Analysis of Pavement Response Data and Use of Nondestructive Testing for Improving Pavement Design

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16. Abstract (Limit 200 words)

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ABSTRACT

The first fully instrumented flexible pavement test section in Maine was constructed in Fall, 2005. This paper presents the description of the instruments, their installation, and analysis of temperature and stress-strain data collected so far. Temperature data was collected for a period of five months, and stress strain data were collected by running a Maine Department of Transportation truck at different speeds. The temperature data at two depths in the Hot Mix Asphalt layer were analyzed to develop models to predict these temperatures on the basis of ambient temperature and solar radiation. The haversine equation was found to be suitable for modeling the strain response in HMA layers, whereas slight variations were used for modeling the responses in the subbase and subgrade layers. The effect of speed on time of loading was evaluated and models were developed. The hot mix asphalt tensile strains were found to be affected significantly by the time of loading as well as temperature, and the measured strains matched well with the predicted strains at lower time of loading and lower temperatures. Stresses from the subbase were greater than predicted values. The subbase strains matched very well with the predicted ones, especially at lower temperature and lower time of loading. The measured subgrade stresses were greater than predicted stress values. For subgrade strain, the predicted values were found to be consistently lower compared to the measured values. For both stresses and strains in the subgrade, the difference was higher for the higher time of loading and higher temperature. Future work includes using an automated system with a weigh in motion sensor to collect data over the internet and evaluating the effect of environmental conditions on response at the different layers.

Keywords: instrumentation, strain gage, pressure cells

INTRODUCTION

The Maine Department of Transportation (DOT) spends more than $50 million on design, construction, and rehabilitation of asphalt pavements every year. Much of the design procedures are based on 1986 and 1993 AASHTO design guides (***1, 2***), which are primarily empirical in nature. These guides were developed on the basis of field tests conducted in Illinois in the 1960's. Results from these field tests are not applicable for a different climatic region, and also for today's traffic and construction materials. Furthermore, significant changes in layer properties occur as a result of change in seasons, and it is critical that such changes are determined, documented, and considered properly for design, construction, and load restrictions. Analysis of data from properly instrumented pavement test sections can provide invaluable information for proper design and rehabilitation of pavements. Pavement instrumentation has been used in a number of states including Minnesota, Virginia and Pennsylvania (***3, 4, 5***). In-place data is absolutely necessary for adopting a more rational design process – such as the Mechanistic-Empirical design method being proposed by the NCHRP (***6***). Moreover, in many reconstruction projects in Maine, the "new" subgrade consists of a layer of old HMA (remnants of old "pancake" layers) over the soil subgrade – something that is not usually considered in typical pavement structures. Hence, collection and proper utilization of in-place response is crucial for understanding the behavior of these pavements, and hence to test the pavement materials, and model their performance in the most appropriate way.

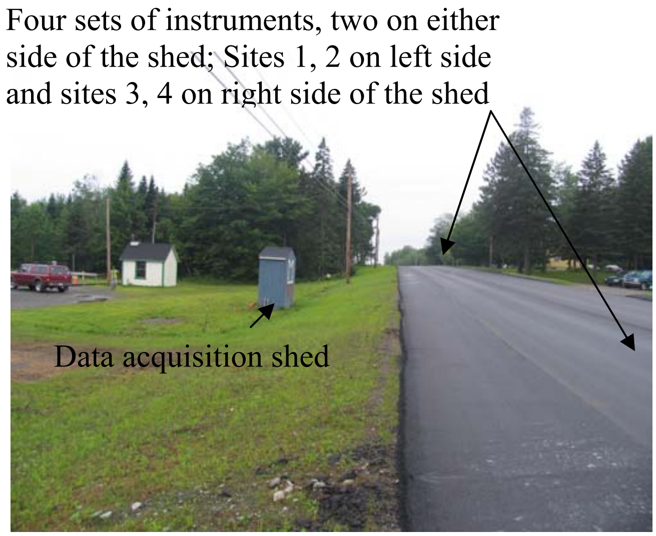
OBJECTIVES

The objectives of this report are to present a description of the instrumentation in the first fully instrumented flexible pavement test section in Maine, experience with the instrumentation and results of testing conducted so far. Specifically, details of instrumentation, modeling of HMA temperature, nature of strain/stress response, effect of speed on time of loading, effect of time of loading and temperature on HMA strain as well as comparison of predicted and measured responses are discussed.

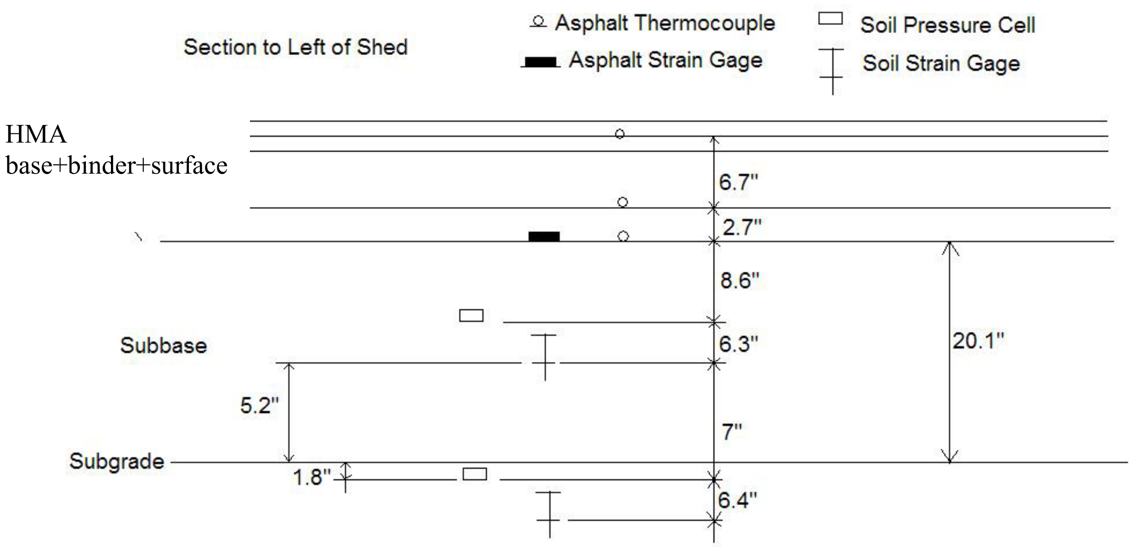
TEST SECTION AND LAYOUT

The test section chosen for this project is a stretch of Route 15 running through Guilford, Maine (Figure 1). The instrumentation consists of thermocouples, moisture gage and resistivity gages as well as HMA strain gages, subbase and subgrade pressure cells and strain gages. Results from thermocouples and the pressure/strain instruments are discussed in this paper.

