JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION
AND PURDUE UNIVERSITY

A Mobile Concrete Laboratory to Support Quality Concrete, Technology Transfer, and Training

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JOINT TRANSPORTATION RESEARCH PROGRAM

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16. Abstract

This report is a summary of work performed by the Mobile Infrastructure Materials Testing Laboratory (MIMTL) as a part of the Joint Transportation Research Program (JTRP) through SPR-3858. The development of the MIMTL began in February of 2014 and it became fully operational by June of 2014. The MIMTL was deployed in the field for a total of 46 days. This report describes the activities of the MIMTL as of December 2015. The MIMTL was involved in the field testing of concrete bridges, concrete pavements, and asphalt pavements. This report describes the development of the mobile testing laboratory and provides some examples of how the MIMTL was used. The main highlights of the MIMTL's implementation are as follows:

- The MIMTL's high mobility and extensive inventory of research equipment allowed graduate students and researchers to conduct field studies on a wide range of infrastructure materials to accomplish the research objectives of their specific projects. More extensive details of the background, objectives, methods, findings, results and implementation from those projects can be found in the respective reports for those projects;
- The MIMTL supported a culture of safety that allowed students to work safely on jobsites in the State of Indiana ranging from roadside interstates, rural country roads, to ready-mix batching plants, often around heavy equipment, traffic, and in close quarters. During the operation of the MTIML described in this report, there were zero workplace accidents, and zero near misses reported;
- The MIMTL assisted in technology transfer between the infrastructure materials experts at Purdue University and contractors and suppliers in the State of Indiana. A wide range of new technologies evaluating infrastructure materials were utilized on a variety of projects. On each of these projects, MIMTL researchers educated industry personnel (contractors and suppliers), agency personnel (INDOT and local agencies), and consultants within the state. The MIMTL attended demonstrations with INDOT district and central office personnel to further highlight capabilities as well as the emerging technologies;
- The MIMTL was established a joint investment with partners in industry, local agencies, and INDOT. Operated by the Joint Transportation Research Program and the Local Technical Assistance Program as pay-per-use model, means this sustainable venture will offer services to researchers, industry, or agency entities that can cover the pay-per-use costs.

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EXECUTIVE SUMMARY

A MOBILE CONCRETE LABORATORY TO SUPPORT QUALITY CONCRETE, TECHNOLOGY TRANSFER, AND TRAINING

Introduction

This report is a summary of work performed by the Mobile Infrastructure Materials Testing Laboratory (MIMTL) as a part of the Joint Transportation Research Program (JTRP) through SPR-3858 and details its use for field testing concrete bridges and concrete and asphalt pavements. The project was intended to support the engineering investigations of other projects as identified in this report.

The MIMTL was designed as a 14-foot trailer to be towed to plants and jobsites using a pickup truck and has essential equipment for performing a wide range of tests on fresh and hardening concrete as well as asphalt. It has been used for three main applications: internally cured (IC) concrete, high early strength (HES) concrete patching, and asphalt tack coats (chip seal).

Findings

The MIMTL safely and effectively provided support and guidance to:

- Multiple graduate students and INDOT research projects with zero workplace accidents and zero near misses while attending different types of jobsites during forty-six operational days.
- Help ready-mix suppliers successfully implement field-produced internally cured concrete as part of SPR-3708. This concrete was tested at the plant and in the field, and results indicate that the supplied internally cured concrete represents a high-quality product. One of the biggest challenges is in the control and testing of aggregate moistures.
- Evaluate high early strength patching materials used as part of SPR-3905. It was found that the temperatures observed in the field were high and significant dosages of admixtures were used, resulting in potential sulfate balance issues that limited flexural strength.
- Conduct site visits related to concrete pavement performance as part of SPR-3708. Information gathered was used to investigate aging for measures of strength and durability and provided typical levels of variation associated with test methods, with particular focus on concrete pavement construction.
- Evaluate a new test for chip sealing as part of SPR-3801. The results demonstrated that electrical measurements show promise in applicability to determining chip seal curing times.

Implementation

The Mobile Infrastructure Materials Testing Laboratory (MIMTL) has been used successfully to verify the value obtained from concrete purchased by the Indiana Department of Transportation (INDOT) for use in bridge decks, pavements, patches, and curbs. Additionally, its implementation has provided the opportunity for hands-on training of INDOT personnel and contractors in how to improve concreting practices and increase service life. With the implementation of the MIMTL, new technologies can be rolled out that provide opportunities to fine-tune specifications and best practices.

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1. INTRODUCTION

This report is a summary of work performed by the Mobile Infrastructure Materials Testing Laboratory (MIMTL) as a part of the Joint Transportation Research Program (JTRP) through SPR-3858. The development of the MIMTL began in February of 2014 and it became fully operational by June of 2014. The MIMTL was deployed in the field for a total of 46 days. This report describes the activities of the MIMTL as of December 2015. The MIMTL was involved in the field testing of concrete bridges (Barrett, 2015), concrete pavements (Spragg, 2016; Spragg, Todak, Shagerdi, Zavattieri, & Weiss, 2016; Todd, 2015; Todd, Olek, & Weiss, 2016), and asphalt pavements (Montoya, Haddock, & Weiss, 2016). This report describes the development of the mobile testing laboratory and provides some examples of how the MIMTL was used. The main highlights of the MIMTL's implementation are as follows:

- The MIMTL's high mobility and extensive inventory of research equipment allowed graduate students and researchers to conduct field studies on a wide range of infrastructure materials to accomplish the research objectives of their specific projects. More extensive details of the background, objectives, methods, findings, results and implementation from those projects can be found in the respective reports for those projects;
- The MIMTL supported a culture of safety that allowed students to work safely on jobsites in the State of Indiana ranging from roadside interstates, rural country roads, to ready-mix batching plants, often around heavy equipment, traffic, and in close quarters. During the operation of the MTIML described in this report, there were zero workplace accidents, and zero near misses reported;
- The MIMTL assisted in technology transfer between the infrastructure materials experts at Purdue University and contractors and suppliers in the State of Indiana. A wide range of new technologies evaluating infrastructure materials were utilized on a variety of projects. On each of these projects, MIMTL researchers educated industry personnel (contractors and suppliers), agency personnel (INDOT and local agencies), and consultants within the state. The MIMTL attended demonstrations with INDOT district and central office personnel to further highlight capabilities as well as the emerging technologies;
- The MIMTL was established a joint investment with partners in industry, local agencies, and INDOT. Operated by the Joint Transportation Research Program and the Local Technical Assistance Program as pay-per-use model, means this sustainable venture will offer services to researchers, industry, or agency entities that can cover the pay-per-use costs.

2. RESEARCH MOTIVATION

A large portion of the INDOT budget is spent on the construction and maintenance of the infrastructure which includes concrete and asphalt pavements, concrete bridge structures, concrete curb, gutter and sidewalks, and other asphalt materials. Concrete is tested on site to ensure that the concrete brought to the site and placed in the concrete structure or pavement is similar to the concrete that is specified. If the proportions of the as-built concrete differ from the specified concrete, the as-built concrete may not provide the anticipated performance and value for INDOT (Barrett, 2015). This is especially true when it comes to durability since minor variations in water content have a larger impact on durability properties than they do strength (Castro, Spragg, Kompare, & Weiss, 2010). As such, field testing for quality control, qualification, and verification is important. In addition, several new testing procedures are being developed that can save time, money or provide additional data; however, deploying these new technologies in practice is often difficult (Castro et al., 2010; Graveen, 2001; Miller, 2014; Spragg, Bu, Snyder, Bentz, & Weiss, 2013). The MIMTL was also used to investigate other infrastructure materials that are commonly used in the State of Indiana.

Testing materials on site however has a unique set of challenges. INDOT has dramatically reduced the number of people onsite and institutional knowledge is lost when highly experienced employees retire or move to new positions within INDOT. In addition, with new contractors and a changing contractor workforce, INDOT is in a constant battle to make sure that in addition to training its workforce the contracting personnel are fully prepared for the task of providing high quality concrete.

This final report describes a project that attempts to develop strategies to address the aforementioned concerns. This report describes the implementation of a Mobile Infrastructure Materials Testing Laboratory (MIMTL). This work also places a focus on providing INDOT with support for the implementation of new technologies. The MIMTL has been used to verify that INDOT is able to obtain high value for the concrete being purchased for use in bridge decks, pavements, patches and curbs. Specifically, the work focuses on helping to improve concreting practices that improve the service life of concrete infrastructure. The project investigated opening times to brushing operations for chip seal pavements. Secondly, the project provided hands-on training which was used to improve the quality of concrete as well as to train personnel (INDOT or INDOT contractors). Finally, new technologies can be rolled out providing opportunities to fine-tune specifications and best practices so they can be most successful.

3. OVERVIEW AND CAPABILITIES OF THE MIMTL

The MIMTL began construction in February 2014. The equipment consisted of a 14-foot box trailer and a 2015 Chevrolet 3500, as shown in Figure 3.1. This versatile combination was chosen to allow for high mobility within the State and ease of setup, in areas ranging from production yards to the shoulder of state highways and interstates. The capacity was also sized to allow transporting specimens and constituent material back to the Pankow Materials Laboratory at Purdue University for additional testing.

Figure 3.1 The Mobile Infrastructure Materials Testing Laboratory pictured at the Center for Aging Infrastructure in 2014.

The 14-foot trailer was outfitted with shelving systems, equipment mounting points, specimen storage, and proper personal protective equipment (PPE). This included proper lighting and reflectivity gear for roadside and night-time roadside work. The MIMTL was outfitted with power generation and water storage capabilities, in case these items were needed on-site. Interior pictures of the MIMTL are shown in Figure 3.2.

The MIMTL offered a full range of infrastructure materials testing, with emphasis on field testing of concrete and concrete constituents. This includes but is not limited to: aggregate properties and specifically lightweight aggregate testing, fresh property testing of concrete, equipment to make a wide range of standard concrete specimens, equipment to monitor temperature and early age properties, mechanical testing, durability testing, and lastly equipment to obtain hardened samples from in-place elements.

