FINAL REPORT

Acquisition/Acceptance, Installation and Operation of FDOT's Accelerated Pavement Testing Vehicle

Contract Number BC-354

UF 4504746/12

Submitted by:

David Bloomquist, Ph.D., P.E.
Department of Civil Engineering
345 Weil Hall
PO Box 116580
University of Florida

Gainesville, Fl 32611

January 30, 2003

FINAL REPORT

BACKGROUND

During the last five years, the FDOT has expended an enormous amount of time and effort in requesting and ultimately acquiring a state-of-the-art accelerated pavement-testing device (APT). The initial effort was carried out by FDOT personnel who located the various manufacturers of these unique devices. After careful consideration, it was decided to purchase a unit from OMC Ltd. in South Africa. This unit, termed a Heavy Vehicle Simulator (HVS) is marketed in the U.S. by Dynatest, and without a doubt, the most sophisticated and modern testing device in existence. The ultimate objective of its usage is that it will provide Florida with an invaluable tool in assessing pavement design and its' long-term performance.

In order to assist the FDOT in the above endeavors, the PI was asked to submit a research request to the FDOT in order to facilitate the coordination of HVS acquisition and preliminary operation. Specifically, the following tasks were submitted for consideration.

PROJECT SCOPE OF WORK

Task 1. The Principal Investigator will be responsible for evaluating and providing comments to the FDOT concerning all aspects of the HVS procurement, delivery and operation. All transmittal documents (progress reports, memoranda, plans and specifications, etc.) between the FDOT, the vendor as well as other consultants involved will be perused for correctness including omission and co-mission errors. Further, it will be the responsibility of the PI to suggest alternatives, additions, and potential problems.

Task 2. The PI will accompany the FDOT representative to South Africa to inspect the HVS and provide consultation with respect to initial acceptance of the unit. Finally, the PI will assist the FDOT upon HVS transport to Gainesville for checkout and final acceptance.

Task 3. Once final acceptance has been completed and the unit is operational, the PI will immediately begin designing a stand-alone data collection system. A detailed listing of sensors, DAC cards, power supplies and appurtenances will be provided.

Task 4. The PI will assist the FDOT in all aspects of the design and installation of the sensors (primarily thermocouples) in the test tracks. In addition, instrumentation/data acquisition and feed back control expertise will be supplied.

Task 5. It will be the responsibility of PI to hire and fully fund a research assistant to coordinate and assist FDOT personnel in the installation, calibration, and operation of any and all HVS related sensors. In addition, the collection and dissemination of data will be conducted.

Once Dynatest's proposal was approved, the PI reviewed the seller's technical documents and provided comments to the FDOT on several pertinent issues. Also, he attended numerous meetings between FDOT and Dynatest personnel during contract negotiations. Ultimately, an agreement was signed that included several optional enhancements.

SYSTEM ACQUISITION

In March of 2000, the PI along with FDOT personnel made a trip to South Africa for preliminary acceptance testing. The main goal of the trip was to carefully document and verify that the specifications of the HVS corresponded to actual system performance characteristics. This visit ended (and acceptance rejected) due to the carriage bearings freezing due to inadequate lubrication. In addition, several hydraulic leaks were discovered. Hence, a second trip was made in May to complete the testing process. This second trip resulted in an acceptable result. The HVS was then prepared for shipment to Gainesville and arrived in late September.

As a side note, during the trips to South Africa, the PI made two visits to the CSIR Institute to exchange information on a variety of pavement related equipment.

DATA ACQUISITION PURCHASE

While the device was in transit, the PI made an extensive search of data acquisition systems and determined that the FIELDPOINT system by National Instruments was the most appropriate for the project. The system is a distributed, remote I/O system that allows for data acquisition and control from remote locations. Hence, FDOT personnel could monitor the data via the Internet if desired. In addition, its' networking technology, the I/O devices can be positioned closer to the sensors /testing location for improved performance. This is due to the absence of long sensor lines running to the DAC. Instead, a RS-232 cable transmits the data digitally from the DAC to the computer – thereby reducing extraneous noise. The system that was purchased and assembled comprised the following items:

Gateway Computer – 500 MHz system
Lookout Software
Fieldpoint Modular I/O system
- FP-1000 Network Interface Module
- FP- TC-120 Thermocouple Modules (8 channels/module, 3 modules)
- FP-DI-300 Digital Input Module
- FP-AI-111 Analog Input Module

The system described above allows for the monitoring of 24 thermocouples in addition to 8 channels of miscellaneous sensors. It is designed to operate in noisy environments and is extremely rugged.

