ANNUAL PROGRESS REPORT (FISCAL YEAR 2008)

Project Name: Field Performance Monitoring and Modeling of Instrumented Pavement on I-35 in McClain County

Item Number: 2200

Duration: October 1, 2007 to September 30, 2008

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Overall:

This combined laboratory and field study is pursued to gain an insight of pavement failure under actual traffic loading and environmental conditions. A 1,000-ft long experimental pavement section was constructed on I-35 in McClain County and instrumented in collaboration with the National Center for Asphalt Technology (NCAT) and ODOT for field data collection. The field data collection is focused on pavement performance data (e.g., distribution of stresses within the pavement structure, longitudinal and transverse strains at the bottom of asphalt layer), environmental data (e.g., air temperature, variation of temperature within the pavement structure, rainfall, wind speed, humidity, solar radiation), and traffic data (e.g., axle load, position, speed). Field tests/measurements (falling weight deflectometer, rut and crack mapping) are conducted periodically to monitor performance of the experimental pavement section. Laboratory tests (volumetric properties, rut and fatigue) are conducted on field compacted and laboratory compacted asphalt specimens to evaluate the rutting and fatigue behavior of the HMA mixes used in the construction of the experimental section. One of the goals of this study is to develop 'shift factors' so that the rutting and fatigue behavior from laboratory data can be correlated with the field data. Such shift factors may be used to estimate rutting and fatigue performance of similar pavements in Oklahoma. To this end, activities in FY2008 included characterization of subgrade soils, construction and instrumentation of the experimental section, development of data collection protocol, data collection and analysis, field testing, and pertinent laboratory testing. Details of the progress made during FY2008 are given in the monthly progress reports. An overview of some of these activities is given in the following.

Overview of Work Done

- **Rut testing of Laboratory and Field compacted samples at different temperature:**

a) Laboratory Compacted Samples:

Approximately 1000-lbs of mix similar to the top asphalt concrete layer (Type S-4, PG 64-22) of the I-35 experimental section were obtained from Haskell Lemon Corporation (the contractor) to determine rutting susceptibility using the Asphalt Pavement Analyzer (APA). Cylindrical specimens (diameter = 150 mm, height = 75 mm) were prepared with a wide range of target air voids (2±1%, 4±1%, 6±1%, 8±1%, 10±1%) using a Superpave Gyratory Compactor after heating the mix at 149°C, as recommended by OHD L-43. These samples were tested at 64°C. More samples will be prepared and tested in Fiscal Year 2009 at 50°C and 40°C to compare the rutting susceptibility of the HMA mix at different temperatures. The APA rut values will be eventually correlated with the field ruts.

b) Field Compacted Samples:

A total of six core-cut cylindrical samples (6" diameter and 7" thick) were removed from near the instrumentation site, before opening the lane for traffic. These cores were further saw-cut for APA rut test on S-4 mix. APA rut test will be conducted on these samples for developing material shift factors. In addition, six masonry saw-cut block samples (18" long x 7" wide x 7" thick) were also collected from the field. Each block sample was further saw-cut into two block samples (S-4: 18" long x 7" wide x 2" thick, S-3: 18" long x 7" wide x 5" thick). Each block sample was further prepared for one APA rut beam (S-4) and two four-point fatigue beams (S-3). The S-4 beam specimens were tested for rutting susceptibility using the Asphalt Pavement Analyzer. The initial APA test results show that beam specimens are more susceptible to rut than cylindrical specimens at comparable air voids and temperature.

In the first week of January 2008, a PMW linear kneading compactor was purchased from Precision Machine & Welding in Salina, Kansas. Using the PMW linear kneading compactor, several beam specimens (length = 12", width = 5", height = 3") were compacted. These specimens were then cut into three equal pieces along the length (length =4", width =5", height =3") by the heavy duty saw available in the Mewbourne School of Petroleum and Geological Engineering to determine the bulk specific gravity (G_{mb}) and percent air voids in accordance with the AASHTO T 166 test method and the AASHTO T 269 test method, respectively. It was evident that the percent air voids of saw-cut specimen are higher than the percent air voids of uncut specimen, indicating non-uniform compaction around edges. This information will be helpful in the interpretation of test results on laboratory compacted specimens.