A laptop computer was included to allow for calculations and data analysis to be conducted on the MIMTL, and for recommendations to be made in real time. The computer also contained videos detailing standard operating procedures relating to infrastructure materials testing, allowing it to be used as a training tool. The MIMTL was outfitted with a weather station, to monitor local climatic conditions during the course of a MIMTL visit. Air temperature, relative humidity, wind speed and UV index were monitored as necessary. Time-lapse photography for documentation of construction processes and for use in training purposes was also possible, based on suggestions from JTRP (Lavrenz & Bullock, 2015).

Based on work during 2013, it was determined that aggregate properties testing are vital to the implementation of high quality concrete (Barrett, Miller, & Weiss, 2013). The MIMTL was outfitted with equipment for aggregate sieve analysis, moisture control, and specific gravity. The MIMTL also was equipped for utilization of ITM 222, a method to determine lightweight aggregate properties for use in internal curing (Miller et al., 2014). This method is currently being evaluated for extension for use in coarse lightweight aggregate as well as conventional weight aggregate. Aggregate properties are one of the important parameters to control to ensure quality concrete.

The MIMTL was outfitted to gather a wide variety of data on fresh properties of concrete. This includes slump, air content, unit weight, and yield. Furthermore, as part of a national pooled-fund study on air entrainment and air entrainment quality, the MIMTL contained the Super Air Meter (SAM; Todak, 2015). Sensors were included for temperature and internal relative humidity measurement, which can assist in assessing thermal control and maturity for early opening to traffic (Graveen et al., 2009b). Embeddable concrete strain gages are also available for use in deflection or strain testing on an as needed basis. The MIMTL contained a device known as water/cement meter which served to estimate the water/cement ratio of fresh mixtures. This device is a product of James Instruments. It was not able to produce repeatable results in the field, therefore it was not used to obtain any useful data about the water/cement ratio of the concrete mixtures in any of the projects that the MIMTL supported.

The MIMTL included equipment for making concrete specimens, including a wheelbarrow, shovels, trowels, rods, sample molds, etc. A wide range of specimens molds were included as well, ranging from standard flexural beams to standard test cylinders.

The MIMTL contains equipment for measuring the mechanical properties of concrete at early ages. The equipment was designed in such a way that it can

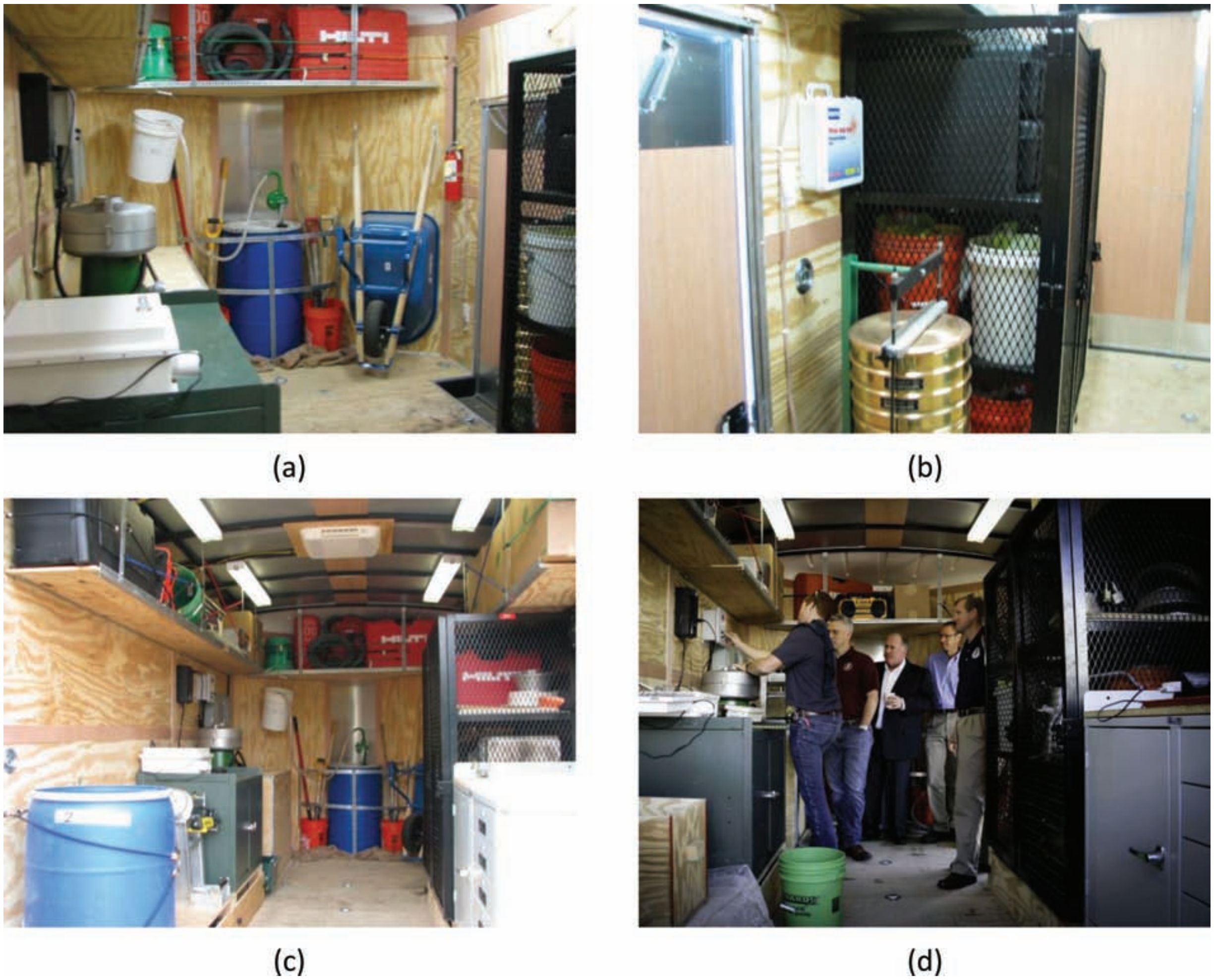

Figure 3.2 Interior pictures of the Mobile Infrastructure Materials Laboratory pictured early in its operation in 2014.

be quickly checked for calibration when the lab is set up and can be used to provide early age modulus, i.e., elastic modulus at early ages, flexural, or split tensile strength. The equipment was particularly designed such that it can be used for the measurement of early age and developing properties. The MIMTL is also equipped with embeddable strain gages for measuring the shrinkage of as-delivered concrete as well as a dual ring for measuring the early age cracking resistance of the as-delivered concrete. This equipment is connected to equipment for data acquisition and temperature control. Non-destructive equipment for measuring strength, such as the Windsor Pin, was provided due to the potential value that these non-destructive methods add.

Durability testing is available on the MIMTL, most notably the use of resistivity. Resistivity is a tool that can assess the consistency and durability of a concrete mixture (Spragg et al., 2013). Coupled with the laptop and a tool to estimate the pore solution chemistry, the formation factor of concrete mixtures can be determined (Spragg, Qiao, Barrett, & Weiss, 2016; Weiss, Barrett, Qiao, & Todak, 2016). Embedded sensors were also available, which can be used with fresh mixtures, and are currently being evaluated to simplify the testing procedure (Castro et al., 2010).

The MIMTL was also equipped to gather specimens from in-place concrete elements. This include equipment and PPE to core-drill, hammer-drill, and saw concrete in the field. Many of these could utilize waterless technology to prevent sample contamination with water.

Towards the end of the operational time-period, the MIMTL assisted with asphalt projects. This included observing standards of practice, measuring emulsion depth, and measuring the electrical properties (resistance and impedance) of the emulsion.

4. OPERATIONAL MODEL AND TIMELINE

The MIMTL was established as a shared facility between INDOT, LTAP, Purdue University, and industry partners to defray costs. The MITML was operated out of the Pankow Materials Laboratory at Purdue University, and was established as a cost-per-use Purdue cost center. This model will hopefully help to keep the MIMTL sustainable into the future. The cost-per-day covered the truck, trailer, equipment use, and technician time. Future users of the MIMTL include researchers, agency, and industry members that can cover the associated cost per use.

The MIMTL was staffed by a laboratory technician, Mr. Cameron Wilson, for the 2014 and 2015 construction seasons. Other graduate and undergraduate research assistants worked on the MIMTL both providing assistance and to complete their respective projects and research.

During the 2014 and 2015 construction seasons, the MIMTL was deployed for a total of 46 days, ending operations in September of 2015. The timeline is summarized in Table 4.1. There are six main categories of site visits:

- Internally Cured (IC) bridges and trial batches;
- High Early Strength (HES) patches and trial batches;
- Concrete Pavement Performance site visits;
- Asphalt tack coats (chip seal);
- Specimen retrieval for analysis at the Pankow Laboratory;
- MIMTL Demonstrations to INDOT District and Central Office Personnel.

The following chapters will provide a summary of the first four categories of site visits. The chapters will provide a quick overview of the project, detail how the MIMTL was used by researchers on-site to obtain and test specimens, and provide some examples of the data that was obtained. More in-depth discussion of motivations, methods, data analysis, conclusions, and recommendation can be found in the respective theses and reports of the projects that are discussed. The goal of this report is to illustrate how the MIMTL helped to accomplish data gathering procedures. The fifth category of MIMTL use involved retrieving specimens in the field for further analysis at the Pankow Laboratory. Since this category only utilized MIMTL equipment to obtain specimen to analyze in accordance with procedures outside the scope of standard civil engineering evaluation, the details are not provided here. For further details regarding those findings, you can see the respective thesis. For the salt interaction study, this is Thomas (2016) and for the acid interaction study is Ding (2015). Likewise, the demonstrations will not be detailed as they simply involved tours to INDOT district or Central Office personnel.

TABLE 4.1
Operational timeline for the MIMTL during the 2014 and 2015 construction seasons.