The software, Lookout, is designed to rapidly change a monitoring parameter and more importantly, resets itself if power is interrupted. This is very important due to the frequency of the HVS's maintenance schedule.

MISCELLANEOUS EFFORT

While not part of the contract requirements, the PI was asked for help in the identification, purchase and assemble of 121 thermocouples for the first FDOT research project. Thus, research was performed to determine the most cost effective method of creating these sensors. After lengthy investigation and numerous inquiries, Type K thermocouple wire was purchased (7000 feet). This wire is identical to the actual thermocouples, but does not have the tig welded measuring junction. This solution was adopted in order to save substantial funds, however the measuring junction had to be created. This was accomplished using a safety-wire twisting device and the PI successfully produced the 121 thermocouples – saving approximately $2500 for the FDOT. This wire-twisting device is a novel use of it for thermocouple construction and will be useful to FDOT in future temperature related projects. Prior to installation of the wires, it was necessary to verify their operational limits. Hence, a series of tests were performed through a temperature range of zero to 100 degrees Celsius. The transient, or sudden response within this range was also evaluated. It was found that the thermocouples performed equally well compared to the manufactured units. There was no measurable difference between the in-house version versus the purchased ones. Therefore, it was concluded that the field thermocouples could be successfully produced by tightly twisting the ends using safety wire pliers and then applying silicone to waterproof them. This method has an added benefit in that they can be rapidly assembled in the field in the event that one becomes damaged or additional sensors are required. This property was very important because the asphalt placement for the test tracks occurred virtually simultaneously with the thermocouple installation and it was imperative that the contractor not be delayed.

DATA ACQUISITION INSTALLATION

Once the computer hardware and software arrived it was set up at the FDOT APT facilities. In order for the Lookout software to display the readings of the thermocouples, the software must communicate with the Fieldpoint hardware. Several ideas were contemplated on how to connect the DAC hardware that is located adjacent to the HVS, to the computer in the control room. The most cost effective method was to use a serial cable as opposed to an Ethernet or wireless modem. However, standard cables are limited to runs of 100 feet or less. This is because noise may affect the digital signals. However, a highly shielded cable was purchased (250 feet) from Black Box Inc. for a very reasonable price. Originally, we had planned to run the cable from the DAC to the mobile lab, and move it as the HVS moved to the various test tracks. However, since the new facility was almost ready for occupancy, it was felt that a permanent method was warranted. Hence the RS-232 communication cable was pulled through the 4” underground power conduit system thereby linking the FieldPoint hardware to the Lookout computer. Utilizing underground conduit served three purposes: to keep the test area free from as much surface clutter as possible, reduces the possibility of damaging the cable by traffic and to decrease to amount of electrical noise the communications wire might be exposed to.

Final DAQ Installation

Prior to the start of the testing, it was decided that the outdoor data acquisition hardware was in need of a weatherproof housing. Initially the Fieldpoint modules were kept under a tarp, which was connected to an indoor computer via the underground Serial RS-232 cable. A large plastic utility box was purchased by the FDOT, and the Fieldpoint modules were subsequently installed within this enclosure. This setup had the additional advantage of providing storage space for the spare parts and equipment necessary for proper maintenance on the thermocouple wires.

After consulting FDOT personnel, it was decided that no more than eight thermocouples were to be used at this time. In their previous setup, the eight thermocouples were spanned over three FP-TC-120 thermocouple modules. This made their identification within the Lookout software program unintuitive. Therefore, all but one of the thermocouple modules were removed. In addition, thermocouples 7 and 8 (surface thermocouples) were installed and run to the utility box. Because these thermocouples were surface mounted, it was necessary for them to be mobile; therefore, they were simply taped into position. This allows them to moved while the HVS switches testing tracks. Thermocouples 1-8 were installed on terminals 0-7 on the thermocouple module. This allowed for faster changes of thermocouples than the previous placement.