This test section was chosen as a best representation of a typical totally reconstructed HMA structure in the state of Maine. The existing badly deteriorated road was removed to the subbase level and reconstructed with new material. In this project the "new" subgrade consists of approximately 75 mm of old HMA layer over soil subgrade. The HMA part of the pavement structure consists of a 35 mm thick 12.5 mm Nominal Maximum Aggregate Size (NMAS) HMA surface layer over a 40 mm thick 12.5 mm NMAS HMA binder layer over a 195 mm thick 19 mm NMAS HMA base layer. The subbase is a 510 mm thick crushed gravel layer over the subgrade. Relevant properties of the HMA and the subbase are shown in Table 1.



(a)



1 inch = 2.54 cm

FIGURE 1 (a) Photo of test section; (b) Schematic of layers and instruments. Note: Subbase and subgrade instruments were installed in two sections, whereas HMA strain gages were installed in four sections

TABLE 1 Properties of materials (source: Maine DOT quality control/pay factor database)

Subbase (Maine DOT Type D)

Gradation		Other Properties
Sieve size, mm	Percent Passing	
150	100	Water Content: 5.3 %; Density: 143.5 lb/ft^3
25	81	
19	76	
12.5	69	
9.5	66	
6.3	57	
4.75	52	
2.36	40	
2.00	37	
1.18	28	
0.850	22	
0.60	17	
0.425	14	
0.30	11	

19 mm NMAS HMA base course

Gradation		Other Properties
Sieve size, mm	Percent Passing	
19	99	Asphalt binder: PG 64-28 Asphalt content: 5.1% Voids in Total Mix (VTM): 5.52 % Voids in Mineral Aggregate (VMA): 14.02 %
2.36	45	
0.600	20	
0.300	13	
0.075	5.2	

12.5 mm NMAS HMA binder course

Gradation		Other Properties
Sieve size, mm	Percent Passing	
12.5	100	Asphalt binder: PG 64-28 Asphalt content: 6.0 % Voids in Total Mix (VTM): 5.48 % Voids in Mineral Aggregate (VMA): 15.47 %
2.36	49	
0.600	22	
0.300	15	
0.075	5.9	

12.5 mm NMAS HMA surface course

Gradation		Other Properties
Sieve size, mm	Percent Passing	
12.5	100	Asphalt binder: PG 64-28 Asphalt content: 6.0 % Voids in Total Mix (VTM): 5.1 % Voids in Mineral Aggregate (VMA): 15.0 %
2.36	46	
0.600	21	
0.300	14	
0.075	6.0	

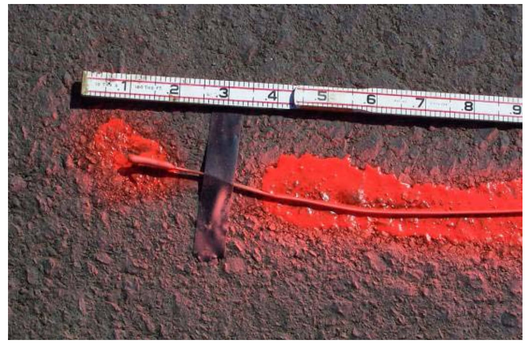
INSTRUMENTS – DESCRIPTION AND INSTALLATION

The following sections provide brief descriptions of the instruments and installation. Figure 2 shows the installation of the different instruments.

Thermocouples

Thermocouples were installed at varying depths to record temperatures in the subgrade, subbase, and HMA layers. Thermocouples are constructed using 20-gauge copper-constantan

Installing Soil Thermocouple



Asphalt Thermocouple Ready for Paving

Soil Pressure Cell Installation Method 1

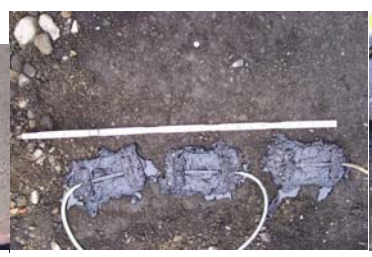
Removing the steel Plug for Pressure Cell Installation Method 2

Soil Strain Gage

Soil Strain Gage Base Installed in Wet Concrete

Soil Strain Gage Top Plate In Place Over Compacted Soil

Geotextile fabric with layer of melted asphalt:



Asphalt Strain Gages Ready for Pavement

Paving over gages

FIGURE 2 Different instruments

(Type T) wire pairs. The end of each wire pair is crimped with a Quick Tip connection and protected with silicone and a heat-shrink cap. The bimetal reaction at the wire tip connection causes an electrical potential that is proportional to the temperature difference between the end of the wire in the ground and the end of the wire connected to a readout device. Using the reference temperature of the readout device, the temperature in the ground can be calculated.

The soil temperatures were measured using two strings of twelve Type T thermocouples. The twelve-pair wire used to construct each thermocouple string was manufactured by the PMC Corporation (Model No. TX-212TE/TE061-20U). For each string, the twelve thermocouples were mounted on a 2.1 meter (7-foot) wooden dowel by threading the wires through holes drilled in the dowel at the following spacing: the lowest five thermocouples were spaced at 0.3 meters (1 foot), and the next six were spaced at 0.15 meters (6 inches). The final thermocouple was left as a flier at the top of the string that could be positioned in the ground away from the other eleven.

Prior to soil thermocouple installation, when the road surface was still at the subgrade level, holes were drilled, and held open with 7.6 centimeter (3 inch) diameter PVC pipe. On the day that the subbase soil was being placed, the pipe was removed, and the wooden dowel with the thermocouple string was lowered into the hole and backfilled with subgrade soil, with a portion of the dowel remaining above the subgrade level. The ends of the wires that would be connected to a readout box were run in 19 centimeter (¾ inch) PVC conduit back to the side of the road. Subbase aggregate was backfilled over this PVC pipe, and around the exposed portion of the thermocouple string, and the top thermocouple flier was positioned approximately one meter out from the dowel and covered with additional soil. With adequate cover over the top of the thermocouple string, normal subbase compaction was completed. This same procedure was used for both thermocouple strings except that the thermocouple flier located on the right side of the instrumented section was not positioned away from the rest of the string. The thermocouples were placed so that the top of each string would be 0.4 to 0.5 meters below finished grade.

The HMA temperatures were measured at three depths (one very recently) using wire that was obtained from Omega Engineering, Inc. (Part # TT-T-20-SLE). This wire was the same as the soil thermocouple wire except that it contained only a single pair of copper-constantan wires instead of twelve and was covered in a heavy duty coating that would withstand paving temperatures. For installation, the temperature measuring ends of the wires were place on the road surface, and paving was completed as normal over the sensors. The wires were extended off and down away from the road in buried PVC conduit.