Date	Grant #	No. of Days	Location	Description
6/22/2014	207237	1	Hanna, IN	IC Bridge Deck
8/13/2014	207898	1	Crown Point, IN	HES Patches on US 30
8/20/2014	207720	1	Crown Point, IN	HES Patches on US 30
9/3/2014	207720	1	Harrison, OH	IC Bridge Deck Trial Batch
9/8/2014	207720	1	Crown Point, IN	HES Patches on US 30
9/16/2014	205833	0.5	West Lafayette, IN	Salt Interaction Slab Cast at CAI
9/17/2014	207720	1	Dyer, IN	HES Patches on US 30
9/19/2014	207720	0.33	West Lafayette, IN	Mobile Lab Demonstration
9/23/2014	207720	1	Frankfurt, IN	HES Trial Batch
9/24/2014	205833	0.5	West Lafayette, IN	Salt Interaction Slab Cast at CAI
9/24/2014	207720	0.5	West Lafayette, IN	HES Patches on US 52
9/25/2014	207720	1	Lafayette, IN	HES Trial Batch
10/6/2014	205833	0.5	West Lafayette, IN	Salt Interaction Slab Cast at CAI
10/7/2014	207720	1	Dyer, IN	HES Patches on US 30
10/16/2014	207646	0.5	West Lafayette, IN	Salt Interaction Slab Cast at CAI
10/20/2014	207646	0.5	West Lafayette, IN	Salt Interaction Slab Cast at CAI
10/21/2014	207720	1	Lafayette, IN	HES Trial Batch
10/22/2014	207646	0.5	West Lafayette, IN	Salt Interaction Slab Cast at CAI

TABLE 4.1
(Continued)

Date	Grant #	No. of Days	Location	Description
10/23/2014	206481	1	Lafayette, IN	Pavement Performance on Earl Ave.
11/5/2014	207237	1	Knox, IN	IC Bridge Deck
11/11/2014	207898	2	Harrison, OH	IC Bridge Deck
11/13/2014	207720	0.33	Crawfordsville, IN	Mobile Lab Demonstration
11/19/2014	207720	0.33	West Lafayette, IN	Mobile Lab Demonstration
11/26/2014	204797	0.5	Lafayette, IN	Coring for Sealer Study US 231
12/2/2014	205833	0.5	West Lafayette, IN	Sealing Salt Interaction Slabs at CAI
12/3/2014	205833	0.5	West Lafayette, IN	Sealing Salt Interaction Slabs at CAI
3/17/2015	204797	1	Fishers, IN	Coring for Sealer Study
3/31/2015	207898	1	Indianapolis, IN	HES Trial Batch
4/7/2015	206805	1	Lafayette, IN	Install Specimens for Acid Interaction Study
4/14/2015	205833	1	West Lafayette, IN	Coring Salt Interaction Slabs at CAI
4/15/2015	206695	2	Fort Branch, IN	IC Bridge Deck Trial Batch
4/21/2015	207237	1	Wheatfield, IN	IC Bridge Deck
5/28/2015	205833	1.5	West Lafayette, IN	Coring Salt Interaction Slabs at CAI
6/10/2015	207237	1	North Judson, IN	IC Bridge Deck
6/30/2015	206481	2	Bloomington, IN	Pavement Performance on I69
7/13/2015	206695	2	Fort Branch, IN	IC Bridge Deck
7/21/2015	206805	1	Lafayette, IN	Retrieve Specimens for Acid Interaction Study
7/21/2015	206481	2	Bloomington, IN	Pavement Performance on I69
8/5/2015	207000	2.5	Lebanon, IN	Chip Seal
8/16/2015	207000	1.5	Auburn, IN	Chip Seal
9/1/2015	207000	1	Mentone, IN	Chip Seal
9/3/2015	207644	1	West Lafayette, IN	Coring Salt Interaction Slabs at CAI
9/8/2015	207644	1	West Lafayette, IN	Coring Salt Interaction Slabs at CAI
9/10/2015	207644	1	West Lafayette, IN	Coring Salt Interaction Slabs at CAI
9/23/2015	207000	1.5	Farmland, IN	Chip Seal
	TOTAL	46		

5. INTERNALLY CURED BRIDGES

5.1 Background

The use of internal curing, has a well-documented use at improving the service life of concrete elements (e.g., Bentz & Weiss, 2011; Castro, Spragg, & Weiss, 2012; De la Varga et al., 2014; Di Bella, Villani, Phares, Hausheer, & Weiss, 2012; Henkensiefken, Bentz, Nantung, & Weiss, 2009; Henkensiefken, Castro, Bentz, Nantung, & Weiss, 2009). Internally cured bridge decks have previously been constructed in the State of Indiana, and evaluated by Purdue University (Barrett et al., 2015; Di Bella et al., 2012). This section will discuss how the MITML was used to evaluate the construction of additional internally cured bridge decks during the past construction seasons. This chapter will specifically focus on the visits to B-37021 (SR 46 over I-74 in the INDOT Seymour District) and B-37022 (SR 61 over I-64 EB/WB in Vincennes District). Both of these contracts for Internally Cured High Performance Concrete (ICHPC) involved deck replacement. The mobile lab provided support and guidance to the ready-mix suppliers and contractors responsible for the construction of the internally cured bridges, as well as INDOT

Figure 5.1 The Mobile Infrastructure Materials Testing Laboratory beginning the day of deck cast by testing aggregate properties at the ready mix batch plant.

personnel that were responsible for quality assurance testing. Of specific interest, was the aggregate properties of the prewetted fine lightweight aggregate (FLWA). The MIMTL attended the trial batches for these internally cured decks, was present at the batch plant the morning of the deck pour, and visited the deck site during construction to gather samples. The MIMTL utilized the newly developed ITM 222 utilizing a centrifuge for characterization performing quality control testing on lightweight aggregates (Miller, 2015; Miller et al., 2014). Samples were also made from concrete mixtures placed in the bridge deck to analyze for hardened mechanical and durability testing.

5.2 Overview of Work Conducted

The work of the mobile laboratory on this type of job can be broken down into three main components: The trial batch, the morning of the pour at the batch plant, and the day of the pour at the bridge deck.

Before construction of the deck, the MIMTL would attend the trial batch. The trial batch process is important, as it allows INDOT to qualify the mixture to make sure that it meets or exceeds expectations in terms of material performance, and is chance for the supplier to demonstrate that they are capable of properly batching an ICHPC mixture. The trial batch stage is an opportunity for INDOT to assess the fresh properties and take samples for later age properties. Samples were collected for strength and durability testing.

The MIMTL assisted in the testing of the FLWA in accordance with ITM 222, which is a rather new test that many concrete suppliers have not had the opportunity to use. MIMTL personnel would offer guidance and help if needed with the batching systems, as some batching systems have difficulty utilizing high absorption aggregates, such as FLWA. Testing of FLWA is shown in Figure 5.2.

At the trial batch, the MIMTL would take air, slump, temperature, and cylinders alongside INDOT and supplier personnel. MIMTL personnel would provide advice on the test method and mixture modification. Typical testing and training opportunities from the trial batch are shown in Figure 5.3.

On the day of the deck pour, the MIMTL would arrive early to the batch plant and assist with aggregate property testing, similar to that shown in Figure 5.1. The MIMTL would then transition to the jobsite and observe the construction sequence and construction practices, assess fresh properties, and gather samples for hardened analysis, examples of this process is shown in Figure 5.4.

5.3 B-37021: SR 46 over I-74 in the Seymour District

The MIMTL, personnel Dr. Timothy Barrett and Cameron Wilson attended the trial batch for this bridge on September 3, 2014. Aggregate properties were taken after arriving on-site. The batch plant personnel had difficulties with the batching software, most likely due to the high absorption capacity of the FLWA. Commercial batch software typically have "safeguards" maximums on absorption capacity (Barrett, 2015). After a delay of approximately two hours, the trial batch

Figure 5.2 Testing of fine lightweight aggregate for use in an internally cured high performance concrete mixture, showing (a) specific gravity testing, (b) ITM 222 centrifuge method, (c) obtaining an oven-dry sample, and (d) measuring oven–dry mass.

proceeded without a problem. This demonstrates the efficacy of a trial batch, as it helps to discover these complexities and develop solutions before the day of the deck cast.

The deck cast took place on November 11, 2014, and was attended by the same Purdue personnel. Aggregate properties were measured the morning of the cast, fresh properties were recorded on a series of trucks throughout the day, and hardened samples were analyzed for production variability, and later-age strength and durability properties. The conclusions can be found in the PhD dissertation of Dr. Timothy Barrett (2015). A final look at the bridge deck can be seen in Figure 5.5.

5.4 B-37022: SR 61 over I-64 in the Vincennes District

The trial batch for this deck took place at Irving Materials Incorporated in Fort Branch, Indiana. The trial batch was attended by Dr. Timothy Barrett, Alex Coyle, Cameron Wilson, and Nathan Todd on April 16, 2015. Aggregate properties were taken after arriving on-site. The batch plant personnel had difficulties with the batching process, specifically weighing the materials within the specified tolerances. The automatic and manual batching systems could not weigh the material within the specified tolerances. Material was thrown away on several occasions. A few observations were observed regarding this problem. First, small batches, such as this 3 cubic feet batch, have difficulty meeting batch tolerances due to such a small amount of material. Second, as FLWA has a much different density than normal-weight aggregate, sometimes it is required to slightly modify the batching software parameters. Specifically, the parameter that controls the amount of time the clam-shell remains open (Barrett, 2015). After batching, the mixture did not meet air and slump requirements. Three trucks were batched before the materials were batched within tolerance and the mixture was accepted.

The ICHPC mixture was a ternary blended mixture, with a minimized paste content. The design mixture proportion is shown in Table 5.1.

Figure 5.3 Testing at trial batches for including training opportunities shown in (a) and (b), (c) air content testing, and (d) hardened samples to take back to assess later age properties.

The deck pour was conducted on the June 14, 2015. The MIMTL arrived early to the batch plant to measure aggregate properties, summarized here in Table 5.2. This included specific gravity, absorption, surface moisture, and total moisture of the lightweight fine aggregate. The total moistures for the normal weight aggregates are also given.

After the aggregate testing was completed at the batch plant, the MIMTL traveled to the location of the deck for field testing. This deck was poured in two phases, with the second phase happening some months later. The MIMTL was only present for Phase 1 of this deck.

