MATERIALS & RESEARCH

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INITIAL REPORT

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THERMAL-IMAGING OF APPLIED BITUMINOUS PAVEMENT STATEWIDE PROJECTS 2005

(INITIAL REPORT)

REFERENCES:

WP 2005-R-10

INTRODUCTION:

The following research initiative examines the phenomenon of thermal segregation and resulting pavement density of flexible wearing courses that were constructed on various projects throughout the State of Vermont during the 2005 construction season. This project was the first to employ an infrared thermal imaging camera in order to identify areas of thermally-induced segregation or temperature differential within the bituminous concrete mats during construction on selected projects administered by the Vermont Agency of Transportation (VTrans). An analysis of data collected is presented herein.

BACKGROUND:

Infrared thermography (IRT) is increasingly being utilized in laboratories and for in-situ measurement of pavement properties. It has also been used in pavement engineering for quality control of paving operations. Cooling of hot mix asphalt (HMA) may occur after the mix is produced until it is applied to the roadway surface and often results in temperature differentials within the mix. This differential may be transmitted through the paver and into the mat. Once applied, the bituminous mat is consolidated with compaction equipment capable of achieving a specific density in accordance with the project specifications. The compaction effort required is often dictated by the temperature of the mix as well as the characteristics of the compaction equipment. If a temperature gradient is present and the compaction effort remains constant across an entire mat, the resulting density will be directly correlated to the mix temperature and will vary with the temperature gradient. This often results in lower compaction and pavement densities below those as indicated in the project specifications. It has been shown that, areas of low density, if left alone, may prematurely crack or form potholes prior to the end of design life.

Four pavement resurfacing projects were selected for monitoring between September 12 and November 12, 2005. All of the projects were designed with various percentages of recycled asphalt pavement (RAP) as part of the completed mix, mix design type and haul distance. The project descriptions are as follows:

1) Barton-Irasburg STP 2107(1)S – The project plans for US 5 specified a leveling course with a Superpave overlay of a 1 ⅜" of a type IV wearing course, which contains a nominal maximum aggregate size of ⅜". The binder specified for this project was a performance graded (PG) 58-34. The rehabilitation began 0.28 miles north of the US 5/VT 16 intersection and extended northerly 5.28 miles in Barton, ending 0.11 miles north of the VT 58 west intersection in Irasburg.

2) Fairlee-Newbury IM 091-2(39) – The project plans for I-91 N in the towns of Fairlee, Bradford, and Newbury specified cold planing and resurfacing with a Superpave overlay of 1 ½" of a type III wearing course, which contains a nominal maximum aggregate size of ½". The binder specified for this project was a PG 64-28. The rehabilitation began approximately 1.0 miles north of exit #15 in Fairlee and extended northerly 12.58 miles in Newbury.

3) Rochester-Granville STP 2124(1) – This project consisted of resurfacing VT 100 in Rochester, Hancock, and Granville, beginning 5.55 miles north of the Stockbridge-Rochester town line and extending northerly 8.30 miles ending in Granville. The project plans specified a leveling course with a Superpave overlay of 1 ⅜" of type III wearing course with a PG 58-34 binder. Please note that this project contains sections of an experimental 50 gyration mix and the standard 75 gyration mix. The number of gyrations refers to the laboratory compaction effort required to produce a test specimen. A 50 gyration mix requires less compaction effort than a 75 gyration mix to achieve the same density.

4) Wallingford-Rutland NH 2207(1) – Resurfacing US 7 in Wallingford, Clarendon, and Rutland Town, beginning 6.229 miles north of the Danby-Wallingford town line and extending northerly 7.722 miles to the Rutland city line, in the northbound lane only. The project plans specified a cold planing, leveling course and a Superpave overlay of type III wearing course with a PG 64-28 binder.

The properties of the binder utilized in the mix has a direct correlation to the compaction effort needed to attain the specified density. As noted above, the two binders that were utilized were a PG 64-28 and PG 58-34. A classification of 58-34 indicates that the binder should perform satisfactorily at an average 7 day high temperature of 58^{o}C at 20 mm below the pavement surface and an average one day low temperature of -34^{o}C at the pavement surface. Both the temperature viscosity curves and experience has shown that a PG 58-34 is easier to compact as compared to a PG 64-28 due to the viscous properties of the binder.

