Use of Infrared Thermography to Control the Quality of Joints Construction and to Detect Reflective Cracking in Asphalt Pavements

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Key Research Area

Transportation infrastructure state of good repair

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OBJECTIVES

The objective of this research is to investigate the potential of using Infrared Thermography (IT) as a Non-Destructive Evaluation (NDE) quality control measure of joints density during asphalt paving construction and to detect reflective cracking potential in hot-mix asphalt (HMA) overlay. Specifically, two applications will be evaluated: (1) control of longitudinal joints density during regular asphalt paving construction and its potential use for taking corrective actions during compaction; and (2) assess density of HMA overlay constructed on top of rigid pavement as an indicator of reflective cracking potential. Field experiments will be used to assess the benefits of this technology and its potential implementation as a quality control NDE tool.

ABSTRACT

Test methods for controlling the construction quality of flexible pavement layers and assuring the quality of new pavements have changed little over the past four decades. State department of transportation (DOT) agencies typically base their quality assessments of asphalt paving construction on localized nuclear density measurements and/or the results of testing conducted on pavement cores. For asphalt paving construction, the performance of asphalt pavements has been linked to the density achieved in the field [1-3]. Field density is intended to provide an indication of the percentage of void content in the mix. High air void may lead to premature failure due to stripping, oxidation, raveling, and ultimately cracking. Low air void may lead to rutting and shoving, see Figure 1.

Figure 1. Rutting failure in asphalt pavement

One limitation of density measurements is that the density is determined after construction is completed. In addition, measurements are localized and do not provide a complete assessment of the mat installation. Therefore, immediate corrective actions may not be taken to improve the quality of the installation. IT, also known as thermal imaging, has the potential for quality control purposes because it can be used during paving operations. This approach measures the heat radiated by the installed mat to provide a color-coded image that identifies cooler areas in blue and warmer regions in red. In recent years, the Washington State Department of Transportation successfully used infrared cameras to detect segregation due to temperature differentials in asphaltic concrete pavements [4-5]. Pavement temperature differentials are a result of cooler concentrated masses of HMA in the mat. The cooler areas tend to resist compaction, creating cyclic areas of low density pavement (Figure 2). These areas will prematurely fail by raveling and/or fatigue cracking. The proposed research will investigate an innovative application of IT to assess the quality of longitudinal joints density between adjacent lanes during asphalt paving construction. This NDE technique will also be used to assess the quality of construction of HMA overlay on top of a rigid pavement as an indicator of reflective cracking potential.

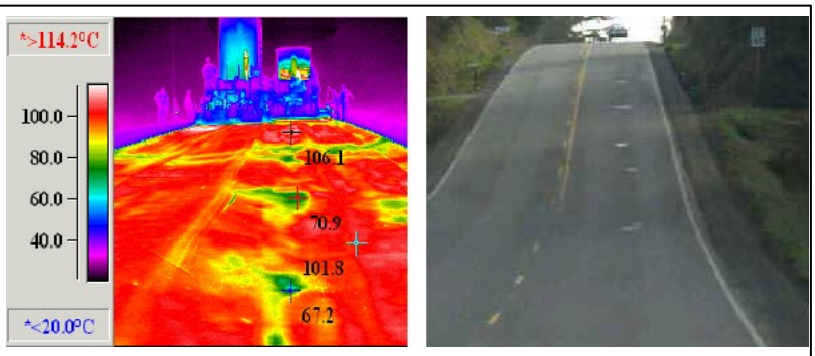

Figure 2. Infrared image and spots in a cyclic pattern [5].

RESEARCH APPROACH

Task 1: Identify Construction Projects in Louisiana

The objective of this task is to identify a number of asphalt paving construction projects in Louisiana to collect field data using IT. Table 1 presents the experimental work plan proposed in this study. A minimum of three projects will be evaluated in the first category, which will assess the use of IT to control longitudinal joints density during regular asphalt paving construction and its potential use for taking corrective actions during compaction. The experimental plan will attempt to identify projects with three nominal maximum aggregate sizes (NMAS) and with different lift thicknesses ranging from 1.5 to 3.0 in. Similarly, a minimum of three projects will be evaluated in the second category, which will assess the use of IT to assess density of HMA overlay constructed on top of rigid pavement. Cores will be extracted or obtained from the district to measure the density and air voids of the mat using conventional methods in the laboratory.