Soil pressure cells

Vertical stresses in the soil are measured using four soil pressure cells installed in the subgrade and subbase soils. The gages are Dynatest Soil Pressure Transducers (SOPT), type FTC 1. The pressure cells are circular with a 68 mm (2.6-inch) diameter, and are 13 mm (0.5 inches) thick. The body of the pressure cell was constructed using titanium to help prevent the deterioration of the gage due to environmental conditions, as well as due to the wear of normal use. The surface of the cell is covered with epoxy and sand, to improve performance in a variety of types of soil. The SOPT cells have a hydraulic design to improve issues with linearity and sensitivity that have been encountered with other pressure cell models. The cell is covered by a thin membrane, and an integrated pressure transducer measures the pressure inside the liquid-filled cell. The pressure cell has an almost constant volume, so the gage is sensitive to pressure over its entire area.

The soil pressure cell’s internal transducer has a full strain gage bridge, and has a maximum excitation voltage of 12 volts. The pressure cells were calibrated, and then installed with a 12-volt power supply. The pressure cells are temperature compensated for the range of -15°C to 150°C, and they have a service life of over three years, and a fatigue life of over three million cycles. The pressure cells are rated to record pressures from 10 to 200 kPa.

Three different techniques were used to install the soil pressure cells. Some of the cells were installed using roofing compound to attach the gage to a flat soil surface so that it would remain in place as fill was placed over it. The second technique involved the use of steel plugs that were machined with the same diameter as the pressure cells. The cylinders of steel were placed in the location where the pressure cell would be installed, and soil was compacted around them. The cylinder was removed from the soil using a magnet, and a hole within the compacted soil remained where the pressure cell could be placed. One of the soil pressure cells at location 3 was installed by just placing the cell at the correct depth, and compacting soil over and around it. Wires from the gages were buried in PVC conduit extended back to the side of the road.

Soil strain gages

The soil strain gages used on the project were Soil Strain and Deformation Transducers (SSDT), type FTC-1. The SSDT gages consist of Linear Variable Differential Transformers (LVDT) that can measure both permanent and dynamic strains in soil. The range of the gages is approximately +/- 5mm (0.2 inches), which corresponds to a change in voltage of +/- 10 volts. The gage is made of stainless steel, and consists of a cylindrical base with a 80mm (3.1 inch) plate on top of it. A thin, movable rod extends up out of the base and plate, and a second plate can be attached at the top of that rod.

The four gages used for the project were each connected to their own signal conditioner. The signal conditioners and a corresponding +/- 15 volt power supply were made by Schaevitz Sensors specifically for use with LVDTs. Prior to installation, the gages were calibrated in the lab with a corresponding signal conditioner. The calibration process was completed to relate gage extension to voltage output, using the gages' ranges of 5mm and 10 volts as a starting point. After calibration, each gage was installed first by filling a hole in the soil with a stiff mortar mix and placing the base of the gage into the material so that it would remain in place during the rest of installation and compaction. Soil sieved through the #4 sieve was placed on the bottom plate, and around the rod, and compacted by hand. Once the rod was almost completely covered, the top plate was screwed into place, and soil was added to cover the gage. More hand compaction was done, and the gage voltages were checked to ensure that the strain gages were adequately within their +/- 10 volt range. In most cases, the gages needed to be uncovered, the top plate removed, and more soil added and compacted. The process was repeated until the soil between the top and bottom strain gage plates was compacted enough, to prevent excessive movement during construction so the gage would still be responsive to traffic driving over the road. Wires extending out of each SSDT base were buried in conduit extending back to the side of the road.

HMA strain gages

Altogether twelve Pavement Strain Transducers (PAST) II Hot Mix Strain Gages were installed. The Past-II gauges have a full range of up to 1500 microstrain based on a 10V excitation scale. The quarter bridge sensor has a 120 ohm resistance, with an effective length of 102 mm, with two anchoring flanges 75 mm in length. There were a total of four sites selected within the section, each with three asphalt strain gauges. For each site, one gauge was laid closest to the middle of the predicted wheel path, and another was placed on either side of center, approximately 7 to 8 centimeters apart. Gauges were placed in the longitudinal direction at sites one and three, and placed in the transverse direction at sites two and four. Before the first lift of 19mm NMAS HMA base course was laid, small strips of geo-synthetic fabric was laid down on the subbase in the location of the strain gauges. A mixture of sand and asphalt binder was heated and poured in a thin layer over the fabric. Before the mixture was allowed to cool, the strain gauges were pressed into the mix, and the wires were run through conduit leading to a shed containing the data acquisition system. A small amount of HMA was shoveled from the back of the paver, and laid over the gauges, then lightly compacted with a small hand roller. The paver was then allowed to continue over the area as it normally would. The responses from longitudinally placed strain gages are discussed in this paper.

ADDITIONAL INSTRUMENTATION

In addition, soil moisture gages, model CS615 water content reflectometers from Campbell Scientific, were installed to monitor the moisture content of the subgrade and subbase. Thermal resistivity probes, built by ABF Manufacturing in Minnesota, were installed to monitor the depth of frost penetration. However, these results will not be discussed in this paper.

DATA ACQUISITION SYSTEM

Each type of gage described has its own scheme of data acquisition. The dynamic stress and strain gages have an in-computer system that allows for high speed data collection, while the static environmental data gages are connected to a data acquisition system that collects hourly readings. The different components of the data acquisition system are shown in Figure 3.

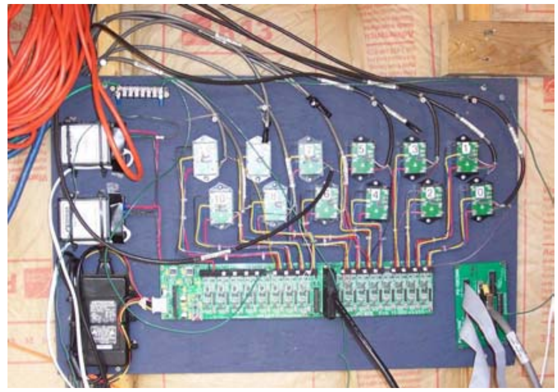
Two high speed data acquisition boards were installed in a Dell Optiplex computer to be kept on-site. Both boards were part of the United Electronics Industries, Inc. (UEI) PD2 series of multifunction data acquisition boards. The PD2-MF-64-333/16L board has 64 single ended/32 differential 16-bit analog input channels, is capable of taking 333,000 readings per second, and is equipped for gains of 1, 10, 100, and 1000. The PD2-MF-16-150/16L board has the same characteristics, except that it has only 16 single ended/8 differential channels, and it collects up to 150,000 readings per second.

