I-35 PAVEMENT INSTRUMENTATION PHASE II

FINAL REPORT - FHWA-OK-09-04

ODOT SPR ITEM NUMBER 2200

By

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December 2009

TECHNICAL REPORT DOCUMENTATION PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT=S CATALOG NO.
FHWA-OK-09-04		

4. TITLE AND SUBTITLE	5. REPORT DATE
I-35 Pavement Instrumentation Phase II	December, 2009
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT
Dr. David H. Timm	
9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. WORK UNIT NO.
National Center for Asphalt Technology 277 Technology Parkway Auburn, AL 36830	11. CONTRACT OR GRANT NO. ODOT SPR Item Number 2200
12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Oklahoma Department of Transportation Planning and Research Division 200 N.E. 21st Street, Room 3A7 Oklahoma City, OK 73105	Final Report October 2008 – September 2009
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report documents work conducted by the National Center of Asphalt Technology (NCAT) in support of the University of Oklahoma's (OU) research efforts on a live pavement test site in Purcell, Oklahoma. Technical consultations were provided in developing written documentation, in addition to a site visit by NCAT personnel. The site visit provided future direction for the project and roadside installation of a variable resistor array for the purpose of fine tuning strain gauges embedded in the pavement. Finally, laboratory testing was conducted at the NCAT lab. Specifically, asphalt pavement analyzer (APA) and beam fatigue tests were conducted and data were provided to the OU researchers.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Pavement Instrumentation	No restrictions. This publication is available from the Planning & Research Div., Oklahoma DOT.

19. SECURITY CLASSIF. (OF THIS REPORT)	20. SECURITY CLASSIF. (OF THIS PAGE)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	12	N/A

SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units

Symbol	When you know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	25.40	millimeters	mm
ft	feet	0.3048	meters	m
yd	yards	0.9144	meters	m
mi	miles	1.609	kilometers	km
	AREA			
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.0929	square meters	m^2
yd^2	square yards	0.8361	square meters	m^2
ac	acres	0.4047	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
	VOLUME			
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0283	cubic meters	m^3
yd^3	cubic yards	0.7645	cubic meters	m^3
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.4536	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C
	FORCE and PRESSURE or STRESS			
lbf	poundforce	4.448	Newtons	N
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa

Approximate Conversions from SI Units

Symbol	When you know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.0394	inches	in
m	meters	3.281	feet	ft
m	meters	1.094	yards	yd
km	kilometers	0.6214	miles	mi
	AREA			
mm^2	square millimeters	0.00155	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.196	square yards	yd^2
ha	hectares	2.471	acres	ac
km^2	square kilometers	0.3861	square miles	mi^2
	VOLUME			
mL	milliliters	0.0338	fluid ounces	fl oz
L	liters	0.2642	gallons	gal
m^3	cubic meters	35.315	cubic feet	ft^3
m^3	cubic meters	1.308	cubic yards	yd^3
	MASS			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.1023	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	degrees Celsius	9/5+32	degrees Fahrenheit	°F
	FORCE and PRESSURE or STRESS			
N	Newtons	0.2248	poundforce	lbf
kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

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BACKGROUND

The Oklahoma Department of Transportation (ODOT) has recently constructed a full-scale flexible pavement test section on I-35 near Purcell, Oklahoma. Working with the University of Oklahoma (OU) and the National Center for Asphalt Technology (NCAT), this ODOT section was constructed in May 2008 and features embedded pavement instrumentation to monitor vehicle speed, vehicle classification, pavement strain, pavement pressure, in situ moisture and temperature. These data sets will be used by ODOT to refine their existing pavement design method and aid in implementation of mechanistic-empirical pavement design methods in the future.

During Phase I of the project, NCAT's primary role was to design, procure and facilitate installation of the embedded instrumentation at the test site. NCAT also developed customized data processing algorithms for the OU team and provided training in their use. At this point in the project, the section has been built and instrumented with data collection and processing ongoing with regular frequency.

During technical meetings held at OU, attended by the OU, ODOT and NCAT teams in July 2008, there was discussion regarding the NCAT team participating in the second phase of the project which will continue with data collection/processing but also involve in-depth pavement analyses using the data sets described above. The areas of the proposed NCAT involvement included the following:

- Technical guidance regarding analyses of the data sets
- Assistance in troubleshooting the data acquisition systems
- Technical review of project reports developed by the OU team

Work in these areas was proposed to be accomplished in FY 2009 (October 2008 – September 2009) through email and teleconferences as needed in addition to one site visit.