METHOD:

Field data was collected with the use of a Raytek ThermoView TI-30 (Now known as the Fluke Ti30) leased by Dwire Tech. The camera was equipped with a spectral range of 7-14 microns. The camera is able to distinguish temperature bands with color coding at intervals of 5-10 degrees. The temperature is displayed at several points inside the temperature for clarity of interpretation. Thermal images were collected during the application of the mix and surrounding vicinity to identify areas of thermal segregation. Areas with temperature differentials greater than 60 ^{o}F were noted by marking the location with keel as a reference point.

Following compaction, the locations cores were extracted from the mat. Samples were brought back to the Materials and Research Laboratory and tested for bulk specific gravity (G_b), which is defined as the ratio of the unit weight of an asphalt mixture, including permeable and impermeable voids, to the unit weight of water. The bulk specific gravity from each field sample was compared to average maximum specific gravity (G_{mm}) attained from daily reporting of the specific mix from the production plant. Both the bulk specific gravity and maximum specific gravity were used to calculate the air void content and percent compaction for each sample. These compaction values were then compared to the values obtained from in-situ density testing as evaluated by nuclear density gauges during each site visit, as well as, the appropriate State specifications. Core locations were chosen by identifying temperature differentials great than 60 ^{o}F and coring at that location as soon as it was possible to extract that core. Sample locations were chosen purely by using data provided by the thermal images. Random quality assurance samples were acquired to establish a comparative range of compaction within the projects specified above.

FIELD OBSERVATIONS:

Barton-Irasburg – Paving for this project was accomplished by Pike Industries Inc. The mix was produced at their batch plant located in Coventry, VT. The average transport time to the project site was 35 minutes. The target application and compaction temperature was 300^{o}F.

Fairlee-Newbury - Paving of this project was completed by Pike Industries Inc. The mix was produced from their batch plant in Waterford, VT. The average haul time was 1 hour. The target lay down and compaction temperature was 290 ^{o}F. Two core samples were obtained from this project for testing. The average application temperature of these samples was found to be 210 ^{o}F. This was determined by taking the target temperatures of each sample obtained by the thermal camera and averaging these values together. Figure 1 is a photographic shot of the pavement constructed in the Fairlee-Newbury project. Figure 2 shows a thermal shot with the Fluke Ti30 camera of the pavement in the vicinity of Figure 1.

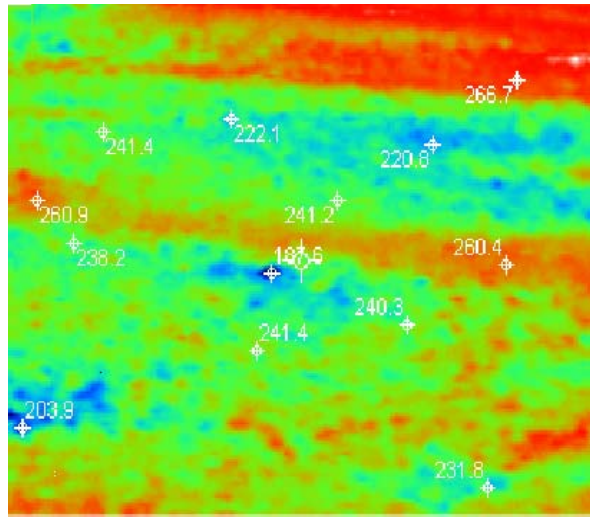

Figure 1
434’ 7” Up-station from mm 95.65

Figure 2
Thermal shot in the area of Figure 1

Rochester-Granville - Paving of this project was accomplished by Pike Industries Inc. The mix was produced from their drum plant in New Haven,VT. The average transport time to the project site was 1 ½ hours. The target application and compaction temperature was 280^{o}F. A few isolated areas of thermal segregation were identified resulting from the relocation of a paver from the lane to the shoulder. The identified segregation locations were minor and occurred at widely varying locations within the HMA mat such that a representative sample could not be obtained. Figure 3 is a photographic shot of the pavement constructed in the Rochester-Granville project. Figure 4 shows a thermal shot with the Fluke Ti30 camera of the pavement in the vicinity of Figure 3.