Project Type	Mix NMAS	Thickness (in)
Regular HMA Construction	19.0	3.0
	12.5	2.0
	9.5	1.5
HMA Overlay on Top of Rigid Pavement	19.0	3.0
	12.5	2.0
	9.5	1.5

Task 2: Conduct Field Testing

The objective of this task is to conduct the experimental plan described in Task 1. Data will be collected continuously during compaction operations with particular emphasis on the locations near the joints. However, areas away from the joints will also be scanned using IT for comparison purposes. The variation of thermal measurements during construction operations will be monitored. For HMA overlays on top of rigid pavement, the locations of the joints in the

underlying concrete layer will be marked prior to asphalt paving. These areas will then be scanned using IT.

Task 3: Analyze Collected Data and Determine Feasibility of the Technology

The objective of this task is to analyze the collected field data and to determine the feasibility of the technology for the proposed application. Sensitivity of IT measurements to change in thermal variations and to weather conditions will be determined. In addition, a statistical analysis will be conducted to determine whether the surface temperature near the joints is statistically different from the surface temperature away from the joints. The change of the trends with NMAS and lift thicknesses will also be investigated.

Task 4: Develop Correlations for Assessing Construction Quality Using IT

In this task, correlations will be established between the thermal fields measured using IT and the density of the extracted cores. These correlations may be used by the Department to establish the need for corrective actions during field compaction of HMA. The change of these correlations and their validity will be determined for different NMAS and lift thicknesses.

Task 5: Preparation of the Final Report

A final report, documenting the entire research effort, will be submitted to LTRC for review and comments. The final report will summarize the process and results of the experimental program. In addition, recommendations for future research to validate the proposed methodology will be developed.

STAFFING PLAN

The PI will be responsible for the management of the research project, collect and analyze quantitative data, and preparing final report and manuscripts for publication. This project will

also require the assistance of a graduate student to help with field testing. The recruited graduate student will pursue his/her Master of Science in a topic related to this project.

WORK SCHEDULE

This project is expected to take one year to complete. The table below presents the timeline for the proposed research project assuming a starting date of May 1st 2013.

	Year 2013/2014					
	05-06	07-08	09-10	11-12	01-02	03-04
Task 1						
Task 2						
Task 3						
Task 4						
Task 5						

POTENTIAL BENEFITS OF THE PROJECT

Years of experience support the fact that deviation from either material or construction specifications often lead to premature pavement distresses or even failure. These recognized benefits have led the majority of states to implement QA specifications as part of their overall quality management program. The availability of a NDE method as proposed in this study to determine the quality of construction during compaction will be of great benefits. In addition, field engineers may direct the contractor to locations and areas near the joints that require immediate attention before the mat cools down. The main deliverable of this proposal will be a detailed evaluation of the use of IT technology to assess the quality of joints construction in asphalt paving operations. Correlations will also be established between the thermal fields measured using IT and the density of HMA. A paper detailing the results of this project will be submitted to the Transportation Research Board (TRB).

To ensure long-term impacts of this research, the PI will pursue additional funding for extending and implementing IT technology to field applications. In addition, theoretical modeling of thermal heat transfer occurring at the pavement surface will be proposed. Potential sponsors to such research initiatives include FHWA, LTRC, and industrial companies, who may be interested in implementing the results of this study.