Air content measurements and measurements using the Super Air Meter (SAM) were conducted on six trucks throughout the deck. Companion cylinders from each truck cast as well, for evaluation of later-age properties. The air content and SAM number are summarized in Table 5.3. Observations from testing of the SAM indicate that it can take approximately twenty minutes to conduct a SAM test, which is longer than a standard air test. While the SAM number is related to the spacing factor and air void quality (Todak, 2015), the time investment makes it a difficult test for quality control. However, this test might still be very beneficial in a mixture qualification stage.

Cylinder specimens were also made from each of the six trucks. These cylinders were tested for compressive strength and resistivity. Figure 5.6 illustrates 7 day and 28 day compressive strength for the trucks tested. The coefficient of variation in strength in the entire day's cast was an average 15.5%, with the 28 day strength approximately 20% higher than the strength at 7 days. Figure 5.7 illustrates the sealed resistivity as a function of time for the day's casting operation. The 7 day coefficient of variation was 12.0%.

Figure 5.4 Testing on site at bridge location shows (a) concrete pumping apparatuses, (b) concrete placement in bridge deck, (c) making hardened samples for later age testing, and (d) Super Air Meter testing.

Figure 5.5 Picture of finalized internally cured high performance bridge deck on SR 46 over I-74.

TABLE 5.1
Mixture design for internally cured high performance concrete bridge deck on B-37022, weights given in SSD condition.

Material	SSD Weight (lbs)
Cement	443
Slag Cement	117
Silica Fume	25
Fine Aggregate	644
Fine Lightweight Aggregate	393
Coarse Aggregate	1758
Water	244.0
Air Content (%)	6.5

TABLE 5.2
Aggregate properties on the day of the internally cured high performance concrete deck cast for B-37022.

Fine Lightweight Aggregate	
G_{LWA}	1.759
Absorption (%)	20.50
Surface Moisture (%)	6.82
Total Moisture (%)	28.71
Fine Aggregate	
Total Moisture (%)	4.43
Coarse Aggregate	
Total Moisture (%)	1.75

TABLE 5.3
Mixture design for internally cured high performance concrete bridge deck on B-37022, weights given in SSD condition.

Truck	Air Content (%)	SAM
1	6.0	–
3	5.5	0.44
5	4.7	0.39
9	8.1	0.23
11	9.5	0.20
13	7.3	0.35
AVERAGE	6.9	0.32
ST DEV	1.79	0.103

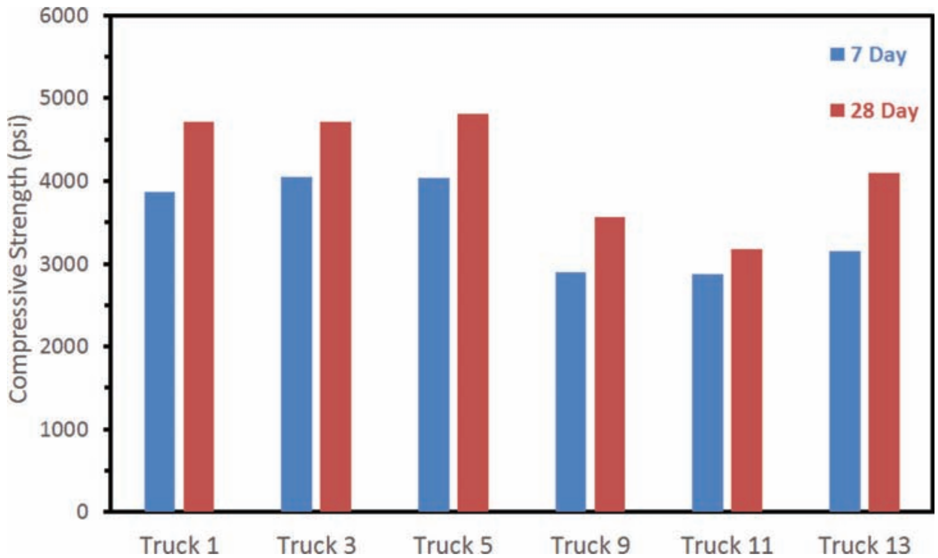

Figure 5.6 7 day (blue) and 28 day (red) compressive strength showed an average coefficient of variation of 15.5%.

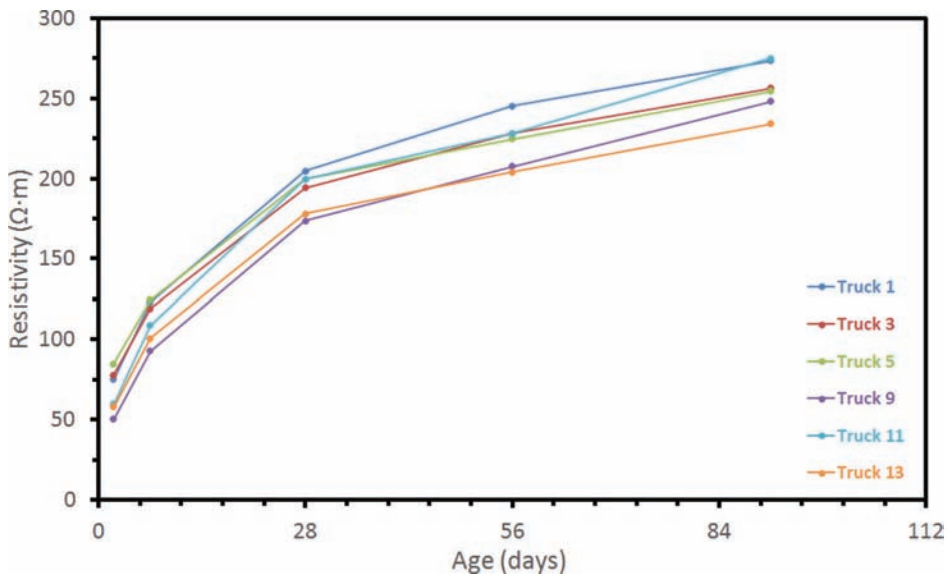

Figure 5.7 Sealed curing resistivity measurements from the six trucks throughout the casting of the internally cured high performance concrete bridge deck.

6. HIGH EARLY STRENGTH CONCRETE MIXTURES

6.1 Background

The MIMTL assisted in site visits and field work for SPR-3905: Concrete Patching Materials and Techniques and Guidelines to Hot Weather Concreting (Todd, 2015). Concrete patches work on an accelerated project time-line, and are typically concrete mixtures that must gain opening strength in approximately four to five hours. These mixtures are typically referred to as High Early Strength (HES) mixtures. These mixtures are characterized by low w/c, high cementitious materials content, and high dosages of accelerating admixtures. The combination of these different techniques to accelerate property development in concrete materials can present some challenges, some of which were investigated using the MIMTL.

6.2 Overview of Work Conducted

The MIMTL attended trial batches, highway and interstate rapid repair projects to evaluate HES mixtures using time-temperature history, flexural strength development, and sample collection for evaluation back at Pankow Laboratory.

Tasks at trial batches included testing of aggregate properties, and assistance with INDOT in development of a maturity curve, in accordance with ITM 402 (INDOT, 2015). To assist with this, a large number of

Figure 6.1 A large number of flexural beams being cast at (a) trial batch for development of maturity curve, and (b) pavement patch site visit for evaluation of strength gain in temperature matched curing regime utilizing industrial heating blankets.

concrete flexural beams, shown in Figure 6.1a, would be cast to measure flexural strengths at various ages. While specimens made by INDOT personnel were subjected to normal curing conditions, as described by ITM 402, Purdue University researchers would cast beams and subject them to temperature matched curing (TMC). TMC is the method in which the temperature of the specimens was elevated and matched the temperature that had previously been reported in HES patches utilizing industrial heating pads and electrical blankets, shown in Figure 6.1b.

These temperature profiles were designed to mimic the temperature seen in the concrete patches, which could often reach in excess of 60 °C. The motivation is explained in more detail by Todd (2015). At various ages ranging from 4 to 24 hours, the flexural strength of these specimens were measured using a Humboldt portable beam breaker in the mobile lab. Later-age strength was measured at the Pankow Materials Laboratory.

When visiting a pavement project site, Purdue University utilized the MIMTL in a similar fashion. Using the safety lights and nighttime PPE, the MIMTL would be setup on a section of roadway to examine the behavior of HES mixtures in the field. Typically, temperature data and flexural strengths were measured during site visits. Using thermocouples and data loggers housed in the MIMTL, temperatures of the concrete inside the patches as well as cast beams were recorded. In addition, as done at trial batches, many concrete beams were cast and subjected to normal curing and temperature matched curing conditions. Flexural strengths were measured at ages ranging from 4 to 24 hours.

6.3 Data Collected

Research regarding high early strength concrete mixtures utilized two main types of data gathered by the MIMTL, temperature history of beams and patches, and flexural strength development. Temperatures were recorded using Measurement Computing's USB-5104 High-Accuracy, 4- Channel Thermocouple Data Logger, with Type-T thermocouples. Thermocouples were placed more than 1 foot into the concrete pavement patches to minimize edge effects. Thermocouples were placed at mid-depth and mid-span of concrete beams. Temperatures were recorded every minute for the duration of the site visit to an accuracy of +/ - 0.01 °C. For measuring flexural strengths of concrete beams, a Humboldt H-3033A, 18" (span) Third-Point Loading Concrete Beam Tester was utilized and stationed in the MIMTL.

An example of temperature data gathered by the MIMTL is illustrated in Figure 6.2. These results indicate on both warm and cool nights, HES concrete patches can reach temperatures in excess of 50 to 60 C. Furthermore, the temperature in concrete beams are much lower than that of concrete in the patches.

An example of flexural strength data obtained by the MIMTL is illustrated in Figure 6.3. The specimens marked Air cured are curing utilizing standard INDOT practices outlined in ITM 402. These specimens exhibit an expected strength gain as a function of time. Specimens marked as TMC were cured utilizing heat blankets to obtain temperature histories similar to that of patch temperatures, such as those shown in Figure 6.2. These specimens show high initial strength gain, as expected because the temperature accelerates the reaction.

