RESEARCH & DEVELOPMENT

# Performance Engineered Concrete Mixtures – FHWA Implementation Funds

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16. Abstract

Performance engineered concrete mixtures (PEM) include optimized mixture designs and advanced quality assurance methods to provide improved economy, durability, and sustainability of concrete mixtures. The North Carolina Department of Transportation (NCDOT) has supported several research studies to support collection of data for targeted PEM testing technologies and some prescriptive measures. Through these studies, performance targets and proposed specification provisions have been developed for surface resistivity, super air meter (SAM), and shrinkage. In 2018, NCDOT applied for funds to support PEM implementation as part of FHWA's "Demonstration Project for Implementation of Performance Engineered Mixtures/AASHTO PP 84." Funding to support three categories of implementation were secured. This report details the efforts associated with these implementation funds, which included (1) use of PEM tests for QC and acceptance (shadow purposes only) at a concrete paving project, (2) analysis of data from the PEM implementation project and integration of this data with that obtained from other laboratory studies supporting the PEM initiative, (3) development of technology transfer documents (test procedures for PEM tests compatible with NCDOT's Concrete Field Technician Study Guide), (4) development and delivery of a seminar/workshop to support technology transfer to NCDOT's division and region personnel, and (5) preparation of the final report of the PEM implementation project to fulfill the required deliverable to FHWA. Data and findings from the implementation site supported specification recommendations made by UNC Charlotte as part of PEM research, and informed additional shadow testing at an implementation project focused on structural concrete. A final report was prepared and submitted to FHWA to fulfill requirements of receipt of PEM Implementation Funds, and a number of additional presentations were made to publicize NCDOT's PEM efforts. Technology transfer tools produced and disseminated as part of this work will provide continued opportunities to educate NCDOT personnel at the divisional and regional levels, as well as other stakeholders, about the PEM initiative and provide training on the PEM tools targeted for use by NCDOT. Advancements made through NCDOT's PEM efforts will impact specifications, design, and construction. More durable, sustainable concrete mixtures will be specified and used in North Carolina highway infrastructure, resulting in cost savings for construction, quality assurance, and extended life of concrete pavements and bridges.


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## EXECUTIVE SUMMARY

The long service life expectations of pavements, bridges, and other components are often difficult to meet by using typical tests for specification and acceptance, which center around three criteria: slump, air content, and compressive strength. These three criteria are only loosely related to deterioration phenomena and so do not always ensure satisfactory field performance. Consistent with the focus of MAP-21 legislation on performance, there is a desire by FHWA, public agencies, and industry to move towards performance-engineered construction materials. Performance-engineered concrete mixtures include optimized mixture designs (materials selection, gradation, cement content, etc.) which, paired with advanced quality assurance methods, provide substantially improved durability, economy and sustainability. AASHTO PP 84, "Performance Engineered Concrete Pavement Mixtures" provides agencies "with tools to prepare a specification for concrete pavement mixtures that moves closer to measuring and basing acceptance on parameters that are truly critical to the long-term performance of the system (AASHTO 2016)."

Initial steps to move towards performance engineered concrete mixtures were made as part of NCDOT Research Project 2018-14, "Durable and Sustainable Concrete Through Performance-Engineered Concrete Mixtures." This resulted in 1) identification of trends in currently used mixtures and linking to performance, 2) establishment of performance-related criteria for several emerging PEM test technologies through targeted laboratory testing, 3) insights into performance of concrete mixtures utilizing sustainable materials (fly ash and portland limestone cement) and 4) development of a "roadmap" of recommendations and guide specifications for additional work and pilot projects for performance engineered concrete. Findings of this work are presented in the final project report (Cavalline et al. 2020). Ongoing work to support refinement of the proposed performance-related criteria and to explore the benefits that could be obtained by use of optimized aggregate gradation mixtures is ongoing as part of NCDOT Research Project 2020-13, "Continuing Towards Implementation of Performance Engineered Concrete Mixtures for Durable and Sustainable Concrete." (NCDOT 2021).

Concurrent with Research Project 2018-14, NCDOT applied for additional funds to support PEM implementation as part of FHWA's "Demonstration Project for Implementation of Performance Engineered Mixtures/AASHTO PP 84." UNC Charlotte was requested to perform work to assist in implementation of PEM, in accordance with the guidelines use of the awarded FHWA PEM Implementation Project funding. Work included in this project included:

- Support of contractor personnel in testing and data collection using PEM technologies at the pilot project site.
- Support of NCDOT division, regional and central lab personnel in testing and data collection using PEM testing technologies for the implementation site.
- Analysis of data (both PEM and conventional test results) received from the implementation site and the NCDOT regional lab.
- Development and presentation of a seminar or workshop on the PEM initiative, NCDOT's PEM implementation project, and the PEM testing technologies being evaluated for use by NCDOT/UNC Charlotte, to be presented to divisional, regional, and/or central office personnel at various locations selected by NCDOT.
- Development of guidance documents for the PEM testing technologies of interest to NCDOT, in a format compatible to the guidance presented in NCDOT's "Concrete Field Technician Study Guide" or other useful format.
- Development of recommendations for future PEM implementation projects.
- Preparation of a report to support NCDOT's deliverable requirements for the FHWA Implementation Funds (a Post-Construction Project Report).

Data and findings from the implementation site supported specification recommendations made by UNC Charlotte as part of PEM research, and informed additional shadow testing at an implementation project focused on structural concrete. A final report was prepared and submitted to FHWA to fulfill requirements of receipt of PEM Implementation Funds, and a number of additional presentations were made to publicize NCDOT's PEM efforts. Technology transfer tools produced and disseminated as part of this work will provide continued opportunities to educate NCDOT personnel at the divisional and regional levels, as well as other stakeholders, about the PEM initiative and provide training on the PEM tools targeted for use by NCDOT. Products from this research could be utilized by several units, including the Materials and Tests Unit, the Construction Unit, the Pavement Management Unit, and the Structures Management Unit. Advancements made through NCDOT's PEM efforts will impact specifications, design, and construction. More durable, sustainable concrete mixtures will be specified and used in North Carolina highway infrastructure, resulting in cost savings for construction, quality assurance, and extended life of concrete pavements and bridges.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| ASTM | American Society for Testing and Materials |
| DOT | Department of Transportation |
| FHWA | Federal Highway Administration |
| ft | foot |
| kΩ | kilo-ohm |
| lb | pound |
| LCA | lifecycle assessment |
| LCCA | lifecycle cost analysis |
| NC | North Carolina |
| NCC | National Concrete Consortium |
| NCDOT | North Carolina Department of Transportation |
| Ω | ohm |
| OPC | ordinary portland cement |
| PEM | performance engineered (concrete) mixtures |
| PCC | portland cement concrete |
| pcf | pounds per cubic foot |
| pcy | pounds per cubic yard |
| PLC | portland limestone cement |
| psi | pounds per square inch |
| PLC | portland limestone cement |
| QA | quality assurance |
| QC | quality control |
| RCPT | rapid chloride permeability test |
| RP | Research Project |
| SCM | supplementary cementitious material |
| SHA | state highway agency |
| SG | specific gravity |
| UNC | University of North Carolina |
| *w/cm* | water to cementitious materials ratio |

# 1. INTRODUCTION AND RESEARCH OBJECTIVES

## 1.1 Introduction

Tests used for specification and acceptance of concrete mixtures have typically centered around three criteria (slump, air content, and strength) that are not always good predictors of long-term performance (AASHTO 2017). However, the current economic and policy environment has forced highway engineers to focus on durability as a means of reducing maintenance and replacement costs. This durability must be imparted to concrete by careful selection of constituent ingredients as well as testing for enhanced acceptance criteria. Changes to concrete mixtures (use of new admixtures and the increased use of combinations of supplementary cementitious materials (SCMs)) and exposure conditions (increased use of deicing chemicals) is resulting in a need to readdress the way that concrete mixtures are specified and tested (Cavalline et al. 2016).

Consistent with the focus of MAP-21 legislation on performance, there is a desire by FHWA, public agencies, and industry to move towards performance-engineered construction materials. Performance-engineered concrete mixtures include optimized mixture designs (materials selection, gradation, cement content, etc.) that are engineered to meet or exceed design requirements, and are predictable, durable, and have increased sustainability (Ahlstrom 2016). The following are keys to implementation of performance engineered concrete (Taylor 2016):

- Design and field control of concrete mixtures around engineering properties related to performance
- Development of practical, performance-based specifications
- Incorporation of this knowledge into an implementation system (Design / Materials / Construction / Maintenance)
- Validation and refinement by performance monitoring

Performance-related specifications provide the ability for agencies to obtain the desired construction quality while allowing contractor greater control and flexibility (Ahlstrom 2016). AASHTO PP 84 "Standard Specification With Commentary for Performance Engineered Concrete Pavement Mixtures" provides a framework and guidance for state highway agencies to develop a specification for performance engineered concrete mixtures that focuses on measurement and acceptance of concrete based on characteristics that have been linked to satisfactory long-term durability performance of the concrete.

Performance-related specifications require measurement of key properties and performance characteristics. In order for performance specifications to be successfully utilized, QC and acceptance tests should be rapid, effective, reliable, and inexpensive (Taylor 2016). A number of state agencies, including NCDOT, are using and evaluating new, rapid, early-age testing technologies such as resistivity, sorptivity, workability, and air void system analysis that support development and use of performance-engineered concrete mixtures. The capabilities of these tests to evaluate the durability performance of concrete mixtures is improving as state highway agencies build sufficient data to correlate the test results with durable field performance.

To support FHWA's performance-engineered concrete initiative and implementation of AASHTO PP 84, ongoing research is being performed at other universities to enhance the knowledge of the basic science and emerging tests that form the foundation of the specification. As such, AASHTO PP 84 has been updated annually between 2017 and the publication of this report. NCDOT has concurrently funded research on North Carolina concrete mixtures to support implementation of certain targeted testing technologies suggested by AASHTO PP 84, and begin movement towards specification and use of performance engineered concrete mixtures. Initial steps to move towards performance engineered concrete mixtures were made as part of ongoing NCDOT Research Project 2018-14, "Durable and Sustainable Concrete Through Performance-Engineered Concrete Mixtures." This project resulted in 1) identification of trends in currently used mixtures and linking to performance, 2) establishment of performance-related criteria for several emerging PEM test technologies through targeted laboratory testing, 3) insights into performance of concrete mixtures utilizing sustainable materials (fly ash and portland limestone cement) and 4) development of a "roadmap" of recommendations and guide specifications for additional work and pilot projects for performance engineered concrete. Findings of this work are presented in the final project report (Cavalline et al. 2020).

Ongoing work to support refinement of the proposed performance-related criteria and to explore the benefits that could be obtained by use of optimized aggregate gradation mixtures is ongoing as part of NCDOT Research Project 2020-13, "Continuing Towards Implementation of Performance Engineered Concrete Mixtures for Durable and Sustainable Concrete." (NCDOT 2021).

## 1.2 Research Objectives

Development and implementation of performance-related specifications is an extensive undertaking, and the shift will impact all stakeholders in the construction process. Concurrent to Research Project 2018-14, NCDOT applied for additional funds to support PEM implementation as part of FHWA's "Demonstration Project for Implementation of Performance Engineered Mixtures/AASHTO PP 84." These funds were awarded to NCDOT in Spring 2018. Some of the FHWA funds were used internally to support equipment purchases and other NCDOT implementation efforts. UNC Charlotte was requested to perform work to assist in implementation of PEM, in accordance with the guidelines use of the awarded FHWA funding. The objectives of this research project included:

1) Support of contractor and NCDOT personnel in testing and collection both at the current PEM implementation project site and at NCDOT facilities.
2) Analysis of data (both PEM and conventional test results) received from the PEM implementation site and the NCDOT Statesville Regional Laboratory, with a goal of evaluating test variability and (in conjunction with findings of ongoing RP 2018-14) identification of performance targets for future specifications.
3) Development of technology transfer documents including guides for PEM testing technologies of interest to NCDOT, compatible with a standard format such as that used in NCDOT's "Concrete Field Technician Study Guide."
4) Development and delivery of a seminar or workshop on the PEM initiative, NCDOT's PEM implementation project, and the PEM testing technologies being evaluated for use by NCDOT/UNC Charlotte, to be presented to local, regional, and/or central office personnel along with other invited industry stakeholders.
5) Preparation of report to assist NCDOT in meeting FHWA submission requirements of a Post-Construction Project Report for the PEM implementation funds.

# 2. BACKGROUND

State highway agencies, including NCDOT, are faced with maintaining an aging infrastructure with increasingly limited resources. A key to ensuring the integrity of concrete highway infrastructure, while promoting movement towards national sustainability goals, includes construction of repairs and new infrastructure with concrete mixtures that provide durable performance and extended service life. Historically, concrete has been specified using three criteria (slump, air content, and compressive strength) which are only loosely correlated with successful, long-term performance. It has long been known that durable concrete is associated with several performance characteristics measurable in a laboratory setting. Low permeability, resistance to cracking, and an adequate air void system are three of these characteristics (TRB 2013).

Additionally, to mitigate placement defects that result in the poor durability of what would otherwise be a satisfactorily performing concrete mixture, workability needs to be considered (Taylor 2016). Conventional mixture designs using ordinary portland cements and quality aggregates, can provide good durability performance if they are properly proportioned with low w/c ratio, good workability, and take advantage of admixtures to create an adequately dispersed air void systems (Taylor et al. 2013). Additionally, SCMs, such as fly ash, have been shown to provide enhanced durability performance (reduced permeability and mitigation of ASR) with the added sustainability benefits (Taylor et al. 2013) by replacing a portion of the energy and greenhouse gas-intensive portland cement.

Consistent with the focus of MAP-21 legislation on performance, there is a desire by FHWA, public agencies, and industry to move towards performance-engineered construction materials. Performance-related specifications with acceptance criteria focused on properties and performance characteristics associated with adequate field performance, are becoming increasingly of interest to those in the highway community (Ahlstrom 2016, Taylor 2016). Performance-engineered concrete mixtures include optimized mixture designs (materials selection, gradation, cement content, etc.) which, paired with advanced quality assurance methods, provide substantially improved durability, economy and sustainability.

Over the past several decades, research has led to new understanding of deterioration mechanisms, advancements in concrete mixture design, and better field and laboratory tests to aid in quality assurance and quality control. With this new knowledge, a Federal Highway Administration (FHWA) initiative to move to performance-engineered concrete mixtures is underway. This initiative has resulted in development of a proposed AASHTO provisional specification and commentary, AASHTO PP 84, "Performance Engineered Concrete Pavement Mixtures." As stated in Section 1 of the 2020 version of AASHTO PP 84, "*Recent trends of blending cementitious materials, reducing paste content, using* *modern additives and admixtures, and other innovations to the industry provide the opportunity to move towards specifying the performance characteristics of concrete mixtures and allowing the industry to design mixtures that meet specific performance requirements. New methods to evaluate concrete performance have been developed, and others are being formulated, that can result in improved performance and economics. Further, shifting responsibility for performance to the contractor provides an opportunity for innovation* (AASHTO 2020).” Although developed for pavement concrete mixtures, the approach outlined in AASHTO PP 84 could be extended to include specifications for performance-engineered concrete mixtures utilized for other infrastructure (bridges, non-structural uses, etc.) as well.

A key feature of AASHTO PP 84 is that it provides a menu of potential specification properties and tests that address seven key parameters (sufficient strength, low risk of cracking and warping due to drying shrinkage, freeze-thaw resistance, resistance to chemical deicers, low absorption/diffusion/transport properties, workability), with recommended test methods and recommended specified criteria that state highway agencies can select (or omit) as they desire. This approach facilitates the ability of state highway agencies to incorporate knowledge of local historical performance, existing risk tolerance, and agency preference into the durability-based specification. NCDOT is currently interested in four targeted technologies, which are being utilized at the PEM implementation site. These targeted technologies are: resistivity (to evaluate permeability to aggressive agents and assess overall potential durability), SAM (to evaluate freeze-thaw durability), shrinkage (to assess the potential for cracking due to drying shrinkage) and the Box Test (to evaluate workability of paving mixtures).

## 3.0 PEM IMPLEMENTATION PROJECT

Work described in this section fulfills the following Tasks outlined in the proposal:

*Task 1: Support of contractor and NCDOT personnel at PEM implementation project*
*Task 2: Data analysis from the PEM implementation project and integration with data from ongoing RP 2018-14*
*Task 5: Preparation of final report to support NCDOT’s required deliverable to FHWA*

Successful movement towards performance specifications will require stakeholder input and engagement. In 2018, NCDOT received funding to support PEM implementation as part of FHWA’s “Demonstration Project for Performance Engineered Mixtures/AASHTO PP 84.” Funding to support three categories of implementation were secured (Praul 2018):

- Category A: Incorporating two or more AASHTO PP 84-17 tests in the mixture design/approval process. Shadow testing was acceptable.
- Category B: Incorporating one or more AASHTO PP 84-17 test in the acceptance process. Shadow testing was acceptable.
- Category D: Requiring the use of control charts, as called for in AASHTO PP 84-17.

A contractor interested in gaining more experience with using PEM approaches to improve their QC partnered with NCDOT to use a concrete paving project as NCDOT’s first pilot project. The project was a design-build urban interstate project: a stretch of I-85 north of Charlotte, NC. Approximately 5.3 miles of mainline pavement was the focus of the PEM testing. The existing four-lane interstate (two lanes in each direction) was widened to provide four additional lanes (two lanes in each direction) to support an eight-lane interstate. The new pavement is 12 inches thick doweled jointed concrete paved on a non-woven geotextile interlayer and a 1¼ inch asphalt surface course interlayer (SF9.5A) placed on stabilized subgrade. Lanes were each 12 feet wide.

PEM tests were included as shadow specifications only. **The full final report on this pilot project is attached to this report as Appendix A (Cavalline et al. 2020b). This report is also posted online at the National Concrete Pavement Technology Center’s website.** Additionally, the FHWA’s post-visit report from the Mobile Concrete Technology Center’s visit to the site was published by FHWA (2020), and a summary is provided below.

QC tests performed by the contractor during the pilot project included the Box Test, the SAM test, and surface resistivity. Data was collected during both phases of the project, during the 2018 and 2019 construction seasons. The contractor found the Box Test highly useful in assessing the workability of mixtures, and the test was performed each time the mixture was adjusted. Surface resistivity testing was performed on almost all cylinders tested for compressive strength. Resistivity testing found to be straightforward, and the mixtures used for the mainline paving readily met the proposed target of 11 kΩ•cm by 90 days (often by 56 days). NCDOT found implementation of the resistivity meter for acceptance testing straightforward, and noted that the agency can equip laboratories with this device for a low cost. SAM tests were typically performed by the contractor once per day, but, as mentioned previously, test results were variable and additional training of agency and contractor personnel was scheduled prior to the next pilot project to help improve these test results.

Overall, the demonstration project was a success. The contractor noted that they could accomplish the PEM tests without additional QC personnel, and indicated they intend to use PEM tests on future projects. Both agency and contractor personnel appreciated the insight the PEM tests gave on the potential durability of the project.

Additional activities performed associated with this task include:

- On May 15 2020, the FHWA Mobile Concrete Technology Center Open House was held at the project site. Tara Cavalline and Brett Tempest gave a presentation "Research to Support NCDOT's Movement Toward Performance Engineered Concrete Mixtures."
- In June 2020, data from the PEM implementation project was also prepared in a format that was appropriate for submission to the Concrete Pavement Technology Center at Iowa State University. The database was sent to the CP Tech Center, and their staff indicated this data was added to the PEM national database.
- On June 11, 2020, Brian Hunter of NCDOT and Tara Cavalline UNC Charlotte were requested to make a presentation, "Movement Towards PEM: North Carolina DOT's Approaches and Accomplishments" to FHWA's PEM State Agency Members Meeting. On July 22, 2020, Tara Cavalline gave a similar presentation to FHWA's PEM Industry Technical Advisory Committee Meeting on July 22, 2020. Copies of these presentations were provided to the project Steering and Implementation Committee in a Quarterly Progress Report.
- During the summer of 2021, Brian Hunter of NCDOT and UNC Charlotte were requested to prepare a portion of an upcoming TRB Circular on State Experiences with PEM. This draft was prepared by Tara Cavalline, Brian Hunter, and Brett Tempest and was submitted to the Chair of TRB Committee AKC50, Concrete Pavement Construction and Rehabilitation, Jagan Gudimettla (FHWA) in August 2021.

## 4.0 TECHNOLOGY TRANSFER DOCUMENTS – PEM TESTING GUIDES

*Work described in this section fulfills Task 3: Development of technology transfer documents*.

NCDOT is interested in several tests to support movement towards PEM. **Simplified test procedures for the following PEM technologies, developed in a format consistent with NCDOT's Concrete Field Study Guide are provided in Appendix B of this report**:

- Surface Resistivity (AASHTO T 358)
- Volumetric Shrinkage (ASTM C157)
- Super Air Meter (AASHTO TP 118)
- Box Test (procedure developed by Oklahoma State University)

## 5.0 WORKSHOP/SEMINAR ON PEM FOR NCDOT PERSONNEL

*Work described in this section fulfills Task 4: Development and delivery of a seminar or workshop to support technology transfer to NCDOT division and region personnel*.

The pandemic-related statewide Stay at Home orders implemented by the state of North Carolina and subsequent travel restrictions eliminated he potential for face-to-face delivery of the workshop during 2020 and much of 2021. The workshop format was therefore changed to a virtual due to the restrictions in travel and in-person gathering. The workshop format is shown below. Due to the digital delivery, the format of the workshop was modified from the originally proposed format to include several relatively short modules, in hopes of better retaining viewer attention.

- 60 minutes – Overview of PEM initiative (Tara Cavalline, Presenter)
    - FHWA Initiative
    - Pooled fund study
    - Ongoing research/implementation

- 30 minutes – Overview of AASHTO PP 84 (Tara Cavalline, Presenter)
    - History and development intent
    - Specification approaches
    - Tests included
    - Moving forward

- 70 minutes – NCDOT's initial steps towards PEM (Tara Cavalline, Presenter)
    - Findings of RP 2018-14, and ongoing research
    - Introduction to surface resistivity, SAM, shrinkage, Box Test
    - Development of shadow specifications
    - FHWA Implementation site – I-85 Widening, Rowan County, NC
    - Current Implementation site – I-485 Widening, Charlotte, NC
    - Resources

**The slide presentations for each of these three modules are attached as Appendix D**. After review by the Steering and Implementation Committee, the presentations were recorded in May 2021. The videos are available at the following links:

*https://drive.google.com/file/d/19l5fowFRrJJx58kJo9YxUgjLhoHW6Z16/view?usp=sharing*
*https://drive.google.com/file/d/16owkIberM-r-r_GbbT1A9yzx-8XVNAAW/view?usp=sharing*
*https://drive.google.com/file/d/1DFAAaHRlVq5v47ULkT04TmacNlPQQGvs/view?usp=sharing*

## 6. SUMMARY AND CONCLUSIONS

This project supported NCDOT's efforts to move towards performance engineered concrete, leveraging field data and NCDOT/contractor experience to supplement findings of Research Project 2018-14 (Cavalline et al. 2020) and ongoing Research Project 2020-13 (NCDOT 2021). Data and findings from the implementation site supported specification recommendations made by UNC Charlotte as part of PEM research, and informed additional shadow testing at an implementation project focused on structural concrete. A final report was prepared and submitted to FHWA to fulfill requirements of receipt of PEM Implementation Funds, and a number of additional presentations were made to publicize NCDOT's PEM efforts.

Development and implementation of performance-related specifications is an extensive undertaking, and the shift will impact all stakeholders in the construction process. Technology transfer tools produced and disseminated as part of this work will provide continued opportunities to educate NCDOT personnel at the divisional and regional levels, as well as other stakeholders, about the PEM initiative and provide training on the PEM tools targeted for use by NCDOT. Products from this research could be utilized by several units, including the Materials and Tests Unit, the Construction Unit, the Pavement Management Unit, and the Structures Management Unit.

Advancements made through NCDOT's PEM efforts will impact specifications, design, and construction. More durable, sustainable concrete mixtures will be specified and used in North Carolina highway infrastructure, resulting in cost savings for construction, quality assurance, and extended life of concrete pavements and bridges.

## 7. VALUE OF RESEARCH FINDINGS and RECOMMENDATIONS

### 7.1 Value of Research Findings

Research products produced from this work included:

- Data and experiential knowledge gained from use of PEM tests for QC and acceptance (shadow purposes only) at a concrete paving project.
- Additional data to support evaluation of PEM testing targets, refinement of provisional specifications, and movement towards PEM specifications.
- A project report submitted to FHWA to fulfill the required deliverable for the PEM Implementation Fund program.
- Simplified test procedures compatible with NCDOT's Concrete Field Technician Study Guide.

- Recorded videos of a seminar on PEM that can be used to train NCDOT's division/region personnel and other stakeholders.

At this time, quantification of the value of this research is challenging. Ultimately, findings of this work should support more durable, economical, and sustainable concrete highway infrastructure. Increased use of SCMs and PLC should allow for lower cementitious materials contents to achieve the same durability performance. This would result in initial cost savings as well as cost savings over the life cycle of infrastructure components, which should achieve longer service lives and will require reduced maintenance and rehabilitation actions. Sustainability benefits will also be achieved, allowing NCDOT to demonstrate progress towards MAP-21 goals. Use of enhanced QC and acceptance testing, including PEM technologies and approaches, should improve the quality of concrete infrastructure constructed. Confidence in QC testing could warrant its inclusion in the acceptance decision, lowering the burden on NCDOT and contractor personnel.