RELATIONSHIP TO RECENTLY COMPLETED, ONGOING OR PROPOSED RESEARCH PROJECTS

Dr. Elseifi is the Lloyd Guillory Distinguished Associate Professor at LSU in the Department of Civil and Environmental Engineering. His research experience focuses on laboratory and field characterization of asphalt mixtures, fracture behavior of asphalt mixtures, full-scale and accelerated pavement testing, and modeling of binder and asphalt mixtures performance. He is currently the Co-PI of NCHRP 9-48: "Field versus Laboratory Volumetrics and Mechanical Properties" and NCHRP 9-40: "Optimization of Tack Coat for HMA Placement." He has been the PI and co-principal investigator on several research projects that involves sustainable asphalt mixtures, pavement performance prediction models, mixture design and evaluation, fundamental materials characterization, and pavement construction and rehabilitation techniques. His federal funding sources include the National Science Foundation (NSF) and the National Cooperative Highway Research Program (NCHRP). Dr. Elseifi has published 50 refereed journal papers in leading journals. One of his publications has received the Grant D. Mickle Award as the best paper in Maintenance, Operation, and Design at the Transportation Research Board. Another paper was the runner-up for the W.J. Emmons Annual Award for the best paper at the AAPT 2010 Annual Meeting. He is a member and friend of more than ten technical committees related

to asphalt materials and pavement analysis. He is also the Associate Editor of the ASCE Journal of Transportation Engineering.

CONTRIBUTION TO THE FIELD OF TRANSPORTATION RESILIENCE

This project is in line with the Gulf Coast Research Center for Evacuation and Transportation Resiliency's mission as it addresses the need to construct long-lasting pavements and to minimize user delays through repetetive repair and rehabilitation activities. In addition, the final report will provide recommendations for future research to validate the proposed methodology and to pursue other funding sources to extend and implement the proposed assessment technique.

FACILITIES

The PI has access to an Infrared FLIR THERMACAM PM 675, which is a handheld thermal imaging camera. The camera has a thermal sensitivity of 0.1°C and a spectral range of 7.5 to 13um. The PI will also work with LTRC to identify field projects and to ensure that the research is conducted in a way that will benefit the asphalt industry. LSU's vast computer facilities and one of its largest research libraries, the Middleton Library, are also readily accessible to the research team for its work.

DELIVERABLES

It is anticipated that the proposed research activities will provide with a detailed assessment of IT technology in asphalt paving construction. Correlation charts will be established between the thermal values measured using IT and the density of the mat. To encourage the implementation of IT technology in QC/QA activities, the final report will provide recommendations for future research to validate the proposed methodology. A paper will be submitted to the Transportation Research Board to present and publish the results of this study.

EXPERTISE

Dr. Elseifi has a strong expertise in using Non-Destructive Evaluation (NDE) methods such as GPR and FWD in pavement assessment and evaluation. He is also continuously working in research projects dealing with QC/QA activities including quantifying the variability between design and produced mixes. The following list of publications demonstrates work done by the PI that is related to the proposed research:

1. Al-Qadi, I.L., Lahouar, S., Loulizi, A., Elseifi, M.A., and Wilkes, J.A. (2004). "Quantifying the benefits of a geocomposite membrane as a pavement moisture barrier using ground penetrating radar and falling weight deflectometer," Journal of Transportation Engineering, American Society of Civil Engineering, Vol. 130, No. 5, 658-664.
2. Elseifi, M.A., J. Trepanier, H. Wakefield, W.J. Pine, and A. Dahhan. (2011). The State of Practice in Hot-Mix Asphalt Sampling. *International Journal of Pavement Engineering*, Vol. 12, No. 2, pp. 111-119.
3. Mohammad, L.N., M.A. Elseifi, S. Cooper, and A. Raghavendra. (2012). Effects of Volumetric and Mechanistic Test Variability on Predicted Performance of Asphalt Pavements Using the MEPDG. Paper accepted by the Transportation Research Record: Journal of the Transportation Research Board, Washington, D.C., In Press.

REFERENCES

1. Brown, E. R., "Density of Asphalt Concrete – How Much Is Needed?" Transportation Research Record, No. 1282, pp. 27-32, 1990.
2. Huber, G. A., and Hernam, G. H., "Effect of Asphalt Concrete Parameters on Rutting Performance – A Field Investigation," Proceedings of the AAPT, Vol. 56, pp. 33-61, 1987.
3. Santucci, L. E., and Allen, D. D., and Coats, R. L., "The effect of Moisture and Compaction on the Quality of Asphalt Pavements," Proceedings of the AAPT, Vol. 54, pp. 168-208, 1985.
4. Hausman, J. J., and Buttlar, W. G., "Laboratory and Field Analysis of the TransTech Model 300 Pavement Quality Indicator ™ for Determining Asphalt Pavement Density," Paper No. 02-4055 Presented at the 81st Transportation Research Annual Meeting, Washington, D. C., 2002.
5. Romero, P., and Kuhnow, F., "Evaluation of New Non-Nuclear Pavement Density Gauges Using Field Projects," Paper No. 02-2352 Presented at the 81st Transportation Research Annual Meeting, Washington, D. C., January 13-17, 2002.