The soil strain gages are connected to their own signal conditioners described earlier. The signal conditioners are connected differentially to UEI's PD-STP-3716 screw terminal panel (STP). The soil pressure cells are connected to their own STP. Both STPs are connected to the PD-5BCONN which serves as a connector back to the 64 channel board in the computer.

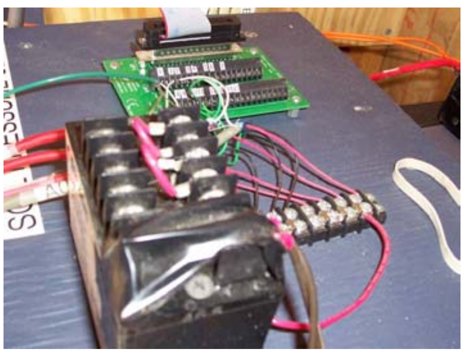
The asphalt strain gages are each connected to an Omega Engineering, Inc. BCM-1 bridge completion resistor that provides bridge completion for the 120 ohm quarter bridge strain gages, as well as a potentiometer for zeroing the gage. The twelve bridge completion resistors are connected to a signal conditioning board made by UEI. The PD-ASTP-16SG is powered by a +/- 15 volt power supply, and is also connected to two 10 volt power supplies which provide the power to the strain gages. The signal conditioner also provides amplification. For the asphalt strain gages, the highest available amplification of 200 was chosen.

The temperature, moisture, and resistivity gages were all connected to CR10x dataloggers made by Campbell Scientific, Inc. AM25T multiplexers were used with the dataloggers for the thermocouples. Readout boxes manufactured by ABF Manufacturing were used as the interface between the datalogger and the resistivity probes. The six moisture gages were connected directly to a CR10x.

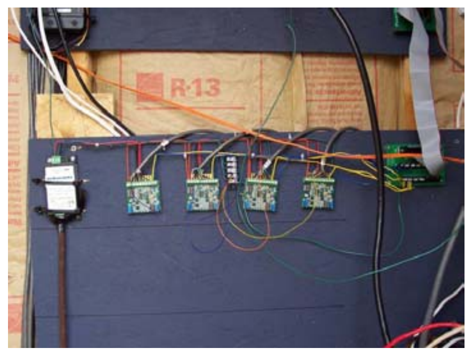
Data Acquisition Computer



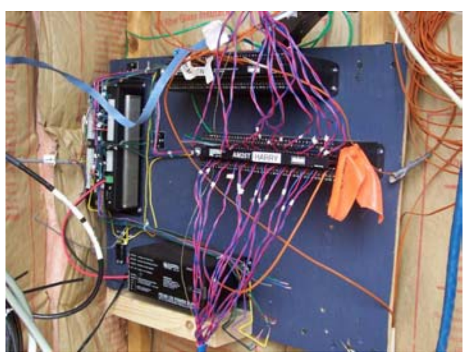
Asphalt Strain Data Acquisition Board – Individual Bridge Completion Resistors, Signal Conditioner, Power Supply for Signal Conditioner, Power Supply, Power Supplies for Gages



Soil Pressure Cells Data Acquisition



Soil strain data acquisition



CR10x Data Acquisition

FIGURE 3 Different components of the data acquisition system

PROBLEMS ENCOUNTERED

In total, twelve asphalt strain gages, six asphalt thermocouples, four soil strain gages, four soil pressure cells, six soil moisture gages, twenty four soil thermocouples (in two strings), and two frost resistivity probes have been installed.

Three of the twelve asphalt strain gages were damaged, and do not give any strain responses. The middle transverse gage at location two was damaged during setup prior to paving. The middle longitudinal gage at location three was damaged during the paving process. The protective asphalt layer placed on the gages either was not thick enough or not compacted properly, and the weight of the paver pushed the gage, so that part of the gage was exposed. Additional HMA was added, but the gage had been damaged. The transverse gage closest to the centerline at location four showed no physical signs of damage before or during paving, but after paving took place, a check of the gage resistances showed that the strain gage was not responsive.

No difficulties were encountered with the soil strain and pressure gages during installation, and all were responsive. After the first winter, the pressure cell in the subbase at location two started giving erratic responses. It is unknown at this time if the problem is with the gage itself, or with the wiring setup, and further investigation is required.

TEMPERATURE DATA

The temperature data from the HMA base thermocouples were used to develop a model to predict subsurface temperature from ambient temperature, depth and solar radiation (*7*). This model can be used for predicting subsurface temperature in different parts of Maine. Since the data from thermocouples at two depths are available, two separate models were developed for the two depths with ambient temperature and solar radiation as the independent variables. A total of 2,753 hourly temperature data points from March through June 2006 were used to develop each model. The equation for the mid depth of the base and the bottom of the base are, respectively,

$$T_{pavement} = -16.72+0.562*T_a+0.448*R_s,\ R^2 = 0.873$$
$$T_{pavement} = -22.85+0.361*T_a+0.648*R_s,\ R^2 = 0.882$$

Where, $T_{pavement}$ = Pavement temperature in ^oC, Ta = ambient temperature in ^oC and R_s = Solar radiation in kJ/m^2 day

Figure 4 shows plots of ambient temperature, recorded pavement temperatures and those predicted according to the Diefenderfer model (*7*). The predicted and the recorded temperatures match very well.