The true measure of the economic benefits of movement towards use of the proposed specification provisions will become evident only after infrastructure components are constructed in this manner, and then the life cycle costs compared to similar components constructed without use of PLC/higher SCM contents and use of PEM technologies. In the future, quantification of the value of this research could be made on one or more projects using several methods:

- A life cycle cost analysis (LCCA) on a roadway or structure constructed using PEM approaches and tests, comparing it to a previously constructed roadway or structure.

- A life cycle assessment (LCA) on a roadway or structure constructed using PEM approaches and tests, comparing it to a previously constructed roadway or structure. An LCA would provide a measure of the sustainability benefits, including economic (cost) savings, reduced environmental impact, and reduced societal impacts associated with PEM initiatives.

### 7.2 Recommendations

Following are the recommendations pertaining to the findings of this study:

- Continue collecting field data at additional PEM implementation projects. Integrate knowledge from field experiences with laboratory findings to confirm preliminary testing targets are suitable and refine provisional specifications for the targeted PEM tests.

- Identify ways to reduce the paste content and total cementitious content of NC concrete mixtures. Research to investigate the benefits associated with use of optimized aggregate gradations is ongoing as part of NCDOT RP 2020-13.

- Engage additional stakeholders, including contractors, ready-mixed concrete suppliers, and other industry partners in PEM initiatives. Incorporate stakeholder feedback, particularly that related to QC procedures and concerns, into PEM shadow specifications, and potentially, QC requirements.

- Continue to implement activities that support stakeholder education, training, and use of the PEM technologies. Presentations at the North Carolina Concrete Pavements Conference (as well as similar meetings) could help engage local/regional industry in the PEM effort.

- Efforts to grow and improve FHWA's PEM initiative are ongoing in many areas, including research, pilot projects, and development of technology transfer tools. NCDOT should continue to stay engaged in this initiative through the Pooled Fund Studies, the National Concrete Consortium, and other avenues that may emerge.

## 8. IMPLEMENTATION AND TECHNOLOGY TRANSFER PLAN

RP 2019-41 provided several opportunities for technology transfer supporting the PEM initiative, including training and use of PEM technologies by a contractor, an open house and demonstration by the by the FHWA's MCTC which was attended by a range of contractors, engineers, and NCDOT personnel. Technology transfer of this work is also ongoing as part of a series of training and seminars being prepared by UNC Charlotte personnel as part of RP 2019-41. Additional, specific technology transfer actions for the products of this research project are listed below.

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| **Research Product 1** | Data and experiential knowledge from use of PEM tests for QC and acceptance (shadow only) at a concrete paving project |
| **Suggested User** | Materials & Tests Unit, Pavement Design & Collection Unit |
| **Recommended Use** | Information contained in this database could serve as reference data for evaluation of concrete mixtures and/or test methods in future work. Data could also be used to supplement additional databases on maintained by the Materials and Tests Unit. |
| **Recommended Training** | None recommended at this time. |

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| **Research Product 2** | Additional data to support evaluation of PEM testing targets, refinement of provisional specifications, and movement towards PEM specifications |
| **Suggested User** | Materials & Tests Unit, Pavement Design & Collection Unit, Structures Management Unit |
| **Recommended Use** | This information will be used to refine and enhance provisional specifications developed as part of RP 2018-14 and RP 2020-13. |
| **Recommended Training** | None recommended at this time. |

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| **Research Product 3** | A project report submitted to FHWA to fulfill the required deliverable for the PEM Implementation Funding program |
| **Suggested User** | Materials & Tests Unit, Pavement Design & Collection Unit, Structures Management Unit |
| **Recommended Use** | This report could be shared with NCDOT personnel and other stakeholders to educate them regarding the PEM initiative and share the experiences of the contractor/agency/research team at the implementation project. |
| **Recommended Training** | None recommended at this time, although this report could be disseminated to stakeholders at NCDOT's discretion. |

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| **Research Product 4** | Simplified test procedures compatible with NCDOT's Concrete Field Technician Study Guide |
| **Suggested User** | Pavement Design & Collection Unit, Materials & Tests Unit, Structures Management Unit |
| **Recommended Use** | The simplified test procedures could be incorporated into NCDOT's Concrete Field Technician Study Guide |
| **Recommended Training** | These simplified test procedures could be used in field technician training at this time or in the future. |

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| **Research Product 5** | Recorded videos of a seminar on PEM that can be used to train NCDOT personnel and other stakeholders |
| **Suggested User** | Materials & Tests Unit, Pavement Design & Collection Unit, Structures Management Unit |
| **Recommended Use** | This report could be shared with NDOT personnel (particularly division/region personnel) and other stakeholders to educate them on the PEM initiative and NCDOT's efforts to move towards performance specifications for more durable, sustainable concrete infrastructure. |
| **Recommended Training** | Recorded videos of the seminar are available for dissemination at this time or in the future. |

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# APPENDICES

**FOR**
**FINAL REPORT**

**North Carolina Department of Transportation**
**Research Project No. 2019-41**

**Performance Engineered Concrete Mixtures – FHWA Implementation Funds**

By

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August 2021

## APPENDIX A –

## PEM IMPLEMENTATION PROJECT
## POST-CONSTRUCTION REPORT SUBMITTED TO FHWA

# Post Construction Report for North Carolina DOT Demonstration Project
# Implementation of Performance Engineered Concrete Mixtures (PEM)/AASHTO PP 84

April 30, 2020

Submitted to:

Michael F. Praul, P.E.
Senior Concrete Engineer
Federal Highway Administration
Office of Preconstruction, Construction, and Pavements (HICP-40)

Report Prepared by:

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## Introduction

The long service life expectations of pavements, bridges, and other components are often difficult to meet by using typical tests for specification and acceptance, which center around three criteria: slump, air content, and compressive strength. These three criteria are only loosely related to deterioration phenomena and so do not always ensure satisfactory field performance. Consistent with the focus of MAP-21 legislation on performance, there is a desire by FHWA, public agencies, and industry to move towards performance-engineered construction materials. Performance-engineered concrete mixtures include optimized mixture designs (materials selection, gradation, cement content, etc.) which, paired with advanced quality assurance methods, provide substantially improved durability, economy and sustainability. AASHTO PP 84, "Performance Engineered Concrete Pavement Mixtures" provides agencies "with tools to prepare a specification for concrete pavement mixtures that moves closer to measuring and basing acceptance on parameters that are truly critical to the long-term performance of the system (AASHTO 2019)."

Initial steps to move towards performance engineered concrete mixtures are being made as part of ongoing NCDOT Research Project 2018-14, "Durable and Sustainable Concrete Through Performance-Engineered Concrete Mixtures," and NCDOT Research Project 2020-13, "Continuing Towards Durable and Sustainable Concrete Through Performance-Engineered Concrete mixtures. Together, these research studies aim to 1) identify trends in currently used mixtures and link to performance, 2) perform targeted laboratory testing to establish performance-related criteria for several emerging PEM test technologies, 3) provide insights into performance of concrete mixtures utilizing sustainable materials (fly ash and portland limestone cement) and 4) provide a "roadmap" of recommendations and guide specifications for additional work and pilot projects for performance engineered concrete.

Concurrently, NCDOT applied for additional funds to support PEM implementation as part of FHWA's "Demonstration Project for Implementation of Performance Engineered Mixtures/AASHTO PP 84." NCDOT applied for $80,000 in funds, in the categories listed below.

> **Category A:** $40,000 for incorporating two or more AASHTO PP 84-17 tests in the mix design/approval process. Shadow testing is acceptable.
> **Category B:** $20,000 for incorporating one or more AASHTO PP 84-17 test in the acceptance process. Shadow testing is acceptable.
> **Category D:** $20,000 for requiring the use of control charts, as called for in AASHTO PP 84-17.

Implementation funds were awarded to NCDOT in Spring 2018. Some of the FHWA funds were used internally to support equipment purchases and other NCDOT PEM implementation efforts. UNC Charlotte was requested to perform work to assist in implementation of PEM, in accordance with the guidelines use of the awarded FHWA PEM Implementation Project funding. UNC Charlotte's work included in project included support of contractor personnel in testing and data collection using PEM technologies at the pilot project site, analysis of data received from the implementation site, and preparation of this Post-Construction report to support NCDOT's deliverable requirements for the FHWA Implementation Funds.

## Project Background

Lane Construction personnel approached UNC Charlotte early in 2018 and had indicated their interest in utilizing PEM tests to improve their QC and in supporting NCDOT's PEM initiatives. Due to this eagerness to become more engaged with PEM initiatives, Lane Construction was asked to partner in supporting a PEM demonstration project as part of the FHWA Implementation Funds program. Lane Construction suggested a design-build urban interstate project they were awarded, a stretch of I-85 widening north of Charlotte, North Carolina (TIP Project I-3802B), for the PEM demonstration project. The contract had been let prior to the decision of NCDOT to utilize this project as a PEM demonstration, but the parties collectively agreed on scopes of work to support the three categories of FHWA Implementation Funding outlined above.

The PEM demonstration project included the widening of 5.3 miles of I-85 in Rowan County, North Carolina. The existing four-lane interstate (two travel lanes in each direction) was widened to provide four additional travel lanes (two lanes in each direction) to support an eight-lane interstate from north of Lane Street (Exit 63) to north of the US 29/UW 601 Connector (Exit 68). The pavement design thickness is 12 inches. In addition to the 500,000 square yards of concrete pavement construction which is the subject of this demonstration project, the scope work also included construction of 6 new bridges, 2 bridge replacements, construction of two roundabouts, and associated storm drainage and asphalt pavement. The total project cost was $140 million (Lane 2020).

A vicinity map from the project drawings is shown in Figure 1. Note that although the project included additional roadway paving on US and State Routes, the mainline I-85 pavement was the focus of this PEM demonstration project. The concrete batch plant and QC laboratory for the project were located at the north end of the project site, just to the west of I-85 near Exit 68. Figure 2 provides an overview of the project site, with the approximate location of the concrete plant indicated with a red star.

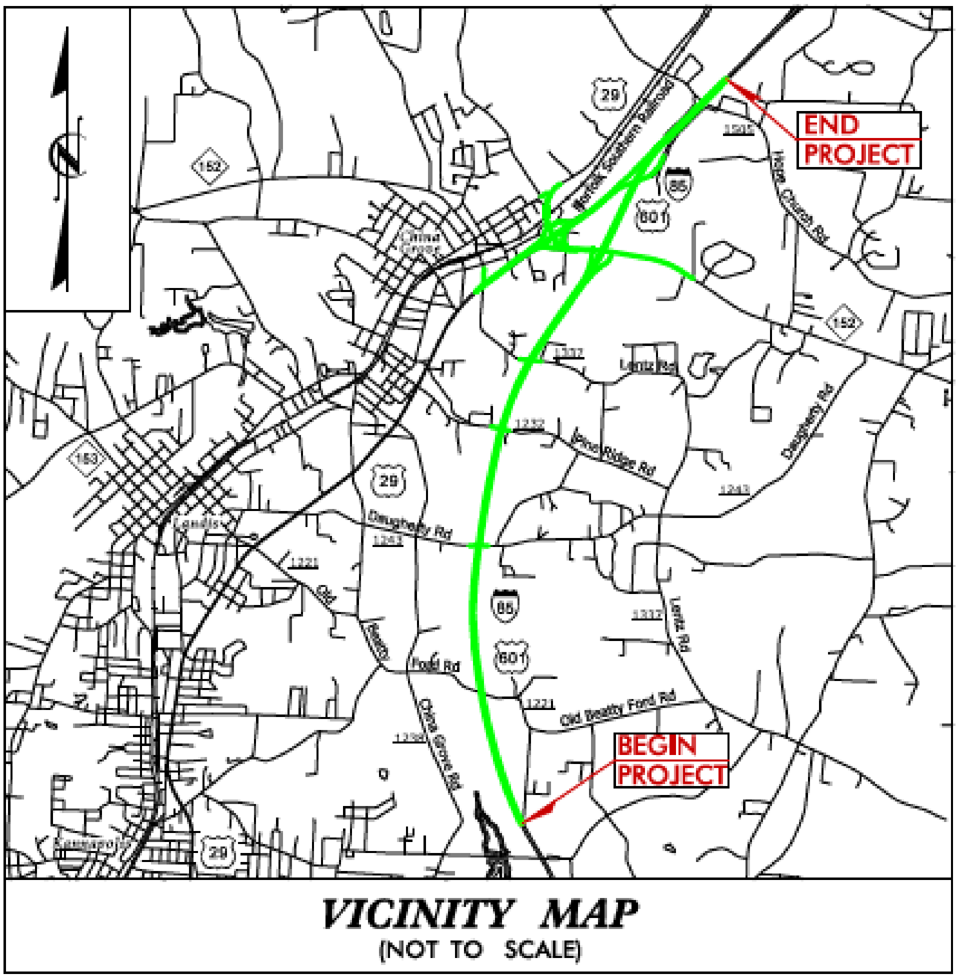



Figure 1: Vicinity map from project drawings showing the PEM implementation project, north of Charlotte, NC.

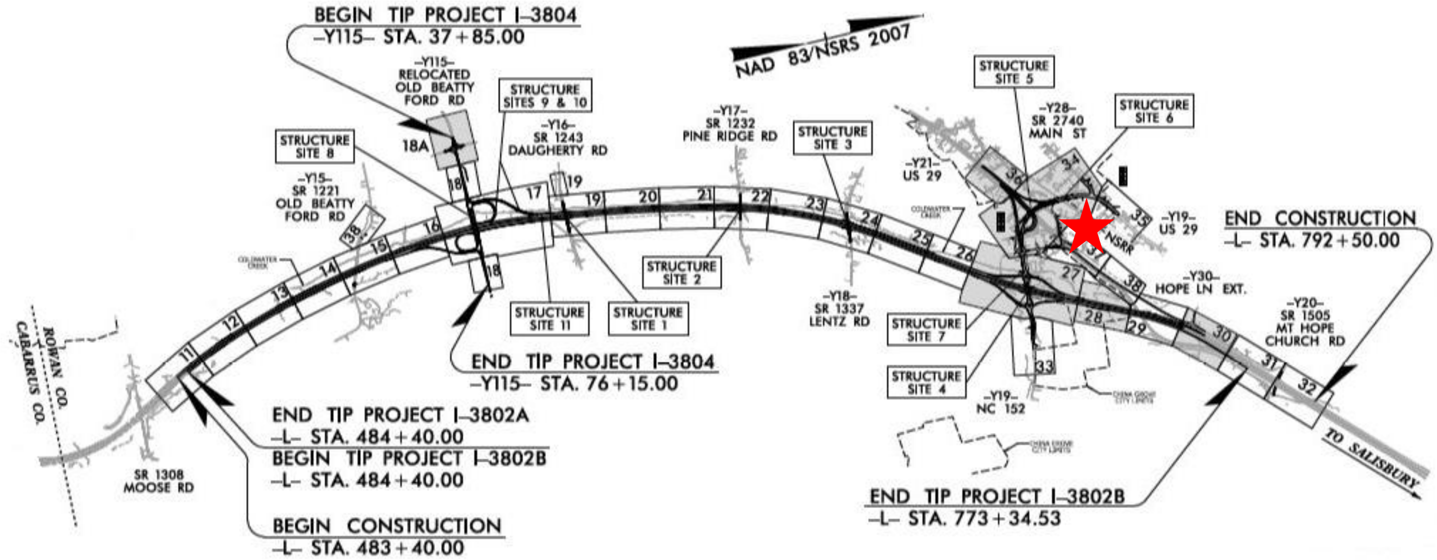



Figure 2: Overview of the project site from project drawings, with the approximate location of the batch plant and QC laboratory shown with red star.

HDR was the design partner for this design-build project. The existing 10-inch thick continuously reinforced concrete pavement was constructed in approximately 1978, was placed on an aggregate base course. The 2015 ADT for this segment of I-85 was 97,100, with a design year (2040) ADT of 179,500. Truck traffic in 2015 was estimated to be 19% (14% TTST and 5% duals). The design speed for this section of I-85 is 70 mph, with a posted speed of 65 mph.

The new mainline concrete pavement is 12-inch thick doweled jointed concrete, paved on a 1¼ inch asphalt cement concrete surface course interlayer (SF9.5A) placed on stabilized subgrade. A section detail is shown in Figure 3. The travel lanes are each 12 feet wide with a 22-foot median separating the four lanes in each direction. A description of phasing at the PEM Implementation project prepared by Lane Construction is provided in Figure 4.

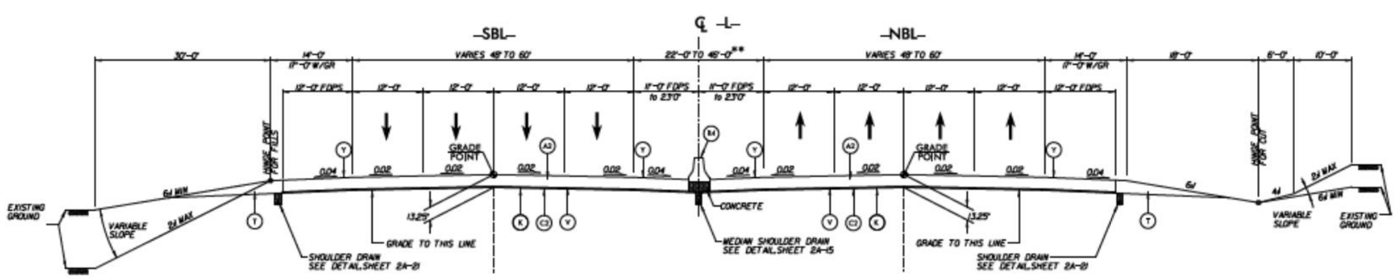



Figure 3: Cross section from project drawings showing widening of northbound and southbound lanes of I-85.

I-85

| PHASE | DESCRIPTION |
|---|---|
| PHASE 1 | **Step 1:**<br>▪ Place portable concrete barrier (PCB) along inside and outside lanes of I-85 for Daugherty Road, Lentz Road and NC 152 (-Y19-).<br>▪ **Using lane closures, a minimum of 1 ½" of asphalt will be placed over the outside shoulder and Phase 1 temporary travel lanes in both directions. This will provide the minimum pavement structural strength on the shoulder to shift I-85 traffic to the outside shoulder in Step 2, as well as a clean, smooth surface (in lieu of the traffic pattern masking) to place temporary markings over the existing travel lanes.**<br>    ▪ The shoulder and lane resurfacing will be completed after work has already begun on Daugherty Road, Lentz Road and NC 152 (-Y19-) bridges over I-85.<br>**Step 2:**<br>▪ Shift traffic to the outside shoulder, place PCB along the inside travel lane and construct the proposed median barrier, inside shoulder, and two inside travel lanes. |
| PHASE 2 | ▪ Shift I-85 traffic to the completed inside lanes, place PCB along the outside travel lane and construct the outside of I-85.<br>    ▪ The following construction will need to be completed in order to shift I-85 traffic to the median along the entire project:<br>        » Proposed median barrier, shoulder and two inside travel lanes<br>        » Reconstruction of Daugherty Road and Lentz Road<br>        » Demolition of the existing flyover bridge center bent and construction of inside lanes, barrier and inside shoulder along I-85 at flyover<br>        » Demolition of existing bridge at Pine Ridge Road and construction of the proposed center bent<br>        » Left side of NC 152 (-Y19-) bridge over I-85 with traffic shifted to the left side, demolition of the center bent on right side of existing bridge and construction of inside lanes, barrier and inside shoulder along I-85 under NC 152 (-Y19-)<br>Note: If work at NC 152 is not complete and/or the flyover bridge has not been demolished, I-85 will still be shifted to the inside lanes with temporary on-site detours around these two locations so work along I-85 can progress. Mill and resurface and replace bridge joints on Mt. Hope Church Road (-Y20-) |

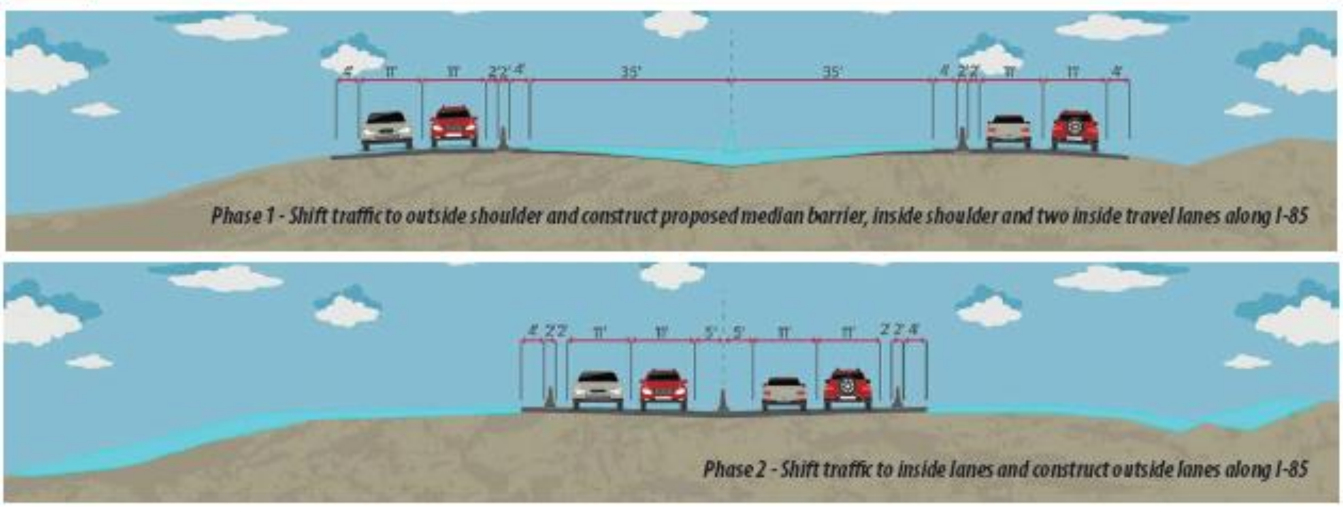



Figure 4: Construction Phasing for PEM Implementation project at I-85.

Phase I mainline paving began in April 2018 and was completed in early September 2018, with work on shoulders completed later in Fall 2018. Phase 2 mainline paving began during April 2019 and concluded in October 2019. Concrete tested using the PEM tests was primarily concrete used in mainline paving, although some concrete used for some ramps and selected shoulder locations was also tested using the PEM tests.

**Concrete Mixture Design**

NCDOT Standard Specifications for Roads and Structures (NCDOT 2018) require that mixture designs for concrete pavements contain at least 526 pounds per cubic yard (pcy) of cement, a maximum water/cementitious materials (w/cm) ratio of 0.559, an air content ranging from 4.5% to 5.5%, a maximum slump of 1.5 inches, a minimum flexural strength of 650 psi at 28 days and a minimum compressive strength of 4,500 at 28 days. Fly ash can be substituted for up to 30% of cement at a replacement rate of 1.0 pounds of fly ash for 1.0 pounds of cement. For approval, the mixture designs must be submitted in terms of saturated surface dry (SSD) weights on NCDOT Materials and Tests From 312U, at least 30 days prior to proposed use. Test results required for approval include 1, 3, 7, 14, and 28 day strengths averaged from two 6 inch by 6 inch by 20 inch beams and averaged from two 6 inch by 12 inch cylinders, made and tested in accordance with AASTHO R 39, AASHTO T 22, and AASHTO T 97 from a certified laboratory. For hand methods of placing and finishing, an adjusted mixture design is required to be submitted for approval. This "hand placed" mixture is allowed to have a maximum slump of 3 inches, and must maintain the same w/cm ratio as the original mixture design.

The concrete mixture designs for the project were developed by Lane Construction. Mixtures were and batched and tested at Lane's QC laboratory facilities to develop the required data for NCDOT approval. Category A of the FHWA PEM Implementation Funds program required incorporating two or more AASHTO PP 84-17 tests in the mix design/approval process, with shadow testing being acceptable.

At the time Lane agreed to partner for the PEM demonstration project, several concrete mixtures had already been approved for this project. However, Lane Construction also developed several additional mixtures during the course of the project, which were subsequently submitted to NCDOT for approval. In addition to tests currently required by NCDOT for approval (slump, air content, and aggregate specific gravity/absorption/unit weight/fineness modulus), PEM test data was collected on these new mixtures using the Box Test (per Appendix X3 of AASHTO PP84-17), the SAM test (per AASHTO TP 118), and surface resistivity testing (per AASHTO T 358). All mixtures were accepted using NCDOT's current process, utilizing the information submitted on the Statement of Concrete Mix Design and Source of Materials - NCDOT Form 312U, shown in Appendix A. PEM tests performed on mixtures developed during the project were considered as "shadow tests" only. Chris Ange and Fred White of Lane Construction led the training of technicians on the Box Test, SAM, and resistivity meter.

Materials used for all mixtures used on the project are shown in Table 1. Three mixture designs were primarily used for the mainline paving for the project. The Lane Construction ID numbers and NCDOT ID numbers for these mixtures are shown in Table 2, along with the cementitious materials contents and w/cm. Mixture proportions for each of these mixtures are shown in Table 3.