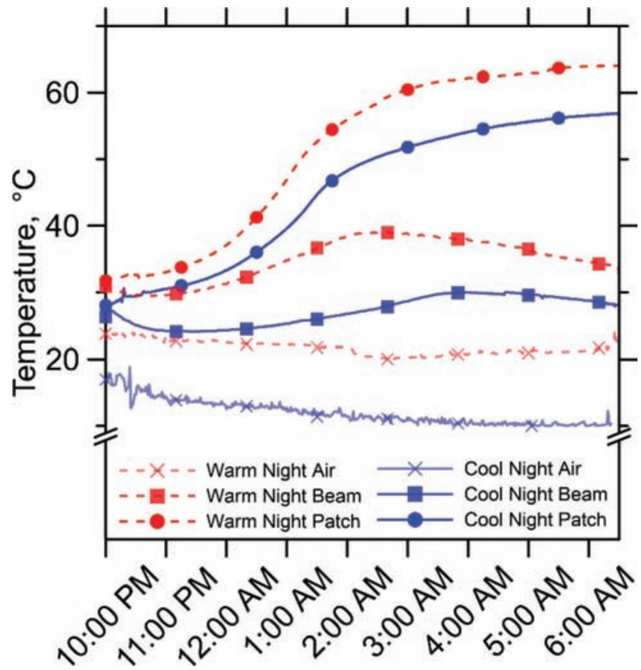

Figure 6.2 Temperature development for US 30 HES project on warm and cool nights for beams and patches.

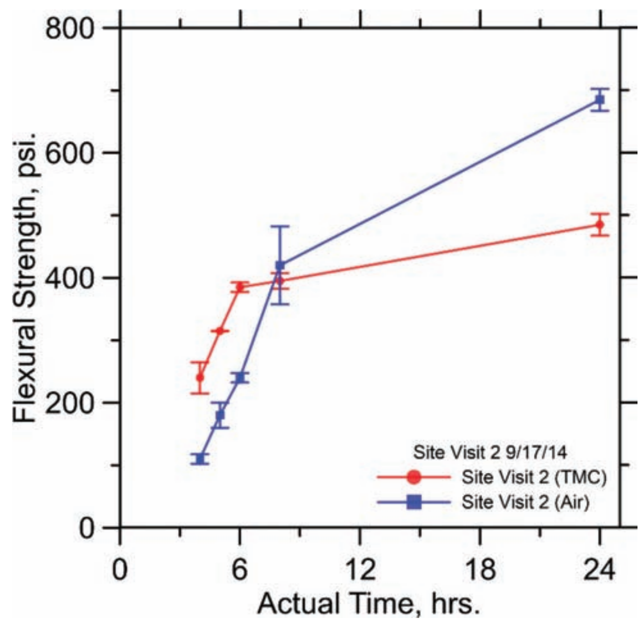

Figure 6.3 Flexural strength development in air cooled beams (blue squares) and temperature matched curing (TMC) beams. TMC beams exhibit a rapid strength gain at early ages, but show stunted strength gain at later ages.

However, at approximately the 6 hour time period, the TMC specimens exhibit stunted strength development. At later ages, the strength of TMC specimens is much lower than that of standard curing beams.

7. CONCRETE PAVEMENT PERFORMANCE

7.1 Background

One of the major tenets of statistical quality control is that the overall quality of a produced product is linked to the variation and consistency (e.g., Darroch, 1968; Derman & Ross, 1997; Venable, 1970). This is extended to concrete pavements, where literature has reported concrete pavements with lower variation exhibit a longer and more consistent service life (Graveen et al., 2009a; Hoerner & Darter, 2000). Since prior research conducted during concrete pavement construction in Indiana (Graveen, 2014; Graveen et al., 2009a), several new test methods have gained a significant traction in the concrete community as well as an increasing emphasis being placed on the durability of the concrete being placed during construction.

7.2 Overview

The MIMTL was used to assist SPR-3708 in the investigation of the variation of performance measures and variation seen during in-progress construction. More detailed discussion of the project objectives, method, and conclusions can be found in the final report for SPR-3708 (Spragg, Todak, Shagerdi, 2016). The MIMTL assisted in this with investigation with four primary objectives:

- Provide the investigating personnel with the proper PPE and all necessary equipment to conduct tests, manufacture specimens, and assist in early age and fresh property testing;
- Assess production variability through a series of different standardized test methods and procedures that are undergoing development in a large scale production environment;
- Investigate the impact of aging on both mechanical and durability test methods;
- Assist with technology transfer activities with both on-site INDOT and consultant quality assurance testing personnel and contractor and supplier personnel.

This chapter will specifically focus on site visits to two in-progress construction sections on I-69 in southwest Indiana. The MIMTL was used to support research personnel during the site visit. The testing personnel arrived on-site at the beginning of the day of production. Samples were taken throughout the day, from different batches during production. The concrete was sampled from directly in front of the paver, such as shown in Figure 7.1 taken immediately before sampling. The samples in this portion of the study were kept in a sealed condition. The two site visits used typical paving concretes. Both mixtures used a w/cm of 0.42, and mixture 1-1 had a low paste content and 21.5% fly ash by mass. Mixture 1-2 had a moderate paste content consisting of straight cement.

Figure 7.1 A photograph of the material in front of the paver, directly before sampling.

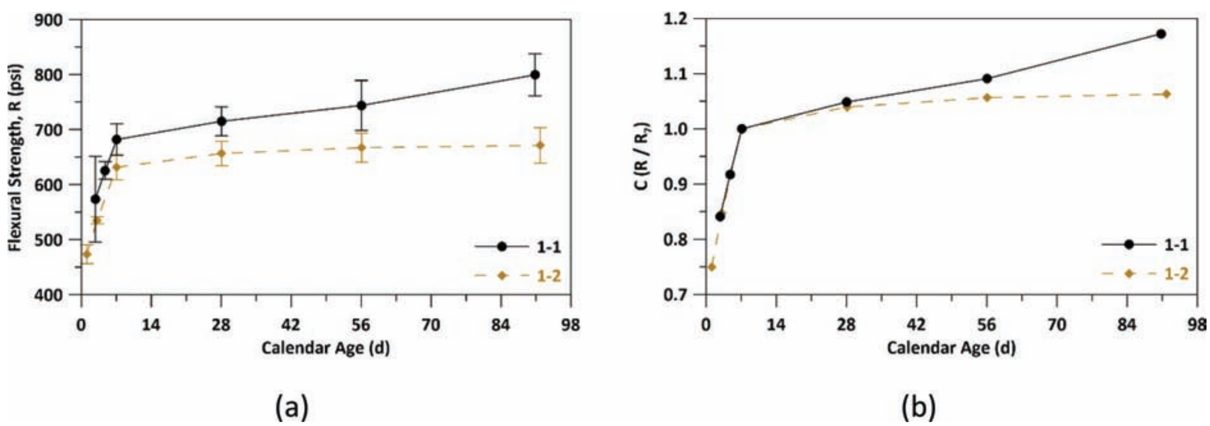

Figure 7.2 Sealed flexural strength, R, in a third point bending test shown vs age, in (a) values of psi and (b) normalized by the 7 d value. Mixture 1-1, a low paste and 21.5% fly ash mixture, shows higher strength gain over time compared to 1-2, a straight cement mixture.

7.3 Data Collected

The first batch after arriving for the day was utilized to produce twenty-five flexural beam specimens. Figure 7.2 presents results for sealed cured flexural strength as a function of time. Recall, both mixtures had a w/cm of 0.42, while mixture 1-1 has a lower paste content and 21.5% fly ash by mass, while mixture 1-2 is a straight cement mixture. Mixture 1-1 shows a higher initial strength, attributed to its lower paste content, and more significant strength development over time, attributed to the inclusion of the SCM. Figure 7.2b presents results that are normalized by the 7 d measurement of flexural strength. Surprisingly, it looks like the two mixtures exhibit the same strength development at early ages, i.e., before 7 d, while later ages the mixture with SCM shows a more significant gain. The average CV was approximately 4.6%, slightly lower than the single-operator testing variation. This is expected, as measurements were done on specimens made from the same batch, which would not include production variation.

The first batch after arriving for the day was utilized to produce eight 4x8 cylinder specimens. The specimens were cast, and sealed in two layers of 6 mil plastic bags on-grade, and at an age of 24 h were taken back to the laboratory. Table 7.1 presents results for the average of four sealed cured specimens tested at 7 d and 28 d for split tensile strength. Opposite of the trend of flexural

TABLE 7.1
Splitting tensile results for site visits, in SSD lb/yd^3.

Age	Mixture ID	1-1	1-2
7 d	Average (psi)	380	389
	CV (%)	11.6	12.0
28 d	Average (psi)	425	413
	CV (%)	11.9	10.9

strength, mixture 1-1 showed a lower initial strength. However, the 28 d measurement for mixture 1-1 was higher. Interestingly, at both ages the mixtures were only approximately 3% different from each other. This would suggest these two mixtures did not have a significant difference in split tensile strength. Furthermore, the CV of the samples was approximately 12% for all the testing ages. This was nearly 2.5 times the testing variation described by Graveen et al. (2009b), but consisted of a sample size quite a bit larger than this this study.

As part of the study, the Super Air Meter (SAM) was investigated. This test method is an active area of development (see superairmeter.com as of June 2016) that is currently under development that has shown good correlation with assessing air void distribution (Ley & Tabb, 2013; Todak, 2015). The test method works by utilizing a slightly modified traditional pressure air meter that utilizes five pressure levels instead of the traditional single pressure level. The method can calculate the total air content, as well as the using pressure differentials to calculate what is termed a “SAM number”, in units of psi. The associated calculations to determine these values are done by an onboard logic unit and are displayed directly on the screen. The SAM number has shown good correlation with an ASTM spacing factor (Ley & Tabb, 2013) and the critical degree of saturation (Todak, 2015). The SAM is a good test in this respect, because it can be used on fresh concrete, and can be completed in ten to twenty minutes. It is worth noting, that subsequent iterations of this equipment currently in development utilize a pressured air tank such that the testing personnel does not need to spend time pressurizing the chamber. This is noted as reducing the testing time significantly.

The site visits in this study evaluated the SAM throughout a day of production. At four points evenly spaced throughout the day, samples were taken from directly in front of the paver. Samples were taken at the same time that INDOT personnel took their quality assurance samples. Figure 7.3 shows the comparison between the total air contents measured by the SAM, shown in closed symbols, and the INDOT measured quality assurance samples, shown in the open symbols. On average, there was less than a 0.2% difference in absolute air content between the INDOT measured value and the value using the SAM meter. This difference is less than the multi-operator standard deviation.