MOSTAFA A ELSEIFI, PHD, P.E.

a. Professional Preparation

Cairo University	Civil Engineering	B.S., 1996
Virginia Tech	Civil Engineering	M.S., 1999
Virginia Tech	Civil Engineering	Ph.D., 2003
Virginia Tech / University of Illinois	Civil Engineering	Post-Doctoral, 2004 – 2005
Professional Engineer	Virginia	2011

b. Appointments

Lloyd Guillory Distinguished Associate Professor, Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA, 2012-present

Lloyd Guillory Distinguished Assistant Professor, Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA, 2011-2012

Assistant Professor, Department of Civil and Environmental Engineering, Louisiana State University, Baton Rouge, LA, 2007-2011

Visiting Assistant Professor, Department of Civil and Environmental Engineering, University of Illinois, Urbana-Champaign, IL, 2007

Assistant Professor, Department of Civil Engineering and Construction, Bradley University, Peoria, IL, August 2005-2007

Research Scientist, Department of Civil and Environmental Engineering, University of Illinois, Urbana-Champaign, IL, November 2004–July 2005

Senior Research Associate, Virginia Tech Transportation Institute, Blacksburg, VA, January 2003–October 2004

Graduate Research Assistant, Department of Civil and Environmental Engineering, Virginia Tech, Blacksburg, VA, August 1998–December 2002

Field Engineering, National Contractor Company, Cairo, Egypt, January 1997, March 1998

c. Selected Awarded Research Grants

2011 Evaluation of the Thixotropy of Asphalt Binder Modified with Recycled Asphalt Shingles – Agency: NSF – EPSCOR Research Infrastructure Improvement Program – Amount: $10,000 – Function: PI.

2010 A New Approach to Recycle Asphalt Shingles in Hot Mix Asphalt – Agency: NSF – Amount: $163,952 – Function: PI.

2009 Field versus Laboratory Volumetrics and Mechanical Properties – Agency: NCHRP – Amount: $ 500,000 – Function: Co-PI.

2009 A Heterogeneous-Based Modeling Approach to Describe the Constitutive Behavior of Asphalt Concrete – Agency: BOR-RCS – Amount: $119,243 – Function: PI.

2008 Analysis of Seasonal Strain Measurements in Asphalt Materials under Accelerated Pavement Testing and Comparing Field Performance and Laboratory Measured Binder Tension Properties – Agency: LTRC – Amount: $115,000 – Function: PI.

2006 Determination of Usable Residual Asphalt Binder in RAP – Agency: IDOT – Amount: $190,000 – Function: Co-PI.

2006 Evaluation of HMA Sampling Techniques – Agency: IDOT – Amount: $22,100 – Function: PI.

d. Selected Honors

2010 Runner-up of the W.J. Emmons Annual Award for the best paper at the AAPT 2010 Annual Meeting

2007 Grant D. Mickle Award. Awarded by the Transportation Research Board (TRB) for the best paper in Maintenance at the Transportation Research Board

e. Selected Publications

Elseifi, M.A., Al-Qadi, I.L., and Flintsch, G.W. (2003). "Quantitative effect of elastomeric modification on binder performance at intermediate and high temperatures," Journal of Materials in Civil Engineering, American Society of Civil Engineering, Vol. 15, No. 1, 32-40.

Al-Qadi, I.L., Loulizi, A., Elseifi, M.A., and Lahouar, S. (2004). "The Virginia Smart Road: The impact of pavement instrumentation on understanding pavement performance," Journal of the Association of Asphalt Pavement Technologists, Vol. 73, 427-465.