The intent of obtaining multiple approved mixture designs was to ensure that the compressive strength required by NCDOT specifications (4500 psi at 28-days) could be met in a variety of construction conditions. Paving operations began utilizing the 472SLNS mixture design, but as the concrete production process became reliable and favorable weather conditions prevailed, the primary mixture utilized for almost the entirety of the mainline pavement became mixture ID 460SLNS, which had a lower cementitious materials content. Mixture 496HPNS was utilized as the "hand placed" mixture, and had an increased water content in order to achieve the desired workability for non-paver placement. To ensure strength at the higher water content the cementitious materials content of this mixture was increased, although the w/cm was held roughly constant between the slipformed and hand placed mixtures. Mixture submittals on NCDOT Form 312U for each of these mixtures are provided in Appendix A. No verification mixtures were batched and tested by NCDOT.

Table 1: Materials used in mainline paving concrete mixtures.

| Material | Producer | Source / Product |
|---|---|---|
| Cement | Roanoke Cement Company | Troutville, VA plant |
| Supplementary cementitious material | Ash Venture | Belews Creek Steam Station |
| Fine aggregate | G.S. Materials | Emery Pit – Candor, NC |
| Coarse aggregate | Martin Marietta | Woodleaf Quarry – Salisbury, NC |
| Water | City | |
| Air entraining admixture | Euclid Chemical Company | EUCON AEA 92 |
| Retarding admixture | Euclid Chemical Company | EUCON LR |
| Water reducer | Euclid Chemical Company | EUCON WR |

Table 2: Mixture IDs, cementitious materials contents, and w/cm for mainline paving mixtures.

| Lane Mixture ID | NCDOT Mixture ID | Cement Content (lb/cy) | Fly Ash Content (lb/cy) | w/cm ratio |
|---|---|---|---|---|
| 460SLNS | 474TVFSLNS598E | 460 | 138 | 0.435 |
| 472SLNS | 474TVFSLNS614E | 472 | 142 | 0.423 |
| 496HPNS | 474TVFHPNS646E | 496 | 150 | 0.433 |

Table 3: Mixture proportions for mainline paving mixtures.

| Material | Lane Mixture ID | | |
|---|---|---|---|
| | 460SLNS (lb/cy) | 472SLNS (lb/cy) | 496HPNS (lb/cy) |
| Cement | 460 | 472 | 496 |
| Supplementary cementitious material | 138 | 142 | 150 |
| Fine aggregate | 1046 | 1039 | 1012 |
| Coarse aggregate | 1940 | 1932 | 1878 |
| Water | 260 | 260 | 280 |
| Air entraining admixture | As recommended | As recommended | As recommended |
| Retarding admixture | As recommended | As recommended | As recommended |
| Water reducer | As recommended | As recommended | As recommended |

**PEM Test Results Obtained During Mixture Development**

As stated previously, the Box Test was performed intermittently during mixture development, and only qualitative assessment was performed. Surface void rankings were not utilized in assessment of the mixtures. However, Figures 5a-e illustrate some of the types of surface void rankings that were obtained during mixture development, prior to identifying a suitable mixture design.

The SAM was utilized on one mixture during the plant verification and test batching stages. The mixture had a fresh air content of 6.4% with a SAM number of 0.23. Resistivity measurements made on this mixture at ages of 1, 6, 7, and 14 days were 1.8, 3.2, 3.3, and 3.8 kΩ•cm.

Figure 5 (a-e): Example Box Test results obtained during mixture development phase.

**Production and Construction**

Lane Construction established a portable central-mixed batch plant at the north end of the project to the west of Exit 68. The double drum batch plant had a 12 cubic yard capacity, producing 10 cubic yard batch loads. The capacity of the plant according to the manufacturer's literature is 700 cubic yards per hour, although Lane typically sees 400 cubic yards per hour at maximum production from this particular batch plant. The site could be readily accessed from the plant, and materials arrived via truck. Aggregates were stockpiled on site, and stockpiles were placed on cement stabilized base to minimize contamination. Cement was stored in four non-pressurized silos, and fly ash was stored in pigs brought to the site by truck (12 loads per day). Concrete was transferred from the mixer into dump trucks for hauling to the paver. Given the location of the plant, the longest haul distance of concrete was approximately 5 miles to the southernmost end of the project. A photograph of the batch plant is shown in Figure 6. Paving operations were performed from both north to south, and from south to north, so hauling times varied over the duration of the work.


Figure 6:  On-site batch plant at I-85 Widening in Rowan County, NC.

The concrete paving construction operation for mainline paving began with dump trucks hauling the fresh concrete over the asphalt interlayer.  Fresh concrete was placed directly onto the prewetted asphalt interlayer and subsequently entered the paver (Figure 7).  Two pavers were utilized for the project.  The primary paver was a Guntert & Zimmerman (G&Z) GZ 850S paver capable of paving 24 feet (2 lanes) in width.  This G&Z paver had dowel-bar inserter (DBI) technology, Trimble GPS guidance system, and a Gomaco GSI realtime smoothness indicator (Figure 8).  A smaller paver, a Gomaco Commander III was used to pave shoulders and ramp areas.  The smaller paver did not have DBI technology, and therefore dowels were installed using baskets prior to concrete placement.

Figure 7:  Concrete placed onto asphalt interlayer prior to entering paver.

Figure 8: G&Z paver with 24 foot width, DBI technology, and Gomaco GSI real-time smoothness used for mainline pavement.

The on-site batch plant was capable of producing in the range of 280 to 320 cubic yards of concrete per hour on full production days. However, production was often limited due to the reduced availability of haul trucks during the exceptionally busy construction seasons of 2018 and 2019. Therefore, a typical production rate was approximately 200 cubic yards of concrete per hour. Typical paver rates were approximately 200 feet per hour, with a maximum of 325 feet per hour on a peak production day.

Consolidation of the concrete was achieved using internal vibrators at 1 foot spacings on center. The two-lane GZ 850S paver had 24 vibrators, while the one-lane Gomaco Commander III had 12 vibrators. Vibrators operated at 3,500 to 8,500 vibrations per minute. Finishing of the pavement behind the paver began with a wet burlap drag. The pavement was hand-floated and transverse tining was applied, with edging done using hand trowels (Figure 9). A membrane curing compound was applied using a Gomaco application machine at a rate of 0.0067 gallons per square foot (Figure 10). Early entry strength was determined using the maturity method. Transverse joints were sawcut to a depth of T/3 (4 inches). Joints were later widened, cleaned, and sealed using a Dow Corning 890 SL (self-leveling) silicone joint sealant applied over a backer rod. Diamond grinding of the pavement was performed to produce longitudinal tining.

Field adjustments within allowable NCDOT tolerances were performed periodically, typically due to haul time or ambient temperatures. On hot days, the dosage of retarding admixture was increased to slow the set times. Occasionally, brief rain showers occurred during the summer months. However, the finishing crew kept plastic on hand to protect the areas of the slab that had not reached initial set. No significant breakdowns of the batch plant or paver equipment occurred. Typical issues, such as belts breaking occasionally, were remedied quickly and did not impact paving operations. Of note, lightning struck the batch plant during one thunderstorm, requiring Lane Construction to obtain a new computer to control the batching.

Figure 9: Finishing operations.

Figure 10: Application of curing compound.

**Production Mixture Properties and PEM Test Results**

QC testing was performed by Lane Construction at their field laboratory (SAM test and hardened concrete tests) and in front of the paver (slump, temperature, and air content via pressure meter). QA tests were performed by consulting firms contracted by NCDOT personnel. Category B of the PEM Implementation funds required that one or more AASHTO PP 84-17 tests be utilized in the acceptance process. For this project, two PEM tests were performed on production mixtures. The SAM test per AASHTO TP 118 was performed on fresh concrete to evaluate the air void system characteristics. SAM tests were performed intermittently, with a target of once per day, on fresh concrete sampled at the batch plant. Samples of concrete used for casting cylinders were also taken at the batch plant. Cylinders were immediately taken into the laboratory for initial cure, then stripped and placed into a lime bath on the following day. Resistivity testing per AASHTO T358 was performed on hardened concrete cylinders typically at ages of 3, 28, 56, and 90 days. It is noted that during Phase 1 paving, resistivity measurements were taken at 90 days, while during Phase 2 paving resistivity measurements were taken at 56 days. This was done in order to help evaluate both 56-day and 90-day resistivity targets for future PEM implementation sites. Shadow testing was acceptable per the FHWA Implementation Funds application, and therefore these tests were only used in this manner for this demonstration project.

NCDOT's required contractor QC practices are outlined in specification section 1000-3 (E) Contractor's Responsibility for Process Control. A QC plan must be provided before or at the preconstruction conference detailing the process control and type and frequency of QC testing and inspection required to meet the project specifications. A Certified Concrete Batch Technician is required to be on site, and this individual is responsible for QC activities including tests and inspections on aggregate stockpiles, plant equipment calibration and inspection, tests of aggregates and concrete, verification of the mixing time and theoretical cement content, verification of vibrator operationality, tests for pavement thickness, and furnishing QC documentation.

In addition to typical contractor QC practices required, Category D of the FHWA PEM Implementation Funds required the contractor to use control charts, as recommended in AASHTO PP 84-17. Although not currently required by NCDOT, Lane Construction typically prepares an Excel-based database/control chart for air content, slump, unit weight, concrete temperature, and compressive strength with one measurement recorded per lot. As part of this PEM Demonstration Project, Lane also utilized an Excel-based database/control chart for the SAM test results and resistivity test results.

*Analysis of SAM test results*

This project marked the first use of the SAM by Lane Construction personnel, and similar to other SAM users, proficiency came with repetition of the test. At first, multiple users took measurements with the device, although roughly the last 70% of SAM measurements were made by a single user. Material was consolidated using the rodding procedure described in AASHTO TP 118. Early in the Phase 1 paving work, a number of SAM test results with very high values were recorded, indicative of the learning curve for technicians prior to becoming proficient with the SAM. As stated in AASHTO TP 118-17, the SAM number shall be reported to the nearest 0.01 and shall be within 0.03 to 0.82 psi. Based on the more extensive experience of UNC Charlotte personnel with typical NCDOT paving mixtures with air contents between 4.5% and 6.5%, SAM numbers greater than 0.60 are uncommon and often indicate an error (such as a leak) during the test procedure. Therefore, prior to analysis, SAM test results with values greater than 0.60 were removed from the dataset prior to analysis. The final data used for analysis presented in this report is provided in Appendix B.

The dataset used for analysis had a total of 78 SAM test results for mixture 460SLNS and 6 SAM test results for mixture 496 HPNS (n = 84 for the full dataset). A summary of the minimum, maximum, and average test results for each mixture and for the combined dataset is shown in Table 4. It is noted that the SAM air content (%) and SAM number (psi) were obtained from a sample at the plant and were used as shadow test results only. The ASTM C231 air content was measured using a Type B pressure meter from a sample taken before the paver, and was utilized for QC purposes.

Table 4: Summary of air content and air void system test results using ASTM C231 Type B pressure meter

| | | 460SLNS | 496HPNS | Both mixtures |
|---|---|---|---|---|
| SAM air content (%) | min | 3.40 | 4.10 | 3.40 |
| | avg | 4.53 | 4.57 | 4.53 |
| | max | 6.70 | 5.40 | 6.70 |
| ASTM C231 air content (%) | min | 4.20 | 5.20 | 4.20 |
| | avg | 5.42 | 5.67 | 5.44 |
| | max | 7.00 | 6.00 | 7.00 |
| SAM number (psi) | min | 0.05 | 0.17 | 0.05 |
| | avg | 0.30 | 0.42 | 0.31 |
| | max | 0.60 | 0.60 | 0.60 |

It can be observed from Table 4 and from Figure 11 (below) that the SAM air content measured at the plant tended to consistently run slightly lower than the ASTM C231 air content measured at the paver using the Type B meter. The reason for this is not readily evident, and many studies including those at UNC Charlotte have shown strong agreement between the SAM and Type B meter (Tanesi et al. 2015, Ley et al. 2017, Cavalline et al. 2018, Cavalline et al. 2019, Cavalline et al. 2020). It is theorized that measurement of the air void system using the SAM at the paver (instead of at the plant) may have provided both total air contents closer to that of the ASTM C231 test and potentially, lower SAM numbers (Ley 2019). It is recommended that in future studies, the SAM test be performed at the same location as the Type B meter to provide a direct comparison.

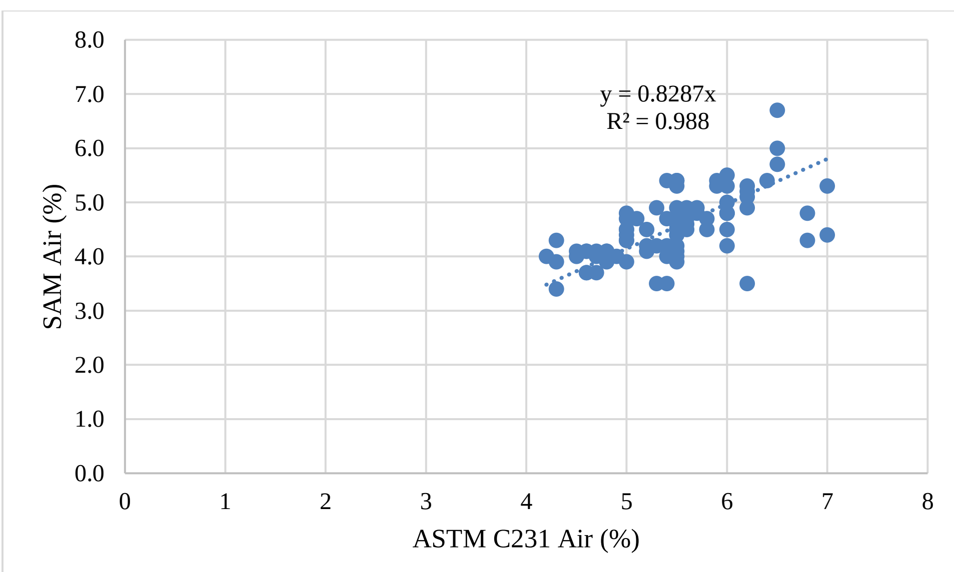
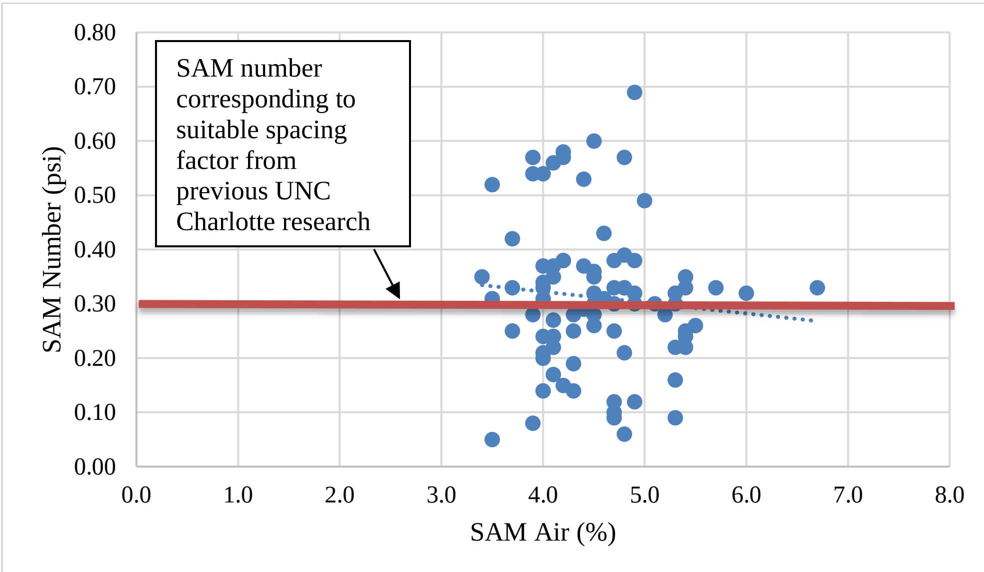
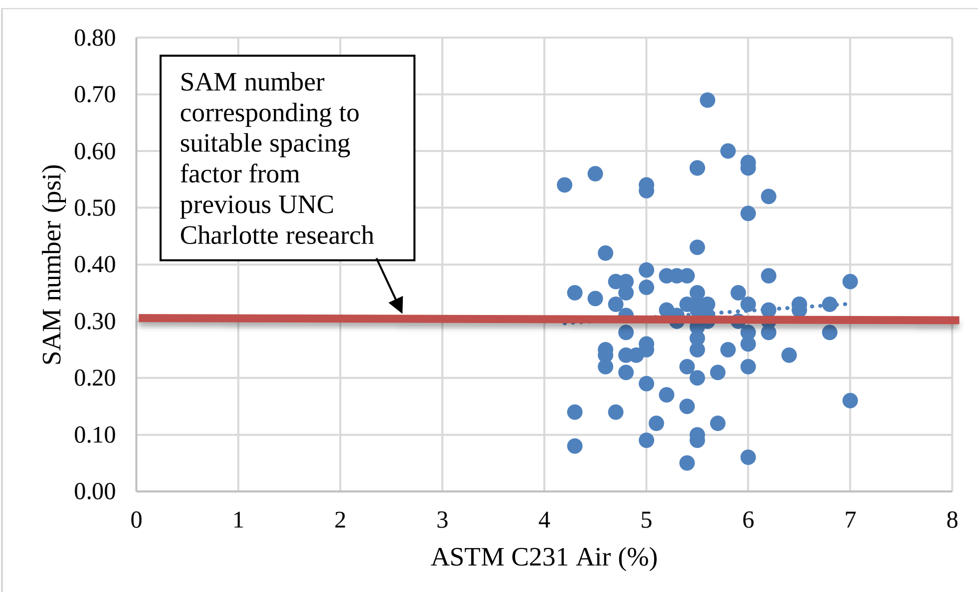



Figure 11: Air content measured using ASTM C231Type B pressure meter at paver vs. SAM at QC laboratory

Previous research at UNC Charlotte using typical NCDOT paving mixtures has shown that a SAM number of approximately 0.30 corresponds to North Carolina concrete mixtures exhibiting satisfactory freeze-thaw performance using the ASTM

C666 Procedure A test (Ojo 2017, Cavalline et al. 2018, Cavalline et al. 2019). In Figures 12a and 12b, the relationship between the SAM number and the air content measured by the SAM device (Figure 12a) and Type B pressure meter (Figure 12b) are shown. As can be observed, for the measurements obtained during this demonstration project very little correlation was observed between the total air content and SAM number, which provides a measurement of the relative dispersion of the air void system. This variability has not been observed in other studies. Ongoing laboratory-based work including manual and automated air void system analysis and freeze-thaw durability testing using ASTM C666 may provide additional insights into these findings. It is likely that SAM measurements made in front of the paver may have provided different (lower) SAM numbers, more consistent with the higher total air contents measured using the Type B pressure meter in front of the paver.




Figures 12a and 12b: Air content measured with SAM (Figure 12a) and Type B pressure meter (Figure 12b) vs. SAM number.

*Analysis of Surface Resistivity Test Results*

Surface resistivity measurements were made throughout both Phase 1 and Phase 2 paving operations. Lane's QC lab used lime water curing tanks, so per AASHTO T 358, the averages of all readings were multiplied by 1.1 to account for this type of curing method. During Phase 1 paving, surface resistivity measurements were made at 3 days, 28 days, and 90 days of age on cylinders cast for compressive strength testing. During Phase 2 paving, surface resistivity measurements were made at 3 days, 28 days, and 56 days of age on cylinders cast for compressive strength testing. The reason that the later-age tests were switched from day 90 (in Phase 1) to day 56 (in Phase 2) was driven by recently completed work at UNC Charlotte that identified 56-day resistivity targets that appear suitable to assess the performance of higher (up to 30%) fly ash mixtures. It was desired to compare 56-day field resistivity measurements from this project with proposed 56-day resistivity targets developed in the laboratory. Also of note, additional surface resistivity tests were made at different ages (e.g. 4 days, 8 days, 29 days, etc.) based upon Lane Construction's need to break cylinders for compressive strength on those days.

A total of 1360 surface resistivity measurements were made during the PEM demonstration project on the primary paving mixture 460SLNS, with 677 measurements made during Phase 1 paving in 2018 and 683 measurements made during Phase 2 paving in 2019. A plot of resistivity measurements for mixture 460SLNS at each testing age is shown in Figure 13. The proposed resistivity target for concrete pavement mixtures of 11 kΩ•cm (identified by UNC Charlotte as part of NCDOT RP 2018-14) is also shown on Figure 13. As can be observed, roughly 3/4 of the lots of the 460SLNS concrete mixture tested at 56-days met the proposed resistivity target of 11 kΩ•cm, and all lots of 460SLNS concrete tested at 90 days met the proposed target. It is noted that the 90-day resistivity of many mixtures significantly exceeded the proposed resistivity targets for North Carolina bridge concrete identified in previous UNC Charlotte research (15 to 16 kΩ•cm, depending on chloride exposure), indicating that the concrete comprising this demonstration project should exhibit a high level of durability.

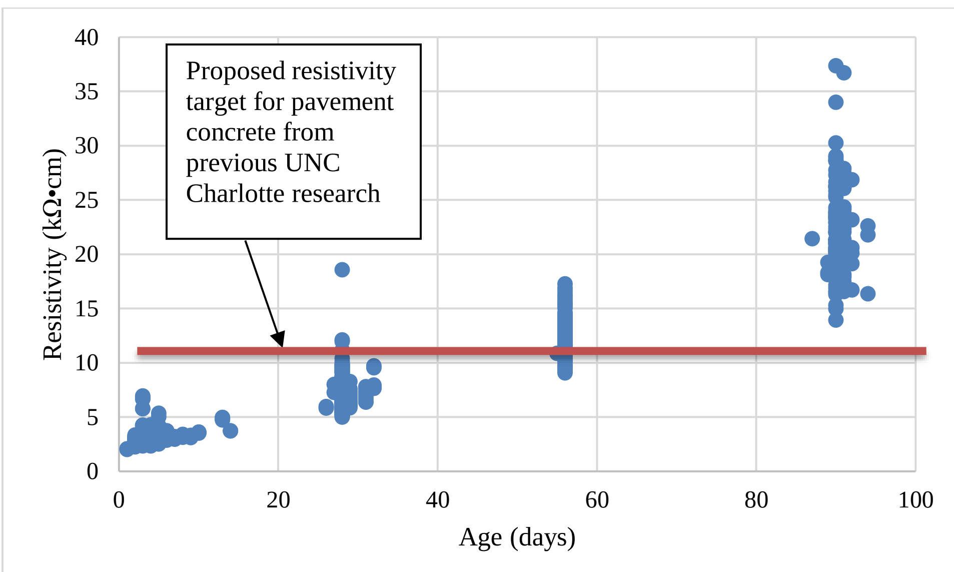



Figure 13: Surface resistivity vs. age for concrete mixture 460SLNS

A total of 125 surface resistivity measurements were made during the PEM demonstration project on the hand-placed mixture 496HPNS, with 67 measurements made during Phase 1 paving in 2018 and 58 measurements made during Phase 2 paving in 2019. A plot of resistivity measurements for mixture 496HPNS at each testing age is shown in Figure 14. The proposed resistivity target for concrete pavement mixtures of 11 kΩ•cm (identified by UNC Charlotte as part of NCDOT RP 2018-14) is also shown on Figure 14. As can be observed, the lots of 496HPNS concrete tested at 56-days did not quite meet the proposed resistivity target of 11 kΩ•cm. However, all lots of 496HPNS concrete tested at 90 days of age readily met the proposed resistivity target for durable performance.

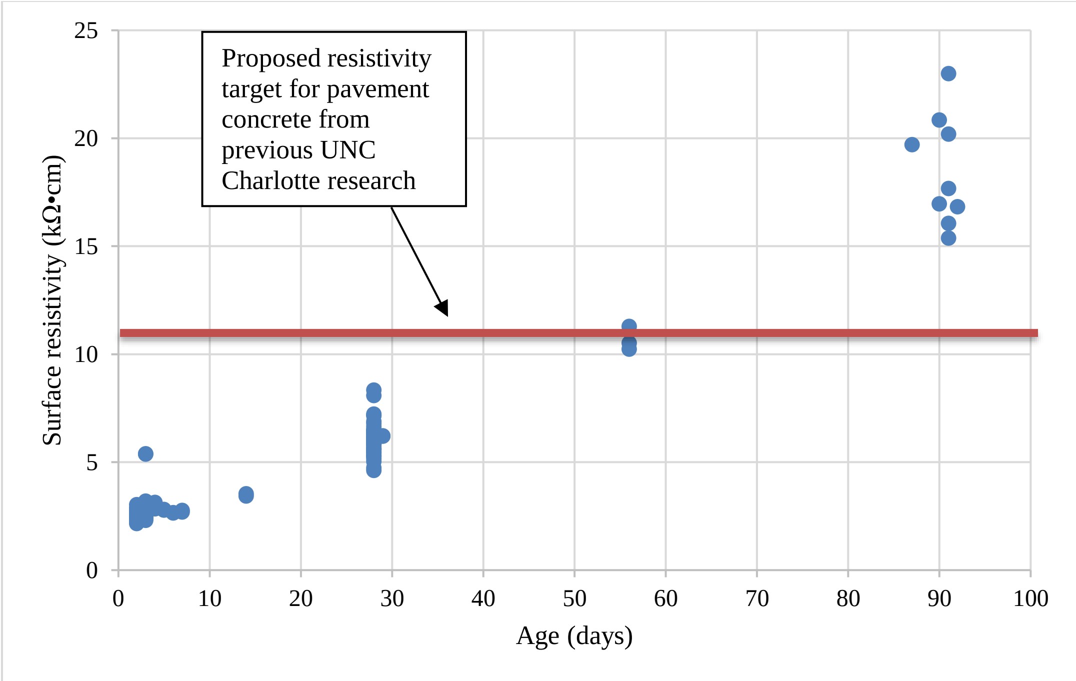



Figure 14: Surface resistivity vs. age for concrete mixture 496HPNS

Control charts for resistivity were prepared using an Excel-based spreadsheet, although lower and upper control limits were not utilized by Lane Construction. The 3-day resistivity of mixture 460SLNS produced during Phase 1 and Phase 2 paving plotted over time in control charts are shown in Figure 15a and 15b, respectively. The 28-day resistivity measurements of mixture 460SLNS produced during Phase 1 and Phase 2 paving plotted over time are shown in Figure 16a and 16b, respectively. It can be observed that although the 3-day and 28-day surface resistivity achieved during Phase 1 paving was fairly consistent, it was highly consistent during Phase 2 paving.