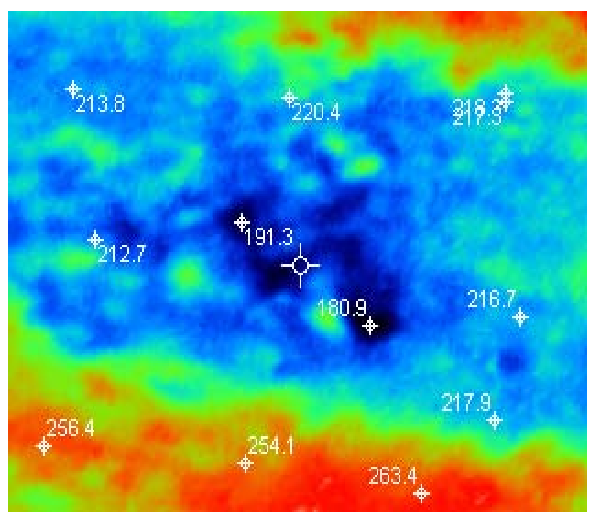

Figure 3
1359’2” Up-station from mm 2.20 in Granville

Figure 4
Thermal shot in the area of figure 3

Wallingford-Rutland – This project was constructed by Pike Industries Inc. The mix was produced from their batch plants located in North Clarendon and Danby, VT. The observed hauling time to the project averaged 15 minutes from the North Clarendon plant and 20 minutes from the Danby plant. The target lay down and compaction temperature was 300^{o}F. No thermal segregation within the HMA mat was detected by the thermal imaging camera.

Table-1 below displays maximum temperature differential observed on images taken for each project.

Project	*Haul Time*	*Ambient Temp* ^oF	*Average Plant HMA Temp* ^oF	*Maximum Temp Differential* ^oF
Fairlee-Newbury	1 hour	58	319	-99
Rochester-Granville	1.5 hours	40	336	-143
Wallingford-Rutland	20 minutes	42	326	-6
Barton-Irasburg	20 minutes	63	331	-11

Table-1 – FIELD OBSERVATIONS

The table identifies haul time and ambient air temperature as contributing factors in thermal segregation. As depicted above, shorter haul distances may have a greater effect on temperature differentials than ambient air temperature.

LABORATORY TESTING RESULTS:

Project	*Haul Time*	*Core ID*	*Core Location*	*Temp* ^oF *Approx Area*	*Lab Testing Compaction*	*Quality Assurance*
Fairlee-Newbury	1 hour	R1	434’ 7” upstation from mm 95.65	220	92.1%	93.8%
Fairlee-Newbury	1 hour	R2	507’ 5” upstation from mm 95.65	200	92.3%	93.8%
Rochester-Granville	1.5 hours	R3	1359’2” upstation from mm 2.20	193	95.2%	94.7%
Rochester-Granville	1.5 hours	R4	947’10” upstation from mm 2.20	226	94.9%	94.7%

The following Table displays the compaction results along with the lay down temperature from the samples that were collected on site.

Table-2 - SAMPLE CORES TAKEN IN THE FIELD

Table-2 identifies four cores that were analyzed by using thermal imaging technology. For a comparison, the quality assurance average compaction value from the day of extraction is also provided. The data on the table appears to neither confirm or deny that thermal segregation has an impact on compaction values. For example, the two results obtained from Fairlee-Newbury do not meet the compaction specifications of 92.5% to 96.5%. The application temperatures of the bituminous concrete associated with these cores are higher than one in Rochester Granville, which exhibits compaction value almost in the center of the specified range. However, these cores from Rochester-Granville were from an experimental 50 gyration asphalt mix which was anticipated to reach optimum compaction with less effort than that required for a 75 or 100 gyration standard Superpave mixture.

Nuclear gauge data was not available for all of the sample core locations. Some contractor based quality control data was used, however this was done sparingly as the results might show bias towards specific locations which did not show adequate compaction. For this project no VTrans employees were available to perform nuclear density testing during our visit.

SUMMARY:

Both thermal imaging and standard photographs have been taken on each of the projects, with laboratory testing being performed on all four procured samples. The core samples were not taken exclusively for the thermal imaging locations, and provide only a general indication of the compaction. The field data that has been collected suggests little evidence of thermal segregation, however the limited number of samples makes it difficult to draw initial conclusions. additional pavement crack and rutting surveys will be conducted to determine if the temperatures noted in the field translate to distress on the pavement surface.

FOLLOW UP:

Additional pavement surveys may be conducted at the locations photographed in these projects to determine the efficacy of using thermal imaging technology on resurfacing projects. These surveys will be done (as part of the annual Pavement Life and Annualized Cost Study) until conclusions can be drawn to the anticipated service life on selected projects and the value of thermal imaging assessed. Additional data, such as nuclear gauge compaction values may be performed on the listed projects.

If future research is conducted, a larger initial sample population is recommended to help establish definitive conclusions concerning the effects thermal segregation on bituminous concrete as related to in-situ pavement density as a means to isolate areas where premature distress may occur.