Technologies to Enhance Quality Control on Asphalt Pavements (R06C)

Summary of Lessons Learned from Pave-IR Field Demonstration Projects

The following is a summary of the lessons learned from the field demonstration projects conducted in conjunction with the departments of transportation in Alaska, Virginia, Maine, New Jersey, Illinois, Missouri, Eastern Federal Lands, North Carolina, West Virginia, and Alabama.

The lessons learned have been categorized into six groups: (1) general observations, (2) equipment installation, (3) getting started, (4) data collection, (5) data analysis, and (6) recommended additions to streamline the data analysis process.

General Suggestions

1. The Pave-IR Scan system is not ideal for multiple short paving pulls where the paver has to stop, backup, and continue paving along a different pull. Although it can be used for these types of pulls, it requires that multiple projects or subsections are set up through the software. The system was designed for longer paving pulls in terms of monitoring temperature differentials of the asphalt concrete mat.
2. The temperature sensor is calibrated by the manufacturer and calibration not affected by the software. The temperature readings have high precision, but the sensor accuracy is not adjustable in the field to get exact temperatures. As such, minor differences can be identified between external point temperature readings (i.e. laser thermometer data) when compared to those from the Pave-IR scanner. The system is intended to be used to determine surface temperature differences of the asphalt concrete mat, which it is very accurate in accordance with AASHTO PP80-14.
3. Best practices for loading and unloading of haul trucks, and delivery of material to the paver are essential and should be followed for an asphalt concrete mat with uniform temperatures or minimal temperature differentials. Consistent and uniform material delivery generally produces the lowest temperature difference in the IR data.
4. Use of a material transfer device/vehicle (MTD/MTV) can be used to improve temperature consistency or minimize temperature differentials as long as MTV best practices are also followed.
5. Best practices for placing the asphalt concrete mix through the paver and maintaining the paver should be followed for an asphalt concrete mat with minimal temperature

differentials. Cold spots or thermal streaks may indicate needed maintenance on paver parts including
    a. Slat Conveyers
    b. Knock-down plates
    c. Screed heaters
    d. Augers
    e. MTV re-mixing paddles
    f. Etc.
6. Screed operators and other workers placing the mat sometimes walk on the mat directly behind the paver, which results in invalid temperature readings. In addition, some roller operators operate the rollers as close as possible to the paver screed in compacting the mat. The rollers, workers, and their tools need to stay short of the scanner line of sight to minimize invalid temperature readings.

Installation of the Paver-IR System (Mast Base, Extension and Arm; Scanner; GPS Unit; DMI; and Monitor)

1. Mounting an Infared (IR) scanner head and display monitor may require drilled holes on the paver, or custom attachment points for proper data collection and viewing the monitor screen.
2. Temporary installation by an experienced team on a known paver can be done in under 2 hours. Permanent installations and temporary installations on certain pavers can take upwards of 6 hours or more.
3. All accessories (light balloons, umbrellas, buckets, tools, etc.) should be in place during installation to ensure they do not interfere with the scanner during actual paving operations.
4. Cables are run specifically for each individual paver setup; make sure:
    a. Zip ties are used to run and secure the cables. Magnets with hooks or clamps can also be used
    b. Cable connectors are color coded and pins are uniquely arranged for ease of correct connection. Additional labeling for use by field crews is encouraged.
    c. Sufficient space is provided between moveable parts of the paver and cables or wires so they do not get pinched and disturb the data collection process.
5. The equipment and cables can get wet but shouldn't be soaked in water.
    a. Wire connectors can hold water, so it is better to keep water out, or get them in a dry environment as quickly as possible.
    b. Boots are not used on the connector as they were found to hold water and cause wire breakage.
    c. For removing water from the connectors, the back part of the connector should be removed and the water blown out with compressed air.