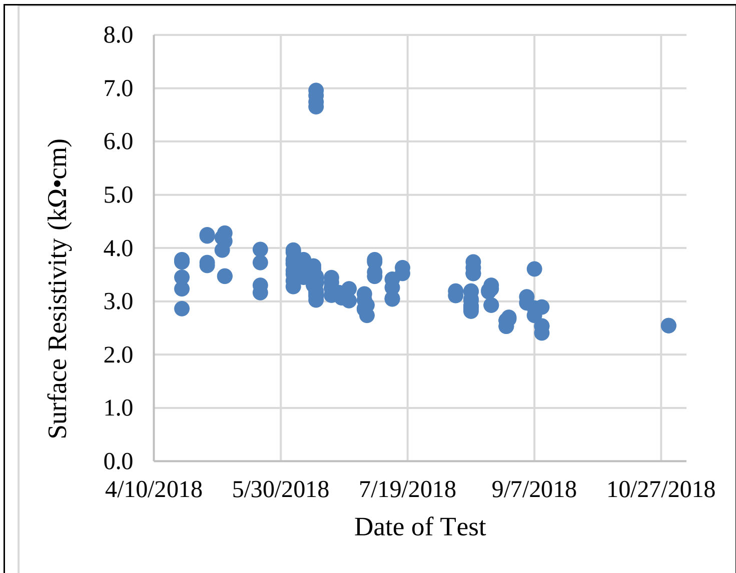



Figure 15a: Control chart showing 3-day resistivity for mixture 460SLNS during Phase 1 paving

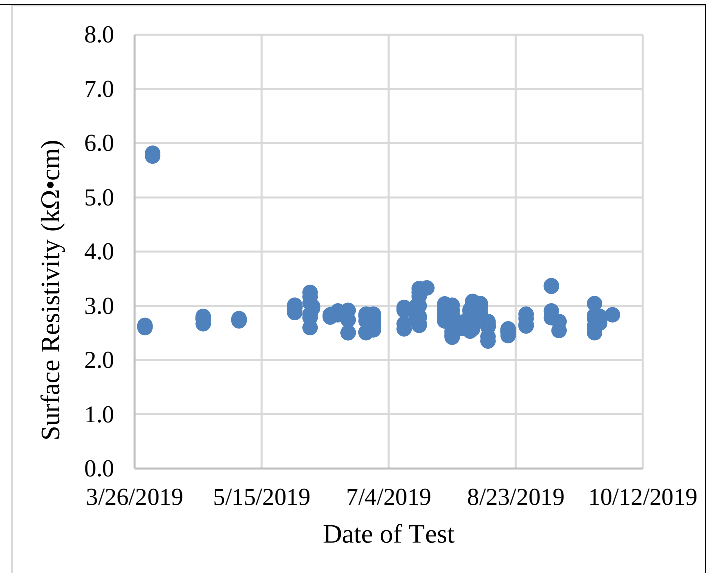



Figure 15b: Control chart showing 3-day resistivity for mixture 460SLNS during Phase 2 paving

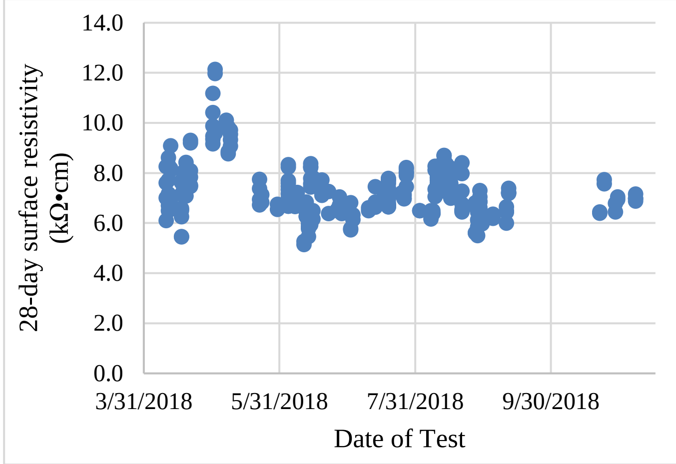



Figure 16a: Control chart showing 28-day resistivity for mixture 460SLNS during Phase 1 paving

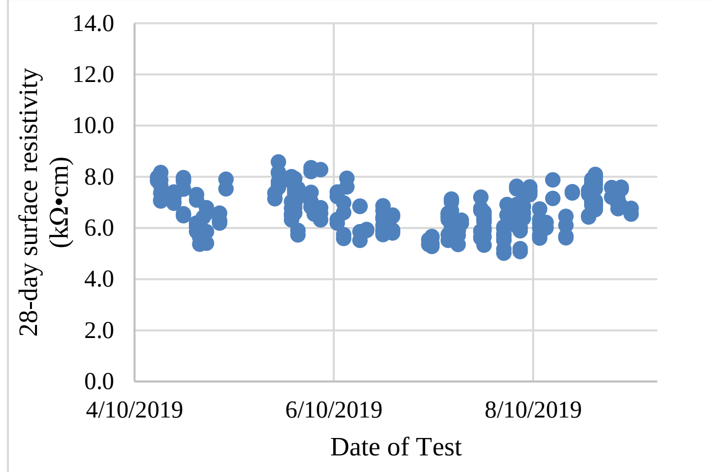



Figure 16b: Control chart showing 28-day resistivity for mixture 460SLNS during Phase 2 paving

Measurements of 56-day resistivity were primarily made on concrete produced during Phase 2 paving. These measurements plotted over time in a control chart are shown in Figure 17. As mentioned previously, it can be observed in Figure 17 that most concrete had met the proposed resistivity target by 56 days. Measurements of 90-day resistivity were primarily made during Phase 1 paving, and are plotted over time in a control chart and shown in Figure 18. It can again be seen in Figure 18 that all concrete met the proposed resistivity target by 90 days.

When comparing to the earlier age resistivity measurements, a larger spread in the data at 56 days and 90 days of age is evident. The proposed resistivity target for North Carolina pavement concrete is shown on these control charts for illustrative purposes. Should enhanced control charting techniques be developed and utilized, a central line would be shown on the control chart, with appropriate upper and lower control limits to prompt consideration of process changes.

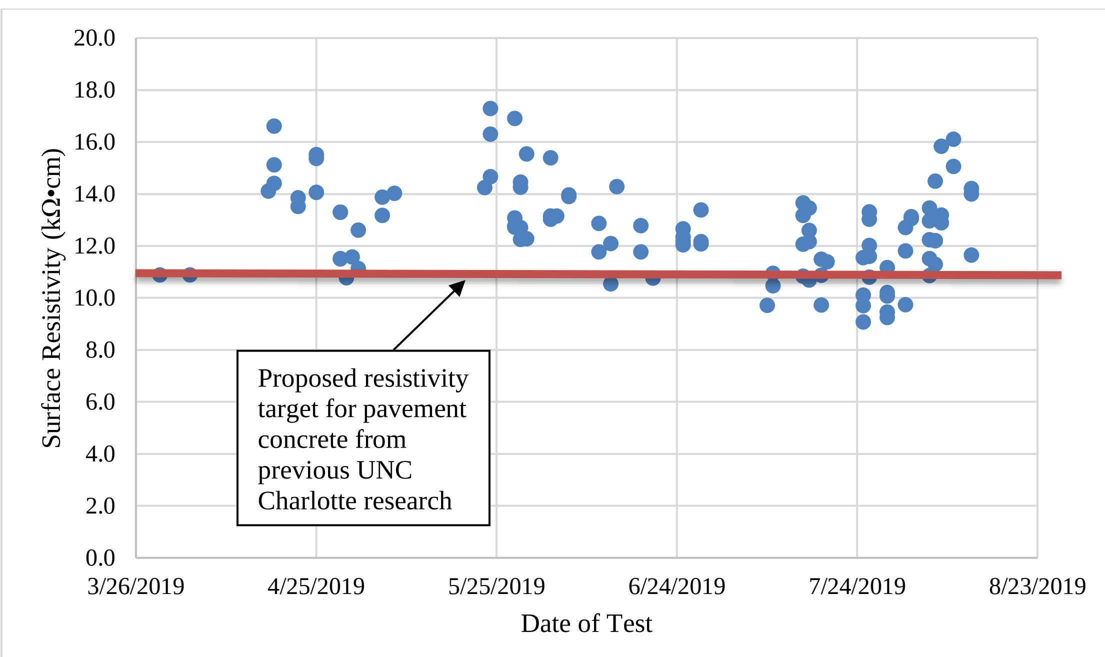



Figure 17: Control chart showing 56-day resistivity for mixture 460SLNS during Phase 2 paving.

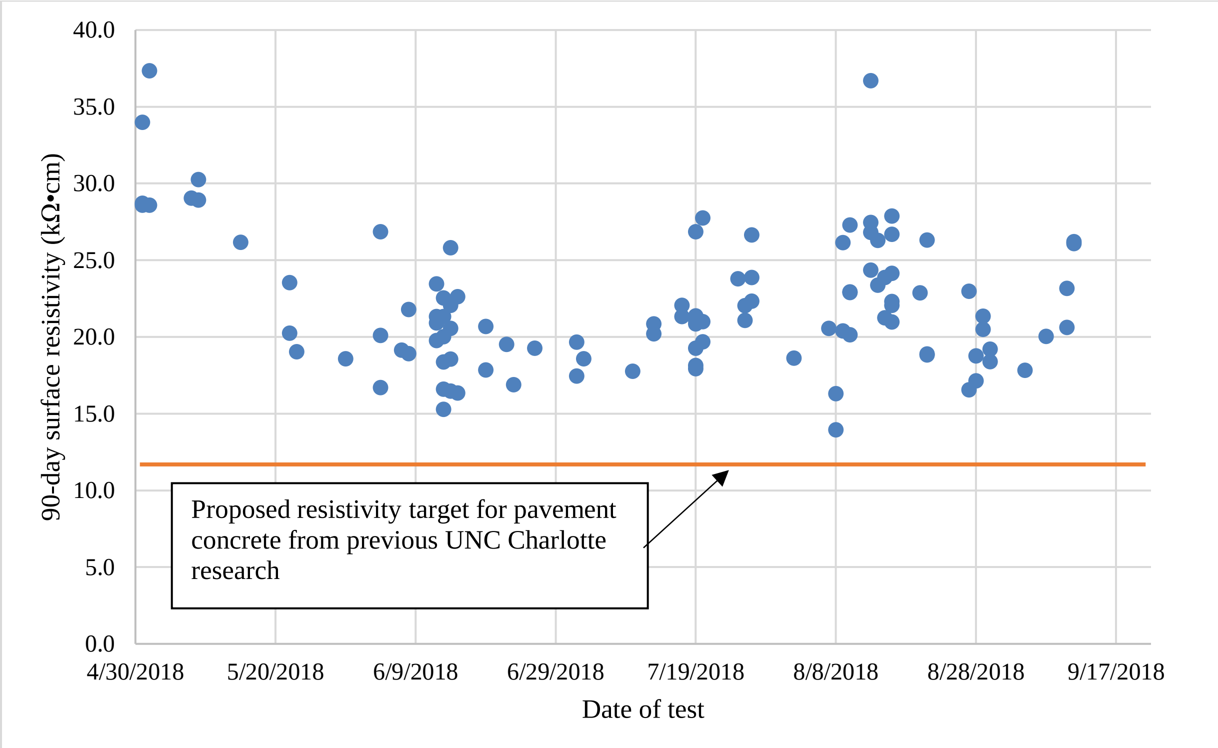



Figure 18: Control chart showing 90-day resistivity for mixture 460SLNS during Phase 1 paving.

**FHWA Mobile Concrete Technology Center Open House**

The FHWA's FHWA Mobile Concrete Technology Center (MCTC) visited the site in Spring 2019 during Phase 2 paving. The MCTC arrived on site the week of April 30, 2019, and the visit lasted approximately two weeks, during which the MCTC personnel sampled and tested concrete from the PEM Demonstration Project and worked with Lane Construction personnel to understand their practices and processes.

The visit culminated in an Open House event, coordinated by Greg Dean of the Carolinas Concrete Paving Association. A number of industry and NCDOT attendees were present, and presentations were made by personnel from Iowa State's Concrete Pavement Technology Center (CP Tech Center), FHWA, NCDOT, UNC Charlotte, Lane Construction, and others. Jagan Gudimettla and Jim Grove with the MCTC, as well as Mike Praul of FHWA were in attendance. During this visit, various PEM technologies were demonstrated at the MCTC, as well as QA/QC practices promoted with the PEM initiative, with both contractor and NCDOT personnel. A summary presentation of the MCTC's findings was presented at the Open House (Gudimettla 2019). A full report regarding FHWA MCTC visit and test results will be published by the MCTC staff in the near future.

**Concluding Remarks**

Overall, the PEM demonstration project was a success, and the PEM implementation funds were utilized in a manner consistent with the requirements of the application. The contractor and NCDOT personnel gained valuable experience with three PEM devices and tests during the course of the demonstration project.

Three PEM tests were utilized during the course of this demonstration project: the Box Test, SAM, and surface resistivity. The Box Test was found by the contractor to be highly useful in mixture development and in evaluation of mixture modifications during the course of the project. The SAM test was successfully performed over the course of the project, but the data was variable, and additional work is needed to understand these results. SAM testing was performed at the QC laboratories near the plant, and the ASTM C231 tests were performed before the paver. The SAM air content was consistently lower than the ASTM C231 air content, and a high degree of variation was observed in the SAM number. Additional field study is recommended, with SAM tests performed closer to the paver alongside the ASTM C231 testing. The "train the trainer" approach used by other agencies, where developers of the SAM visit the jobsite or agency facility may be a useful approach for future PEM shadow projects. The daily leak check procedure suggested by the SAM developer should be implemented, and the reliability algorithm could be utilized to check the accuracy of the run. Additionally, the vibration procedure for consolidation of the concrete for the SAM could be utilized, as it would more consistently consolidate the concrete in the measuring bowl of the device. The contractor found that surface resistivity testing was very straightforward to perform and could be readily implemented in their QC practices. The primary concrete mixtures utilized for the I-85 pavement met the suggested resistivity target of 11 kΩ•cm by 90 days (and often by 56 days), indicating that the pavement constructed as part of this PEM demonstration project should provide satisfactory durability performance. Specific feedback includes:

*From Lane Construction*:

- *The training provided by the UNC Charlotte team gave us unique exposure to new testing equipment and methods, which we did not have access to previously. Our personnel gained useful insight into the mechanical properties of concrete, which improved our understanding of the impact of concrete quality on pavement durability and longevity.*

- *With the help of the UNC Charlotte team, we were able to quickly and easily implement the SAM and resistivity meter into our standard testing procedures. The SAM was used during routine sampling of plastic concrete during production, and the resistivity meter during routine breaking of hardened samples. We were pleased with the ease of these tests, and did not find a need to provide additional – scarce – QC staff to support the extra testing.*

- *As a result of our project schedule, we were unable to apply the PEM criteria during the preliminary mix design phase. However, going forward, we intend to implement PEM guidelines on future PCCP projects.*

*From NCDOT Materials & Tests Unit:*

*Resistivity Meter*

- *The surface resistivity test is a very easy test to perform and is non-destructive.*
- *We will be able to equip each of our labs with a testing instrument for a low cost.*
- *We are typically done performing cylinder compressive strength tests at 28 days. If surface resistivity specification targets are established at 56 or 90 days, the additional samples may pose a storage issue. Also, we would need to have a plan to concerns about low surface resistivity test results at 56 and or 90 days.*
- *UNC Charlotte research is identifying a 28-day surface resistivity target that generally correlates to a 56 56 day or 90 day resistivity that predicts good durability performance. This would likely address the concerns above.*

*SAM Air Meter*

- *We will do more shadow testing to get comfortable with this test.*
- *During this PEM Demonstration project, many SAM numbers were above the preliminary target value of 0.3. Historically we see good freeze thaw resistance with our mixtures. Additional laboratory and field data using the SAM will be used to refine the performance target.*

*Box Test*

- *This is a simple test that could provide the producer and contractor beneficial information on their concrete paving mixture performance.*
- *NCDOT could potentially add this as a requirement for pavement mix design submittals.*

*Overall, we are very pleased with the results we saw and the cooperation by all parties involved. For the most part North Carolina has had very good concrete pavement performance with the prescriptive specifications that* *we currently utilize. The Department will continue to explore PEM to see how these tests and other AASHTO PP 84 provisions will work with our daily operations.*

As part of the FHWA MCTC Open House held at the demonstration project, a large number of industry stakeholders and NCDOT personnel were able to become familiar with FHWA's PEM initiative, PEM devices and tests, and NCDOT's goals for improving the durability and sustainability of future concrete infrastructure using selected PEM approaches. NCDOT and UNC Charlotte also gained insight into the reasonableness of proposed performance targets for surface resistivity and SAM. Experience gained during this PEM demonstration project will guide two future PEM demonstration projects planned as part of ongoing NCDOT research project 2020-13, "Continuing Toward Durable and Sustainable Concrete Through Performance Engineered Concrete Mixtures." For this future work, efforts will support implementation of PEM on bridge applications. Two pilot projects are anticipated: 1) construction of a new bridge (substructure, superstructure, and deck if possible) and 2) construction of a concrete overlay.

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## Appendix A: Mixture Submittals on NCDOT Form 312U

Form 312U
3-96

### North Carolina Department of Transportation, Division of Highways, Materials and Tests Unit
### Statement of Concrete Mix Design and Source of Materials

| | |
|---|---|
| **Project** | **Date Expires** 12/31/2075 |
| **Mix Design Status** Active | **Concrete Producer** LANE CONSTRUCTION CORPORATION |
| **County** | **Plant Location & DOT No.** HAMPTONVILLE, NC - 474 |
| **Resident Engr.** | **Contractor** |
| **Class of Concrete** PAVEMENT | **Date Assigned** |
| **Mix Design No.** 474TVFSLNS598E | **Contractor's Signature** |
| **Note Mix Design Units (English or Metric)** ENGLISH | |

**Mix Design Proportions Based on SSD Mass of Aggregates**

| Material | Producer | Source | Qty. per Cu. Yard |
|---|---|---|---|
| **Cement** | ROANOKE CEMENT COMPANY | ROANOKE - TROUTVILLE, VA | 460 lbs. |
| **Pozzolan** | ASH VENTURE | ASH VENTURE - BELEWS CREEK STEAM STATI | 138 lbs. |
| **Fine Aggregate** | G.S. MATERIALS | EMERY PIT | 1046 lbs. |
| **Coarse Aggregate** | MARTIN MARIETTA | WOODLEAF QUARRY - SALISBURY | 1940 lbs. |
| **Total Water** | | CITY | 31.2 gals. |
| **Air. Entr. Agent** | EUCLID CHEMICAL CO. | EUCON AEA 92 | As recommended |
| **Retarder** | EUCLID CHEMICAL CO. | EUCON LR | As recommended |
| **Water Reducer** | EUCLID CHEMICAL CO. | EUCON WR | As recommended |
| **Superplasticizer** | | | |
| **Corrosion Inhibitor** | | | |

**Mix Properties and Specifications**

| | | | |
|---|---|---|---|
| **Slump** | 1.50 in. | **Mortar Content** | 15.22 cu. ft. |
| **Max Water** | 38.6 gals. | **Air Content** | 5.0 % |

| Material | Specific Gravity | % Absorption | Unit Mass | Fineness Modulus |
|---|---|---|---|---|
| Fine Aggregate | 2.63 | 0.8 | NA | 2.81 |
| Coarse Aggregate, #57 | 2.64 | 0.5 | 97.5 | NA |

**Comment** Coarse Aggregate is a blend of 1434 lbs. # 57 and 506 lbs. # 78M.

Cast-in-place concrete shall conform to Section 1000, precast concrete to Section 1077, and prestressed concrete to Section 1078 of the applicable edition of the Standard Specifications for Roads and Structures plus all applicable Special Provisions.

Form 312U
3-96

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## Statement of Concrete Mix Design and Source of Materials

| | |
|---|---|
| **Project** | **Date Expires** 12/31/2075 |
| **Mix Design Status** Active | **Concrete Producer** LANE CONSTRUCTION CORPORATION |
| **County** | **Plant Location & DOT No.** HAMPTONVILLE, NC - 474 |
| **Resident Engr.** | **Contractor** |
| **Class of Concrete** PAVEMENT | **Date Assigned** |
| **Mix Design No.** 474TVFSLNS614E | **Contractor's Signature** |
| **Note Mix Design Units (English or Metric)** ENGLISH | |

**Mix Design Proportions Based on SSD Mass of Aggregates**

| Material | Producer | Source | Qty. per Cu. Yard |
|---|---|---|---|
| Cement | ROANOKE CEMENT COMPANY | ROANOKE - TROUTVILLE, VA | 472 lbs. |
| Pozzolan | ASH VENTURE | ASH VENTURE - BELEWS CREEK STEAM STATI | 142 lbs. |
| Fine Aggregate | G.S. MATERIALS | EMERY PIT | 1039 lbs. |
| Coarse Aggregate | MARTIN MARIETTA | WOODLEAF QUARRY - SALISBURY | 1932 lbs. |
| Total Water | | CITY | 31.2 gals. |
| Air. Entr. Agent | EUCLID CHEMICAL CO. | EUCON AEA 92 | As recommended |
| Retarder | EUCLID CHEMICAL CO. | EUCON LR | As recommended |
| Water Reducer | EUCLID CHEMICAL CO. | EUCON WR | As recommended |
| Superplasticizer | | | |
| Corrosion Inhibitor | | | |

**Mix Properties and Specifications**

| | | | |
|---|---|---|---|
| **Slump** | 1.50 in. | **Mortar Content** | 15.27 cu. ft. |
| **Max Water** | 39.6 gals. | **Air Content** | 5.0 % |

| Material | Specific Gravity | % Absorption | Unit Mass | Fineness Modulus |
|---|---|---|---|---|
| Fine Aggregate | 2.63 | 0.8 | NA | 2.81 |
| Coarse Aggregate, #57 | 2.64 | 0.5 | 97.5 | NA |

**Comment** Coarse aggregate is a blend of 1428 lbs. # 57 and 504 lbs. # 78M.

Cast-in-place concrete shall conform to Section 1000, precast concrete to Section 1077, and prestressed concrete to Section 1078 of the applicable edition of the Standard Specifications for Roads and Structures plus all applicable Special Provisions.

Form 312U
3-96

# North Carolina Department of Transportation, Division of Highways, Materials and Tests Unit
## Statement of Concrete Mix Design and Source of Materials

| | |
|---|---|
| **Project** | **Date Expires** 12/31/2075 |
| **Mix Design Status** Active | **Concrete Producer** LANE CONSTRUCTION CORPORATION |
| **County** | **Plant Location & DOT No.** HAMPTONVILLE, NC - 474 |
| **Resident Engr.** | **Contractor** |
| **Class of Concrete** PAVEMENT | **Date Assigned** |
| **Mix Design No.** 474TVFHPNS646E | **Contractor's Signature** |
| **Note Mix Design Units (English or Metric)** ENGLISH | |

**Mix Design Proportions Based on SSD Mass of Aggregates**

| Material | Producer | Source | Qty. per Cu. Yard |
|---|---|---|---|
| Cement | ROANOKE CEMENT COMPANY | ROANOKE - TROUTVILLE, VA | 496 lbs. |
| Pozzolan | ASH VENTURE | ASH VENTURE - BELEWS CREEK STEAM STATI | 150 lbs. |
| Fine Aggregate | G.S. MATERIALS | EMERY PIT | 1012 lbs. |
| Coarse Aggregate | MARTIN MARIETTA | WOODLEAF QUARRY - SALISBURY | 1878 lbs. |
| Total Water | | CITY | 33.6 gals. |
| Air. Entr. Agent | EUCLID CHEMICAL CO. | EUCON AEA 92 | As recommended |
| Retarder | EUCLID CHEMICAL CO. | EUCON LR | As recommended |
| Water Reducer | EUCLID CHEMICAL CO. | EUCON WR | As recommended |
| Superplasticizer | | | |
| Corrosion Inhibitor | | | |

**Mix Properties and Specifications**

| | | | |
|---|---|---|---|
| **Slump** | 3.00 in. | **Mortar Content** | 15.60 cu. ft. |
| **Max Water** | 41.7 gals. | **Air Content** | 5.0 % |

| Material | Specific Gravity | % Absorption | Unit Mass | Fineness Modulus |
|---|---|---|---|---|
| Fine Aggregate | 2.63 | 0.8 | NA | 2.81 |
| Coarse Aggregate, #57 | 2.64 | 0.5 | 97.5 | NA |

**Comment** Coarse Aggregate is a blend of 1388 lbs. # 57 and 490 lbs. # 78M.

Cast-in-place concrete shall conform to Section 1000, precast concrete to Section 1077, and prestressed concrete to Section 1078 of the applicable edition of the Standard Specifications for Roads and Structures plus all applicable Special Provisions.