TASK 1 – TECHNICAL GUIDANCE AND REVIEW

During FY 2009, there were two primary documents developed by the OU team for which the NCAT team provided technical review and assistance. They included:

1. Solanki, P., M. Zaman, K. Muraleetharan and D. Timm, "Evaluation of Resilient Moduli of Pavement Layers at an Instrumented Section on I-35 in Oklahoma," International Journal of Road Materials and Pavement Design, Volume No. 10, Special Issue, 2009, pp. 167-188.
2. Solanki, P., M. Zaman and K.K. Muraleetharan, "Field Performance Monitoring and Modeling of Instrumented Pavement on I-35 in McClain County – Construction and Instrumentation Report," ODOT Item No. 2200, August, 2009.

Both documents were reviewed and edited by the NCAT team. Direct feedback was provided to the OU team and necessary modifications were made to each. These

documents are not included with this report for the sake of brevity, but are available from the OU team. In addition to developing these documents, there were numerous technical consultations via phone and email with OU project personnel.

TASK 2 – SITE VISITS

In the original proposal for this project, two site visits were scheduled. The first was for the NCAT service center to provide troubleshooting/maintenance at the roadside installation. The second was for the NCAT team to visit with ODOT and OU to discuss data and findings from the project and continue to progress toward further data and report development. Since the roadside equipement was performing extremely well, it was decided by ODOT/OU that a troubleshooting/maintenance visit was not needed. A budget reallocation request dated August 14, 2009 was approved by ODOT to eliminate this visit and instead provide laboratory fatigue testing at the NCAT service center. This work is described in Task 3 below.

The other visit, including NCAT, ODOT and OU team members, was held on September 17 – 18, 2009 at the OU campus. The first day was devoted to reviewing data sets where the NCAT team provided guidance to the OU team in future data analyses. Discussion focused on characterizing strain and pressure on a continuous basis from which fatigue and rutting transfer functions will be developed. It is NCAT's understanding that this work is ongoing by the OU team.

The second day of the visit was devoted to inspecting the I-35 project location and retrofitting the roadside data acquisition equipment with a custom-built variable resistor array. This equipment was developed and supplied by the NCAT service center. Pictured in Figure 1, this array replaced the many individual resistors that had been added by the OU team to zero strain gauges since the beginning of the project. After adding the array to the system, each gauge was successfully returned to an optimal baseline voltage. Future adjustments can now be easily made by simply "tuning" each gauge rather than physically removing and adding fixed resistors to each sensor.