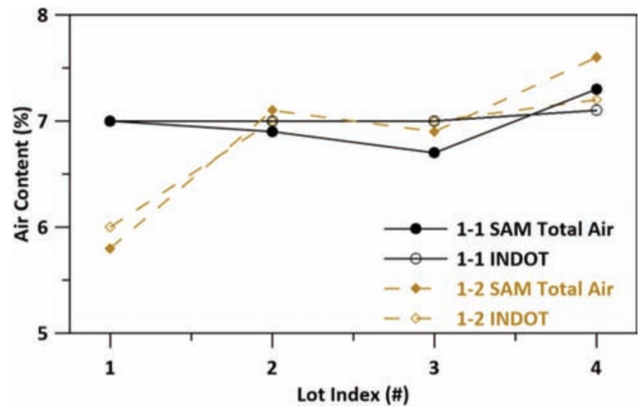

Figure 7.3 Air content determined using the Super Air Meter (SAM) or INDOT testing personnel. Average difference of less than 0.2% between equipment is within the testing variation.

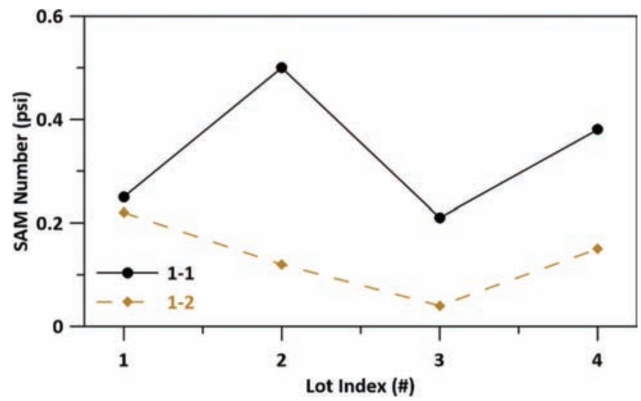

Figure 7.4 Super Air Meter number, shown to have good correlation with freeze/thaw resistance for different sample indices taken from a day of production. Samples with fly ash and lower paste content showed a higher average SAM number.

The SAM meter could be used in place of a standard air meter without any required conversions.

In additional to the total air content, the SAM can also the determined the aforementioned property of “SAM Number”. The SAM number is determined from multiple pressure levels in the SAM chamber. Correlations have shown a SAM Number below 0.2 psi was shown by Tenesi, Kim, Beyene, and Ardani (2015) to be ideal in preventing freeze/thaw damage. Todak has shown that higher SAM numbers correlate to a lower critical degree of saturation and reduction in estimated service life (Todak, 2015).

The site visits evaluated the SAM number on the same mixtures evaluated for air content as described above. The SAM was tested concurrent with INDOT acceptance testing for total air. The results are presented in Figure 7.4 indicate that throughout a production during a typical day, mixture 1-1 showed an average value of 0.33 with a standard deviation of 0.13, while mixture 1-2 had an average value of 0.13 with a standard deviation of 0.07. The estimated testing

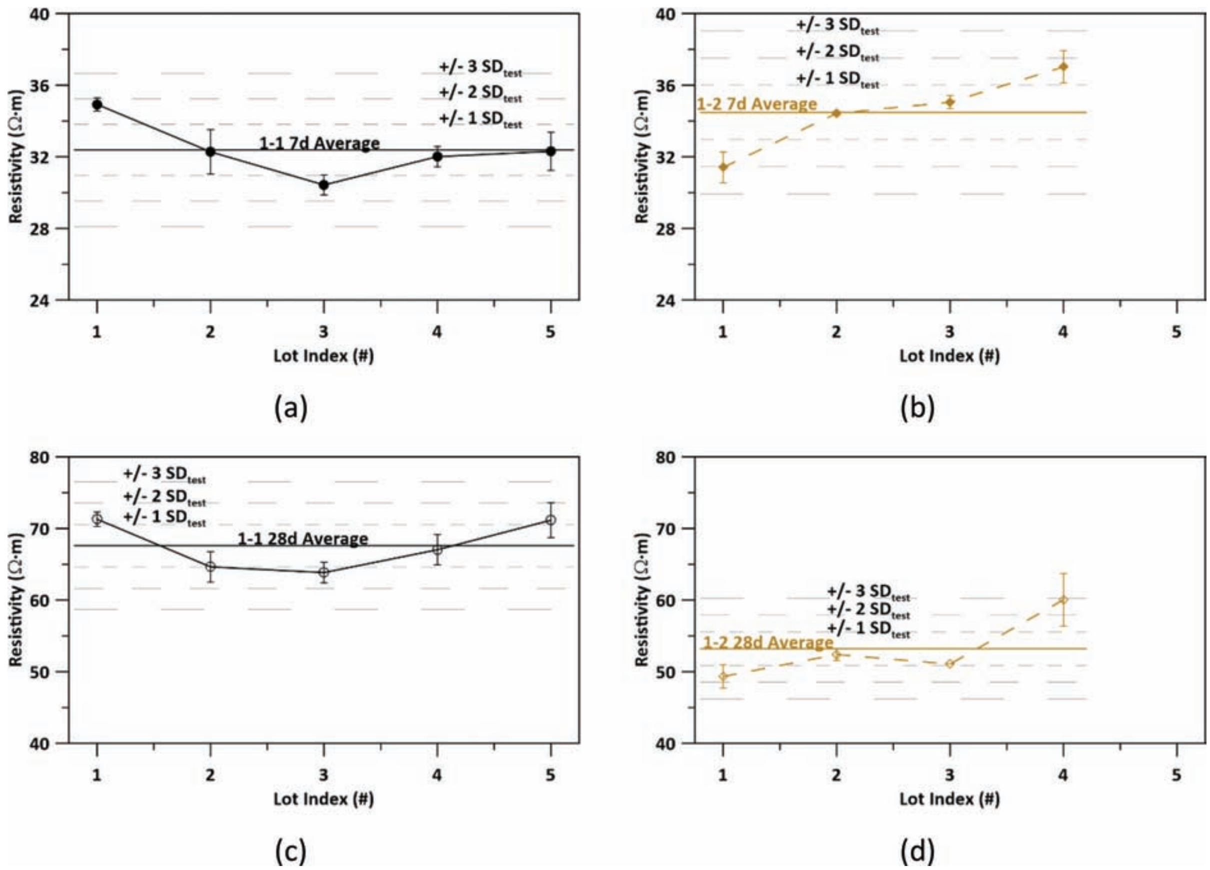

Figure 7.5 Sealed resistivity for (a) 7 d Mixture 1-1, (b) 7 d Mixture 1-2, (c) 28 d Mixture 1-1, and (d) 28 d Mixture 1-2. Solid lines indicate the average of all the samples measured, with ranges shown for +/- 1, 2, 3 times the testing standard deviation from the average.

standard deviation for the SAM number is 0.11 psi, so the variation noticed in these measurements is not far outside the testing variation of the test method. Furthermore, assessing the pore distribution for freeze thaw resistance is a somewhat variable activity. Another popular test method, ASTM C457, has a multi operator coefficient of variation of 20% (ASTM C 457, 2013). The sample with a lower paste content fly ash mixture, 1-1, was noticed to have a higher SAM number.

However, as Todak describes, SAM number, or any measure of air void distribution and spacing, is only one parameter that influences the freeze thaw durability of a concrete material (Todak, 2015). It is argued using sorption a sorption based model, that measures of the total volume of air, and the rate at which the air voids are filled in with absorbing fluid are more important in determining the estimated life cycle of a concrete material (Todak, Lucero, & Weiss, 2015; Weiss, Tsiu Chang, & Todak, 2016). Based on the amount of time it takes to conduct a typical SAM test and the variation not significantly outside the testing variation, the authors believe the SAM is a worthwhile test for mixture qualification, but does not lend itself well to regular quality acceptance testing. The authors believe that it would be more worthwhile to control total air and a measure of transport properties or consistency.

Resistivity was also evaluated as part of the site visits conducted during this study. The specimens were sampled from the same batch of the concrete sampled for SAM testing. For each batch, three samples were made. Immediately after casting, the specimens were sealed in two layers of 6 mil plastic bags. The specimens were kept in a sealed condition and taken to the lab at an age of 24 h. At an age of 7 d, the specimens were demolded, tested, and returned to the bag and tested at an age of 28 d. The temperature of the specimens were measured with an infrared thermometer and the resistivity was tested according to AASHTO TP119 (2015).

Figure 7.5 shows resistivity measurements on sealed specimens conducted as part of the first category of site visits. The solid line represents the average of all the measurements, while the dashed lines represent +/- 1,2, and 3 testing standard deviations from the mean. The testing standard deviation was determined from the single-operator testing CV described by Spragg, Castro, Nantung, Paredes, and Weiss (2012). Figure 7.5a and Figure 7.5b are measurements conducted at 7d, while Figure 7.5c and Figure 7.5d are 28 d measurements. Two specimens were identified as outliers with resistivity values nearly double that of the other two specimens in the set. The specimens lost an average of 0.25% of their 7 d mass between the age of 7d and 28 d, while other specimens fluctuated +/- 0.02%. A recently round robin has suggested that a value of 0.4% of mass loss is correlated to outliers, but the paste content of those structural concrete mixtures tended to be a little higher (Spragg, Coyle, Fu, Amirkhanian, & Weiss, 2016). This suggests that the amount of initial water in the mixture might be a better measure to judge mass loss. Regardless, specimens that lose mass are correlated to higher resistivity measurements and specimens that lose mass an order of magnitude higher than other specimens in the set can be considered as outliers. The use of embedded samples that can ensure better protection against moisture loss are being investigated.