Due to the unforeseen effects of the weather on written tags that labeled the different thermocouple wires, identification of each individual thermocouple was made impossible. Two ways were developed to determine the location of the thermocouples. The first method involved placing an ice bag and/or water over the probable location of a thermocouple and the checking the temperature readings of the various thermocouples until two were found that were significantly below the rest. The thermocouple with the lowest temperature was the higher thermocouple i.e. thermocouples 4, 5, or 6. The thermocouple with the higher temperature was the lower one i.e. thermocouples 1, 2, or 3. The second method involved using a heat lamp early in the morning when temperatures are cool. Instead of looking for the lowest temperature, one looked for the highest temperature. The heat lamp had the advantage of being many times faster than the ice method. For example, the heat lamp caused a temperature change in a matter of minutes, while the ice bag method took hours. The newly found thermocouples were them labeled with a metallic labeler. The new label was more permanent and resistant to the weather. It was also decided that in the future, if and when new thermocouples are placed down, that each set of thermocouple wires be grouped in some fashion. It was suggested that small pieces of PVC pipe to form collars for each bundle would perform well for this purpose.

Because of the hardware changes made to the Fieldpoint modules, adjustments to the Lookout software were also necessary. These consisted of changing the addresses referenced by the various displays within the Lookout panel. Aliases were created for each thermocouple, specifically Thermo 1 – 7. Displays on the display panel were referenced back to the thermocouple aliases. Thus, changing the locations of the thermocouples on the thermocouple modules no longer required the panel displays to be reconfigured, but rather just the thermocouple aliases. Temperature indicators were also added for the two surface thermocouples.