## Appendix B: Data used for Analysis of SAM test results

| LOT # | Sample Made | Mix ID | Concrete Temp | Ambient Temp | Unit Weight | Slump | Air | SAM | SAM Air |
|---|---|---|---|---|---|---|---|---|---|
| | | | (degrees) | (degrees) | (pcf) | (in) | (%) | | (%) |
| LOT32 | 5/7/2018 | 496HPNS | 80 | 79 | 142.4 | 3.25 | 6.0 | 0.57 | 4.8 |
| 496HP TTF | 5/31/2018 | 496HPNS | 84 | 80 | 143.2 | 2.50 | 6.0 | 0.58 | 4.2 |
| LOT 89 | 7/16/2018 | 496HP | 86 | 73 | 147.8 | 2.75 | 5.5 | 0.29 | 4.4 |
| LOT 154 | 9/11/2018 | 496HP | 91 | 84 | | 3 | 5.8 | 0.60 | 4.5 |
| LOT 329 | 9/16/2019 | 496 HP | 88 | | 142.4 | 3 | 5.2 | 0.17 | 4.1 |
| LOT 330 | 9/25/2019 | 496 HP | 72 | | 141.0 | 3 | 5.5 | 0.33 | 5.4 |
| Test StripNB (Lot 1) | 4/10/2018 | 460SLNS | 58 | 41 | 145.6 | 1.75 | 6.2 | 0.52 | 3.5 |
| LOT30 | 5/7/2018 | 460SLNS | 71 | 65 | 146.4 | 0.75 | 5.2 | 0.38 | 4.2 |
| LOT33 | 5/8/2018 | 460SLNS | 80 | 72 | 141.2 | 2.75 | 6.0 | 0.49 | 5.0 |
| LOT34 | 5/9/2018 | 460SLNS | 78 | 61 | 143.2 | 2.00 | 4.6 | 0.42 | 3.7 |
| LOT35 | 5/9/2018 | 460SLNS | 80 | 79 | 145.2 | 2.00 | 4.5 | 0.56 | 4.1 |
| LOT37 | 5/22/2018 | 460SLNS | 76 | 70 | 145.9 | 1.50 | 5.3 | 0.30 | 4.9 |
| LOT38 | 5/22/2018 | 460SLNS | 82 | 83 | 146.5 | 1.75 | 4.8 | 0.35 | 4.1 |
| LOT39 | 5/23/2018 | 460SLNS | 80 | 74 | 147.0 | 2.50 | 5.5 | 0.43 | 4.6 |
| LOT 40 | 5/30/2018 | 460SLNS | 80 | 72 | 140.8 | 2.00 | 7.0 | 0.37 | 4.4 |
| LOT 42 | 6/4/2018 | 460SLNS | 80 | 73 | 144.9 | 1.25 | 6.0 | 0.33 | 4.8 |
| LOT 43 | 6/4/2018 | 460SLNS | 84 | 83 | 144.8 | 1.25 | 6.2 | 0.32 | 5.3 |
| LOT 46 | 6/7/2018 | 460SLNS | 84 | 80 | 143.4 | 2.00 | 5.4 | 0.38 | 4.7 |
| LOT 47 | 6/8/2018 | 460SLNS | 84 | 72 | 144.2 | 1.50 | 5.5 | 0.57 | 3.9 |
| LOT 48 | 6/8/2018 | 460SLNS | 86 | 80 | 143.5 | 1.50 | 5.5 | 0.57 | 4.2 |
| LOT 49 | 6/11/2018 | 460SLNS | 86 | 77 | 142.4 | 3.00 | 5.0 | 0.54 | 3.9 |
| LOT 51 | 6/12/2018 | 460LNS | 82 | 64 | 145.0 | 1.00 | 5.0 | 0.36 | 4.5 |
| LOT 52 | 6/12/2018 | 460LNS | 82 | 66 | 145.5 | 1.00 | 4.6 | 0.25 | 3.7 |
| LOT 55 | 6/13/2018 | 460LNS | 80 | 68 | 145.4 | 1.25 | 5.3 | 0.38 | 4.2 |
| LOT 56 | 6/13/2018 | 460LNS | 84 | 78 | 144.6 | 1.00 | 5.6 | 0.30 | 4.5 |
| LOT 61 | 6/14/2018 | 460LNS | 81 | 71 | 143.5 | 1.50 | 5.5 | 0.35 | 4.5 |
| LOT 62 | 6/14/2018 | 460LNS | 84 | 73 | 144.0 | 1.50 | 4.7 | 0.37 | 4.1 |
| LOT 63 | 6/14/2018 | 460LNS | 86 | 82 | 146.1 | 1.25 | 5.6 | 0.69 | 4.9 |
| LOT 74 | 6/26/2018 | 460LNS | 84 | 70 | 143.6 | 1.75 | 6.0 | 0.28 | 4.5 |
| LOT 75 TTF | 6/27/2018 | 460LNS | 86 | 70 | 145.1 | 1.75 | 4.8 | 0.28 | 3.9 |
| LOT 77 | 6/28/2018 | 460LNS | 86 | 76 | 143.7 | 1.75 | 6.4 | 0.24 | 5.4 |
| LOT 78 | 7/2/2018 | 460LNS | 88 | 76 | 145.2 | 1.50 | 5.5 | 0.20 | 4.0 |
| LOT 80 | 7/3/2018 | 460LNS | 88 | 72 | 142.5 | 2.00 | 6.2 | 0.28 | 5.2 |
| LOT 81 | 7/6/2018 | 460LNS | 88 | 73 | 144.8 | 1.50 | 4.6 | 0.24 | 4.1 |
| LOT 82 | 7/6/2018 | 460LNS | 92 | 88 | 142.2 | 2.00 | 6.2 | 0.38 | 4.9 |
| LOT 83 | 7/10/2018 | 460LNS | 83 | 61 | 141.4 | 2.00 | 6.8 | 0.33 | 4.8 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| LOT 88 | 7/17/2018 | 460LNS | 86 | 72 | 143.3 | 1.00 | 5.6 | 0.31 | 4.6 |
| LOT 90 | 7/17/2018 | 460LNS | 88 | 78 | 144.2 | 0.75 | 4.7 | 0.33 | 3.7 |
| LOT 98 | 7/20/2018 | 460LNS | 86 | 72 | 143.6 | 1.00 | 5.5 | 0.25 | 5.4 |
| LOT 102 | 7/26/2018 | 460LNS | | | 140.6 | 1.75 | 6.5 | 0.33 | 5.7 |
| LOT 104 | 7/27/2018 | 460LNS | 86 | 72 | 143.0 | 1.00 | 5.7 | 0.12 | 4.9 |
| LOT # | Sample Made | Mix ID | Concrete Temp (degrees) | Ambient Temp (degrees) | Unit Weight (pcf) | Slump (in) | Air (%) | SAM | SAM Air (%) |
| LOT 105 | 7/27/2018 | 460LNS | 90 | 78 | 144.1 | 1.00 | 5.9 | 0.30 | 5.3 |
| LOT 109 | 8/8/2018 | 460LNS | 84 | 70 | 145.3 | 0.75 | 4.7 | 0.14 | 4.0 |
| LOT 111 | 8/9/2018 | 460LNS | 90 | 78 | 143.2 | 1.75 | 6.0 | 0.22 | 5.3 |
| LOT 113 | 8/10/2018 | 460LNS | 86 | 72 | | 1.00 | 4.3 | 0.08 | 3.9 |
| LOT 117 | 8/13/2018 | 460LNS | 86 | 72 | 142.9 | 1.50 | 5.0 | 0.26 | 4.5 |
| LOT 119 | 8/13/2018 | 460LNS | 90 | 74 | 141.9 | 1.50 | 6.0 | 0.26 | 5.5 |
| LOT 122 | 8/14/2018 | 460LNS | 86 | 69 | 144.4 | 1.25 | 5.5 | 0.10 | 4.7 |
| LOT 123 | 8/14/2018 | 460LNS | 90 | 75 | 145.0 | 0.5 | 4.9 | 0.24 | 4.0 |
| LOT 124 | 8/15/2018 | 460LNS | 86 | 72 | 143.0 | 1.5 | 5.9 | 0.35 | 5.4 |
| LOT 139 | 8/28/2018 | 460LNS | 88 | 68 | | 3 | 6.5 | 0.32 | 6.0 |
| LOT 141 | 8/29/2018 | 460LNS | 87 | 72 | 143.4 | 1.5 | 4.8 | 0.31 | 4.0 |
| LOT 143 | 8/29/2018 | 460LNS | 90 | 86 | 144.5 | 0.75 | 5 | 0.53 | 4.4 |
| LOT 146 | 9/4/2018 | 460LNS | 88 | 70 | 143.8 | 1.5 | 5.4 | 0.33 | 4.0 |
| LOT 201 | 5/2/2019 | 460SLNS | 77 | 68 | 143.0 | 1.2 | 4.2 | 0.54 | 4.0 |
| LOT 225 TTF | 6/6/2019 | 460SLNS | 80 | 73 | 140.2 | 2.25 | 6.8 | 0.28 | 4.3 |
| LOT 227 TTF | 6/11/2019 | 460SLNS | 80 | 69 | | 2 | 6.5 | 0.33 | 6.7 |
| LOT 229 | 6/13/2019 | 460SLNS | 84 | 71 | 141.2 | 2.75 | 6.2 | 0.30 | 5.1 |
| LOT 233 | 6/18/2019 | 460SLNS | 78 | 70 | 142.0 | 2.5 | 7 | 0.16 | 5.3 |
| LOT 236 | 6/25/2019 | 460SLNS | 84 | 70 | | 1.5 | 4.3 | 0.35 | 3.4 |
| LOT 241 TTF | 6/28/2019 | 460SLNS | 80 | 67 | 142.1 | 2 | 5.3 | 0.31 | 3.5 |
| LOT 245 | 7/10/2019 | 460SLNS | 85 | 73 | 143.0 | 2 | 4.5 | 0.34 | 4.0 |
| LOT 247 | 7/15/2019 | 460SLNS | 80 | 74 | 142.4 | 1.25 | 5 | 0.19 | 4.3 |
| LOT 252 | 7/16/2019 | 460SLNS | 88 | 77 | 142.0 | 1.25 | 5.6 | 0.33 | 4.7 |
| LOT 255 | 7/18/2019 | 460SLNS | 84 | 72 | 141.8 | 1.75 | 5.4 | 0.05 | 3.5 |
| LOT 258 TTF | 7/19/2019 | 460SLNS | 88 | 73 | 140.2 | 2.25 | 5.7 | 0.21 | 4.8 |
| LOT 262 | 7/25/2019 | 460SLNS | 89 | 83 | 141.4 | 1 | 5.5 | 0.09 | 5.3 |
| LOT 263 | 7/26/2019 | 460SLNS | 80 | 62 | 144.3 | 1 | 5 | 0.39 | 4.8 |
| LOT 269 TTF | 7/29/2019 | 460SLNS | 84 | 73 | 142.4 | 2.25 | 6 | 0.06 | 4.8 |
| LOT 273 | 8/1/2019 | 460SLNS | 84 | 67 | 143.7 | 1 | 5 | 0.09 | 4.7 |
| LOT 282 | 8/5/2019 | 460SLNS | 88 | 75 | 143.7 | 1.25 | 4.8 | 0.21 | 4.0 |
| LOT 284 | 8/6/2019 | 460SLNS | 82 | 67 | 144.2 | 1.25 | 5.4 | 0.15 | 4.2 |
| LOT 288 | 8/7/2019 | 460SLNS | 86 | 74 | 144.2 | 1 | 4.8 | 0.37 | 4.0 |
| LOT 298 | 8/16/2019 | 460SLNS | 84 | 75 | 141.6 | 1.25 | 5 | 0.25 | 4.3 |
| LOT 299 | 8/20/2019 | 460SLNS | 84 | 75 | 143.0 | 1.5 | 5.4 | 0.22 | 5.4 |

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|---|---|---|---|---|---|---|---|---|---|
| LOT 302 TTF | 9/3/2019 | 460SLNS | 84 | 81 | 142.7 | 1.75 | 5.2 | 0.32 | 4.5 |
| LOT 315 | 9/5/2019 | 460SLNS | 83 | 73 | 143.9 | 1.25 | 5.5 | 0.27 | 4.1 |
| LOT 316 | 9/6/2019 | 460SLNS | 88 | 82 | 145.3 | 1.5 | 5.1 | 0.12 | 4.7 |
| LOT 318 | 9/9/2019 | 460SLNS | 82 | 73 | 143.9 | 1.5 | 4.6 | 0.22 | 4.1 |
| LOT 320 | 9/11/2019 | 460SLNS | 84 | 73 | 145.4 | 1.5 | 4.8 | 0.24 | 4.1 |
| LOT 325 | 9/13/2019 | 460SLNS | 82 | 75 | 144.6 | 1.5 | 4.3 | 0.14 | 4.3 |
| LOT 328 | 9/19/2019 | 460SLNS | 76 | 55 | 142.8 | 1.5 | 5.8 | 0.25 | 4.7 |
| LOT 335 | 9/20/2019 | 460SLNS | 82 | 73 | 144.2 | 2 | 5.5 | 0.32 | 4.9 |
| LOT 337 | 9/23/2019 | 460SLNS | 78 | 61 | 142.7 | 1.5 | 5.5 | 0.30 | 4.7 |

## Appendix C: Data used for Analysis of Resistivity Test Results for Mixture 460SLNS

| LOT # | Sample Made | Test Age | Concrete Temp | Ambient Temp | Unit Weight | Air | Surface Resistivity | Surface Resistivity Adjusted (x1.1) | Compressive Strength | NCDOT 28DAY comp str |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (days) | (°F) | (°F) | (pcf) | (%) | k-ohm*cm | k-ohm*cm | (psi) | (psi) |
| Lot 1 | 4/10/2018 | 1 | 58 | 41 | 145.6 | 6.2 | | | 2285 | |
| Lot 1 | 4/10/2018 | 1 | 58 | 41 | 145.6 | 6.2 | | | 2354 | |
| Lot 1 | 4/10/2018 | 2 | 58 | 41 | 145.6 | 6.2 | | | 3125 | |
| Lot 1 | 4/10/2018 | 2 | 58 | 41 | 145.6 | 6.2 | | | 3143 | |
| Lot 1 | 4/10/2018 | 2 | 58 | 41 | 145.6 | 6.2 | | | 3074 | |
| Lot 1 | 4/10/2018 | 28 | 58 | 41 | 145.6 | 6.2 | 6.9 | 7.6 | 5379 | 5837 |
| Lot 1 | 4/10/2018 | 28 | 58 | 41 | 145.6 | 6.2 | 7.5 | 8.3 | 5785 | 5677 |
| Lot 1 | 4/10/2018 | 28 | 55 | | | 4.5 | | | | |
| Lot 2 | 4/10/2018 | 3 | 64 | 66 | 143.6 | 6.8 | 3.1 | 3.4 | 3441 | |
| Lot 2 | 4/10/2018 | 3 | 64 | 66 | 143.6 | 6.8 | 3.0 | 3.3 | 3189 | |
| Lot 2 | 4/10/2018 | 3 | 64 | 66 | 143.6 | 6.8 | | | 3412 | |
| Lot 2 | 4/10/2018 | 28 | 64 | 66 | 143.6 | 6.8 | 6.4 | 7.0 | 5724 | 4743 |
| Lot 2 | 4/10/2018 | 28 | 64 | 66 | 143.6 | 6.8 | 5.5 | 6.1 | 5762 | 5152 |
| Lot 3 | 4/11/2018 | 3 | 62 | 57 | 148.3 | 4.5 | | | 4010 | |
| Lot 3 | 4/11/2018 | 3 | 62 | 57 | 148.3 | 4.5 | | | 4048 | |
| Lot 3 | 4/11/2018 | 28 | 62 | 57 | 148.3 | 4.5 | 6.5 | 7.2 | 6419 | 6306 |
| Lot 3 | 4/11/2018 | 28 | 62 | 57 | 148.3 | 4.5 | 7.0 | 7.7 | 6383 | 6206 |
| Lot 3 | 4/11/2018 | 90 | 62 | 57 | 148.3 | 4.5 | 18.5 | 20.3 | 8202 | |
| Lot 4 | 4/11/2018 | 3 | 58 | 48 | 149.1 | 4.0 | | | 4157 | |
| Lot 4 | 4/11/2018 | 3 | 58 | 48 | 149.1 | 4.0 | | | 4200 | |
| Lot 4 | 4/11/2018 | 28 | 58 | 48 | 149.1 | 4.0 | 7.8 | 8.6 | 7241 | 6970 |
| Lot 4 | 4/11/2018 | 28 | 58 | 48 | 149.1 | 4.0 | 7.6 | 8.3 | 6486 | 6641 |
| Lot 4 | 4/11/2018 | 90 | 58 | 48 | 149.1 | 4.0 | 21.5 | 23.6 | 8158 | |
| Lot 5 | 4/11/2018 | 3 | 60 | 46 | 148.3 | 4.5 | | | 3461 | |
| Lot 5 | 4/11/2018 | 3 | 60 | 46 | 148.3 | 4.5 | | | 3349 | |
| Lot 5 | 4/11/2018 | 28 | 60 | 46 | 148.3 | 4.5 | 5.9 | 6.5 | 6117 | 6363 |
| Lot 5 | 4/11/2018 | 28 | 60 | 46 | 148.3 | 4.5 | 6.1 | 6.7 | 6160 | 6588 |
| Lot 5 | 4/11/2018 | 90 | 60 | 46 | 148.3 | 4.5 | 17.7 | 19.5 | 7561 | |
| Lot 6 | 4/11/2018 | 3 | 58 | 45 | 147.1 | 4.7 | | | 3618 | |
| Lot 6 | 4/11/2018 | 3 | 58 | 45 | 147.1 | 4.7 | | | 3474 | |
| Lot 6 | 4/11/2018 | 28 | 58 | 45 | 147.1 | 4.7 | 6.2 | 6.8 | 6156 | 6280 |
| Lot 6 | 4/11/2018 | 28 | 58 | 45 | 147.1 | 4.7 | 6.4 | 7.0 | 6617 | 6072 |
| Lot 6 | 4/11/2018 | 90 | 58 | 45 | 147.1 | 4.7 | 17.0 | 18.7 | 8467 | |
| Lot 7 | 4/12/2018 | 4 | 64 | 68 | N/A | 3.8 | 3.3 | 3.7 | 4637 | |
| Lot 7 | 4/12/2018 | 4 | 64 | 68 | N/A | 3.8 | 3.3 | 3.6 | 4606 | |
| Lot 7 | 4/12/2018 | 28 | 64 | 68 | N/A | 3.8 | 7.4 | 8.1 | 6664 | 6478 |
| Lot 7 | 4/12/2018 | 28 | 64 | 68 | N/A | 3.8 | 7.4 | 8.2 | 6933 | 6477 |
| Lot 7 | 4/12/2018 | 90 | 64 | 68 | N/A | 3.8 | 23.0 | 25.3 | 7888 | |
| Lot 8 | 4/12/2018 | 4 | 66 | 61 | 147.5 | 3.8 | 3.9 | 4.3 | 4933 | |
| Lot 8 | 4/12/2018 | 4 | 66 | 61 | 147.5 | 3.8 | | | 5148 | |
| Lot 8 | 4/12/2018 | 28 | 66 | 61 | 147.5 | 3.8 | | | 5345 | 7597 |
| Lot 8 | 4/12/2018 | 28 | 66 | 61 | 147.5 | 3.8 | 8.3 | 9.1 | 7625 | 8091 |
| Lot 8 | 4/12/2018 | 90 | 66 | 61 | 147.5 | 3.8 | | | 5258 | |
| Lot 9 | 4/12/2018 | 28 | 62 | 57 | 147.1 | 4.8 | 6.1 | 6.7 | 6130 | 5697 |
| Lot 9 | 4/12/2018 | 28 | 62 | 57 | 147.1 | 4.8 | 6.2 | 6.8 | 5650 | 5934 |
| Lot 9 | 4/12/2018 | 90 | 62 | 57 | 147.1 | 4.8 | 17.0 | 18.7 | 7593 | |
| Lot 9 | 4/12/2018 | 4 | 62 | 57 | 147.1 | 4.8 | 3.0 | 3.3 | 3969 | |
| Lot 9 | 4/12/2018 | 4 | 62 | 57 | 147.1 | 4.8 | 3.0 | 3.3 | 4152 | |

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|---|---|---|---|---|---|---|---|---|---|---|
| Lot 10 | 4/17/2018 | 3 | 64 | 70 | 146.9 | 6.0 | | | 3964 | |
| Lot 10 | 4/17/2018 | 3 | 64 | 70 | 146.9 | 6.0 | | | 4199 | |
| Lot 10 | 4/17/2018 | 28 | 64 | 70 | 146.9 | 6.0 | 6.5 | 7.2 | 6401 | 5777 |
| Lot 10 | 4/17/2018 | 28 | 64 | 70 | 146.9 | 6.0 | 6.9 | 7.6 | 6018 | 5962 |
| Lot 10 | 4/17/2018 | 90 | 64 | 70 | 146.9 | 6.0 | 16.8 | 18.5 | 6828 | |
| Lot 11 | 4/17/2018 | 3 | 60 | 57 | 147.5 | 5.2 | | | 4299 | |
| Lot 11 | 4/17/2018 | 3 | 60 | 57 | 147.5 | 5.2 | | | 3997 | |
| Lot 11 | 4/17/2018 | 28 | 60 | 57 | 147.5 | 5.2 | 7.0 | 7.7 | 7006 | 6804 |
| Lot 11 | 4/17/2018 | 28 | 60 | 57 | 147.5 | 5.2 | 5.9 | 6.5 | 6189 | 6289 |
| Lot 11 | 4/17/2018 | 90 | 60 | 57 | 147.5 | 5.2 | 21.1 | 23.2 | 8032 | |
| Lot 12 | 4/17/2018 | 3 | 60 | 50 | 146.7 | 5.0 | | | 3393 | |
| Lot 12 | 4/17/2018 | 3 | 60 | 50 | 146.7 | 5.0 | | | 3443 | |
| Lot 12 | 4/17/2018 | 28 | 60 | 50 | 146.7 | 5.0 | 6.0 | 6.6 | 5219 | 5317 |
| Lot 12 | 4/17/2018 | 28 | 60 | 50 | 146.7 | 5.0 | 5.7 | 6.2 | 4998 | 5769 |
| Lot 12 | 4/17/2018 | 90 | 60 | 50 | 146.7 | 5.0 | 21.2 | 23.4 | 7326 | |
| Lot 13 | 4/17/2018 | 3 | 60 | 50 | 146.7 | 5.0 | | | 2669 | |
| Lot 13 | 4/17/2018 | 3 | 60 | 50 | 146.7 | 5.0 | | | 2510 | |
| Lot 13 | 4/17/2018 | 28 | 60 | 50 | 146.7 | 5.0 | 5.0 | 5.5 | 5360 | 5621 |
| Lot 13 | 4/17/2018 | 28 | 60 | 50 | 146.7 | 5.0 | 5.0 | 5.4 | 4846 | 5606 |
| Lot 13 | 4/17/2018 | 90 | 60 | 50 | 146.7 | 5.0 | 13.6 | 15.0 | 6572 | |
| Lot 15 | 4/18/2018 | 5 | 70 | 73 | 146.3 | 5.4 | 2.9 | 3.2 | 4229 | |
| Lot 15 | 4/18/2018 | 5 | 70 | 73 | 146.3 | 5.4 | 3.0 | 3.3 | 3974 | |
| Lot 15 | 4/18/2018 | 28 | 70 | 73 | 146.3 | 5.4 | 6.4 | 7.1 | 6146 | 5506 |
| Lot 15 | 4/18/2018 | 28 | 70 | 73 | 146.3 | 5.4 | 6.7 | 7.4 | 6377 | 5431 |
| Lot 15 | 4/18/2018 | 90 | 70 | 73 | 146.3 | 5.4 | 18.5 | 20.4 | 7078 | |
| Lot 16 | 4/18/2018 | 5 | 68 | 72 | 146.3 | 5.3 | 3.5 | 3.8 | 4419 | |
| Lot 16 | 4/18/2018 | 5 | 68 | 72 | 146.3 | 5.3 | 3.2 | 3.5 | 4539 | |
| Lot 16 | 4/18/2018 | 28 | 68 | 72 | 146.3 | 5.3 | 7.3 | 8.0 | 6377 | 5957 |
| Lot 16 | 4/18/2018 | 28 | 68 | 72 | 146.3 | 5.3 | 7.2 | 8.0 | 6118 | 6153 |
| Lot 16 | 4/18/2018 | 90 | 68 | 72 | 146.3 | 5.3 | 21.7 | 23.8 | 7983 | |
| Lot 17 | 4/19/2018 | 4 | 68 | 65 | 147.1 | 4.7 | 3.2 | 3.5 | 4663 | |
| Lot 17 | 4/19/2018 | 4 | 68 | 65 | 147.1 | 4.7 | 3.2 | 3.6 | 5149 | |
| Lot 17 | 4/19/2018 | 27 | 68 | 65 | 147.1 | 4.7 | 7.3 | 8.0 | 6971 | 5907 |
| Lot 17 | 4/19/2018 | 27 | 68 | 65 | 147.1 | 4.7 | 6.6 | 7.3 | 6472 | 5894 |
| Lot 17 | 4/19/2018 | 90 | 68 | 65 | 147.1 | 4.7 | 22.1 | 24.3 | 7858 | |
| Lot 18 | 4/19/2018 | 4 | 66 | 55 | | 5.6 | 3.1 | 3.4 | 4096 | |
| Lot 18 | 4/19/2018 | 4 | 66 | 55 | | 5.6 | 3.1 | 3.4 | 4226 | |
| Lot 18 | 4/19/2018 | 28 | 66 | 55 | | 5.6 | 7.0 | 7.7 | 6048 | 5497 |
| Lot 18 | 4/19/2018 | 28 | 66 | 55 | | 5.6 | 6.7 | 7.4 | 5777 | 5915 |
| Lot 18 | 4/19/2018 | 90 | 66 | 55 | | 5.6 | 20.0 | 22.0 | 7086 | |
| Lot 19 | 4/19/2018 | 4 | 66 | 48 | 146.7 | 4.5 | 3.2 | 3.5 | 4322 | |
| Lot 19 | 4/19/2018 | 4 | 66 | 48 | 146.7 | 4.5 | 2.9 | 3.1 | 4479 | |
| Lot 19 | 4/19/2018 | 28 | 66 | 48 | 146.7 | 4.5 | 7.3 | 8.1 | 6567 | 6027 |
| Lot 19 | 4/19/2018 | 28 | 66 | 48 | 146.7 | 4.5 | 7.1 | 7.8 | 6236 | 5947 |
| 7/18/2019 | 4/19/2018 | 90 | 66 | 48 | 146.7 | 4.5 | 23.2 | 25.5 | 7572 | |
| Lot 20 | 4/19/2018 | 4 | 66 | 43 | | 4.8 | 3.0 | 3.2 | 4619 | |
| Lot 20 | 4/19/2018 | 4 | 66 | 43 | | 4.8 | 3.1 | 3.4 | 4453 | |
| Lot 20 | 4/19/2018 | 28 | 66 | 43 | | 4.8 | 6.4 | 7.1 | 6600 | 6276 |
| Lot 20 | 4/19/2018 | 28 | 66 | 43 | | 4.8 | 7.4 | 8.1 | 6802 | 6112 |
| Lot 20 | 4/19/2018 | 90 | 66 | 43 | | 4.8 | 21.9 | 24.1 | 8225 | |
| Lot 21 | 4/19/2018 | 4 | 66 | 41 | | 4.6 | 2.4 | 2.6 | 5167 | |
| Lot 21 | 4/19/2018 | 4 | 66 | 41 | | 4.6 | 3.1 | 3.4 | 5026 | |
| Lot 21 | 4/19/2018 | 28 | 66 | 41 | | 4.6 | 7.7 | 8.4 | 7755 | 6278 |
| Lot 21 | 4/19/2018 | 28 | 66 | 41 | | 4.6 | 7.4 | 8.1 | 7171 | 6513 |
| Lot 21 | 4/19/2018 | 90 | 66 | 41 | | 4.6 | 23.9 | 26.2 | 9154 | |