Between 7 d and 28 d, mixture 1-1 increased resistivity by a factor of 2.1, while mixture 1-2 increased by a factor of 1.5. While these two cementitious systems exhibit different pore solution properties, the inclusion of fly in mixture 1-1 will result in an expected delay of pore refinement, similarly to that seen with strength development in the previous section. This highlights the importance of evaluating, at least during the mixture qualification stage, the mixture at a later age, such at 28 d or even 91 d. While this does present slightly more problems during the preplanning stages of a project, i.e. requiring two or three months before production, this will ensure the mixtures will obtain the desired level of performance during their service life. By testing at a later age, measures need not be taken that ensure the high performance at an early age, e.g., a lower w/cm, which might increase the price of the mixture. However, by conducting a 3 d or 7 d test, targets can be set for production and quality assurance, where it can be assumed that the same degree of aging occurs. If significant deviation from the targets are noticed during production, either a change in materials occurred which affected the measured resistivity, most namely the alkali contents of the cement changed, or the production variation and control of the mixture needs investigated. The non-destructive nature of resistivity measurements means the specimens could be kept and evaluated at a later age if disputes arise.

The average variation seen in the resistivity measurements at 28 d for mixture 1-1 was an average of 5.0% and for mixture 1-2 an average of 6.7%. The individual sublots tested were shown an average deviation from the mean of 0.7 SD for mixture 1-1 and 1.0 SD for mixture 1-2 at 7 d. This deviation increased when tested at 28 days. For all but one of the sublots tested, the variation of the three-specimen set was below the testing variation, 4.4% CV. Therefore, the variation seen between sublots corresponds to production variation.

8. ASPHALT TACK COATS

The MIMTL was used to aide in the establishment of a sound evaluation technique for quantitatively determining chip seal curing times using asphalt emulsion. Under SPR-3801, the MIMTL performed field work at five Indiana State Roads pavement sections (Montoya et al., 2016). Chip seal projects were located on SR 19 (approximately 3 miles north of Mentone), SR 8 (approximately 5 miles west Auburn), SR 1 (approximately 1mile north Farmland) and SR 39 (near Lizton and near Lebanon). The field work was aimed to explore the capability of the proposed electrically-based approach to quantify chip seal curing times under various field conditions.

The field research was used to monitor the curing process, electrical property development and mechanical strength of the fresh seal coat. To a great extent, the curing process is a function of the portion of water that evaporates. In this context, a fresh core sample was taken from the roadway to record the water evaporation rate. Electrical measurements were performed using a hand-held electrical device that was employed to examine whether the curing time could be determined using alternating electric current. The chip seals were swept at intervals in order to evaluate when the asphalt emulsion had gain enough stiffness to withstand uncontrolled traffic or brooming. Additionally, chip seal materials, climatic conditions, types of equipment and engineering practices were documented, and detailed finding will be available in the final report for SPR-3801 (Montoya et al., 2016). More detailed information can be found in M. Montoya's (2016) thesis.

Asphalt emulsion binders and cover aggregate make up the finished chip seal system. At the five shadowed projects, the type of bitumen emulsion used was AE-90S. Table 8.1 presents the aggregate types applied at each pavement section. Also, asphalt emulsion and aggregate samples were collected at each location for further material property characterization.

Chip seal curing times vary upon different climatic conditions. The MIMTL mounted weather station and a thermocouple embedded on the pavement were utilized to record the ambient temperature, ambient relative humidity, wind speed, cloudiness and pavement temperature, at 15 minutes intervals throughout the duration of the site visits at the shadow projects, summarized in Table 8.2.

Plywood pads (4 in x 8 in) covered by aluminum foil were placed on the existing surface prior to the spraying and chipping, as shown in Figure 8.1a. After rolling, the

TABLE 8.1
Aggregate types for the tack coat shadow projects.

	Aggregate	
Pavement Section	**Type**	**Size**
SR19 Mentone	Stone	SC 16
SR8 Auburn	Dolomite	SC 16
SR1 Farmland	Stone	SC 11
SR 39 Lizton	Gravel	SC 16
SR 39 Lebanon	Gravel	SC 16

TABLE 8.2
Climatic and pavement conditions during the tack coat site visits.

Pavement Section	Ambient Temperature Range (°F)	Relative Humidity Range (%)	Wind Speed Range (mi/hr)	Prevalent Cloudiness	Pavement Temperature Range (°F)
SR19 Mentone	81.2–95.1	49.3–76.5	5.2–14.7	Sunny	77.0–91.4
SR8 Auburn	69.2–95.2	23.6–64.1	2.2–13.7	Sunny	68.0–86.0
SR1 Farmland	56.4–98.5	22.1–96.4	0.5–10.4	Sunny	66.2–98.6
SR 39 Lizton	60.3–76.6	56.5–91.5	2.4–9.7	Cloudy	64.4–86.0
SR 39 Lebanon	70.8–108.5	17.6–66.2	2.4–6.9	Sunny	75.2–93.2

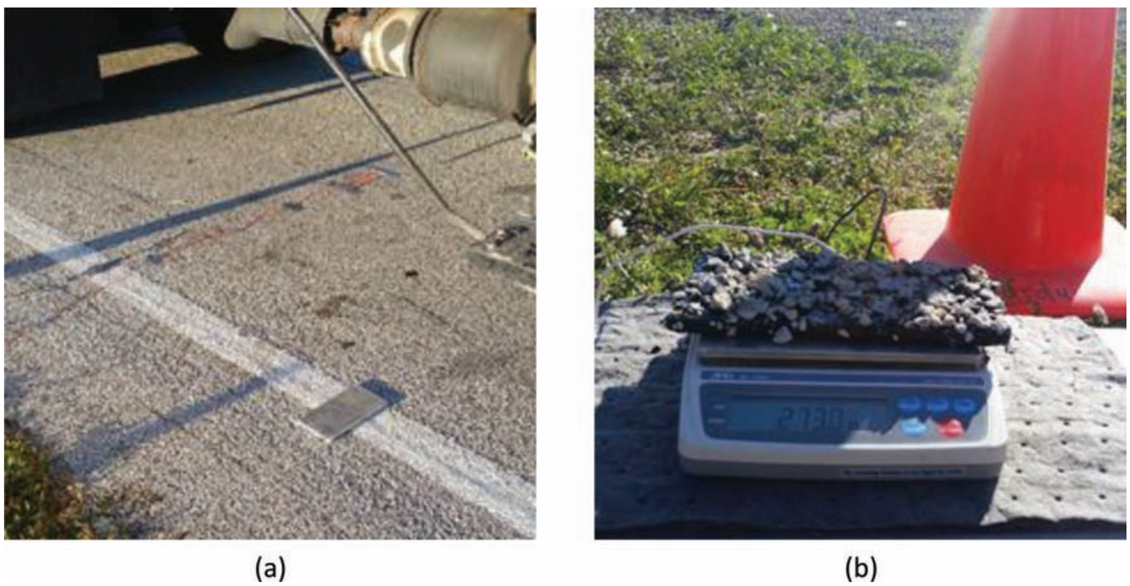

Figure 8.1 Tack coat testing, showing (a) aluminum wrapped plywood pad, prior to tack coat application, to allow for easy extraction of core, (b) fresh extracted tack coat specimen placed on a balance to monitor mass loss.

pads were extracted as a core sample. These specimens were set on a balance to monitor the water evaporation rate under the particular climatic conditions, shown in Figure 8.1b.

Since there is wind-induced error in the field mass measurements, the readings were logged at 10 seconds intervals, allowing to develop a linear regression analysis to fundamentally estimate the water evaporation rate over time. Figure 8.2 presents the mass measurements recorded and regression model generated for the data obtained at SR 8 in Auburn.

A LCR meter device was used to characterize the electrical properties of the residual material over curing time. This handheld test equipment is capable of measuring the electrical resistance at a specific frequency. The electrical properties were monitored on the in-place chip seal, utilizing a two-point embedded electrode probe, as shown in Figure 8.3.

The electrical resistance measurements were recorded at 1 minute intervals. Figure 8.4 shows the electrical resistance measurements logged at SR 39 in Lebanon, as the tack coat cured. As noticed, a longer curing time correlates to a higher electrical resistance, and electrical measurements show great promise in quantifying the amount of water loss.

Shear forces applied by brooms and uncontrolled traffic to fresh seal coats were simulated to assess the potential mechanical performance. An industrial broom, shown in Figure 8.5 was used on chip seals at MIMTL site visits to sweep the pavement at specific intervals. The dislodgement potential was evaluated through visual inspections.

The chip seal operations of Fort Wayne, Greenfield, and Crawfordsville INDOT Districts were surveyed. MIMTL personnel spent five days with the chip seal crews. In general, the construction practices within the districts exhibit marginal variations. Example of the observed operations are shown in Figure 8.6.

The present field work results are encouraging and show that electrical measurements can be used to quantify chip seal curing times. Further discussion and findings will be available on the report under the SPR-3801 research program, Using Field Electrical Conductivity Measurements for Scheduling Chip Seal Spreading/Sweeping Operations (Montoya et al., 2016).

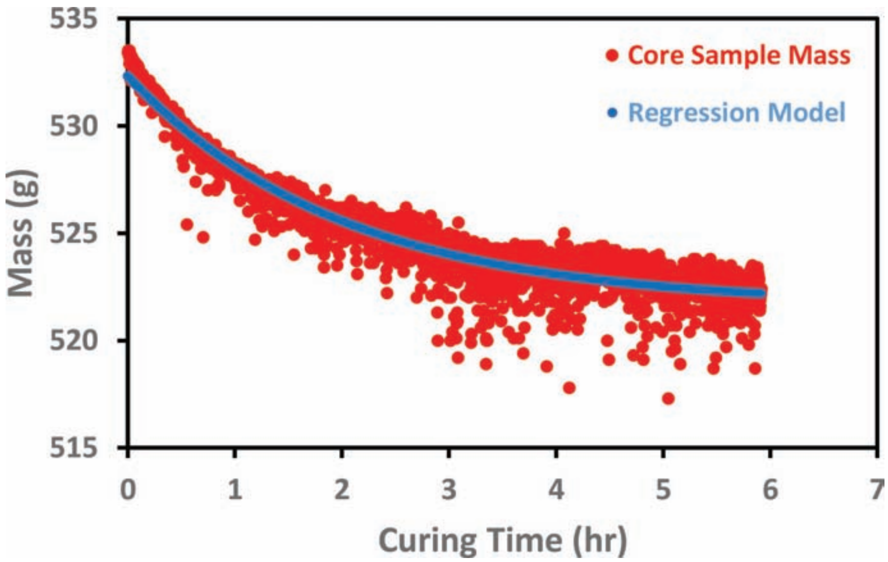

Figure 8.2 Mass loss as a function of curing time for chip seal core samples from SR 8 in Auburn. The linear regression fit is also given.