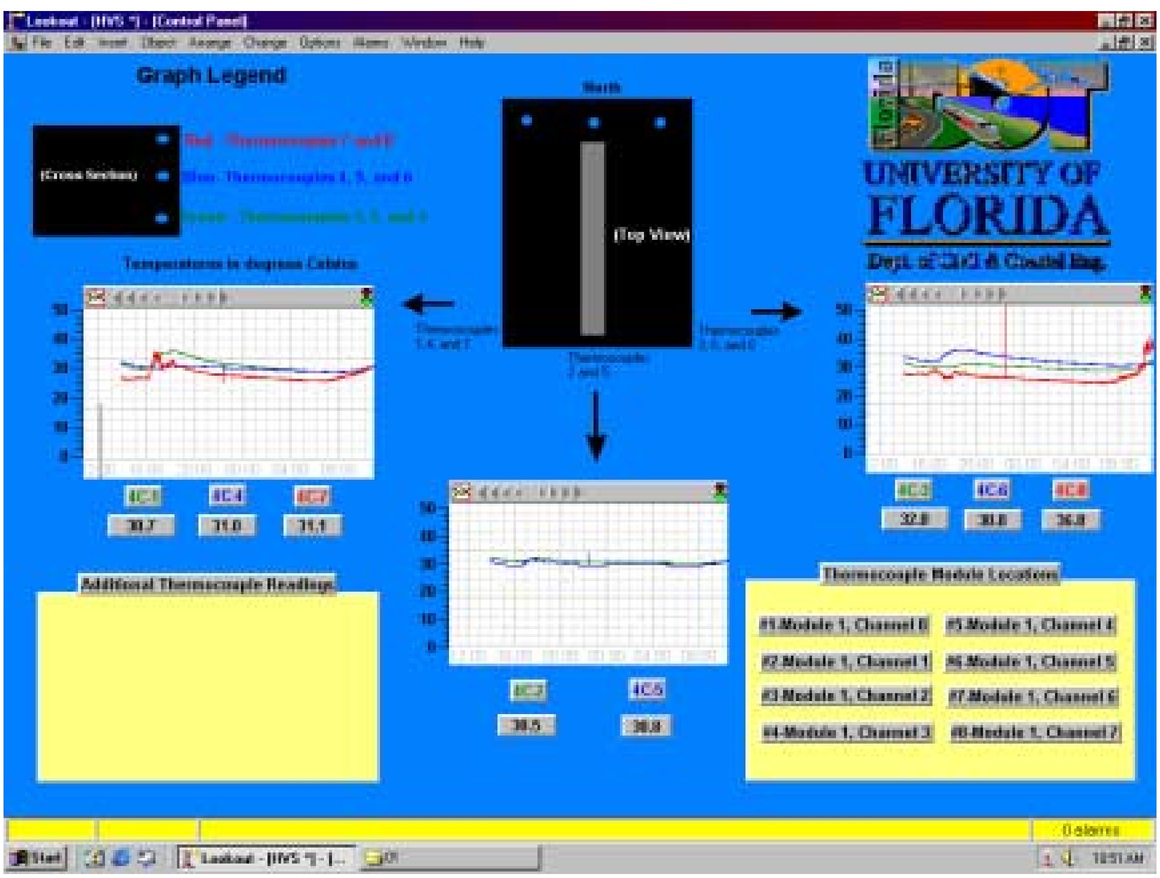
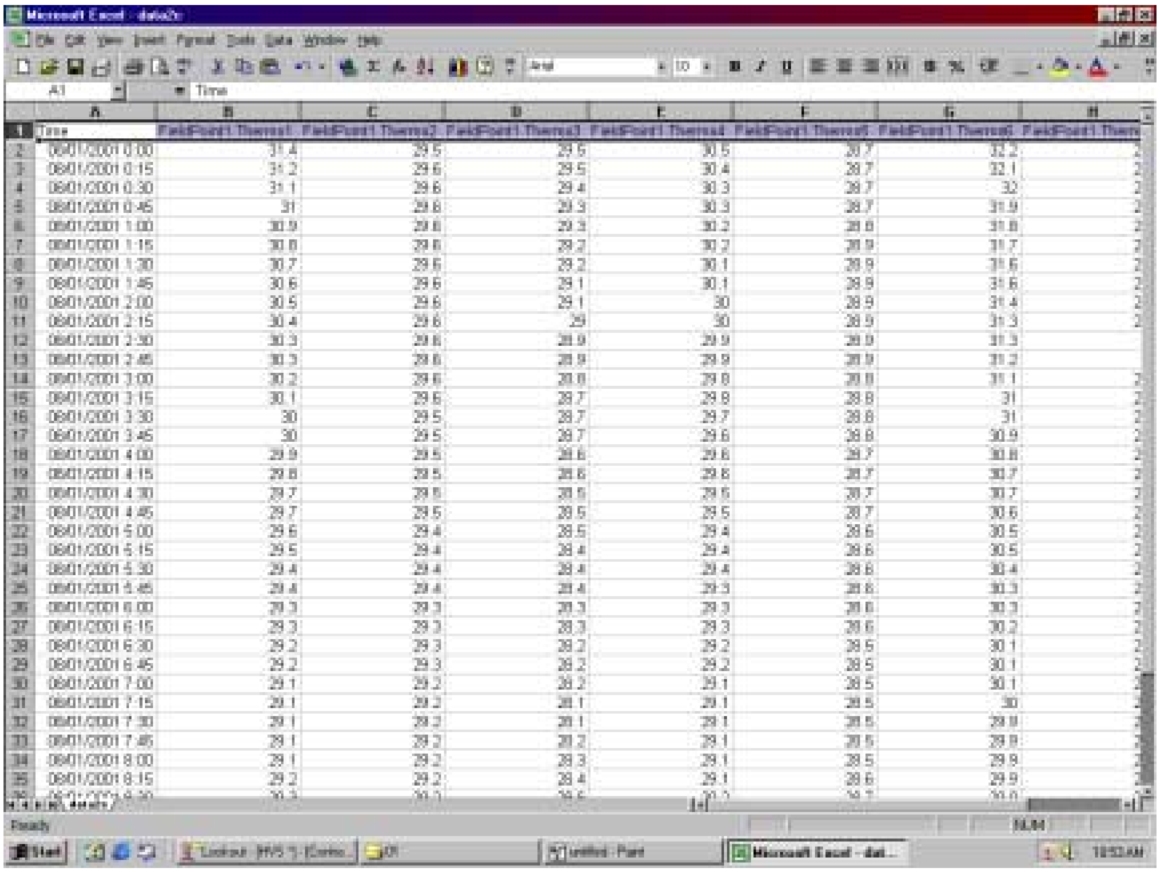


Fig. 3- Panel Display

With the addition of these thermocouples, the spreadsheet was also modified to accommodate them with places for additional thermocouples as well as the daily running average for each thermocouple.



