAY                                4.2
  DISTRICT TEMPERATURE CONSTANT                                          31.0
  SUBGRADE ELASTIC MODULUS by COUNTY (ksi)                               32.00
  INTEREST RATE OR TIME VALUE OF MONEY (PERCENT)                          6.0

PROGRAM CONTROLS AND CONSTRAINTS
**********************************

  NUMBER OF SUMMARY OUTPUT PAGES DESIRED ( 8 DESIGNS/PAGE)                3
  MAX FUNDS AVAILABLE PER SQ.YD. FOR INITIAL DESIGN (DOLLARS)            99.00
  MAXIMUM ALLOWED THICKNESS OF INITIAL CONSTRUCTION (INCHES)             69.0
  ACCUMULATED MAX DEPTH OF ALL OVERLAYS (INCHES) (EXCLUDING LEVEL-UP)     2.0

TRAFFIC DATA
*************

  ADT AT BEGINNING OF ANALYSIS PERIOD (VEHICLES/DAY)                    2600.
  ADT AT END OF TWENTY YEARS (VEHICLES/DAY)                             3600.
  ONE-DIRECTION 20YEAR 18 kip ESAL (millions)                          1.775
  AVERAGE APPROACH SPEED TO THE OVERLAY ZONE(MPH)                        70.0
  AVERAGE SPEED THROUGH OVERLAY ZONE (OVERLAY DIRECTION)(MPH)            60.0
  AVERAGE SPEED THROUGH OVERLAY ZONE (NON-OVERLAY DIRECTION) (MPH)       70.0
  PROPORTION OF ADT ARRIVING EACH HOUR OF CONSTRUCTION (PERCENT)          6.0
  PERCENT TRUCKS IN ADT                                                  19.3
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TEXAS DEPARTMENT OF TRANSPORTATION
FPS21 -1.3 FLEXIBLE PAVEMENT SYSTEM Release:6-1-2012

PAVEMENT DESIGN TYPE # 1 -- SURFACE TREATED + FLEX BASE OVER SUBGRADE

PROB	DIST.- 6	COUNTY-156	CONT.	SECT.	JOB	HIGHWAY	DATE	PAGE
002	Odessa	MARTIN	NA	NA	NA	SH 349	12/18/2014	2

INPUT DATA CONTINUED

CONSTRUCTION AND MAINTENANCE DATA
****

MINIMUM OVERLAY THICKNESS (INCHES)	1.5
OVERLAY CONSTRUCTION TIME (HOURS/DAY)	10.0
ASPHALTIC CONCRETE COMPACTED DENSITY (TONS/C.Y.)	1.98
ASPHALTIC CONCRETE PRODUCTION RATE (TONS/HOUR)	150.0
WIDTH OF EACH LANE (FEET)	12.0
FIRST YEAR COST OF ROUTINE MAINTENANCE (DOLLARS/LANE-MILE)	100.00
ANNUAL INCREMENTAL INCREASE IN MAINTENANCE COST (DOLLARS/LANE-MILE)	10.00

DETOUR DESIGN FOR OVERLAYS
****

TRAFFIC MODEL USED DURING OVERLAYING	1
TOTAL NUMBER OF LANES OF THE FACILITY	2
NUMBER OF OPEN LANES IN RESTRICTED ZONE (OVERLAY DIRECTION)	1
NUMBER OF OPEN LANES IN RESTRICTED ZONE (NON-OVERLAY DIRECTION)	1
DISTANCE TRAFFIC IS SLOWED (OVERLAY DIRECTION) (MILES)	0.60
DISTANCE TRAFFIC IS SLOWED (NON-OVERLAY DIRECTION) (MILES)	0.60
DETOUR DISTANCE AROUND THE OVERLAY ZONE (MILES)	0.00

PAVING MATERIALS INFORMATION
****

LAYER	CODE	MATERIALS NAME	COST PER CY	E MODULUS	POISSON RATIO	MIN. DEPTH	MAX. DEPTH	SALVAGE PCT.
1	A	SURFACE TREATMENT	70.00	70000.	0.35	0.50	0.50	30.00
2	B	FLEXIBLE BASE	28.00	70000.	0.35	9.00	9.00	75.00
3	C	SUBGRADE(200)	2.00	32000.	0.40	200.00	200.00	90.00

NOTE -- THE CALCULATED BASE VALUE WAS OVER-WRITTEN BY THE USER FOR PAVEMENT DESIGN TYPE #1

NOTE -- THE CALCULATED BASE VALUE WAS OVER-WRITTEN BY THE USER FOR PAVEMENT DESIGN TYPE #1

TEXAS DEPARTMENT OF TRANSPORTATION
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PAVEMENT DESIGN TYPE # 1 -- SURFACE TREATED + FLEX BASE OVER SUBGRADE

PROB	DIST.- 6	COUNTY-156	CONT.	SECT.	JOB	HIGHWAY	DATE	PAGE
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C. LEVEL C SUMMARY OF THE BEST DESIGN STRATEGIES
IN ORDER OF INCREASING TOTAL COST

	1
MATERIAL ARRANGEMENT	AB
INIT. CONST. COST	7.97
OVERLAY CONST. COST	2.30
USER COST	0.00
ROUTINE MAINT. COST	0.24
SALVAGE VALUE	-2.00
TOTAL COST	8.51
NUMBER OF LAYERS	2
LAYER DEPTH (INCHES)	
D(1)	0.50
D(2)	9.00
NO.OF PERF.PERIODS	2
PERF. TIME (YEARS)	
T(1)	9.
T(2)	22.
OVERLAY POLICY(INCH) (INCLUDING LEVEL-UP)	
O(1)	2.0

THE TOTAL NUMBER OF FEASIBLE DESIGNS CONSIDERED WAS 1