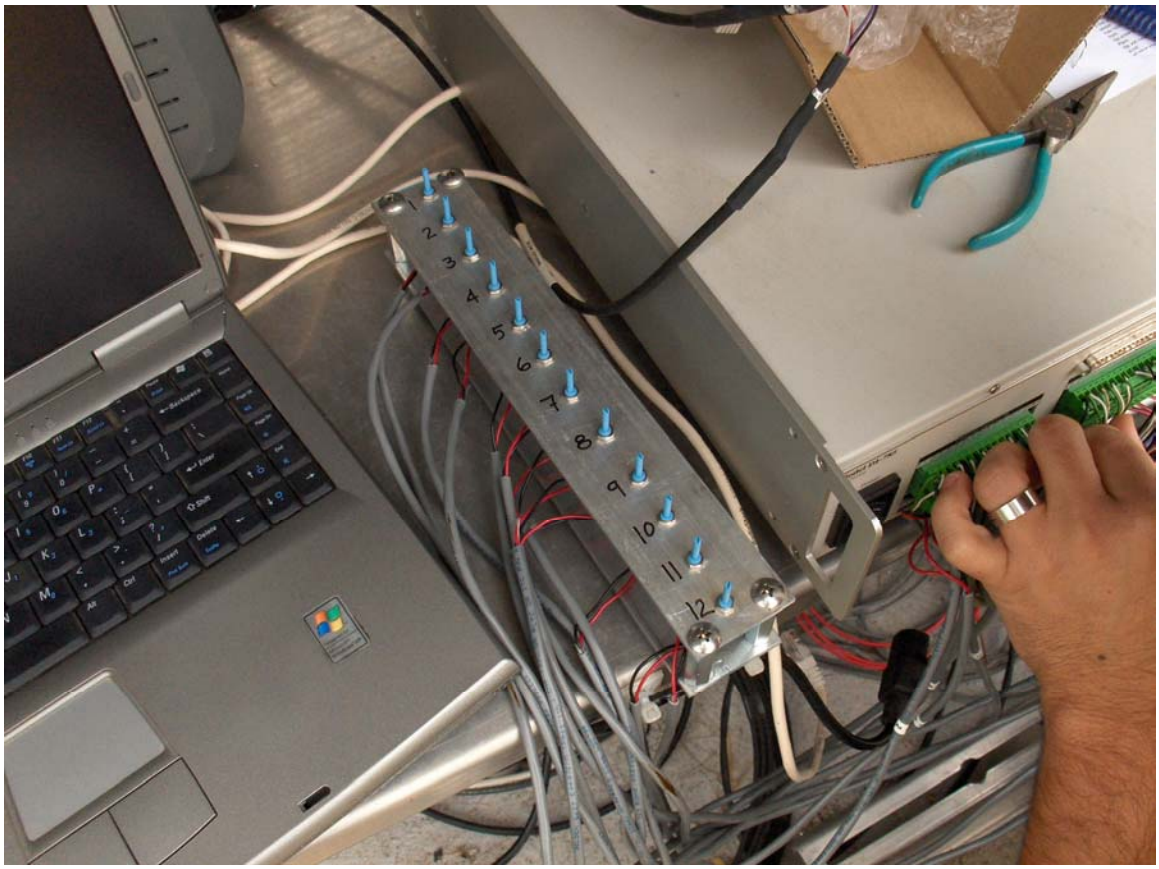

Figure 1. Twelve Channel Variable Resistor Array

TASK 3 – LABORATORY TESTING

As noted above, a budget reallocation request was approved by ODOT for NCAT to provide beam fatigue and asphalt pavement analyzer (APA) testing on specimens fabricated and shipped by the OU team. The request from OU was to complete the following:

1. APA testing (6 specimens at 64^{o}C, hose pressure = 100 psi and wheel load = 100 lb)
2. Four-point fatigue test on standard plastic beam sample (No. of samples = 1)
3. Four-point fatigue test on laboratory compacted asphalt concrete samples (No. of samples = 24; 12 @ T = 5^{o}C, 12 @ T = 20^{o}C)

It is important to note that analysis by the NCAT team was not requested by OU. The task was to simply conduct the testing and provide the data to OU.

The APA testing was completed on September 22, 2009. The results are summarized in Table 1 while Figure 2 illustrates the samples at the conclusion of testing.

Table 1. APA Rut Depth Measurements

Specimen #	Automated Rut Depths, mm	Manual Rut Depths, mm
T6	3.27	4.30
T8	3.16	4.12
T18	4.67	7.23
T19	4.99	7.82
T17	3.12	4.85
T16	3.45	6.09
Average	**3.78**	**5.74**

Figure 2. APA Samples After Testing

The beam fatigue testing was a bit more complicated due to issues with shipping specimens to NCAT. The first set of specimens were shipped mid-August to NCAT. Upon arrival, it was noted by NCAT engineers that several of the specimens had experienced enough bending during shipment that testing should not proceed, or at least be noted in case the results appeared erroneous. Another set of specimens were received on September 4, 2009. These were better supported to prevent bending, but experienced cracking due to handling by the shipper. The last set of specimens arrived at NCAT at the end of September (29th). The arrival of the specimens on this date prevented testing from being completed by the end project (Sept. 30th). Given the numerous issues with shipping, only 10 specimens were tested before the end of the contract period. Eight were tested at 20°C and two were tested at 5°C. The 5°C specimens failed immediately

upon commencement of the test so the data are not included here. Table 2 summarizes the data for the 20°C specimens.

Table 2. Beam Fatigue Testing Summary

Sample ID	1-1	1-2*	2-1	2-2*	5-1	10-1*	10-2	11-1*
Strain Level (ms)	400	400	400	400	400	400	400	400
Chamber Temperature (C)	20	20	20	20	20	20	20	20
Beam Width (mm)	63.794	60.582	61.102	63.488	62.89	60.198	62.638	59.2
Beam Height (mm)	48.844	51.502	51.998	52.276	48.566	50.434	48.792	51.68
Beam Length (mm)	379.64	381.58	380.64	380.39	380.69	381.39	380.92	380.51
Cycles to Failure (ASTM)	287290	194980	110910	146770	95980	149620	261010	69530
Cycles to Failure (AASHTO)	185490	84890	54250	82540	47980	111340	183370	37530
Initial Beam Stiffness (MPa)	8144	10636	7565	7723	8668	6868	6114	9460
Termination Stiffness (MPa)	2036	2659	1891.25	1930.75	2167	1717	1528.5	2365

*Specimen exceeded ASTM fabrication tolerance of +/- 2mm