	Time	FieldPoint1.Therm1	FieldPoint1.Therm2	FieldPoint1.Therm3	FieldPoint1.Therm4	FieldPoint1.Therm5	FieldPoint1.Therm6	FieldPoint1.Therm
2	06/01/2001 0:00	31.4	29.5	29.5	30.5	28.7	32.2	2
3	06/01/2001 0:15	31.2	29.6	29.5	30.4	28.7	32.1	2
4	06/01/2001 0:30	31.1	29.6	29.4	30.3	28.7	32	2
5	06/01/2001 0:45	31	29.6	29.3	30.3	28.7	31.9	2
6	06/01/2001 1:00	30.9	29.6	29.3	30.2	28.8	31.8	2
7	06/01/2001 1:15	30.8	29.6	29.2	30.2	28.9	31.7	2
8	06/01/2001 1:30	30.7	29.6	29.2	30.1	28.9	31.6	2
9	06/01/2001 1:45	30.6	29.6	29.1	30.1	28.9	31.6	2
10	06/01/2001 2:00	30.5	29.6	29.1	30	28.9	31.4	2
11	06/01/2001 2:15	30.4	29.6	29	30	28.9	31.3	2
12	06/01/2001 2:30	30.3	29.6	28.9	29.9	28.9	31.3	
13	06/01/2001 2:45	30.3	29.6	28.9	29.9	28.9	31.2	
14	06/01/2001 3:00	30.2	29.6	28.8	29.8	28.8	31.1	2
15	06/01/2001 3:15	30.1	29.6	28.7	29.8	28.8	31	2
16	06/01/2001 3:30	30	29.5	28.7	29.7	28.8	31	2
17	06/01/2001 3:45	30	29.5	28.7	29.6	28.8	30.9	2
18	06/01/2001 4:00	29.9	29.5	28.6	29.6	28.7	30.8	2
19	06/01/2001 4:15	29.8	29.5	28.6	29.6	28.7	30.7	2
20	06/01/2001 4:30	29.7	29.5	28.5	29.5	28.7	30.7	2
21	06/01/2001 4:45	29.7	29.5	28.5	29.5	28.7	30.6	2
22	06/01/2001 5:00	29.6	29.4	28.5	29.4	28.6	30.5	2
23	06/01/2001 5:15	29.5	29.4	28.4	29.4	28.6	30.5	2
24	06/01/2001 5:30	29.4	29.4	28.4	29.4	28.6	30.4	2
25	06/01/2001 5:45	29.4	29.4	28.4	29.3	28.6	30.3	2
26	06/01/2001 6:00	29.3	29.3	28.3	29.3	28.6	30.3	2
27	06/01/2001 6:15	29.3	29.3	28.3	29.3	28.6	30.2	2
28	06/01/2001 6:30	29.2	29.3	28.2	29.2	28.5	30.1	2
29	06/01/2001 6:45	29.2	29.3	28.2	29.2	28.5	30.1	2
30	06/01/2001 7:00	29.1	29.2	28.2	29.1	28.5	30.1	2
31	06/01/2001 7:15	29.1	29.2	28.1	29.1	28.5	30	2
32	06/01/2001 7:30	29.1	29.2	28.1	29.1	28.5	29.8	2
33	06/01/2001 7:45	29.1	29.2	28.2	29.1	28.5	29.8	2
34	06/01/2001 8:00	29.1	29.2	28.3	29.1	28.5	29.9	2
35	06/01/2001 8:15	29.2	29.2	28.4	29.1	28.6	29.9	2

Fig 4. Spreadsheet Thermocouple Display

General Electrical Maintenance Work

After HVS testing began, maintenance work was necessary to keep the DAQ system running. This consisted of switching thermocouple wires to new tracks as the HVS was moved, and performing repairs to Lookout software package and the Windows operating system. The DAC computer was also configured so that in the event of a system failure, DAQ operations could be brought back online with a simple reboot of the computer.