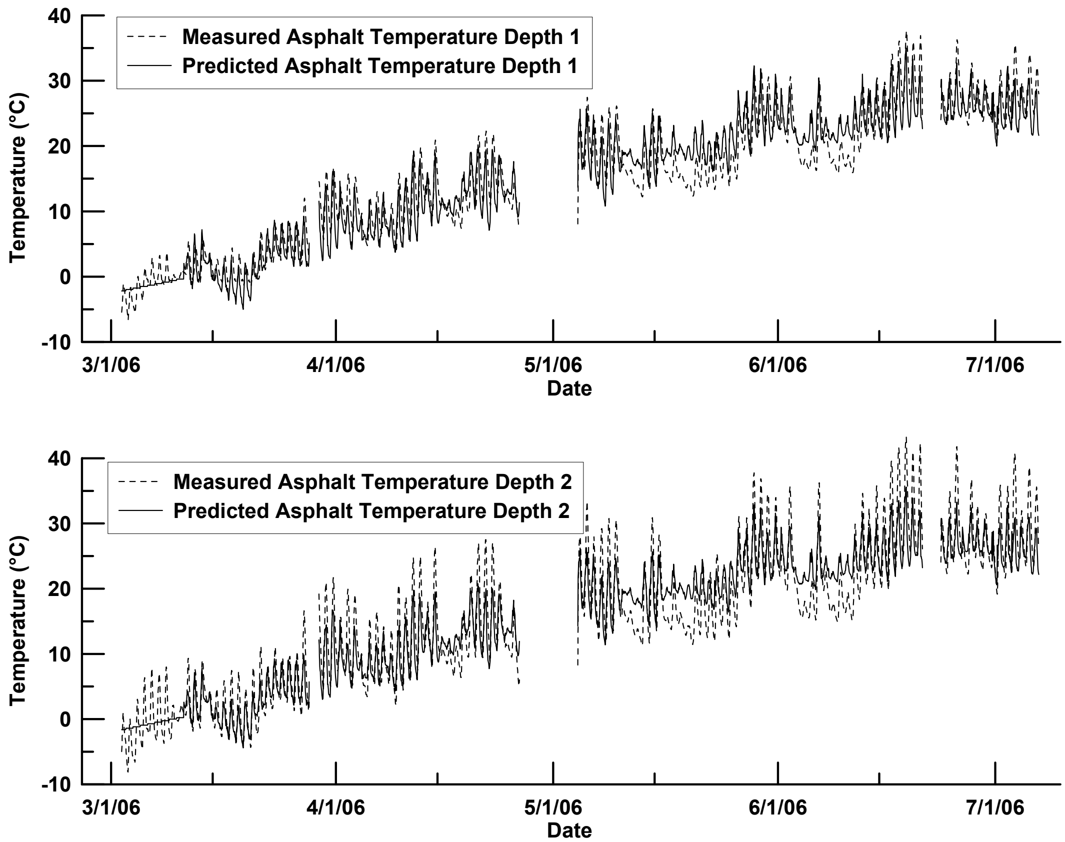


FIGURE 4 Plots of temperature versus time

STRESS-STRAIN DATA

Stress/strain data was collected from the field with a filled dump truck supplied by Maine DOT. Scales were used to determine the load applied by each tire (front and back, 5,750 lb and 15,100 lb, respectively), and contact stresses were determined using these loads. Data was collected with the truck running at various speeds within a short range of temperature. Three sets of runs were made to determine the effect of (rising) temperature. In each set, the truck was run at five different speeds, to capture the effect of speed on the responses. Figure 5a shows typical HMA strains and subbase pressure and strains resulting from the passage of the front and back axles of the truck.

Response Pulse

The responses were studied to develop models for theoretical analysis. The derived models as well as the fitted curves for HMA strain and typical subbase/subgrade stress and strain are shown in Figure 5b. Note that while the traditionally used $y=\sin^2(pi/2 + pi*t/d)$ (where t is time and d is duration) equation is well suited for the HMA strain response, slightly different equations were found to be better suited for the soil pressure ($y=\sin^9(pi/2 + pi*t/d)$)/strains ($y=\sin^6(pi/2 + pi*t/d)$). Note that the time lag in strain recovery (elongated shape of the recovery part) is evident for both HMA and soil strains. This has been also noted by Al-Qadi et al (*4*), and has been attributed to the viscoelastic nature of the HMA material. The presence of old HMA in the subgrade most likely contributed to the lag noted in the subgrade strain.