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|---|---|---|---|---|---|---|---|---|---|---|
| LOT 22 | 4/21/2018 | 3 | 66 | 64 | 144.8 | 4.2 | 2.9 | 3.2 | 3841 | |
| LOT 22 | 4/21/2018 | 3 | 66 | 64 | 144.8 | 4.2 | 2.6 | 2.9 | 3885 | |
| LOT 22 | 4/21/2018 | 28 | 66 | 64 | 144.8 | 4.2 | 6.8 | 7.5 | 4950 | 5442 |
| LOT 22 | 4/21/2018 | 28 | 66 | 64 | 144.8 | 4.2 | 6.8 | 7.5 | 5996 | 5290 |
| LOT 22 | 4/21/2018 | 90 | 66 | 64 | 144.8 | 4.2 | 18.5 | 20.4 | 6946 | |
| LOT 23 | 4/21/2018 | 3 | 64 | 57 | 144.4 | 3.8 | 3.4 | 3.8 | 4340 | |
| LOT 23 | 4/21/2018 | 3 | 64 | 57 | 144.4 | 3.8 | 3.1 | 3.5 | 3793 | |
| LOT 23 | 4/21/2018 | 28 | 64 | 57 | 144.4 | 3.8 | 7.1 | 7.8 | 6623 | 5563 |
| LOT 23 | 4/21/2018 | 28 | 64 | 57 | 144.4 | 3.8 | 8.4 | 9.2 | 6438 | 6155 |
| LOT 23 | 4/21/2018 | 90 | 64 | 57 | 144.4 | 3.8 | 19.1 | 21.0 | 7040 | |
| LOT 24 | 4/21/2018 | 3 | 60 | 45 | | 4.7 | 3.4 | 3.7 | 4046 | |
| LOT 24 | 4/21/2018 | 3 | 60 | 45 | | 4.7 | 3.4 | 3.8 | 3958 | |
| LOT 24 | 4/21/2018 | 28 | 60 | 45 | | 4.7 | 7.4 | 8.1 | 6457 | 6028 |
| LOT 24 | 4/21/2018 | 28 | 60 | 45 | | 4.7 | 8.5 | 9.3 | 6618 | 5870 |
| LOT 24 | 4/21/2018 | 90 | 60 | 45 | | 4.7 | 17.4 | 19.1 | 7336 | |
| LOT 25 | 5/1/2018 | 2 | 61 | 64 | | 4.1 | 3.0 | 3.3 | 3642 | |
| LOT 25 | 5/1/2018 | 2 | 61 | 64 | | 4.1 | 3.0 | 3.3 | 3825 | |
| LOT 25 | 5/1/2018 | 2 | 61 | 64 | | 4.1 | 2.9 | 3.2 | 4159 | |
| LOT 25 | 5/1/2018 | 28 | 61 | 64 | | 4.1 | 8.6 | 9.5 | 6215 | 6606 |
| LOT 25 | 5/1/2018 | 28 | 61 | 64 | | 4.1 | 8.3 | 9.2 | 5936 | 6572 |
| LOT 25 | 5/1/2018 | 90 | | | | | 26.0 | 28.6 | 8425 | |
| LOT 26 | 5/1/2018 | 3 | 72 | 81 | 143.6 | 4.8 | 3.4 | 3.7 | 4011 | |
| LOT 26 | 5/1/2018 | 3 | 72 | 81 | 143.6 | 4.8 | 3.3 | 3.7 | 3976 | |
| LOT 26 | 5/1/2018 | 28 | 72 | 81 | 143.6 | 4.8 | 9.0 | 9.9 | 6120 | 6029 |
| LOT 26 | 5/1/2018 | 28 | 72 | 81 | 143.6 | 4.8 | 8.5 | 9.4 | 6190 | 5956 |
| LOT 26 | 5/1/2018 | 90 | 72 | 81 | 143.6 | 4.8 | 26.1 | 28.7 | 6930 | |
| LOT 27 | 5/1/2018 | 3 | 76 | 81 | | 4.0 | 3.9 | 4.2 | 4435 | |
| LOT 27 | 5/1/2018 | 3 | 76 | 81 | | 4.0 | 3.8 | 4.2 | 4546 | |
| LOT 27 | 5/1/2018 | 28 | 76 | 81 | | 4.0 | 10.2 | 11.2 | 7229 | 6453 |
| LOT 27 | 5/1/2018 | 28 | 76 | 81 | | 4.0 | 9.5 | 10.4 | 6874 | 6794 |
| LOT 27 | 5/1/2018 | 90 | 76 | 81 | | 4.0 | 30.9 | 34.0 | 8718 | |
| LOT 28 | 5/2/2018 | 5 | 70 | 50 | 144.4 | 4.1 | 3.8 | 4.2 | 4577 | |
| LOT28 | 5/2/2018 | 5 | 70 | 50 | 144.4 | 4.1 | 3.7 | 4.1 | 4737 | |
| LOT 28 | 5/2/2018 | 5 | 70 | 50 | 144.4 | 4.1 | 3.7 | 4.1 | 4737 | |
| LOT 28 | 5/2/2018 | 28 | 70 | 50 | 144.4 | 4.1 | 8.8 | 9.7 | 6412 | 5994 |
| LOT 28 | 5/2/2018 | 28 | 70 | 50 | 144.4 | 4.1 | 8.7 | 9.6 | 6558 | 6217 |
| LOT 28 | 5/2/2018 | 90 | 70 | 50 | 144.4 | 4.1 | 26.0 | 28.6 | 8187 | |
| LOT 29 | 5/2/2018 | 5 | 72 | 56 | 145.2 | 4.0 | 4.6 | 5.0 | 5250 | |
| LOT 29 | 5/2/2018 | 5 | 72 | 56 | 145.2 | 4.0 | 4.9 | 5.4 | 5565 | |
| LOT 29 | 5/2/2018 | 28 | 72 | 56 | 145.2 | 4.0 | 11.0 | 12.1 | 7258 | 6554 |
| LOT 29 | 5/2/2018 | 28 | 72 | 56 | 145.2 | 4.0 | 10.9 | 12.0 | 7193 | 7019 |
| LOT 29 | 5/2/2018 | 90 | 72 | 56 | 145.2 | 4.0 | 34.0 | 37.4 | 8984 | |
| LOT30 | 5/7/2018 | 3 | 71 | 65 | 146.4 | 5.2 | 3.8 | 4.2 | 4033 | |
| LOT 30 | 5/7/2018 | 3 | 71 | 65 | 146.4 | 5.2 | 3.6 | 4.0 | 4024 | |
| LOT30 | 5/7/2018 | 28 | 71 | 65 | 146.4 | 5.2 | 9.2 | 10.1 | 6451 | 5832 |
| LOT30 | 5/7/2018 | 28 | 71 | 65 | 146.4 | 5.2 | 9.0 | 9.9 | 6068 | 5913 |
| LOT31 | 5/8/2018 | 3 | 78 | 70 | 142.8 | 5.8 | 3.9 | 4.3 | 4124 | |
| LOT31 | 5/8/2018 | 3 | 78 | 70 | 142.8 | 5.8 | 3.8 | 4.1 | 4105 | |
| LOT31 | 5/8/2018 | 28 | 78 | 70 | 142.8 | 5.8 | 8.9 | 9.7 | 6305 | 5808 |
| LOT31 | 5/8/2018 | 28 | 78 | 70 | 142.8 | 5.8 | 8.9 | 9.8 | 6433 | 6069 |
| LOT31 | 5/8/2018 | 90 | 78 | 70 | 142.8 | 5.8 | 26.4 | 29.0 | 7360 | |
| LOT33 | 5/8/2018 | 3 | 80 | 72 | 141.2 | 6.0 | 3.2 | 3.5 | 3500 | |
| LOT33 | 5/8/2018 | 3 | 80 | 72 | 141.2 | 6.0 | 3.2 | 3.5 | 3817 | |
| LOT33 | 5/8/2018 | 28 | 80 | 72 | 141.2 | 6.0 | 8.1 | 8.9 | 5543 | 5448 |
| LOT33 | 5/8/2018 | 28 | 80 | 72 | 141.2 | 6.0 | 8.0 | 8.8 | 6044 | 5474 |

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| LOT34 | 5/9/2018 | 5 | 78 | 61 | 143.2 | 4.6 | 3.4 | 3.7 | 4592 | |
| LOT34 | 5/9/2018 | 5 | 78 | 61 | 143.2 | 4.6 | 3.4 | 3.8 | 4625 | |
| LOT34 | 5/9/2018 | 28 | 78 | 61 | 143.2 | 4.6 | 8.8 | 9.7 | 6388 | 6162 |
| LOT34 | 5/9/2018 | 28 | 78 | 61 | 143.2 | 4.6 | 8.7 | 9.5 | 6488 | 6013 |
| LOT34 | 5/9/2018 | 90 | 78 | 61 | 143.2 | 4.6 | 27.5 | 30.3 | 8282 | |
| LOT35 | 5/9/2018 | 5 | 80 | 79 | 145.2 | 4.5 | 3.6 | 3.9 | 4404 | |
| LOT35 | 5/9/2018 | 5 | 80 | 79 | 145.2 | 4.5 | 3.4 | 3.7 | 4269 | |
| LOT35 | 5/9/2018 | 28 | 80 | 79 | 145.2 | 4.5 | 8.3 | 9.1 | 6342 | 5902 |
| LOT35 | 5/9/2018 | 28 | 80 | 79 | 145.2 | 4.5 | 8.5 | 9.3 | 6174 | 5812 |
| LOT35 | 5/9/2018 | 90 | 80 | 79 | 145.2 | 4.5 | 26.3 | 28.9 | 8383 | |
| LOT36 | 5/15/2018 | 2 | 82 | 76 | 142.0 | 5.0 | 2.8 | 3.1 | 3575 | |
| LOT36 | 5/15/2018 | 2 | 82 | 76 | 142.0 | 5.0 | 2.8 | 3.1 | 3462 | |
| LOT36 | 5/15/2018 | 2 | 82 | 76 | 142.0 | 5.0 | 2.9 | 3.1 | 3802 | |
| LOT36 | 5/15/2018 | 28 | 82 | 76 | 142.0 | 5.0 | | | 6244 | 5991 |
| LOT36 | 5/15/2018 | 28 | 82 | 76 | 142.0 | 5.0 | | | 5938 | 5850 |
| LOT 36 | 5/15/2018 | 90 | | | | | 23.8 | 26.2 | 7404 | |
| LOT37 | 5/22/2018 | 3 | 76 | 70 | 145.9 | 5.3 | 3.4 | 3.7 | 4011 | |
| LOT37 | 5/22/2018 | 3 | 76 | 70 | 145.9 | 5.3 | 3.6 | 4.0 | 3860 | |
| LOT37 | 5/22/2018 | 28 | 76 | 70 | 145.9 | 5.3 | 6.7 | 7.4 | 5762 | 5483 |
| LOT37 | 5/22/2018 | 28 | 76 | 70 | 145.9 | 5.3 | 7.0 | 7.7 | 6058 | 5297 |
| LOT37 | 5/22/2018 | 90 | 76 | 70 | 145.9 | 5.3 | 21.4 | 23.5 | 7232 | |
| LOT38 | 5/22/2018 | 3 | 82 | 83 | 146.5 | 4.8 | 3.0 | 3.3 | 3967 | |
| LOT38 | 5/22/2018 | 3 | 82 | 83 | 146.5 | 4.8 | 2.9 | 3.2 | 3841 | |
| LOT38 | 5/22/2018 | 28 | 82 | 83 | 146.5 | 4.8 | 6.1 | 6.7 | 5929 | 5276 |
| LOT38 | 5/22/2018 | 28 | 82 | 83 | 146.5 | 4.8 | 6.3 | 6.9 | 6325 | 5364 |
| LOT38 | 5/22/2018 | 90 | 82 | 83 | 146.5 | 4.8 | 18.4 | 20.2 | 6972 | |
| LOT39 | 5/23/2018 | 2 | 80 | 74 | 147.0 | 5.5 | 2.8 | 3.1 | 3076 | |
| LOT39 | 5/23/2018 | 2 | 80 | 74 | 147.0 | 5.5 | 3.0 | 3.3 | 3079 | |
| LOT39 | 5/23/2018 | 28 | 80 | 74 | 147.0 | 5.5 | 6.5 | 7.1 | 5422 | 5613 |
| LOT39 | 5/23/2018 | 28 | 80 | 74 | 147.0 | 5.5 | 6.2 | 6.8 | 5472 | 5312 |
| LOT39 | 5/23/2018 | 90 | 80 | 74 | 147.0 | 5.5 | 17.3 | 19.0 | 6719 | |
| LOT 40 | 5/30/2018 | 2 | 80 | 72 | 140.8 | 7.0 | 2.8 | 3.1 | 3062 | |
| LOT 40 | 5/30/2018 | 2 | 80 | 72 | 140.8 | 7.0 | 2.7 | 2.9 | 3119 | |
| LOT 40 | 5/30/2018 | 2 | 80 | 72 | 140.8 | 7.0 | 2.7 | 3.0 | 3045 | |
| LOT 40 | 5/30/2018 | 28 | 80 | 72 | 140.8 | 7.0 | 6.0 | 6.5 | 5478 | 4814 |
| LOT 40 | 5/30/2018 | 28 | 80 | 72 | 140.8 | 7.0 | 6.1 | 6.8 | 5654 | 5223 |
| LOT 40 | 5/30/2018 | 90 | 80 | 72 | 140.8 | 7.0 | 16.9 | 18.6 | 6810 | |
| LOT41 | 6/4/2018 | 3 | 80 | 72 | 144.6 | 4.8 | 3.0 | 3.3 | 4093 | |
| LOT41 | 6/4/2018 | 3 | 80 | 72 | 144.6 | 4.8 | 3.1 | 3.4 | 3993 | |
| LOT41 | 6/4/2018 | 28 | 80 | 72 | 144.6 | 4.8 | 7.0 | 7.7 | 6332 | 5989 |
| LOT41 | 6/4/2018 | 28 | 80 | 72 | 144.6 | 4.8 | 6.8 | 7.5 | 6366 | 5960 |
| LOT41 | 6/4/2018 | 87 | 80 | 72 | 144.6 | 4.8 | 19.5 | 21.5 | 7926 | |
| LOT 42 | 6/4/2018 | 3 | 80 | 73 | 144.9 | 6.0 | 3.6 | 4.0 | 4083 | |
| LOT 42 | 6/4/2018 | 3 | 80 | 73 | 144.9 | 6.0 | 3.6 | 3.9 | 4079 | |
| LOT 42 | 6/4/2018 | 28 | 80 | 73 | 144.9 | 6.0 | 7.5 | 8.2 | 6794 | 6305 |
| LOT 42 | 6/4/2018 | 28 | 80 | 73 | 144.9 | 6.0 | 7.6 | 8.3 | 6628 | 5871 |
| LOT 42 | 6/4/2018 | 92 | 80 | 73 | 144.9 | 6.0 | 24.4 | 26.9 | 7992 | |
| LOT 43 | 6/4/2018 | 3 | 84 | 83 | 144.8 | 6.2 | 3.4 | 3.8 | 4107 | |
| LOT 43 | 6/4/2018 | 3 | 84 | 83 | 144.8 | 6.2 | 3.4 | 3.7 | 4112 | |
| LOT 43 | 6/4/2018 | 28 | 84 | 83 | 144.8 | 6.2 | 6.5 | 7.2 | 5598 | 5892 |
| LOT 43 | 6/4/2018 | 28 | 84 | 83 | 144.8 | 6.2 | 6.7 | 7.3 | 5851 | 5579 |
| LOT 43 | 6/4/2018 | 92 | 84 | 83 | 144.8 | 6.2 | 18.3 | 20.1 | 7366 | |
| LOT 44 | 6/4/2018 | 3 | 84 | 80 | 143.8 | 6.2 | 3.4 | 3.7 | 3237 | |
| LOT 44 | 6/4/2018 | 3 | 84 | 80 | 143.8 | 6.2 | 3.4 | 3.8 | 3214 | |
| LOT 44 | 6/4/2018 | 28 | 84 | 80 | 143.8 | 6.2 | 6.1 | 6.7 | 5323 | 4711 |

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| LOT 44 | 6/4/2018 | 28 | 84 | 80 | 143.8 | 6.2 | 6.1 | 6.7 | 4547 | 4641 |
| LOT 44 | 6/4/2018 | 92 | 84 | 80 | 143.8 | 6.2 | 15.2 | 16.7 | 5812 | |
| LOT 45 | 6/4/2018 | 3 | 84 | 82 | 144.1 | 5.2 | 3.2 | 3.5 | 3933 | |
| LOT 45 | 6/4/2018 | 3 | 84 | 82 | 144.1 | 5.2 | 3.3 | 3.6 | 4124 | |
| LOT 45 | 6/4/2018 | 28 | 84 | 82 | 144.1 | 5.2 | 6.4 | 7.0 | 6249 | 5630 |
| LOT 45 | 6/4/2018 | 28 | 84 | 82 | 144.1 | 5.2 | 6.1 | 6.7 | 6028 | 5744 |
| LOT 45 | 6/4/2018 | 28 | 84 | 82 | 144.1 | 5.2 | 16.9 | 18.6 | 7632 | |
| LOT 46 | 6/7/2018 | 4 | 84 | 80 | 143.4 | 5.4 | 3.2 | 3.5 | 4116 | |
| LOT 46 | 6/7/2018 | 4 | 84 | 80 | 143.4 | 5.4 | 3.3 | 3.6 | 4283 | |
| LOT 46 | 6/7/2018 | 28 | 84 | 80 | 143.4 | 5.4 | 6.2 | 6.8 | 5881 | 5825 |
| LOT 46 | 6/7/2018 | 28 | 84 | 80 | 143.4 | 5.4 | 6.1 | 6.7 | 5999 | 5826 |
| LOT 46 | 6/7/2018 | 92 | 84 | 80 | 143.4 | 5.4 | 17.4 | 19.1 | 7365 | |
| LOT 47 | 6/8/2018 | 3 | 84 | 72 | 144.2 | 5.5 | 3.1 | 3.5 | 3917 | |
| LOT 47 | 6/8/2018 | 3 | 84 | 72 | 144.2 | 5.5 | 3.4 | 3.8 | 3928 | |
| LOT 47 | 6/8/2018 | 28 | 84 | 72 | 144.2 | 5.5 | 6.3 | 6.9 | 5510 | 5620 |
| LOT 47 | 6/8/2018 | 28 | 84 | 72 | 144.2 | 5.5 | 6.3 | 6.9 | 5531 | 5314 |
| LOT 47 | 6/8/2018 | 91 | 84 | 72 | 144.2 | 5.5 | 17.2 | 18.9 | 7344 | |
| LOT 48 | 6/8/2018 | 3 | 86 | 80 | 143.5 | 5.5 | 3.3 | 3.7 | 4002 | |
| LOT 48 | 6/8/2018 | 3 | 86 | 80 | 143.5 | 5.5 | 3.4 | 3.7 | 3923 | |
| LOT 48 | 6/8/2018 | 28 | 86 | 80 | 143.5 | 5.5 | 6.6 | 7.2 | 6178 | 6028 |
| LOT 48 | 6/8/2018 | 28 | 86 | 80 | 143.5 | 5.5 | 6.3 | 6.9 | 5707 | 6020 |
| LOT 48 | 6/8/2018 | 94 | 86 | 80 | 143.5 | 5.5 | 19.8 | 21.8 | 7278 | |
| LOT 49 | 6/11/2018 | 2 | 86 | 77 | 142.4 | 5.0 | 2.3 | 2.5 | 2942 | |
| LOT 49 | 6/11/2018 | 2 | 86 | 77 | 142.4 | 5.0 | 2.2 | 2.4 | 3033 | |
| LOT 49 | 6/11/2018 | 2 | 86 | 77 | 142.4 | 5.0 | 2.3 | 2.6 | 2919 | |
| LOT 49 | 6/11/2018 | 28 | 86 | 77 | 142.4 | 5.0 | 4.8 | 5.3 | 5184 | 4982 |
| LOT 49 | 6/11/2018 | 28 | 86 | 77 | 142.4 | 5.0 | 4.7 | 5.1 | 5284 | 5167 |
| LOT 50 | 6/12/2018 | 3 | 82 | 64 | 145.6 | 4.0 | 3.0 | 3.3 | 3962 | |
| LOT 50 | 6/12/2018 | 3 | | | | | 3.0 | 3.3 | 4230 | |
| LOT 50 | 6/12/2018 | 13 | | | | | 4.3 | 4.7 | 5723 | 6398 |
| LOT 50 | 6/12/2018 | 13 | | | | | 4.4 | 4.9 | 5989 | 6244 |
| LOT 50 | 6/12/2018 | 90 | | | | | | | 7581 | |
| LOT 51 | 6/12/2018 | 3 | 82 | 64 | 145.0 | 5.0 | 3.3 | 3.7 | 4121 | |
| LOT 51 | 6/12/2018 | 3 | | | | | 3.3 | 3.7 | 3850 | |
| LOT 51 | 6/12/2018 | 13 | | | | | 4.5 | 5.0 | 5226 | 5811 |
| LOT 51 | 6/12/2018 | 13 | | | | | 4.4 | 4.9 | 5114 | 5940 |
| LOT 51 | 6/12/2018 | 90 | | | | | 19.0 | 20.9 | 7386 | |
| LOT 52 | 6/12/2018 | 3 | 82 | 66 | 145.5 | 4.6 | 3.1 | 3.4 | 4026 | |
| LOT 52 | 6/12/2018 | 3 | | | | | 3.3 | 3.6 | 4068 | |
| LOT 52 | 6/12/2018 | 13 | | | | | 4.5 | 5.0 | 5481 | 6098 |
| LOT 52 | 6/12/2018 | 13 | | | | | 4.4 | 4.9 | 5421 | 6069 |
| LOT 52 | 6/12/2018 | 90 | | | | | 21.3 | 23.5 | 7701 | |
| LOT 53 | 6/12/2018 | 3 | 82 | 68 | 144.4 | 5.4 | 3.2 | 3.5 | 3942 | |
| LOT 53 | 6/12/2018 | 3 | | | | | 3.2 | 3.6 | 3825 | |
| LOT 53 | 6/12/2018 | 28 | | | | | 6.2 | 6.8 | 6259 | 6218 |
| LOT 53 | 6/12/2018 | 28 | | | | | 5.9 | 6.4 | 6115 | 6235 |
| LOT 53 | 6/12/2018 | 90 | | | | | 19.4 | 21.3 | 7458 | |
| LOT 54 | 6/12/2018 | 3 | 82 | 72 | | 5.4 | 3.0 | 3.3 | 3577 | |
| LOY 54 | 6/12/2018 | 3 | | | | | 3.1 | 3.4 | 3698 | |
| LOT 54 | 6/12/2018 | 28 | | | | | 5.7 | 6.3 | 5463 | 5225 |
| LOT 54 | 6/12/2018 | 28 | | | | | 5.7 | 6.3 | 5588 | 5651 |
| LOT 54 | 6/12/2018 | 90 | | | | | 18.0 | 19.8 | 7424 | |
| LOT 55 | 6/13/2018 | 3 | 80 | 68 | 145.4 | 5.3 | 3.1 | 3.4 | 3738 | 5608 |
| LOT 55 | 6/13/2018 | 3 | | | | | 2.9 | 3.2 | 3615 | 5596 |
| LOT 55 | 6/13/2018 | 28 | | | | | 5.4 | 6.0 | 5526 | |