Due to unforeseen circumstances, both the Fieldpoint data modules and the DAQ computer were damaged following lightning storms. The damage to the Fieldpoint modules consisted of the FP-1000 module not responding to attempts to communicate with it over its serial connection. It was also found, that the serial port on the computer was damaged. Thus, a PCI serial card was added to the computer, to replaced the damaged port. The FP-1000 module was also sent back to National Instruments for repairs. To prevent interruptions in DAQ operations, an additional FP-1000 module was ordered. It was initially assumed the damage had been a freak occurrence, but subsequent repeat failures of the DAQ system occurred, necessitating the need for a long-term solution. Following a series of strikes that damaged the two working FP-1000 modules, a third was bought to continue uninterrupted monitoring of temperature data. A new PCI serial card was required for this as the previous one was also damaged. To protect the computer from further damage, an optical isolator was purchased for the serial cable linking the computer to the FP-1000 module. In addition, after the HVS was damaged by these same strikes, it was determined that the testing facility has a poor ground connection. The damage to both the HVS and the DAQ system are theorized to be caused by this faulty ground. HVS testing was stopped, and a new ground rod was installed near the test tracks. The HVS was then attached to this ground rod via a length of cable. The power supply powering the DAQ was also attached to this new ground rod. The theory is that the faulty ground prevented a safe disposal for the surges in the system, thus causing internal damage. With the new ground installed, the surges were properly handled by the installed UPS. With the three FP-1000 modules, any further damaged to the DAQ system should be able to be dealt with without an interruption in operations.

During operations, the installed thermocouples worked properly. A daily plot of the data, as it appears on the DAQ screen is shown below.

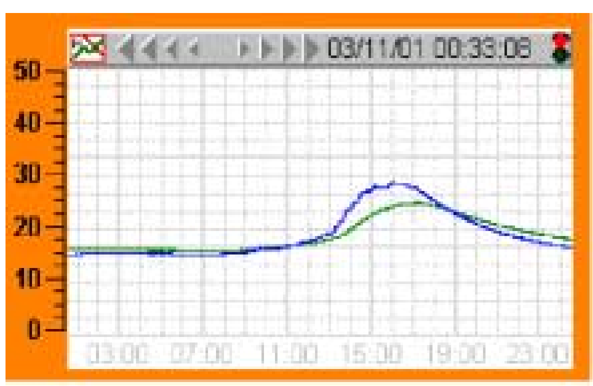


Figure 5: Example of Thermocouple Data

However, when electrical noise was present, the graphs of the data became filled with “spikes,” - data points that are the extreme values of the thermocouple. Since thermocouples voltage data is measured in millivolts, even a small amount of noise can create vastly erroneous data.

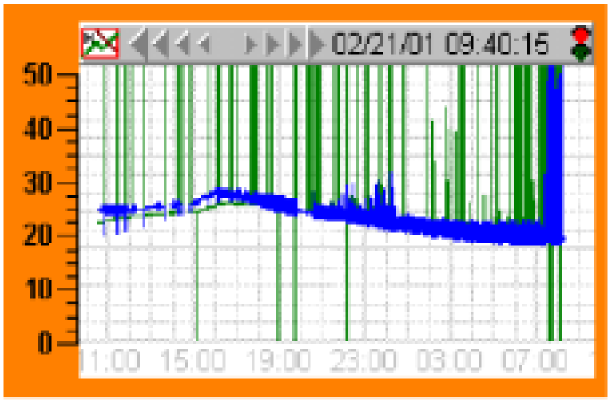


Figure 6: Example of Noise in Thermocouple Data

When the data acquisition system was initially installed, there was no noise and the entire data appeared as shown in Figure 6. After a period of time however, spikes began appearing during the evening hours. Eventually, the spikes occurred during the course of the entire day. The cause of this noise generation was baffling and great lengths were taken to: a. determine its source, and b. eliminate the noise. Because it is virtually impossible to eliminate all the noise from a field-installed system – especially one in which 480 VAC permeates the surrounding environment, the basic goal of this process was to create data reliable enough so that the spreadsheet data was not compromised. Fortunately, through the following process, the majority of the noise was virtually eliminated from the data.

When spikes were first seen, they only occurred during the evening hours. These times corresponded very closely to the times when the high voltage outdoor lighting system was activated at the Materials Office. Therefore it was thought that the noise could be originating from electrical noise produced from the sodium vapor lamps. However, this theory was disproved when the spikes re-occurred on a night when the lighting system was purposely left off.

Once the corrupted data began occurring at all hours, several alternative ideas were brought up as possible reasons. Among these was that the thermocouples were acting as strain gages, as the HVS wheel passed over the particular sensor. However, it was felt that the magnitude of the voltage output was too high to be created by the straining of the twisted pairs of thermocouple wires. A more likely scenario was that of static electricity. This theory was further enhanced because as cooler weather materialized, the spikes worsened. The HVS testing program started during the Fall when the relative humidity was high – typical of Florida's atmospheric conditions. The spikes began to worsen as cooler weather moved in.