6. The distance measuring instrument (DMI) should be installed on a drive hub whenever possible. When the screed support bar interferes with the location of the DMI, the DMI can be moved, but care must be taken to ensure good cable clearance is maintained.
7. **Scanner Height is crucial!** The height determines the scan pattern of 25 cm by setting the angle of the sensor laterally for the scan.
    a. A ladder can be useful to install the scanner each day if the mast is in an inaccessible location from the paver screed.
    b. Ensure the screed is sitting on the ground during height measurement and not supported by wood or debris
8. The distance between the IR scanner and the top of the mat should be about 10 feet. The scanner, however, can be installed at a lower height for ease of installation.
    a. At a 10 foot height, the camera scans an 8 meter width (26.25 ft).
    b. A laser distance measurement tool or a rigid tape should be used to measure the distance from the scanner to the top of the mat. Ensure the angle of the scanner is taken into account so the value can be measured and entered into the display monitor/software.
9. The IR scanner angle is adjustable to get closer or further from the screed.
    a. 5 to 6 feet behind the screed has been found to be a reasonable distance to keep workers out of the data scans, but still result in a good measure of mat temperature directly behind the screed.
10. The GPS unit gets threaded to about a ½ inch, but it only needs to be threaded or installed so that it is secured to the mast and will not vibrate off the mast during paving operations. By only using ½ inch of threading the time to install and remove the GPS unit is reduced.
11. A 12 to 36 volt power source is sufficient, but the system can also operate using a 110 volt generator power.
    a. It is suggested or advisable to connect the Paver-IR unit to the machine power so that the IR system is on when the machine is on.
    b. A shut-off switch may also be needed just for the scanner. This will allow data to continue to upload to the data server even if the paver is temporarily shut down.
12. Generate some slack in the cables for moving the display around to allow clear observation of the monitor during paving operations.
13. Velcro straps can be used to keep cables or the power block temporarily in position.
14. Computer cables are marked and pinned for correct installation.
15. Confirm proper installation of the USB drive, as the system will not run without the drive

Getting Started

1. Set up the project details by scrolling through the menu on the monitor.
2. The DMI calibration should be done at the beginning of each day or after any significant delays in a set of paving operations, especially if the paver is moved to different locations between successive days of paving. This is done through the display software.
    a. The recommended DMI calibration distance is 150 feet.

    b. A paint marker can be used around the DMI mount location on the wheel hub to ensure consistency day to day.
3. The DMI does not count down when the paver moves backwards. As such, a new file should be created anytime the paver moves backwards to shift direction to be certain all paving is scanned by the Pave-IR Scanner.
4. If backing the paver cannot be avoided, the distance will not be measured in the forward direction until the same distance has been covered in the forward direction as was covered in the backwards direction.
5. Two methods of scan can be used.
    a. Manually setting the scan width allows the operator to set specific paving widths and an offset to a significant joint. The scanner will limit itself to these areas.
    b. The auto scan detects paving edges, and is recommended for use in terms of data analyses.
    c. Automatic edge detection will "see" the temperature of the underlying paving materials. If used in echelon paving or multiple layers on the same day, however, temperature thresholds will need to be adjusted to maintain the scan of only the mat currently being placed by the paver.
6. No equipment/monitor adjustments need to be made between day and night paving.
7. The scanner is always moving, but only saves scans based on the set scan distance and the DMI trigger. The scanner may pause scanning during long stoppages, and restart once paver movement resumes.
8. Beware of low wires (clothesline hazard) or dropping the IR unit if the power cord is too short.
9. Make sure the GPS has the unit on the map; the upper right of the display shows the connection status.
    a. Do NOT adjust the GPS offset.
10. Heavy smoke and large raindrops will affect the temperature measurements by the scanner.
11. The scanner can be monitored for relative changes in temperature that can allow some "on-the-fly" adjustments at the plant based on field temperature data and knowledge of the haul route.
12. Be constantly aware of the current temperature scale on the display monitor since the color display can be misleading at a glance.
13. The software effectively eliminates temperatures below the threshold when calculating the temperature difference severity in the field.
14. The paving run on the field computer must be ended at the end of paving or the IR data file may not be closed correctly and not get properly uploaded to the server.
15. Data download is possible by wireless through a computer or via an external flash drive (UPS port) provided with the scanner.
16. Remove the camera, monitor/screen, GPS, and DMI each night, or at the end of paving, to prevent vandalism and weather-related issues.

a. Note the wheel to which the DMI is secured. Consider using a paint marker to outline the DMI location on the hub to ensure proper attachment before paving.