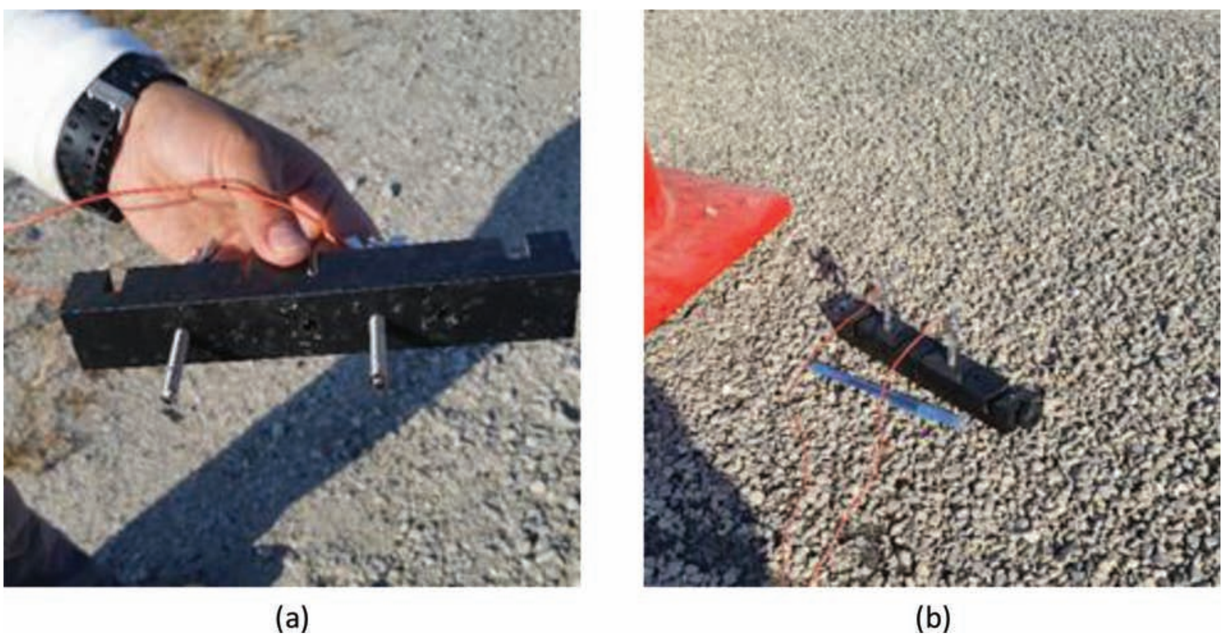

Figure 8.3 Embedded probe to measure the resistance of the in-place tack coat (a) shows the fixture and the embedded stainless steel electrodes, and (b) is the probe embedded in the tack coat.

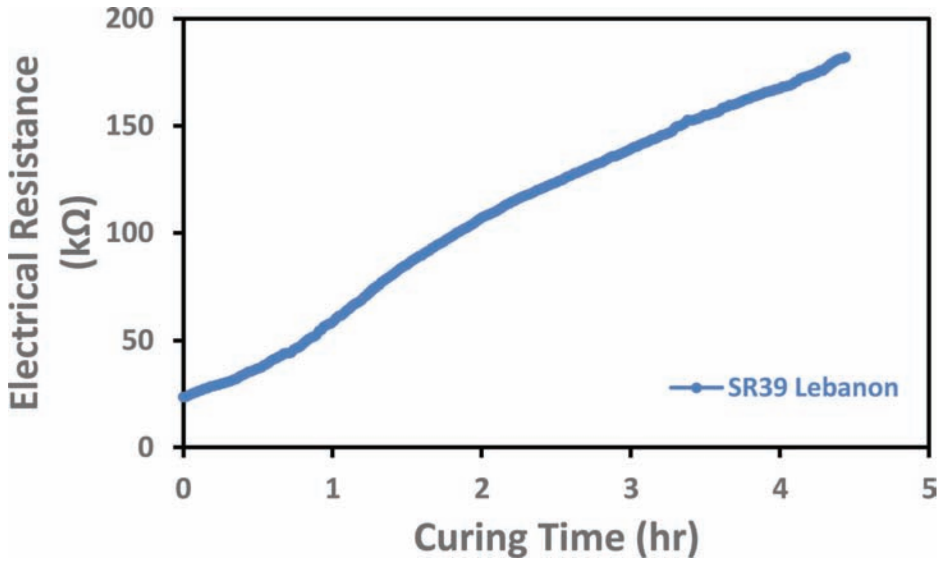

Figure 8.4 Electrical resistance vs. curing time on SR 39 in Lebanon.

Figure 8.5 Shear force simulations using an industrial broom.

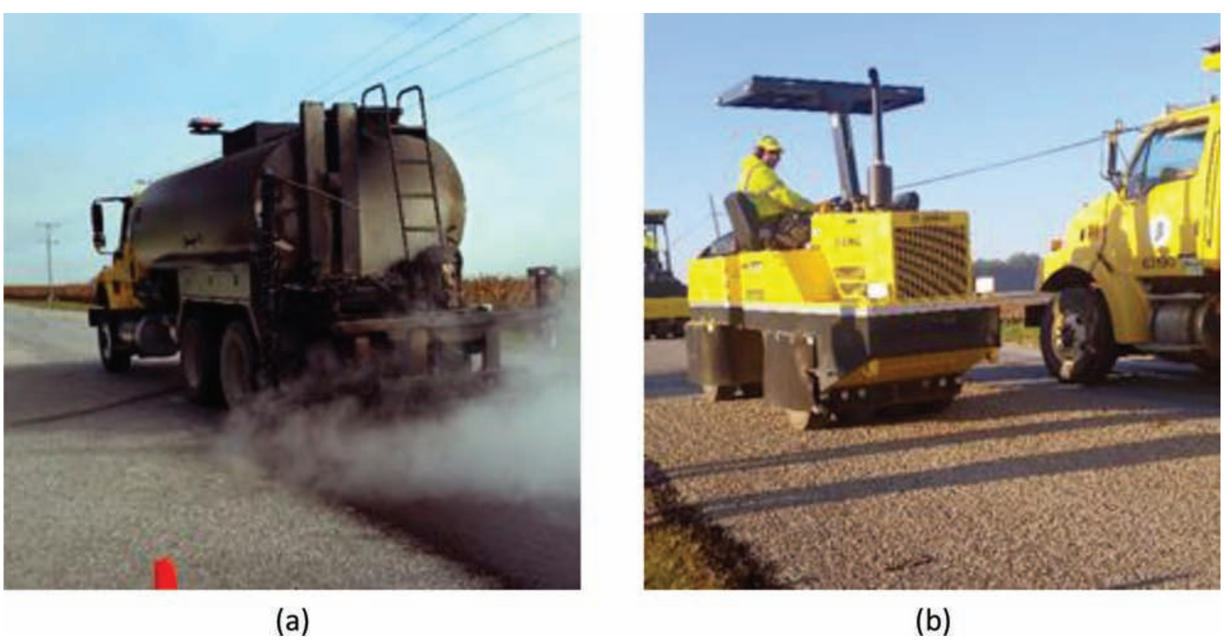

Figure 8.6 Examples of chip sealing operations observed in three INDOT districts.

9. SUMMARY AND CONCLUSIONS

This report is a summary of work performed by the Mobile Infrastructure Materials Testing Laboratory (MIMTL) as a part of the Joint Transportation Research Program (JTRP) through SPR-3858. This report describes use of the mobile lab for testing the field performance of internally cured concrete bridge decks (Barrett, 2015), concrete pavements (Spragg, Todak, Shagerdi, 2016; Todd et al., 2016), and asphalt pavements (Montoya et al., 2016). The work described in this report was intended to support the engineering investigations of other projects as identified. The laboratory was developed and implemented successfully, leading to a laboratory that could be utilized to deploy new technology in the field and provide training to INDOT and industry personnel in an efficient and safe manner.

The MIMTL assisted in the evaluation of the field performance of internally cured bridge decks. Important conclusions from this work are that aggregate properties, especially those of the fine lightweight aggregate, greatly influence the quality and consistency of the supplied concrete. Some batching software has "safeguards" that prevent the input of high absorption values of aggregates. Lastly, since lightweight aggregate has different densities than normal weight aggregate, clamshell opening times on batch plants might need recalibration when producing concrete with lightweight aggregate.

The MIMTL was utilized and essential to the success of field evaluations of concrete patching projects on Indiana interstates and highways. These projects operate on accelerated timelines to accommodate overnight lane closures. The concrete mixtures on these projects are termed "High Early Strength" mixtures, because they must meet opening to traffic strength criteria anywhere from 4 to 8 hours. The main conclusions from field evaluation that the MIMTL helped to evaluated are summarized in the final report for SPR-3905 as well as by Todd (2015). These conclusions are that concrete temperature in patches can exceed 50 to 60 °C, and high concrete temperatures coupled with the use of high dosages of chemical accelerators can lead to poisoned chemical reactions and negligible strength development in high early strength mixtures.

Lastly, the MIMTL assisted in monitoring the construction operations for chip sealing in three INDOT districts, and observed consistent practices between these three districts. The MIMTL helped to provide field evaluation on the use of electrical-based sensors for the use in chip seal scheduling operations. The findings from this portion of the MIMTL's work will be provided in the final report for SPR-3801 (Montoya et al., 2016).

10. ACKNOWLEDGMENTS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Indiana Department of Transportation and this report does not constitute a standard, specification, or regulation. Certain commercial products are identified in this report to specify the materials used and procedures employed. In no case does such identification imply endorsement or recommendation by Purdue University or the Indiana Department of Transportation, nor does it indicate that the products are necessarily the best available for the purpose.

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About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,500 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at: http://docs.lib.purdue.edu/jtrp

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