To test these ideas, the HVS wheel was run along the track at full load, and then using ever-decreasing wheel loads. Eventually it was found that the spikes always occurred when the tire was directly over the affected thermocouples, and that they occurred regardless of the load on the tire. In fact, the spikes occurred even when the tire was run over the thermocouples, without being in contact with the ground. Therefore, it was concluded that the noise was generated from static electricity build up on the tire itself. The spikes did not occur early on in the testing program because the relative humidity outside was sufficient to attenuate electron discharge from the tire to the thermocouple. As winter arrived, the humidity would drop during the night at first and hence the spikes only were evident during that time. However, eventually the RH was low enough during the entire day. In fact, a recommendation was made to install a weather station at the test facility to monitor RH, air temperature and rainfall.

Once the cause of the spikes was identified, effort focused on two areas: grounding protection for the thermocouples and/or static removal. Because the AC power to the Fieldpoint hardware was running from an outlet located on the HVS, it was not clear if a ground loop was created. Therefore, a large copper-grounding rod was inserted in the ground near the system and connected to the data acquisition unit. The channels displaying noise were then each grounded to this common point. This setup improved the data significantly. In addition, a separate AC power source running from the control room to the DAC hardware was installed which further enhanced the data.

Static removal devices were also utilized in the attempt to eliminate the spikes. It was found that using a product such as Static Guard could eliminate the noise for a short period of time.

Therefore, an industrial static removal spray was purchased, and its application was made part of the daily maintenance of the machine. Also, anti-static brushes were mounted to the HVS so that they were always in contact with the tire. The sum of all of these efforts was the elimination of nearly all the noise in the system. As the weather continued to warm and the relative humidity increased, the data continued to improve.

During HVS testing, maintenance work was also necessary to keep the DAQ system running properly. This consisted of switching the thermocouple wires to new tracks as the HVS was moved, and performing repairs to the Lookout software package and the Windows operating system. The DAQ computer was configured so that in the event of a system failure, DAQ operations could be brought back online with a simple reboot of the computer.

Heating System

As anticipated, a thermal heating system was purchased and eventually installed on the HVS. This new heating system is equipped with its own temperature monitoring system. It was originally planned to discontinue the use of the Fieldpoint/Lookout system entirely and rely solely on the data generated from the heating system's feedback/control unit. However, this idea was abandoned after it was determined that the thermocouples used for the heating system feedback loop would be located at a depth of 4 inches, which is the same elevation needed for the analysis of the asphalt pavement response. Hence, the new plan was to run both the thermal heating system and the Fieldpoint DAQ system simultaneously in order to compare data and check the accuracy of both.

The thermal heating system software required a serial connection between a computer and the heating unit. Using a 100 ft cable would have been unfeasible due to the mobility of the HVS. Therefore, it was concluded that a wireless serial link would be necessary. Different techniques of achieving this goal were considered and a Aerocomm ConnexLink system was purchased. This system operates with two small transceivers that allow a bidirectional RS-232 link for up to 1000 feet.

Fig. 7- ConnexLink Units

The installation of this wireless radio link between the HVS and monitoring computer, for the Heating System, took longer than originally anticipated. The Aerocomm modems were not designed to be exposed to the elements. Therefore, a sealed box had to be designed and constructed to house them. This was task was conducted by FDOT personnel. Following completion of the sealed housing, it was discovered that the heating system supplied an RS-485 connection. The Aerocomm radio modems only connect via a standard RS-232 connection. Thus a converter was purchased to allow for their use with the HVS.   Unfortunately, successful operation of the Aerocomm radio modems was never properly achieved with the new converter. Originally suspecting the fault to lie with the RS-485 converter, the heating system manufacture was contacted. Eventually a new wiring diagram was supplied that would allow for the communications port on the heating system to be wired for RS-232 communication directly. This too, proved ineffective. The radios themselves were considered the next problem. The original Aerocomm radio modems were then replaced with Maxstream radio modems. These new modems operate at 900 MHz rather than 2.4 GHz, and have a line of site range of 10 miles. In addition, unlike the previous Aerocomm units, these modems are packaged in a metal casing, which makes them considerably more durable, and less affected by inclement weather and conditions. Finally these new modems contained all necessary cables and null modem adapters to properly install them. After several hours of installation and setup, the new Maxstream modems enabled a connection, and the HVS heating system finally became truly wireless.