- **Fatigue Test on Beam Specimens:**

A total of 1000-lbs of type S-3 mix were also obtained from Haskell Lemon for conducting laboratory testing. As noted later, similar mix was used during paving of bottom layer. To determine the fatigue life of laboratory compacted beam specimens, a four-point bending fixture was purchased from James Cox & Sons, Inc., Colfax, CA. Also, MTS software (Model 793.17) was purchased from MTS Systems Corporation to monitor dynamic properties vs. fatigue cycle of the beam specimen, representing a pavement section, being tested. For better understanding on fatigue testing, a visit was also made to SEM Materials, located at Tulsa.

- **Design and Material Properties of the Experimental Section**

A pavement section thinner than a typical Interstate pavement and similar to state highway pavement was designed by ODOT for the experimental section so that field performance data collected over a five-year period could be used by the agency to estimate the long-term (20 years) service life of state highways having similar pavement structure. A typical profile of the instrumented section is shown in Figure 1.

a) Asphalt concrete layer (Top layer): The asphalt concrete mix was supplied by Haskell Lemon Construction Co. from its plant located in Norman, OK. The top layer (2.0-in. thick) was constructed with S-4 mix (PG 64-22) having a nominal maximum size of ½ in. The optimum binder content used in the S-4 mix was 4.6.

b) Asphalt concrete layer (The layer below the top layer): This layer (5.0 in. thick) was constructed with a coarser S-3 mix having a nominal maximum size of ¾ in. The binder content used in this mix was 4.1.

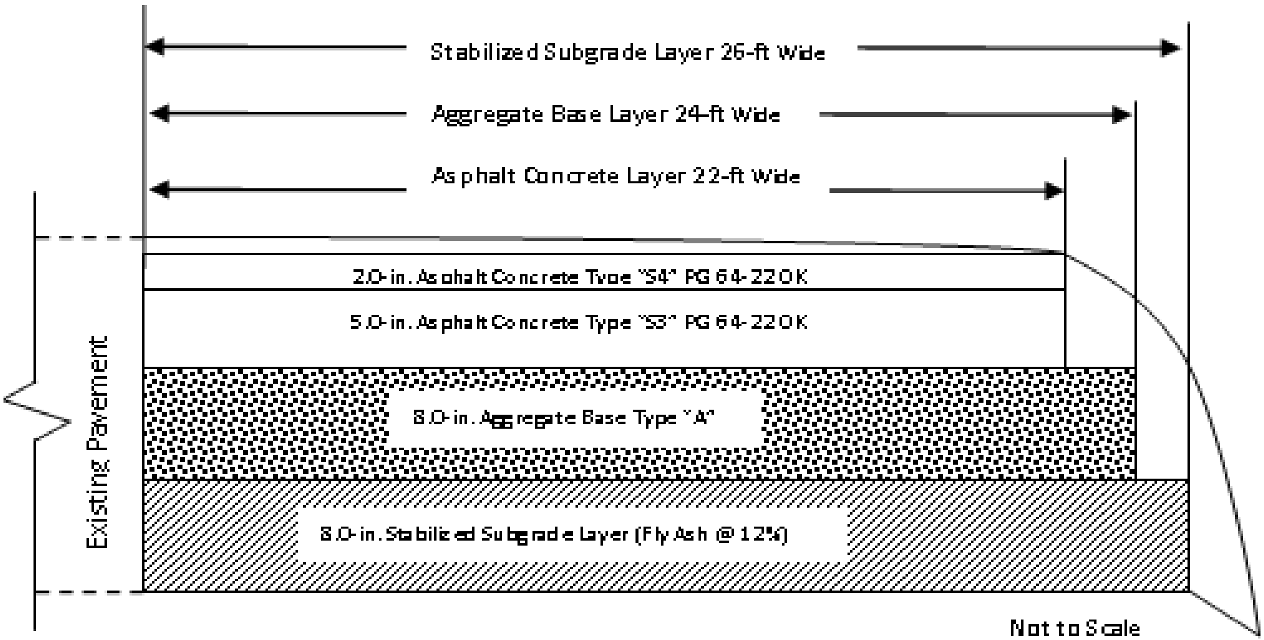

Figure 1: Sketch of Typical Section

c) Aggregate base layer: The aggregate base (thickness 8.0-in.) consists of "Type A" aggregate base, as specified by ODOT, having a maximum aggregate size of 1.5-in. The aggregate used in the construction of the experimental section was supplied by the Dolese Co, Oklahoma. Bulk aggregate samples were collected from the instrumentation site from five different locations during the construction of the aggregate base layer. The bulk samples were then tested for gradation, standard Proctor, modified Proctor and resilient modulus in the Broce Material Testing Laboratory at OU. The optimum moisture content (OMC) and maximum dry density (MDD) for aggregate base was approximately 4.5% and 127 pcf, respectively. The resilient modulus (M_r) values of the tested specimens were in the range of 14 ksi – 48 ksi. These M_r values were used as guidelines in the back calculations of HMA moduli from FWD tests on the pavement surface.