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| LOT 55 | 6/13/2018 | 28 | | | | | 5.3 | 5.8 | 5849 | |
| LOT 55 | 6/13/2018 | 90 | | | | | 15.1 | 16.6 | 7324 | |
| LOT 56 | 6/13/2018 | 3 | 84 | 78 | 144.6 | 5.6 | 2.8 | 3.0 | 3350 | 5432 |
| LOT 56 | 6/13/2018 | 3 | | | | | | | 3693 | 5522 |
| LOT 56 | 6/13/2018 | 28 | | | | | 5.3 | 5.9 | 5308 | |
| LOT 56 | 6/13/2018 | 28 | | | | | 5.0 | 5.5 | 5221 | |
| LOT 56 | 6/13/2018 | 90 | | | | | 13.9 | 15.3 | 6614 | |
| LOT 57 | 6/13/2018 | 3 | 84 | 78 | 143.8 | 5.5 | 3.1 | 3.4 | 3757 | 6106 |
| LOT 57 | 6/13/2018 | 3 | | | | | 3.1 | 3.4 | 3823 | 5526 |
| LOT 57 | 6/13/2018 | 3 | | | | | 6.0 | 6.6 | 5876 | |
| LOT 57 | 6/13/2018 | 3 | | | | | 6.3 | 7.0 | 5604 | |
| LOT 57 | 6/13/2018 | 90 | | | | | 20.5 | 22.6 | 7053 | |
| LOT 58 | 6/13/2018 | 3 | 84 | 82 | 144.3 | 5.5 | 2.8 | 3.1 | 3352 | 5923 |
| LOT 58 | 6/13/2018 | 3 | | | | | 2.8 | 3.1 | 3406 | 6073 |
| LOT 58 | 6/13/2018 | 28 | | | | | 5.8 | 6.4 | 5845 | |
| LOT 58 | 6/13/2018 | 28 | | | | | 5.7 | 6.3 | 5937 | |
| LOT 58 | 6/13/2018 | 90 | | | | | 16.7 | 18.4 | 7112 | |
| LOT 59 | 6/13/2018 | 3 | 84 | 80 | 143.8 | 6.0 | 3.2 | 3.5 | 3644 | 5252 |
| LOT 59 | 6/13/2018 | 3 | | | | | 3.1 | 3.4 | 3472 | 5613 |
| LOT 59 | 6/13/2018 | 3 | | | | | 6.1 | 6.7 | 5512 | |
| LOT 59 | 6/13/2018 | 3 | | | | | 6.2 | 6.9 | 5296 | |
| LOT 59 | 6/13/2018 | 90 | | | | | 19.4 | 21.3 | 7041 | |
| LOT 60 | 6/13/2018 | 3 | 86 | 84 | 145.9 | 3.8 | 2.9 | 3.2 | 3827 | 5893 |
| LOT60 | 6/13/2018 | 3 | | | | | 3.0 | 3.3 | 3968 | 5989 |
| LOT 60 | 6/13/2018 | 28 | | | | | 5.7 | 6.3 | 6028 | |
| LOT 60 | 6/13/2018 | 28 | | | | | 6.0 | 6.6 | 5862 | |
| LOT 60 | 6/13/2018 | 90 | | | | | 18.2 | 20.0 | 7993 | |
| LOT 61 | 6/14/2018 | 4 | 81 | 71 | 143.5 | 5.5 | 3.1 | 3.5 | 4071 | |
| LOT 61 | 6/14/2018 | 4 | | | | | 3.4 | 3.7 | 4214 | |
| LOT 61 | 6/14/2018 | 28 | | | | | 5.9 | 6.5 | 5627 | 5569 |
| LOT 61 | 6/14/2018 | 28 | | | | | 5.9 | 6.5 | 5599 | 5368 |
| LOT 61 | 6/14/2018 | 90 | | | | | 16.9 | 18.6 | 7056 | |
| LOT 62 | 6/14/2018 | 4 | 84 | 73 | 144.0 | 4.7 | 2.7 | 3.0 | 3803 | |
| LOT62 | 6/14/2018 | 4 | | | | | 2.7 | 3.0 | 3866 | |
| LOT 62 | 6/14/2018 | 28 | | | | | 5.4 | 5.9 | 5731 | 5562 |
| LOT 62 | 6/14/2018 | 28 | | | | | 5.4 | 6.0 | 5560 | 5227 |
| LOT 62 | 6/14/2018 | 90 | | | | | 15.0 | 16.5 | 7169 | |
| LOT 63 | 6/14/2018 | 4 | 86 | 82 | 146.1 | 5.6 | 3.4 | 3.8 | 4060 | |
| LOT 63 | 6/14/2018 | 4 | | | | | 3.4 | 3.8 | 4195 | |
| LOT 63 | 6/14/2018 | 28 | | | | | 6.9 | 7.6 | 5742 | 5371 |
| LOT 63 | 6/14/2018 | 28 | | | | | 6.8 | 7.4 | 5825 | 6049 |
| LOT 63 | 6/14/2018 | 90 | | | | | 18.7 | 20.6 | 7510 | |
| LOT 64 | 6/14/2018 | 4 | 88 | 86 | 145.2 | 6.0 | 3.6 | 4.0 | 4425 | |
| LOT 64 | 6/14/2018 | 4 | | | | | 3.5 | 3.9 | 4436 | |
| LOT 64 | 6/14/2018 | 28 | | | | | 7.6 | 8.4 | 5970 | 5653 |
| LOT 64 | 6/14/2018 | 28 | | | | | 7.1 | 7.8 | 6282 | 5551 |
| LOT 64 | 6/14/2018 | 90 | | | | | 20.1 | 22.1 | 7242 | |
| LOT 65 | 6/14/2018 | 4 | 88 | 86 | 148.1 | 3.6 | 3.3 | 3.6 | 4489 | |
| LOT 65 | 6/14/2018 | 4 | | | | | 3.4 | 3.7 | 4500 | |
| LOT 65 | 6/14/2018 | 28 | | | | | 7.5 | 8.3 | 6520 | 6429 |
| LOT 65 | 6/14/2018 | 28 | | | | | 7.5 | 8.2 | 6419 | 6094 |
| LOT 65 | 6/14/2018 | 90 | | | | | 23.5 | 25.8 | 7788 | |
| LOT 66 | 6/15/2018 | 4 | 80 | 64 | 143.0 | 5.5 | 2.9 | 3.2 | 3884 | |
| LOT 66 | 6/15/2018 | 4 | | | | | 3.0 | 3.2 | 3939 | |
| LOT 66 | 6/15/2018 | 28 | | | | | 5.6 | 6.2 | 5629 | 5984 |

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| LOT 66 | 6/15/2018 | 28 | | | | | 5.9 | 6.5 | 5707 | 6018 |
| LOT 66 | 6/15/2018 | 94 | | | | | 14.9 | 16.3 | 6811 | |
| LOT 67 | 6/15/2018 | 4 | 86 | 78 | 144.1 | 4.4 | 3.1 | 3.4 | 3737 | |
| LOT 67 | 6/15/2018 | 4 | | | | | 3.1 | 3.4 | 3646 | |
| LOT 67 | 6/15/2018 | 28 | | | | | 7.1 | 7.8 | 5764 | 5490 |
| LOT 67 | 6/15/2018 | 28 | | | | | 7.1 | 7.8 | 5853 | 5468 |
| LOT 67 | 6/15/2018 | 94 | | | | | 20.6 | 22.6 | 7279 | |
| LOT 68 | 6/19/2018 | 3 | 86 | 78 | | 4.5 | 2.8 | 3.1 | 3991 | |
| LOT 68 | 6/19/2018 | 3 | | | | | 3.0 | 3.2 | 3903 | |
| LOT 68 | 6/19/2018 | 28 | | | | | 6.6 | 7.3 | 6074 | 5456 |
| LOT 68 | 6/19/2018 | 28 | | | | | 6.5 | 7.2 | 6176 | 5775 |
| LOT 68 | 6/19/2018 | 90 | | | | | 16.2 | 17.9 | 7263 | |
| LOT 70 | 6/19/2018 | 3 | 83 | 90 | | 4.5 | 3.1 | 3.4 | 3790 | |
| LOT 70 | 6/19/2018 | 3 | | | | | 3.1 | 3.4 | 3993 | |
| LOT 70 | 6/19/2018 | 28 | | | | | 7.0 | 7.7 | 6113 | 5586 |
| LOT 70 | 6/19/2018 | 28 | | | | | 6.5 | 7.1 | 6002 | 5588 |
| LOT 70 | 6/19/2018 | 90 | | | | | 18.8 | 20.7 | 7381 | |
| LOT 72 | 6/22/2018 | 3 | 86 | 79 | | 5.8 | 2.9 | 3.2 | 3351 | |
| LOT 72 | 6/22/2018 | 3 | | | | | 2.9 | 3.1 | 3560 | |
| LOT 72 | 6/22/2018 | 28 | | | | | 6.6 | 7.3 | 5500 | 5167 |
| LOT 72 | 6/22/2018 | 28 | | | | | 5.8 | 6.4 | 5262 | 5075 |
| LOT 72 | 6/22/2018 | 90 | | | | | 17.7 | 19.5 | 6400 | |
| LOT 73 | 6/23/2018 | 3 | 86 | 72 | | 7.2 | 2.8 | 3.1 | 2966 | |
| LOT 73 | 6/23/2018 | 3 | | | | | 2.8 | 3.1 | 3081 | |
| LOT 73 | 6/23/2018 | 31 | | | | | 5.8 | 6.4 | 4880 | 4586 |
| LOT 73 | 6/23/2018 | 31 | | | | | 5.8 | 6.4 | 4997 | 4579 |
| LOT 73 | 6/23/2018 | 90 | | | | | 15.4 | 16.9 | 5596 | |
| LOT 74 | 6/26/2018 | 3 | 84 | 70 | 143.6 | 6.0 | 2.9 | 3.2 | 3473 | |
| LOT 74 | 6/26/2018 | 3 | | | | | 2.7 | 3.0 | 3395 | |
| LOT 74 | 6/26/2018 | 28 | | | | | 5.9 | 6.5 | 5194 | 5239 |
| LOT 74 | 6/26/2018 | 28 | | | | | 5.9 | 6.5 | 5435 | 5180 |
| LOT 74 | 6/26/2018 | 90 | | | | | 17.5 | 19.3 | 6583 | |
| LOT 75 TTF | 6/27/2018 | 2 | 86 | 70 | 145.1 | 4.8 | 2.7 | 3.0 | 3352 | |
| LOT 75 TTF | 6/27/2018 | 2 | | | | | 2.6 | 2.8 | 3333 | |
| LOT 75 TTF | 6/27/2018 | 2 | | | | | 2.7 | 2.9 | 3455 | |
| LOT 75 TTF | 6/27/2018 | 28 | | | | | 6.1 | 6.7 | 5712 | 5464 |
| LOT 75 TTF | 6/27/2018 | 28 | | | | | 6.4 | 7.0 | 5892 | 5817 |
| LOT 75 TTF | 6/27/2018 | 89 | | | | | 17.5 | 19.3 | 7041 | |
| LOT 76 State 28D | 6/27/2018 | 28 | 89 | | | 5.1 | | 0.0 | | 4936/5093 |
| LOT 77 | 6/28/2018 | 2 | 86 | 76 | 143.7 | 6.4 | 2.5 | 2.8 | 2883 | |
| LOT 77 | 6/28/2018 | 2 | | | | | 2.5 | 2.8 | 2796 | |
| LOT 77 | 6/28/2018 | 28 | | | | | 5.8 | 6.4 | 5241 | 5152 |
| LOT 77 | 6/28/2018 | 28 | | | | | 6.1 | 6.7 | 5295 | 5161 |
| LOT 77 | 6/28/2018 | 89 | | | | | 16.5 | 18.1 | 6552 | |
| LOT 78 | 7/2/2018 | 3 | 88 | 76 | 145.2 | 5.5 | 2.8 | 3.0 | 3377 | |
| LOT 78 | 7/2/2018 | 3 | | | | | 2.9 | 3.1 | 3148 | |
| LOT 78 | 7/2/2018 | 28 | | | | | 6.2 | 6.8 | 5933 | 5517 |
| LOT 78 | 7/2/2018 | 28 | | | | | 5.8 | 6.4 | 5789 | 5373 |
| LOT 78 | 7/2/2018 | 91 | | | | | 17.9 | 19.7 | 6488 | |
| LOT 79 | 7/2/2018 | 3 | 92 | 88 | 141.2 | 7.2 | 2.6 | 2.8 | 2797 | |
| LOT79 | 7/2/2018 | 3 | | | | | 2.6 | 2.9 | 2819 | |
| LOT 79 | 7/2/2018 | 3 | | | | | | 0.0 | 3082 | |
| LOT 79 | 7/2/2018 | 28 | | | | | 5.3 | 5.8 | 4729 | 4523 |
| LOT 79 | 7/2/2018 | 28 | | | | | 5.2 | 5.7 | 5255 | 5007 |

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| LOT 79 | 7/2/2018 | 91 | | | | | 15.9 | 17.5 | 6379 | |
| LOT 80 | 7/3/2018 | 3 | 88 | 72 | 142.5 | 6.2 | 2.7 | 2.9 | 3148 | |
| LOT 80 | 7/3/2018 | 3 | | | | | 2.5 | 2.7 | 3062 | |
| LOT 80 | 7/3/2018 | 28 | | | | | 5.8 | 6.3 | 4983 | 4967 |
| LOT 80 | 7/3/2018 | 28 | | | | | 5.6 | 6.1 | 5110 | 5374 |
| LOT 80 | 7/3/2018 | 90 | | | | | 16.9 | 18.6 | 6553 | |
| LOT 81 | 7/6/2018 | 3 | 88 | 73 | 144.8 | 4.6 | 3.4 | 3.7 | 2961 | |
| LOT 81 | 7/6/2018 | 3 | | | | | 3.2 | 3.5 | 3426 | |
| LOT 81 | 7/6/2018 | 31 | | | | | 7.0 | 7.7 | 5753 | 5573 |
| LOT 81 | 7/6/2018 | 31 | | | | | 7.0 | 7.7 | 5754 | 5320 |
| LOT 81 | 7/6/2018 | 31 | | | | | | 0.0 | | |
| LOT 82 | 7/6/2018 | 3 | 92 | 88 | 142.2 | 6.2 | 3.2 | 3.5 | 3167 | |
| LOT 82 | 7/6/2018 | 3 | | | | | 3.4 | 3.8 | 3303 | |
| LOT 82 | 7/6/2018 | 31 | | | | | 6.9 | 7.6 | 4975 | 4809 |
| LOT 82 | 7/6/2018 | 31 | | | | | 7.1 | 7.8 | 5188 | 4829 |
| LOT 82 | 7/6/2018 | 31 | | | | | | 0.0 | | |
| LOT 83 | 7/10/2018 | 2 | 83 | 61 | 141.4 | 6.8 | 2.5 | 2.7 | 3013 | |
| LOT 83 | 7/10/2018 | 2 | | | | | 2.6 | 2.9 | 2811 | |
| LOT 83 | 7/10/2018 | 2 | | | | | 2.6 | 2.8 | 2842 | |
| LOT 83 | 7/10/2018 | 28 | | | | | 6.0 | 6.6 | 4766 | 4756 |
| LOT 83 | 7/10/2018 | 28 | | | | | 5.9 | 6.5 | 4690 | 5129 |
| LOT 83 | 7/10/2018 | 90 | | | | | 16.2 | 17.8 | 6144 | |
| LOT 85 | 7/13/2018 | 3 | 86 | 75 | 140.8 | 7.2 | 2.8 | 3.1 | 2867 | |
| LOT 85 | 7/13/2018 | 3 | | | | | 2.8 | 3.0 | 2793 | |
| LOT 85 | 7/13/2018 | 28 | | | | | 6.0 | 6.6 | 4535 | 4344 |
| LOT 85 | 7/13/2018 | 28 | | | | | 6.1 | 6.7 | 4618 | 4282 |
| LOT 85 | 7/13/2018 | 91 | | | | | 18.4 | 20.2 | 5833 | |
| LOT 87 | 7/13/2018 | 3 | 88 | 81 | 142.2 | 6.0 | 3.1 | 3.4 | 3319 | |
| LOT 87 | 7/13/2018 | 3 | | | | | 3.0 | 3.3 | 3129 | |
| LOT 87 | 7/13/2018 | 28 | | | | | 6.8 | 7.5 | 5373 | 4776 |
| LOT 87 | 7/13/2018 | 28 | | | | | 6.2 | 6.8 | 5469 | 4912 |
| LOT 87 | 7/13/2018 | 91 | | | | | 19.0 | 20.9 | 6438 | |
| LOT 88 | 7/17/2018 | 3 | 86 | 72 | 143.3 | 5.6 | 3.2 | 3.5 | 3974 | |
| LOT 88 | 7/17/2018 | 3 | | | | | 3.3 | 3.6 | 3946 | |
| LOT 88 | 7/17/2018 | 28 | | | | | 6.6 | 7.3 | 5851 | 5703 |
| LOT 88 | 7/17/2018 | 28 | | | | | 6.2 | 6.9 | 5893 | 5226 |
| LOT 88 | 7/17/2018 | 90 | | | | | 19.4 | 21.3 | 7722 | |
| LOT 90 | 7/17/2018 | 6 | 88 | 78 | 144.2 | 4.7 | 3.4 | 3.7 | 4708 | |
| LOT 90 | 7/17/2018 | 6 | | | | | 3.4 | 3.7 | 5097 | |
| LOT 90 | 7/17/2018 | 28 | | | | | 6.4 | 7.0 | 6202 | 6226 |
| LOT 90 | 7/17/2018 | 28 | | | | | 6.3 | 6.9 | 6198 | 6323 |
| LOT 90 | 7/17/2018 | 90 | | | | | 20.1 | 22.1 | 7660 | |
| LOT 91 | 7/19/2018 | 4 | 84 | 70 | 146.7 | 4.4 | 3.6 | 4.0 | 4818 | |
| LOT 91 | 7/19/2018 | 4 | | | | | 3.4 | 3.7 | 4652 | |
| LOT 91 | 7/19/2018 | 28 | | | | | 7.1 | 7.8 | 6452 | 6047 |
| LOT 91 | 7/19/2018 | 28 | | | | | 6.0 | 6.6 | 6692 | 6159 |
| LOT 91 | 7/19/2018 | 91 | | | | | 19.0 | 20.9 | 8391 | |
| LOT 92 | 7/19/2018 | 4 | 84 | 71 | 145.0 | 5.0 | 3.1 | 3.4 | 4197 | |
| LOT 92 | 7/19/2018 | 4 | | | | | 3.1 | 3.4 | 4053 | |
| LOT 92 | 7/19/2018 | 28 | | | | | 6.0 | 6.6 | 6105 | 5508 |
| LOT 92 | 7/19/2018 | 28 | | | | | 6.1 | 6.7 | 6120 | 5572 |
| LOT 92 | 7/19/2018 | 91 | | | | | 17.5 | 19.3 | 7592 | |
| LOT 93 | 7/19/2018 | 4 | 86 | 73 | 144.2 | 5.7 | 3.1 | 3.4 | 4209 | |
| LOT 93 | 7/19/2018 | 4 | | | | | 3.1 | 3.4 | 4209 | |
| LOT 93 | 7/19/2018 | 28 | | | | | 6.1 | 6.7 | 5434 | 5687 |

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| LOT 93 | 7/19/2018 | 28 | | | | | 6.1 | 6.7 | 5658 | 5612 |
| LOT 93 | 7/19/2018 | 91 | | | | | 16.3 | 17.9 | 6916 | |
| LOT 94 | 7/19/2018 | 4 | 88 | 82 | 145.2 | 5.2 | 3.6 | 4.0 | 4540 | |
| LOT 94 | 7/19/2018 | 4 | | | | | 3.5 | 3.9 | 4597 | |
| LOT 94 | 7/19/2018 | 28 | | | | | 6.6 | 7.2 | 6391 | 5417 |
| LOT 94 | 7/19/2018 | 28 | | | | | 6.9 | 7.6 | 6371 | 5330 |
| LOT 94 | 7/19/2018 | 91 | | | | | 19.4 | 21.4 | 8140 | |
| LOT 95 | 7/19/2018 | 4 | 88 | 82 | 144.2 | 5.6 | 3.3 | 3.6 | 3895 | |
| LOT 95 | 7/19/2018 | 4 | | | | | 3.4 | 3.7 | 4049 | |
| LOT 95 | 7/19/2018 | 28 | | | | | 7.0 | 7.7 | 5918 | 5269 |
| LOT 95 | 7/19/2018 | 28 | | | | | 7.1 | 7.8 | 6095 | 5182 |
| LOT 95 | 7/19/2018 | 91 | | | | | 24.4 | 26.9 | 7203 | |
| LOT 96 | 7/19/2018 | 4 | 90 | 86 | 145.5 | 5.4 | 3.4 | 3.7 | 4349 | |
| LOT 96 | 7/19/2018 | 4 | | | | | 3.5 | 3.9 | 4215 | |
| LOT 96 | 7/19/2018 | 28 | | | | | 6.7 | 7.4 | 6136 | 5586 |
| LOT 96 | 7/19/2018 | 28 | | | | | 6.7 | 7.3 | 6055 | 5425 |
| LOT 96 | 7/19/2018 | 91 | | | | | 19.2 | 21.1 | 7631 | |
| LOT 97 | 7/19/2018 | 4 | 90 | 87 | | 8.5 | 3.3 | 3.6 | 3000 | |
| LOT 97 | 7/19/2018 | 4 | | | | | 3.2 | 3.5 | 3194 | |
| LOT 97 | 7/19/2018 | 28 | | | | | 6.3 | 6.9 | 4089 | 4553 |
| LOT 97 | 7/19/2018 | 28 | | | | | 6.2 | 6.8 | 4728 | 4529 |
| LOT 97 | 7/19/2018 | 91 | | | | | 16.5 | 18.1 | 5837 | |
| LOT 98 | 7/20/2018 | 3 | 86 | 72 | 143.6 | 5.5 | | | 3806 | |
| LOT 98 | 7/20/2018 | 3 | | | | | | | 3726 | |
| LOT 98 | 7/20/2018 | 32 | | | | | 7.2 | 7.9 | 6091 | 6104 |
| LOT 98 | 7/20/2018 | 32 | | | | | 7.2 | 7.9 | 6226 | 6030 |
| LOT 98 | 7/20/2018 | 90 | | | | | 17.9 | 19.7 | 7330 | |
| LOT 99 | 7/20/2018 | 3 | 90 | 73 | | 5.6 | | | 3586 | |
| LOT 99 | 7/20/2018 | 3 | | | | | | | 3585 | |
| LOT 99 | 7/20/2018 | 32 | | | | | 7.0 | 7.7 | 5607 | 5395 |
| LOT 99 | 7/20/2018 | 32 | | | | | 7.0 | 7.6 | 5901 | 5417 |
| LOT 99 | 7/20/2018 | 90 | | | | | 19.1 | 21.0 | 6896 | |
| LOT 100 | 7/20/2018 | 3 | 90 | 78 | 147.8 | 3.7 | | | 4056 | |
| LOT 100 | 7/20/2018 | 3 | | | | | | | 4260 | |
| LOT 100 | 7/20/2018 | 32 | | | | | 8.8 | 9.7 | 6932 | 6197 |
| LOT 100 | 7/20/2018 | 32 | | | | | 8.7 | 9.5 | 6541 | 6112 |
| LOT 100 | 7/20/2018 | 90 | | | | | 25.2 | 27.7 | 8367 | |
| LOT 101 TTF | 7/25/2018 | 2 | 86 | 71 | 141.4 | 6.0 | 2.5 | 2.8 | 2692 | |
| LOT 101 TTF | 7/25/2018 | 2 | | | | | 2.5 | 2.8 | 2788 | |
| LOT 101 TTF | 7/25/2018 | 2 | | | | | 2.5 | 2.8 | 2646 | |
| LOT 101 | 7/25/2018 | 28 | | | | | 6.6 | 7.2 | 5220 | 5470 |
| LOT 101 | 7/25/2018 | 28 | | | | | 6.5 | 7.1 | 5212 | 5534 |
| LOT 101 | 7/25/2018 | 91 | | | | | 21.6 | 23.8 | 5920 | |
| LOT 102 | 7/26/2018 | 4 | 83 | 70 | | | 3.0 | 3.3 | 3092 | |
| LOT 102 | 7/26/2018 | 4 | | | 140.6 | 6.5 | 2.9 | 3.2 | 3393 | |
| LOT 102 | 7/26/2018 | 28 | | | | | 6.5 | 7.1 | 5134 | 4640 |
| LOT 102 | 7/26/2018 | 28 | | | | | 6.3 | 7.0 | 4601 | 4443 |
| LOT 102 | 7/26/2018 | 90 | | | | | 20.0 | 22.0 | 5920 | |
| LOT 103 | 7/26/2018 | 4 | 88 | 72 | 142.6 | 5.8 | 3.1 | 3.4 | 3340 | |
| LOT 103 | 7/26/2018 | 4 | | | | | 3.0 | 3.3 | 3517 | |
| LOT 103 | 7/26/2018 | 28 | | | | | 6.3 | 7.0 | 5002 | 4998 |
| LOT 103 | 7/26/2018 | 28 | | | | | 6.5 | 7.1 | 5275 | 4965 |
| LOT 103 | 7/26/2018 | 90 | | | | | 19.2 | 21.1 | 6204 | |
| LOT 104 | 7/27/2018 | 3 | 86 | 72 | 143.0 | 5.7 | | | 3692 | |
| LOT 104 | 7/27/2018 | 3 | | | | | | | 3478 | |