Elseifi, M.A., Al-Qadi, I.L., and Yoo, P.J. (2006). "Viscoelastic modeling and field validation of flexible pavements," Journal of Engineering Mechanics, American Society of Civil Engineers, Vol. 132, No. 2, 172-178.

Al-Qadi, I.L., Fini, E.H., Elseifi, M.A., Masson, J-F., and McGhee, K.M. (2006). "Viscosity determination of hot-poured bituminous sealants," Journal of the Transportation Research Board 1958, National Research Council, Washington, D.C., 74-81.

Elseifi, M.A., Al-Qadi, I.L., Dessouky, S., and Yang, S-H. (2006). "A viscoelastic model to describe the mechanical response of bituminous sealants at low temperature," Journal of the Transportation Research Board 1958, National Research Council, Washington, D.C., 82-89 (BEST TRB PAPER AWARD).

Elseifi, M.A., I.L. Al-Qadi, S-H. Yang, and S. Carpenter. (2008). Validity of Asphalt Binder Film Thickness Concept in Hot-Mix Asphalt. Transportation Research Record: Journal of the Transportation Research Board, No. 2057, Washington, D.C., 37-45.

Mohammad, L.N., A. Bae, M.A. Elseifi, J.W. Button, and J.A. Scherocman. (2009). Interface Shear Strength Characteristics of Emulsified Tack Coats. Journal of the Association of Asphalt Paving Technologists, Vol. 78, 249-279 (2nd BEST AAPT PAPER AWARD).

Elseifi, M.A., L.N. Mohammad, I. Glover, I. Negulescu, W.H. Daly, and C. Abadie. (2010). Relationship between Molecular Compositions and Rheological Properties of Neat Asphalt Binder at Low and Intermediate Temperatures. Journal of Materials in Civil Engineering, ASCE, Vol. 22, No. 12, pp. 1288-1294.

Elseifi, M.A., Trepanier, J., Wakefield, H., Pine, W.J., and Dahhan, A. (2011). The State of Practice in Hot-Mix Asphalt Sampling. International Journal of Pavement Engineering, Vol. 12, No. 2, pp. 111-119.

Cooper, S.B., L.N. Mohammad, and M.A. Elseifi. (2011). Laboratory Performance Characteristics of Sulfur-Modified Warm-Mix Asphalt. Journal of Materials in Civil Engineering, ASCE, Vol. 23, No. 9, pp. 1338-1345.

Elseifi, M.A., L.N. Mohammad, and S.B. Cooper. (2011). Laboratory Evaluation of Asphalt Mixtures Containing Sustainable Technologies. Journal of the Association of Asphalt Paving Technologists, Vol. 80, pp. 227-254.

Mohammad, L.N., S.B. Cooper, and M.A. Elseifi. (2011). Characterization of HMA Mixtures Containing High Reclaimed Asphalt Pavement Content with Crumb Rubber Additives. ASCE Special Edition, Vol. 23, No. 11, 1560-1568.

Elseifi, M.A., L.N. Mohammad, E. Kassem, H. Ying, and E. Masad. (2011). Quantification of Damage in the Dynamic Complex Modulus and Flow Number Tests Using X-Ray Computed Tomography. Journal of Materials in Civil Engineering, ASCE, Vol. 23, No. 12, 1687-1696.

Mohammad, L.N., M.A. Elseifi, S. Cooper, and A. Raghavendra. (2012). Effects of Volumetric and Mechanistic Test Variability on Predicted Performance of Asphalt Pavements Using the MEPDG. Paper accepted by the Transportation Research Record: Journal of the Transportation Research Board, Washington, D.C., In Press.

f. Other Publications

Mohammad, L.N., M.A. Elseifi, A. Bae, and J.W. Button, (2012). "Optimization of Tack Coat for HMA Placement," NCHRP 9-40, National Academy of Sciences, Washington, D.C., In Press.

Elseifi, M.A. (2009). "Analysis of Seasonal Strain Measurements in Asphalt Materials under Accelerated Pavement Testing and Comparing Field Performance and Laboratory Measured Binder Tension Properties," Research Report FHWA/ LA.09/444, Louisiana Transportation Research Center, Baton Rouge, LA.