d) Stabilized subgrade layer: The subgrade layer (8.0-in. thick) was stabilized with 12% class C fly ash (CFA), provided by Lafarge Corporation, Red Rock, Oklahoma. The CFA used had a combined silica, alumina, and ferric oxide (SAF) content of approximately 62.2%. The average calcium oxide (CaO) content was approximately 24.0%. The subgrade soil was mixed manually with 12% CFA for determining the moisture-density relationship of the soil-CFA mixture in the Broce laboratory. From these tests, the MDD and the OMC of the soil-CFA mix were found to be approximately 111 pcf and 14.0%, respectively. Also, a total of four specimens: (1) two at OMC and (2) two at 2% wetter then OMC (OMC+2%) were prepared for M_r testing. The specimens were duly compacted and cured at a temperature of 23.0 ± 1.7°C with a relative humidity of approximately 96% and then tested at five different curing periods: 2, 8, 16, 23 and 30 days. It was evident from these tests that addition of 12% CFA increases the M_r value of the subgrade soil specimen by 470% and 886% after 2 days and 30 days of curing, respectively. These M_r values were used as guidelines in the back calculations of HMA moduli from FWD tests on the pavement surface.

e) Subgrade soil: The bottom layer (or subgrade soil) is basically lean clay (having liquid limit at 33 and plasticity index of 15) and dark brown in color. Limited geotechnical investigations were conducted on the existing subgrade at the site (see Subsurface Characterization). As part of this investigation, approximately 100-lb. bulk soil was collected from the location close to the center of the proposed instrumentation array. Several tests, namely standard Proctor and resilient modulus (M_r), were conducted on this soil. From the standard Proctor test, the MDD of the subgrade soil was approximately 110.4 pcf at the OMC of 14.5%. From the resilient modulus tests, the pavement design M_r values (deviatoric stress of 6 psi and a confining pressure of 4 psi) at OMC and OMC+2% were found to be approximately 17 ksi and 12 ksi, respectively. The specimens compacted at OMC were further tested by the subjecting them to two unloading-reloading sequences and then loading up to failure in the third sequence of reloading at an axial strain rate of 1% per minute. The detailed procedure has been discussed in Solanki et al. (2007).

Subsurface Characterization

We also performed soil profiling and Dynamic Cone Penetrometer (DCP) test for subsurface characterization and assessing geotechnical issues associated with the performance of pavement under vehicular traffic. The soil profiling and the DCP tests are briefly discussed below:

a) Soil Profiling: The soil profiling included drilling one bore hole at a selected location using a hand operated posthole auger in accordance with the ASTM D 1452 test method. A field log of the surface conditions obtained was reported and maintained in accordance with ASTM D 5434. The drilling was done to a maximum depth of 12.0-ft. below the compacted subgrade elevation with one foot interval. The representative portions of the on-site soil samples were brought to Broce Laboratory in sealed bags to determine the natural moisture content (ASTM D 2216), Atterberg limits (ASTM D 4318), and gradation (ASTM D 6913) for classification according to the Unified Soil Classification System (USCS). The results show that this site consists of lean clay up to a depth of 7.0 – 8.0 ft. from the top of the existing subgrade. Below this layer it is sand. Water table was encountered at a depth of about 10.8-ft.

b) Dynamic Cone Penetrometer Test: Dynamic Cone Penetrometer (DCP) tests were performed at three selected locations on the top of aggregate base layer in accordance with the test procedure described in SHT (1992). The DCP tests were performed to a depth of approximately 0.8-m. (2.5-ft.), as suggested by Miller and Zaman (2000). Pertinent results were reported in the monthly progress reports

Construction and Instrumentation of the Experimental Section

After checking and labeling all the required instruments, the OU, NCAT, ODOT team along with Haskell Lemon collaborated on the construction and instrumentation of the experimental pavement section. The chronological sequence of construction and sensor installation of instrumented section is shown in Figure 2.