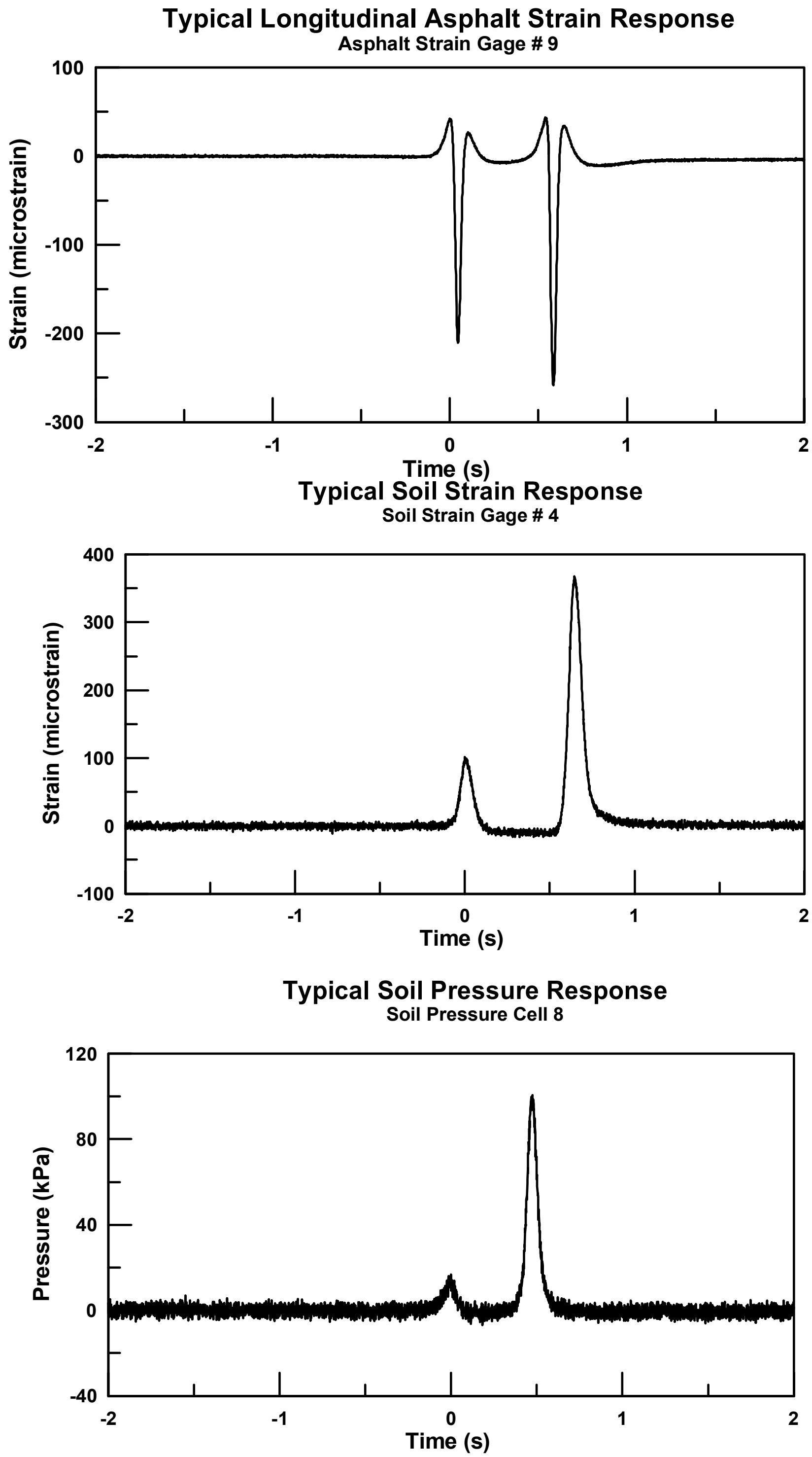


FIGURE 5a Typical HMA strain and subbase pressure and strain

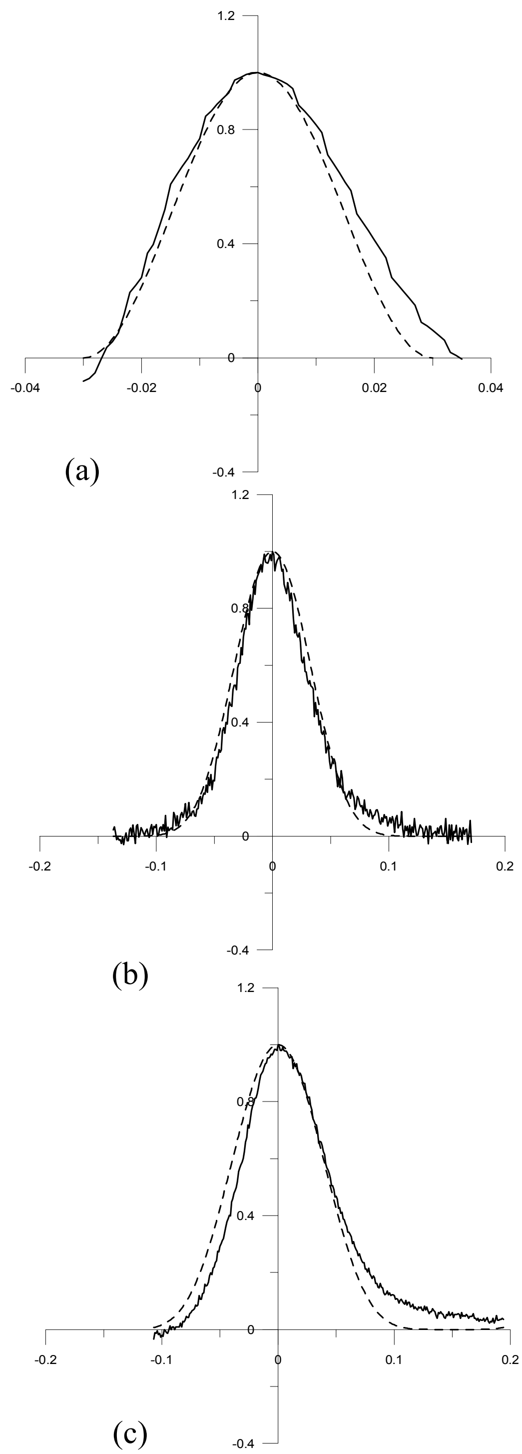
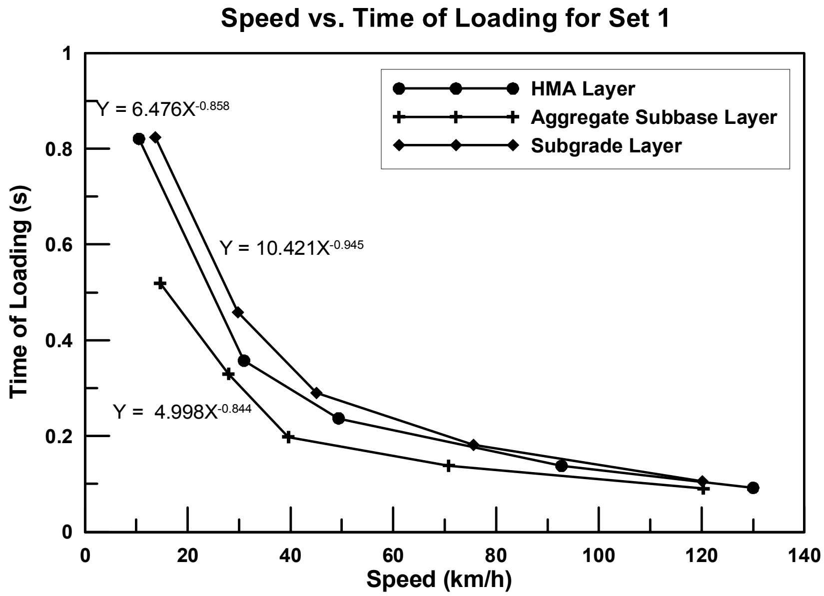


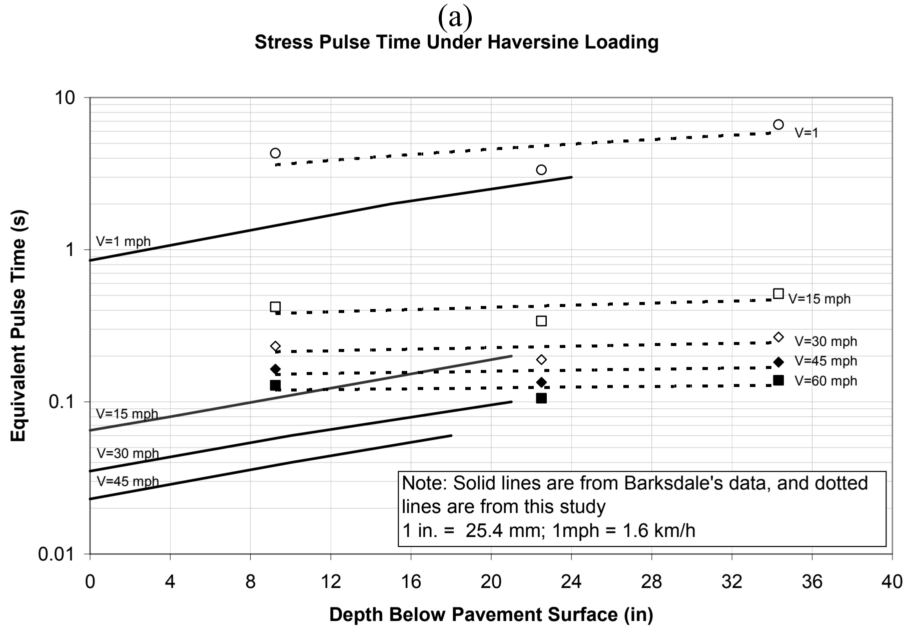
FIGURE 5b Fitted curves on measured responses; (a) HMA strain; (b) soil pressure; (c) soil strain

Effect of Speed/Loading Time

The responses were studied to determine the time of loading corresponding to the different speeds. Although the truck was instructed to run at specific speeds (from slow to fast), the speed was determined from the time interval between the responses due to the passage of the first and the second axle, and the known distance between the two axles (4.6 meters). Plots of speed versus time of loading for the three different layers are shown in Figure 6a. Good models in the form of $Y=AX^{-B}$ (*7*) were obtained between speed and time of loading for all of the layers. Figure 6b compares time of loading data calculated using the model equations obtained from this study to data for similar depths and speeds taken from the first comprehensive study on this by Barksdale, 1971 (***8***). Note that the data for the different depths in this study are obtained from different layers (HMA strain pulse, subbase and subgrade stress pulses) and are not from the HMA layer only. Nevertheless, it is worth noting that for such a pavement, the time of loading is two to three times greater than the loading times from Barksdale's data. This increased loading time should be considered during laboratory testing and theoretical modeling.