Data Collection

1. Split the data collection file for longer paving segments (continuous day of paving in one direction) to efficiently analyze the raw data.
    a. Large raw data output files can become too large to handle in terms of the data processing and can slow down the analysis.
    b. Separate the data using some logical site feature or difference in paving during the same day (intersections, a delay in paving operations for acceptance materials sampling, etc.).
    c. Recommend using 2.5 miles as maximum run length before creating a new file if another feature is not available
2. Ensure that the IR sensor scans beyond the paving edges, or turn on the automatic edge detection to represent the entire width of paving lane.
3. Collect GPS coordinates with Pave-IR data for post processing/analysis of data.
4. Update inputs to reflect most current paving project (daily and/or when a new MOBA/Pave-IR file is created).

Data Analysis

1. Prescreen data to eliminate outliers and invalid data. In order to eliminate invalid temperature readings recorded during paving, all thermal profiles should be pre-processed using a clearly defined set of criteria. The following criteria have been typically used, which were adopted from Tex-244-F.
    a. **Eliminate temperature measurements within two feet of the edge of the uncompacted mat**: To meet this criterion, the raw data temperature contour plots should be visually inspected to determine the edge of the paving lane. The edge of the paving lane can vary for the different paving days or collection times. The required point locations must be excluded based on the mat edge. Figure 1 (on last page of this document) shows a schematic of the analysis zones and the contour plot configuration. As seen in Figure 1, the paving area and scanning widths are the same in this configuration.
    b. **Eliminate locations of paver stops greater than 10 seconds and beyond the control of the contractor**: The raw thermal profiles from the sampling locations should be examined and locations identified where the paver was stopped for more than 10 seconds. Per Tex-244-F, the thermal profile within 2 ft. behind and 8 ft. in front of each of these areas (in the direction of paving) should be eliminated from the analysis. These areas typically include stops of the paver to allow samples of the mixture to be collected for quality control and acceptance testing. However, the second criterion (eliminate paver stops) is debatable and should only be used when the paver stop is beyond the control of the contractor.

   c. **Eliminate temperature readings below 170°F or above 400°F**: This criterion is to remove any temperature readings influenced by other potential interferences such as human interference, roller interference, and any random error associated with data collection. The minimum and maximum temperature threshold values are project and/or mixture specific.
2. Create a combined Project Summary (for analysis extraction and figures, especially for large raw data files).
3. Create a combined Analysis Summary (to see how many segments show medium and severe temperature differentials).
4. Perform analysis with and without paver delay simultaneously, unless the acceptance plan specifies and/or defines how paver stops are considered.
5. Collect and summarize density data to be incorporated as part of the IR data analysis. The asphalt concrete density data can be entered into the software for evaluating the impact of low temperatures (areas with significant temperature differences).
6. Establish a threshold for minimum paving temperatures for the specific asphalt concrete mat being produced and placed (for outlier detection).

Recommended Additions to Streamline Data Processing

The following are items and features that have been recommended as enhancements to the data analysis software that is currently being used to process IR data. Adding these features to the software tools will be determined and considered under the SHRP R06C project.

1. Add efficiency to data analysis procedures by creating an automation program that:
   a. opens raw data files based on a filename
   b. copy and pastes the raw data into new files, file types, or template created for the analysis
   c. closes the raw file to maintain raw data integrity
2. Queue multiple text files for analysis (i.e., using a batch run capability)
3. Create contour plots automatically (e.g., using R (open source statistical software) or other graphics software)
4. Fix potential issue with paver delays during nighttime paving operations at midnight (overnight paving; 11:59 – 0:00 transition issue).
5. Better streamline asphalt concrete mat data extraction and create automated summary tools (figures, tables, etc.) for evaluating and analyzing temperatures with other properties of the asphalt concrete mat (density, percent compaction, smoothness, etc.).
6. Add option to MOBA software to include random points (PQI/Core identification location and result).