Broadly, the construction and instrumentation of the site was divided into four phases. The first phase consisted of grading, leveling, and compacting of the subgrade and then installation of sensors on the top of subgrade. The second phase consisted of constructing the stabilized subgrade layer (SSG) and then installation of gauges on SSG. In the third phase aggregate base layer (AGB) was constructed and sensors were installed on the top of AGB, and the last phase involved paving the road with asphalt concrete (AC).

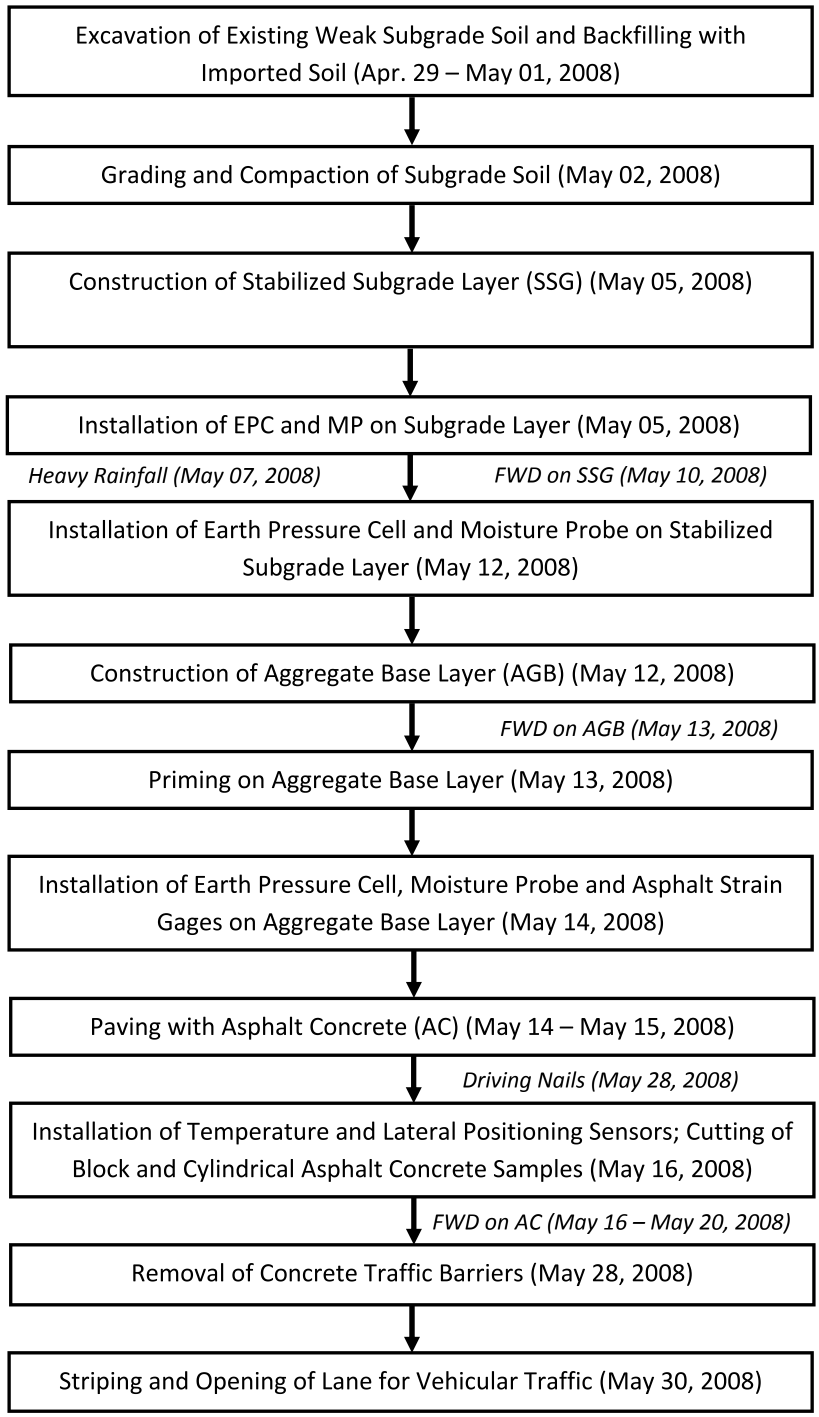

Figure 2: Flow Chart of Construction and Instrumentation Process

- **Development of Data Collection Protocol**

A pre-construction meeting was conducted at ODOT on March 19, 2008. Research team members from ODOT, NCAT and OU participated in this meeting. Based upon the discussions at the meeting, a data collection protocol was developed, in coordination with NCAT. It was decided that four types of data will be collected from the field. They are:

a) Traffic Data: This data is being collected by using the WIM (Weigh-In-Motion) system installed about 1/8 mile from the instrumented site. This data includes weight/axle, ESAL, speed, length, gross weight and classification of each vehicle according to the FHWA 13-category scheme. This data will be used to analyze the traffic spectrum for the test site.

b) Dynamic Data: This includes data collected from the lateral positioning sensors (axle count, axle spacing, speed, and offset), earth pressure cells (vertical stress), and asphalt strain gauges (strains) using the DATAQ data acquisition system (Model Number: DI 785-32).

c) Environmental Data: Environmental data includes data collected by temperature probes (temperature), humidity sensors (moisture data), and weather station (ambient temperature, ambient humidity, wind speed, wind direction, incoming solar radiation, and rainfall).

d) Performance Data: This includes modulus obtained from the FWD data, visual crack mapping and rut measurements. FWD data is being collected at six different locations within the 1000-ft test section. Crack mapping is conducted by visual observation of cracks. Fatigue cracking of 20 percent of the total lane area or 45-50 percent of the wheel path will be considered as failure. Rut measurements are made using a rut depth gage (a series of 0.1" thick plates) and a straight edge.

- **Field Testing and Distress Survey**

A field testing and distress survey was conducted by the project team in August on the newly constructed instrumented pavement section. The activities included rut measurements, crack mapping, FWD testing, and replacement of axle sensors. A maximum rut value of 0.4 in. (10.16 mm) was observed from the field survey. There was no sign of cracking on the pavement so far.

- **Plan for Fiscal Year 2009**

Overall the project is on track. The FY09 activities will include the following:

a) Preparation of samples and testing of APA rut at 50°C and 40°C, and to compare with the APA rut data obtained at 64°C. The laboratory rut data will show susceptibility of rutting due to temperature. The APA rut will be compared with the field rut as more field data become available.
b) Fatigue testing on more beam samples will continue.
c) Collection of various data, namely traffic data, dynamic data, environmental data, and performance data, will continue.
d) Field testing and distress survey will be conducted periodically as noted in the data collection protocol.
e) Field data will be processed, and efforts on establishing correlations among important parameters (e.g., ESAL vs. rut, ESAL vs. FWD modulus, temperature vs. strain, etc.) will be enhanced.
f) A meeting will be held with ODOT personnel to discuss the progress of the project so far.
g) Maintenance of the instrumentation such as temperature probes, axle sensors and will be done as needed.

Selected References:

1. Monthly reports of the project " Field Performance Monitoring and Modeling of Instrumented Pavement on I-35 in McClain County" submitted to ODOT by the University of Oklahoma team from October 2007 to September 2008.
2. Solanki, P., Khoury, N. and Zaman, M. M. (2007), "Engineering Behavior and Microstructure of Soil Stabilized with Cement Kiln Dust," Geotechnical Special Publication, 172, 1-10
3. Oklahoma Department of Transportation (ODOT) (1999), "Standard Specifications for Highway Construction."
4. Solanki, P., Zaman, M. and Muraleetharan, K. K. (2008). "Field Performance Monitoring and Modeling of Instrumented Pavement on I-35 in McClain County," Construction and Instrumentation report, ODOT Item 2200, Oklahoma.
5. Saskatchewan Highways and Transportation (SHT) (1992), "Evaluation of Bearing Capacities of Subbase and Subgrade Using Dynamic Cone Penetration Test," Standard Test Procedure Manual, STP 240-20, http://www.highways.gov.sk.ca/docs/reports_manuals/manuals/STP_DOC/stp240-20.pdf
6. Miller, G. A. and Zaman, M. M. (2000), "Field and Laboratory Evaluation of Cement Kiln Dust as a Soil Stabilizer," Transportation Research Record, Transportation Research Board, 1714. 25-32