(a)



(b)

FIGURE 6 Plots of speed versus time of loading for different layers

Plots of time of loading versus strain for the HMA layer show a significant effect of time of loading (Figure 7). The strains show an increase with increase in time, and this increase is more pronounced at the two higher temperatures. The increase in strain between a time of loading of 0.1 and 0.6 seconds from 27°C to 29°C ranges from 18 to 61 percent.

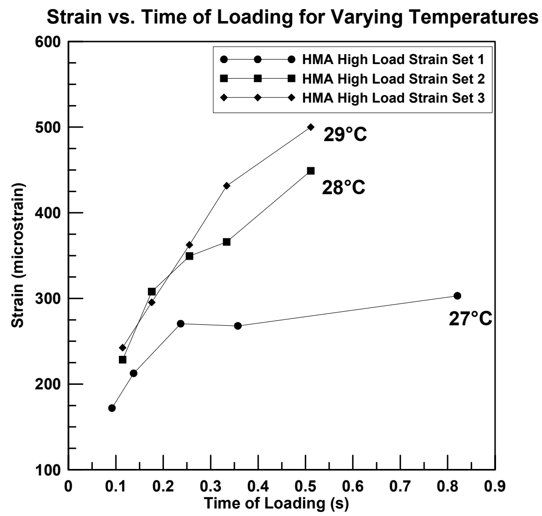


FIGURE 7 Plots of time of loading versus HMA strain

Comparison with Predicted Responses

All of the available material properties were used along with the structural information in layered elastic analysis to predict stress and strain responses. The layered elastic program, BISAR (***9***), was used for prediction of stress/strain. Note that there was a slight difference in thickness of the subbase and the base layers between the sections 1,2 and 3,4. These differences were considered during analysis with BISAR. The in-place material properties were obtained from backcalculation of data from Falling Weight Deflectometer (FWD) tests conducted on the sections – one set on sites 1, 2 and another on sites 3, 4. The average temperature during the FWD tests was 27°C. While comparing the measured data with the predicted data, only those measured values which showed reasonable trend (such as increasing strain with increasing time of loading) were used. The comparisons for HMA strain, subbase stress and strain and subgrade stress and strain data are shown in Figure 8.

Tensile strain in HMA

In each plot, the results from three different runs, at three different temperatures are shown. For data from each run shown on the HMA strain plots, the measured values at lower time of loading are closer to the predicted values than the measured values at higher time of loading. The plots indicate that the predicted value overestimates strain values at lower time of loading but underestimates them at higher time of loading. Also, for each time of loading, the measured values at higher temperature are higher than the measured values at lower temperature.

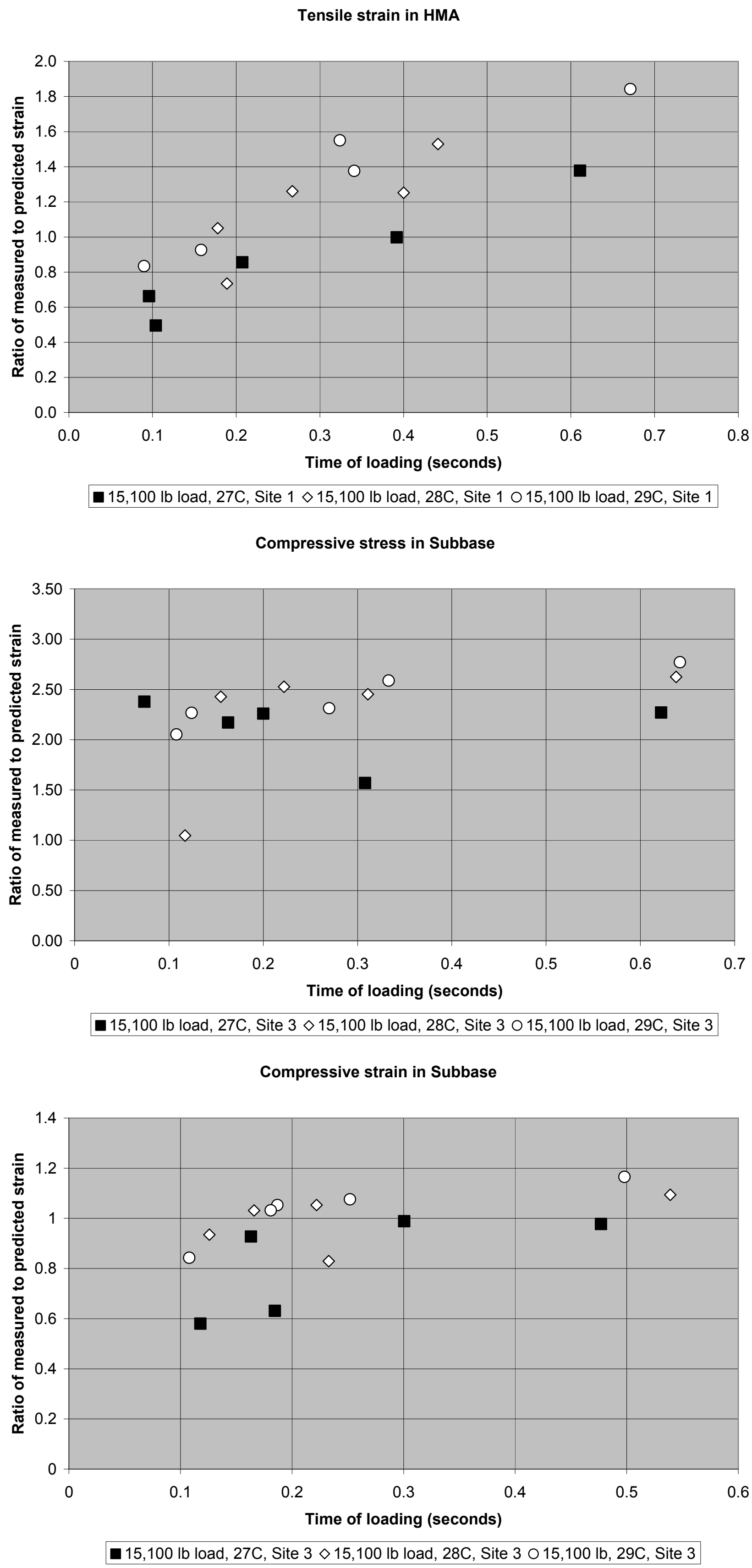
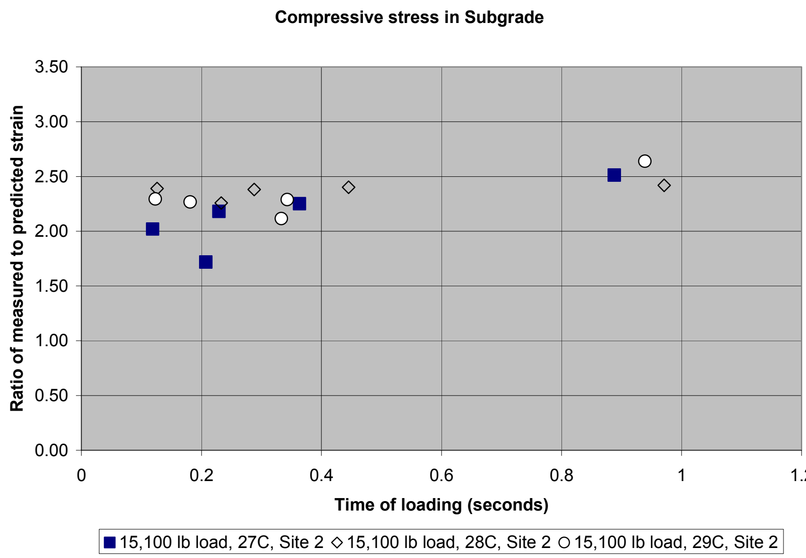