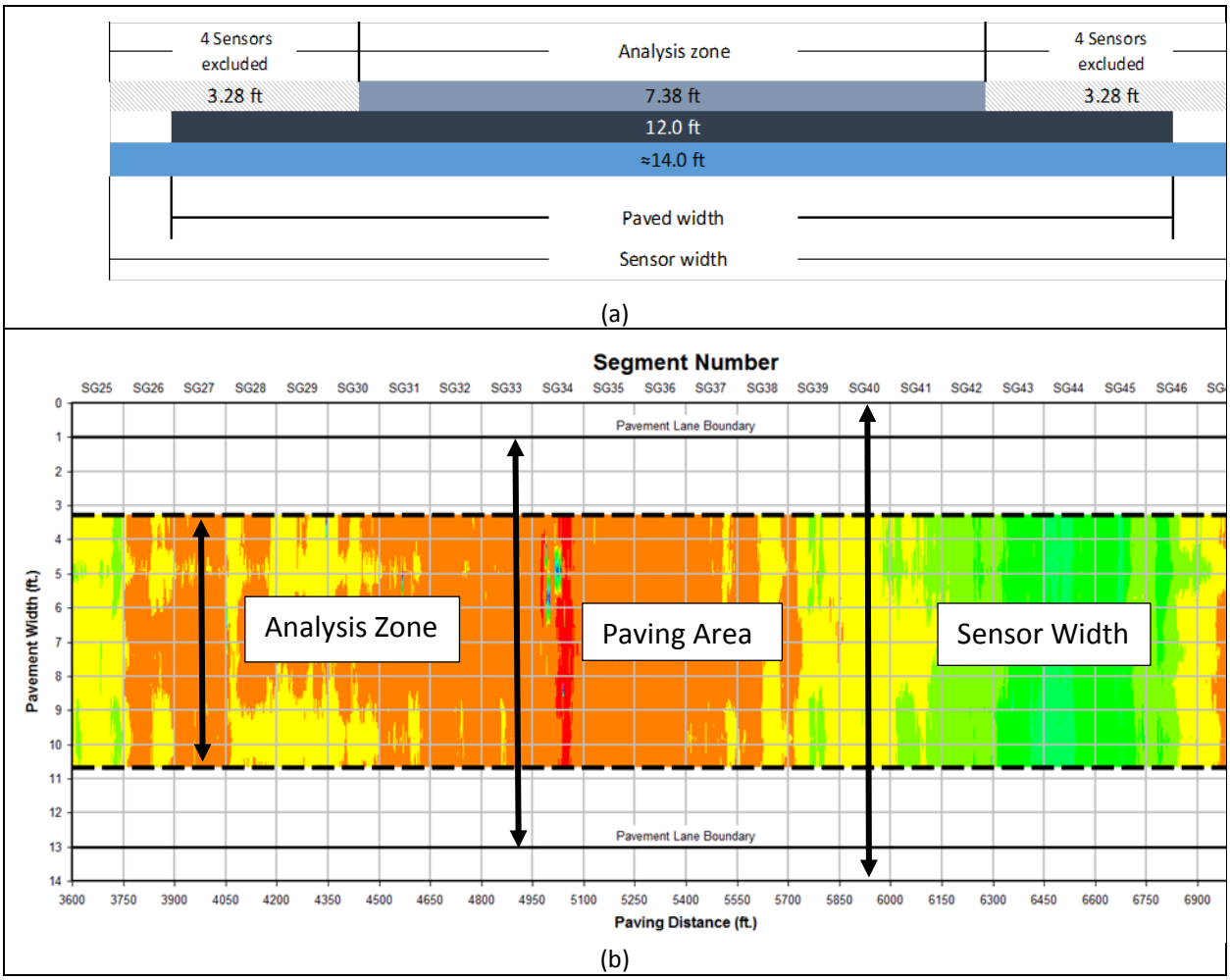

Figure 1. Analysis Zone Adjustments and Contour Plot Configuration