Fig. 8 Maxstream Unit

Windows 2000 Upgrade

The DAQ monitoring computer received an upgrade to Windows 2000 Professional. This was done to allow the computer to be connected to the local DOT network. As expected, this caused no insurmountable problems with either the Lookout software or the Fieldpoint hardware. One problem did occur with the computer's serial card drivers, but was eventually resolved with the assistance of the FDOT IT department. The use of Windows 2000 also had the added benefit of allowing higher security for the Lookout software, thus preventing unauthorized users from signing on to the computer and making catastrophic changes to the program or its operating environment.

New Thermocouple Installation Technique

A new method of installing the thermocouples into the ground was developed. Instead of placing them during the asphalt placement, the thermocouples are installed after the asphalt is set. Installation is done by drilling small holes into the asphalt, inserting the thermocouples (using the probe style as opposed to the tig welded junction) inside, and lastly, filling the holes with epoxy. It was found that thermocouples installed in this way are nearly as accurate as the previous method, yet much easier to accurately locate and install.

SUMMARY

The primary focus of this project was the acquisition of the Heavy Vehicle Simulator (HVS). In addition to the HVS, a data acquisition system from National Instruments was ordered and installed. To supplement this DAQ equipment, two wireless serial links were also purchased to allow a more versatile environment for the testing system. During the course of the testing, a laser profiler, and heating system were also added to the HVS, to improve its' testing capabilities.

The following sections outline the areas of effort expended on the project.

Heavy Vehicle Simulator

The FDOT's HVS was successfully acquired, set up and enhanced with several accessories. This involved two visits to South Africa prior to final acceptance of the unit.

Data Acquisition System

To supplement the test performed on the pavement tracks, a temperature data acquisition system, consisting of a Gateway Computer, and DAQ hardware by National Instruments, was purchased. This DAQ system measured temperature data from different sets of thermocouples embedded within the asphalt.

The NI DAQ equipment consisted of hardware modules called Fieldpoint modules, and a software interface called Lookout. The Lookout interface provided a means for graphically display the current and historical thermocouple readings via charts and digital gauges. In addition to these live readings, the Lookout software was also capable of logging the values of the thermocouples into a spreadsheet.

Laser Profiler & Heating System

Through the course of the project two major pieces of equipment were added to the HVS. To enhance measurement of the rut created by the wheel, a laser profiler was added. This device was added to replace the previous manual method of obtaining the rut depth. Using the lasers, the computer is able to calculate the depth of the rut relative to the rest of the asphalt.

To eliminate temperature changes of the asphalt, an infrared heating system was installed on the lower portion of the HVS. This system uses infrared heat lamps and fans to maintain a near constant temperature within the asphalt. This system is controlled with an additional software application that uses an RS-232 link to control the Heating Hardware onboard the HVS. To facilitate this, an additional Maxstream wireless-link was purchased to replace the required hard-wire link.

Vishay Instrumentation Equipment

At the projects conclusion, the FDOT requested that any remaining funds be used to purchase specialized Data Acquisition hardware for future HVS tests. Vishay Micro-Measurements manufactures this strain/deformation hardware. The hardware consists of a Model 6100 Scanner, Model 6101 PCI Interface Card and Cable, seven Model 6010A Strain Gage Input Cards, and five Model 6040A LVDT Input Cards. In addition to the hardware, the

StrainSmart Software package was also purchased.

These various input cards are installed within the 6100 Scanner. This scanner then connects to the DAQ Computer using the PCI Interface Card. Finally, using the StrainSmart software the FDOT will be able to take the various measurements and readings with the Strain Gages and LVDT's attached to the input cards.

The total value of the hardware and software purchased from Vishay was $16,020. This amount consumed the remaining funds thereby completing the project within budget.

CONCLUSION

FDOT is to be commended for its proactive effort in acquiring and implementing the HVS at the Research Park facility. The resources now available to both in-house and university researchers are first class. These resources also include a very capable technical team that should provide users with a vast amount of collective experience and expertise. The PI would like to thank FDOT, in particular Dr. Bouzid Chourbane for allowing me to participate in the this worthwhile endeavor. If my services are needed in the future, I will undoubtedly be ready to help in any way I can.