FIGURE 8 Comparison of predicted and measured responses



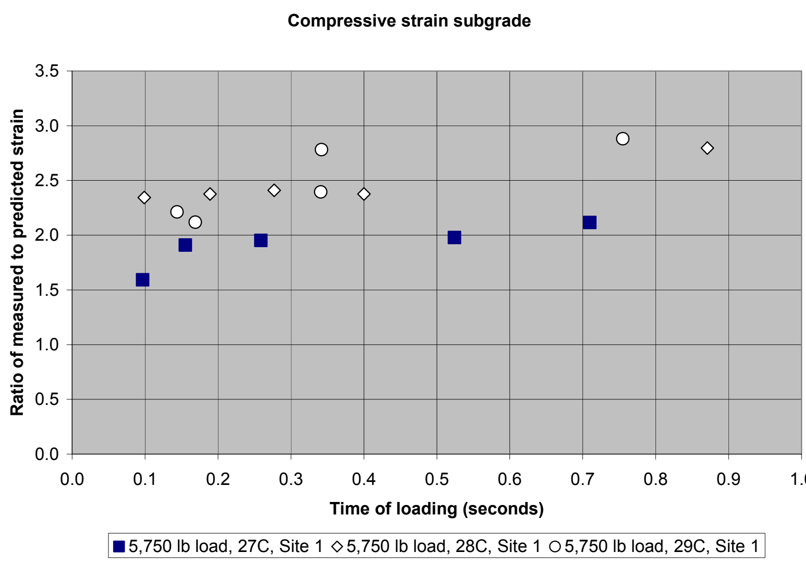


FIGURE 8 Comparison of predicted and measured responses (continued)

Stress/strain in Subbase

Measured subbase stresses are typically underpredicted, and this is shown by the 1 to 2.8 range of the ratio of measured stresses to predicted stresses. The general trend shows a small increase in this ratio as the time of loading increases. In contrast, the subbase strains compare well with the predicted ones, especially for the 27^{o}C data. The ratio of measured to predicted values range from 0.6 to 1 for the 27^{o}C, and from 0.8 to 1.2 for the higher temperature data. The time of loading seems to have a small effect on the strain values – the ratios increase with an increase in time of loading.

Stress/strain in Subgrade

Subgrade stresses measured using pressure cells are higher than the predicted values. The ratio of measured to predicted values ranges from 1.7 to 2.6. There is a slight trend showing an increase in the measured to predicted ratio as the time of loading and the temperature increases. The strain behavior is similar to the stress behavior. For compressive strain in subgrade, the ratio of measured to predicted values show values that are consistently higher than 1, ranging from 1.6 to 2.9. The ratios are lower for lower time of loading and lower temperatures, indicating a greater difference between the measured and predicted strains for higher time of loading and higher temperature.

FUTURE WORK

Installation of a Weigh in Motion (WIM) sensor and multilayer deflectometers are planned in the 2006-2007 period. The data acquisition system will be programmed to be triggered by the WIM instrumentation, so that automatic recording of data could be made. Also, the data acquisition system is being hooked up to network so that the data can be accessed through the internet. Temperature, moisture and frost data are being collected through different seasons and the data will be analyzed to determine the effect of environmental conditions on the stress-strain response in different layers.

SUMMARY

This report presents a description of instrumentation at the first fully instrumented flexible test pavement test section in Maine. Strain gages were installed at the bottom of the HMA layer as well as in the subbase and subgrade, while pressure cells were installed in the subbase and the subgrade. Other instruments consist of thermocouples, moisture and thermal resistivity probes. Models relating temperature at two depths of the HMA layer with ambient temperature and solar radiation were developed. Stress/strain data were collected using a loaded truck running at different speeds at different temperatures. The response pulses at different layers were modeled with the haversine equation and its slight variations. The effect of speed on the time of loading at the different layers was examined, to develop equations for predicting time of loading for laboratory testing, for example, for different traffic speeds for similar structures in Maine. The effect of time of loading on HMA strains, especially at higher temperatures, was well manifested in the measured data. Comparisons of predicted versus measured responses showed that the tensile strains in the HMA layer match with the predicted ones at lower temperature and lower time of loading. For subbase, the stresses were under predicted, whereas predicted strains matched quite well with the measured strains. In the case of subgrade, both the stresses and the strains were consistently higher than the predicted values – the difference increased with an increase in time of loading and temperature. The results from this ongoing study provide much needed information on response of typical reconstructed pavement in Maine, which can be used for laboratory testing and theoretical modeling, as well as in structural design using mechanistic procedures.

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