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| LOT 104 | 7/27/2018 | 28 | | | | | 7.2 | 7.9 | 5634 | 5215 |
| LOT 104 | 7/27/2018 | 28 | | | | | 6.8 | 7.5 | 4979 | 5463 |
| LOT 104 | 7/27/2018 | 90 | | | | | 21.7 | 23.9 | 6630 | |
| LOT 105 | 7/27/2018 | 3 | 90 | 78 | 144.1 | 5.9 | | | 3877 | |
| LOT 105 | 7/27/2018 | 3 | | | | | | | 3853 | |
| LOT 105 | 7/27/2018 | 28 | | | | | 7.3 | 8.0 | 5322 | 5411 |
| LOT 105 | 7/27/2018 | 28 | | | | | 7.3 | 8.0 | 5401 | 5478 |
| LOT 105 | 7/27/2018 | 90 | | | | | 20.3 | 22.3 | 6603 | |
| LOT 106 | 7/27/2018 | 3 | 90 | 86 | 143.7 | 5.5 | | | 3336 | |
| LOT 106 | 7/27/2018 | 3 | | | | | | | 3385 | |
| LOT 106 | 7/27/2018 | 28 | | | | | 7.5 | 8.2 | 5048 | 5468 |
| LOT 106 | 7/27/2018 | 28 | | | | | 7.4 | 8.2 | 5381 | 5219 |
| LOT 106 | 7/27/2018 | 90 | | | | | 24.2 | 26.6 | 6677 | |
| LOT 107 | 8/2/2018 | 4 | 86 | 73 | 142.0 | 6.8 | 3.1 | 3.4 | 3744 | |
| LOT 107 | 8/2/2018 | 4 | | | | | 3.1 | 3.4 | 3755 | |
| LOT 107 | 8/2/2018 | 28 | | | | | 5.9 | 6.5 | 5533 | |
| LOT 107 | 8/2/2018 | 28 | | | | | 5.9 | 6.5 | 5459 | |
| LOT 107 | 8/2/2018 | 90 | | | | | 16.9 | 18.6 | 6534 | |
| LOT 108 | 8/7/2018 | 3 | 84 | 68 | 143.0 | 6.0 | 2.8 | 3.1 | 3740 | |
| LOT 108 | 8/7/2018 | 3 | | | | | 2.9 | 3.2 | 3185 | |
| LOT 108 | 8/7/2018 | 29 | | | | | 5.6 | 6.2 | 5557 | |
| LOT 108 | 8/7/2018 | 29 | | | | | 5.9 | 6.5 | 5963 | |
| LOT 108 | 8/7/2018 | 90 | | | | | 18.7 | 20.6 | 6953 | |
| LOT 109 | 8/8/2018 | 5 | 84 | 70 | 145.3 | 4.7 | 2.8 | 3.1 | 4193 | |
| LOT 109 | 8/8/2018 | 5 | | | | | 2.9 | 3.2 | 4212 | |
| LOT 109 | 8/8/2018 | 28 | | | | | 5.8 | 6.4 | 5708 | |
| LOT 109 | 8/8/2018 | 28 | | | | | 5.9 | 6.5 | 5913 | |
| LOT 109 | 8/8/2018 | 90 | | | | | 14.8 | 16.3 | 6550 | |
| LOT 110 | 8/8/2018 | 2 | 88 | 76 | 143.8 | 5.4 | 2.2 | 2.4 | 2515 | |
| LOT 110 | 8/8/2018 | 5 | | | | | 2.3 | 2.5 | 3532 | |
| LOT 110 | 8/8/2018 | 28 | | | | | 5.8 | 6.4 | 4825 | |
| LOT 110 | 8/8/2018 | 28 | | | | | 5.8 | 6.4 | 5525 | |
| LOT 110 | 8/8/2018 | 90 | | | | | 12.7 | 14.0 | 6187 | |
| LOT 111 | 8/9/2018 | 4 | 90 | 78 | 143.2 | 6.0 | | | 3618 | |
| LOT 111 | 8/9/2018 | 4 | | | | | | | 3598 | |
| LOT 111 | 8/9/2018 | 28 | | | | | 6.4 | 7.1 | 4966 | |
| LOT 111 | 8/9/2018 | 28 | | | | | 6.7 | 7.3 | 5006 | |
| LOT 111 | 8/9/2018 | 91 | | | | | 18.6 | 20.4 | 6209 | |
| LOT 112 | 8/9/2018 | 4 | 90 | 86 | 142.9 | 5.2 | | | 4075 | |
| LOT 112 | 8/9/2018 | 4 | | | | | | | 3912 | |
| LOT 112 | 8/9/2018 | 28 | | | | | 7.5 | 8.3 | 5609 | |
| LOT 112 | 8/9/2018 | 28 | | | | | 7.4 | 8.1 | 5573 | |
| LOT 112 | 8/9/2018 | 91 | | | | | 23.8 | 26.2 | 7007 | |
| LOT 113 | 8/10/2018 | 3 | 86 | 72 | | 4.3 | | | 3627 | |
| LOT 113 | 8/10/2018 | 3 | | | | | | | 3700 | |
| LOT 113 | 8/10/2018 | 28 | | | | | 7.0 | 7.7 | 5638 | |
| LOT 113 | 8/10/2018 | 28 | | | | | 7.1 | 7.8 | 5598 | |
| LOT 113 | 8/10/2018 | 90 | | | | | 18.3 | 20.1 | 6585 | |
| LOT 114 | 8/10/2018 | 3 | 90 | 81 | 143.2 | 5.5 | | | 3747 | |
| LOT 114 | 8/10/2018 | 3 | | | | | | | 3508 | |
| LOT 114 | 8/10/2018 | 28 | | | | | 7.1 | 7.8 | 5898 | |
| LOT 114 | 8/10/2018 | 28 | | | | | 6.9 | 7.6 | 5646 | |
| LOT 114 | 8/10/2018 | 90 | | | | | 20.9 | 22.9 | 6542 | |
| LOT 115 | 8/10/2018 | 3 | 90 | 84 | 144.7 | 4.4 | | | 3775 | |
| LOT 115 | 8/10/2018 | 3 | | | | | | | 3709 | |

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| LOT 115 | 8/10/2018 | 28 | | | | | 7.2 | 7.9 | 5690 | |
| LOT 115 | 8/10/2018 | 28 | | | | | 7.4 | 8.1 | 6011 | |
| LOT 115 | 8/10/2018 | 90 | | | | | 20.8 | 22.9 | 7398 | |
| LOT 116 | 8/10/2018 | 3 | 92 | 87 | 144.1 | 5.0 | | | 3178 | |
| LOT 116 | 8/10/2018 | 3 | | | | | | | 3121 | |
| LOT 116 | 8/10/2018 | 28 | | | | | 7.2 | 7.9 | 5600 | |
| LOT 116 | 8/10/2018 | 28 | | | | | 7.3 | 8.0 | 5778 | |
| LOT 116 | 8/10/2018 | 90 | | | | | 24.8 | 27.3 | 7262 | |
| LOT 117 | 8/13/2018 | 3 | 86 | 72 | 142.9 | 5.0 | 2.6 | 2.8 | 2813 | |
| LOT 117 | 8/13/2018 | 3 | | | | | 2.8 | 3.0 | 3737 | |
| LOT 117 | 8/13/2018 | 28 | | | | | 7.7 | 8.5 | 6272 | |
| LOT 117 | 8/13/2018 | 28 | | | | | 7.7 | 8.5 | 6272 | |
| LOT 117 | 8/13/2018 | 91 | | | | | 25.0 | 27.5 | 7498 | |
| LOT 119 | 8/13/2018 | 3 | 90 | 74 | 141.9 | 6.0 | 2.6 | 2.9 | 3383 | |
| LOT 119 | 8/13/2018 | 3 | | | | | 2.6 | 2.9 | 3347 | |
| LOT 119 | 8/13/2018 | 28 | | | | | 7.1 | 7.8 | 5123 | |
| LOT 119 | 8/13/2018 | 28 | | | | | 6.9 | 7.6 | 5441 | |
| LOT 119 | 8/13/2018 | 91 | | | | | 33.4 | 36.7 | 6732 | |
| LOT 120 | 8/13/2018 | 3 | 86 | 76 | 145.4 | 4.4 | 2.9 | 3.2 | 3696 | |
| LOT 120 | 8/13/2018 | 3 | | | | | 2.9 | 3.2 | 3736 | |
| LOT 120 | 8/13/2018 | 28 | | | | | 7.9 | 8.7 | 6226 | |
| LOT 120 | 8/13/2018 | 28 | | | | | 7.9 | 8.7 | 6588 | |
| LOT 120 | 8/13/2018 | 91 | | | | | 24.4 | 26.8 | 7341 | |
| LOT 121 | 8/13/2018 | 3 | 89 | 83 | 144.7 | 4.8 | 2.7 | 3.0 | 3569 | |
| LOT 121 | 8/13/2018 | 3 | | | | | 2.7 | 2.9 | 3724 | |
| LOT 121 | 8/13/2018 | 28 | | | | | 7.3 | 8.0 | 6580 | |
| LOT 121 | 8/13/2018 | 28 | | | | | | | 6305 | |
| LOT 121 | 8/13/2018 | 91 | | | | | 22.2 | 24.4 | 7796 | |
| LOT 122 | 8/14/2018 | 3 | 86 | 69 | 144.4 | 5.5 | 3.4 | 3.7 | 4169 | |
| LOT 122 | 8/14/2018 | 3 | | | | | 3.2 | 3.5 | 4164 | |
| LOT 122 | 8/14/2018 | 28 | | | | | 7.5 | 8.3 | 6482 | |
| LOT 122 | 8/14/2018 | 28 | | | | | 7.5 | 8.3 | 6304 | |
| LOT 122 | 8/14/2018 | 90 | | | | | 21.3 | 23.4 | 7582 | |
| LOT 123 | 8/14/2018 | 3 | 90 | 75 | 145.0 | 4.9 | 3.2 | 3.5 | 3830 | |
| LOT 123 | 8/14/2018 | 3 | | | | | 3.3 | 3.6 | 3914 | |
| LOT 123 | 8/14/2018 | 28 | | | | | 7.6 | 8.4 | 5802 | |
| LOT 123 | 8/14/2018 | 28 | | | | | 7.5 | 8.3 | 6127 | |
| LOT 123 | 8/14/2018 | 90 | | | | | 23.9 | 26.3 | 7692 | |
| LOT 124 | 8/15/2018 | 5 | 86 | 72 | 143.0 | 5.9 | 3.4 | 3.7 | 4006 | |
| LOT 124 | 8/15/2018 | 5 | | | | | 3.4 | 3.8 | 4066 | |
| LOT 124 | 8/15/2018 | 28 | | | | | 7.1 | 7.8 | 5887 | 4535 |
| LOT 124 | 8/15/2018 | 28 | | | | | 6.5 | 7.2 | 5652 | 5508 |
| LOT 124 | 8/15/2018 | 90 | | | | | 19.3 | 21.2 | 7049 | |
| LOT 125 | 8/15/2018 | 5 | 88 | 82 | 142.6 | 5.5 | 3.4 | 3.7 | 4205 | |
| LOT 125 | 8/15/2018 | 5 | | | | | 3.2 | 3.5 | 3998 | |
| LOT 125 | 8/15/2018 | 28 | | | | | 7.0 | 7.7 | 6050 | 4963 |
| LOT 125 | 8/15/2018 | 28 | | | | | | | 6001 | 5105 |
| LOT 125 | 8/15/2018 | 90 | | | | | 21.7 | 23.9 | 7003 | |
| LOT 126 | 8/16/2018 | 4 | 89 | 77 | 143.8 | 5.5 | 3.1 | 3.4 | 3709 | |
| LOT 126 | 8/16/2018 | 4 | | | | | 3.1 | 3.4 | 3808 | |
| LOT 126 | 8/16/2018 | 28 | | | | | 6.8 | 7.5 | 6017 | 5530 |
| LOT 126 | 8/16/2018 | 28 | | | | | 6.9 | 7.6 | 5851 | 4952 |
| LOT 126 | 8/16/2018 | 91 | | | | | 22.0 | 24.2 | 7252 | |
| LOT 127 | 8/16/2018 | 4 | 90 | 84 | 144.9 | 5.3 | 3.4 | 3.7 | 4009 | |
| LOT 127 | 8/16/2018 | 4 | | | | | 3.2 | 3.5 | 3780 | |

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| LOT 127 | 8/16/2018 | 28 | | | | | 7.5 | 8.2 | 6280 | 5114 |
| LOT 127 | 8/16/2018 | 28 | | | | | 7.4 | 8.1 | 6556 | 5716 |
| LOT 127 | 8/16/2018 | 91 | | | | | 25.4 | 27.9 | 7343 | |
| LOT 128 | 8/16/2018 | 4 | 90 | 86 | 144.8 | 5.1 | 3.3 | 3.6 | 3991 | |
| LOT 128 | 8/16/2018 | 4 | | | | | 3.1 | 3.5 | 4038 | |
| LOT 128 | 8/16/2018 | 28 | | | | | 6.6 | 7.2 | 5738 | 5365 |
| LOT 128 | 8/16/2018 | 28 | | | | | 6.4 | 7.0 | 6273 | 5410 |
| LOT 128 | 8/16/2018 | 91 | | | | | 19.1 | 21.0 | 7164 | |
| LOT 129 | 8/16/2018 | 4 | 90 | 87 | 144.1 | 5.1 | 2.9 | 3.2 | 3716 | |
| LOT 129 | 8/16/2018 | 4 | | | | | 2.9 | 3.2 | 3775 | |
| LOT 129 | 8/16/2018 | 28 | | | | | 6.8 | 7.4 | 5886 | 5318 |
| LOT 129 | 8/16/2018 | 28 | | | | | 6.4 | 7.1 | 5623 | 4985 |
| LOT 129 | 8/16/2018 | 91 | | | | | 20.1 | 22.1 | 7513 | |
| LOT 130 | 8/16/2018 | 4 | 91 | 88 | 146.1 | 3.8 | 2.8 | 3.1 | 3818 | |
| LOT 130 | 8/16/2018 | 4 | | | | | 3.0 | 3.3 | 4118 | |
| LOT 130 | 8/16/2018 | 28 | | | | | 7.1 | 7.8 | 6528 | 5125 |
| LOT 130 | 8/16/2018 | 28 | | | | | 6.8 | 7.4 | 6567 | 5800 |
| LOT 130 | 8/16/2018 | 91 | | | | | 24.3 | 26.7 | 8637 | |
| LOT 131 | 8/16/2018 | 4 | 90 | 90 | 145.6 | 3.7 | 2.8 | 3.0 | 3804 | |
| LOT 131 | 8/16/2018 | 4 | | | | | 2.8 | 3.0 | 4046 | |
| LOT 131 | 8/16/2018 | 28 | | | | | 6.6 | 7.2 | 6079 | 5556 |
| LOT 131 | 8/16/2018 | 28 | | | | | 6.7 | 7.4 | 5820 | 4907 |
| LOT 131 | 8/16/2018 | 91 | | | | | 20.3 | 22.3 | 7046 | |
| LOT 132 | 8/20/2018 | 3 | 86 | 75 | 144.3 | 4.9 | 2.9 | 3.2 | 3718 | |
| LOT 132 | 8/20/2018 | 3 | | | | | 2.9 | 3.2 | 3736 | |
| LOT 132 | 8/20/2018 | 91 | | | | | 20.8 | 22.9 | 7609 | 5173 |
| LOT 132 | 8/20/2018 | 91 | | | | | | | | 5334 |
| LOT 132 | 8/20/2018 | 91 | | | | | | | | |
| LOT 133 | 8/21/2018 | 3 | 86 | 73 | 143.4 | 5.6 | 2.9 | 3.2 | 3615 | |
| LOT 133 | 8/21/2018 | 3 | | | | | 3.0 | 3.3 | 3709 | |
| LOT 133 | 8/21/2018 | 28 | | | | | 7.6 | 8.4 | 6287 | 5521 |
| LOT 133 | 8/21/2018 | 28 | | | | | 7.3 | 8.0 | 6358 | 5864 |
| LOT 133 | 8/21/2018 | 90 | | | | | 23.9 | 26.3 | 7504 | |
| LOT 134 | 8/21/2018 | 3 | 88 | 80 | 141.8 | 6 | 2.7 | 2.9 | 3314 | |
| LOT 134 | 8/21/2018 | 3 | | | | | 2.7 | 2.9 | 3382 | |
| LOT 134 | 8/21/2018 | 28 | | | | | 6.6 | 7.3 | 5793 | 4792 |
| LOT 134 | 8/21/2018 | 28 | | | | | 6.2 | 6.8 | 5894 | 5300 |
| LOT 134 | 8/21/2018 | 90 | | | | | 17.1 | 18.8 | 6925 | |
| LOT 135 | 8/21/2018 | 6 | 88 | 81 | 141.5 | 6 | 3.2 | 3.5 | 3416 | |
| LOT 135 | 8/21/2018 | 6 | | | | | 3.1 | 3.4 | 3404 | |
| LOT 135 | 8/21/2018 | 28 | | | | | 5.9 | 6.4 | 5119 | 4840 |
| LOT 135 | 8/21/2018 | 28 | | | | | 5.9 | 6.5 | 5043 | 4219 |
| LOT 135 | 8/21/2018 | 90 | | | | | 17.2 | 18.9 | 6252 | |
| LOT 136 | 8/27/2018 | 3 | 86 | 75 | 142.4 | 6 | 2.3 | 2.5 | 3299 | |
| LOT 136 | 8/27/2018 | 3 | | | | | 2.4 | 2.6 | 3077 | |
| LOT 136 | 8/27/2018 | 3 | | | | | 2.4 | 2.6 | 3021 | |
| LOT 136 | 8/27/2018 | 28 | | | | | 6.2 | 6.8 | 5180 | 4814 |
| LOT 136 | 8/27/2018 | 28 | | | | | 6.1 | 6.7 | 5523 | 5343 |
| LOT 136 | 8/27/2018 | 91 | | | | | 20.9 | 23.0 | 7035 | |
| LOT 138 | 8/27/2018 | 3 | 90 | 88 | 140.6 | 6.4 | 2.4 | 2.6 | 2971 | |
| LOT 138 | 8/27/2018 | 3 | | | | | 2.3 | 2.5 | 2773 | |
| LOT 138 | 8/27/2018 | 28 | | | | | 5.1 | 5.6 | 5523 | 4872 |
| LOT 138 | 8/27/2018 | 28 | | | | | 5.1 | 5.6 | 5072 | 4824 |
| LOT 138 | 8/27/2018 | 91 | | | | | 15.1 | 16.6 | 6252 | |
| LOT 139 | 8/28/2018 | 3 | 88 | 68 | | 6.5 | 2.5 | 2.7 | 3036 | |

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| LOT 139 | 8/28/2018 | 3 | | | | | 2.4 | 2.7 | 2826 | |
| LOT 139 | 8/28/2018 | 28 | | | | | 5.3 | 5.8 | 4883 | 4623 |
| LOT 139 | 8/28/2018 | 28 | | | | | 5.0 | 5.5 | 5007 | 4541 |
| LOT 139 | 8/28/2018 | 90 | | | | | 15.6 | 17.1 | 6557 | |
| LOT 140 | 8/28/2018 | 7 | 90 | 84 | 143.9 | 5.3 | 2.8 | 3.1 | 3888 | |
| LOT 140 | 8/28/2018 | 7 | | | | | 2.9 | 3.2 | 3868 | |
| LOT 140 | 8/28/2018 | 28 | | | | | 5.6 | 6.1 | 5424 | 5089 |
| LOT 140 | 8/28/2018 | 28 | | | | | 5.9 | 6.4 | 5348 | 4954 |
| LOT 140 | 8/28/2018 | 90 | | | | | 17.1 | 18.8 | 7021 | |
| LOT 141 | 8/29/2018 | 6 | 87 | 72 | 143.4 | 4.8 | 2.8 | 3.0 | 3848 | |
| LOT 141 | 8/29/2018 | 6 | | | | | 2.8 | 3.0 | 4039 | |
| LOT 141 | 8/29/2018 | 29 | | | | | 5.9 | 6.5 | 5608 | 5348 |
| LOT 141 | 8/29/2018 | 29 | | | | | 6.0 | 6.6 | 6022 | 5432 |
| LOT 141 | 8/29/2018 | 90 | | | | | 18.6 | 20.5 | 4809 | |
| LOT 142 | 8/29/2018 | 6 | 88 | 75 | 145.0 | 4.5 | 3.3 | 3.6 | 4971 | |
| LOT 142 | 8/29/2018 | 6 | | | | | 3.1 | 3.4 | 4636 | |
| LOT 142 | 8/29/2018 | 29 | | | | | 6.4 | 7.0 | 5967 | 5348 |
| LOT 142 | 8/29/2018 | 29 | | | | | 6.6 | 7.3 | 6714 | 5432 |
| LOT 142 | 8/29/2018 | 29 | | | | | | | | |
| LOT 143 | 8/29/2018 | 6 | 90 | 86 | 144.5 | 5 | 3.2 | 3.6 | 4401 | |
| LOT 143 | 8/29/2018 | 6 | | | | | 3.1 | 3.4 | 4499 | |
| LOT 143 | 8/29/2018 | 29 | | | | | 6.2 | 6.9 | 6174 | 5198 |
| LOT 143 | 8/29/2018 | 29 | | | | | 6.2 | 6.8 | 6450 | 5472 |
| LOT 143 | 8/29/2018 | 90 | | | | | 19.4 | 21.4 | 7284 | |
| LOT 144 | 8/30/2018 | 5 | 86 | 71 | 144.6 | 5 | 3.2 | 3.5 | 4083 | |
| LOT 144 | 8/30/2018 | 5 | | | | | 3.0 | 3.3 | 4152 | |
| LOT 144 | 8/30/2018 | 28 | | | | | 5.8 | 6.4 | 5865 | 5660 |
| LOT 144 | 8/30/2018 | 28 | | | | | 5.7 | 6.3 | 5679 | 5214 |
| LOT 144 | 8/30/2018 | 90 | | | | | 16.7 | 18.4 | 6944 | |
| LOT 145 | 8/30/2018 | 5 | 90 | 80 | | 4.5 | 2.6 | 2.8 | 4144 | |
| LOT 145 | 8/30/2018 | 5 | | | | | 2.9 | 3.2 | 3999 | |
| LOT 145 | 8/30/2018 | 28 | | | | | 5.4 | 6.0 | 6353 | 4878 |
| LOT 145 | 8/30/2018 | 28 | | | | | 5.5 | 6.1 | 5957 | 5578 |
| LOT 145 | 8/30/2018 | 90 | | | | | 17.5 | 19.2 | 7145 | |
| LOT 146 | 9/4/2018 | 3 | 88 | 70 | 143.8 | 5.4 | 2.7 | 3.0 | 3175 | |
| LOT 146 | 9/4/2018 | 3 | | | | | 2.8 | 3.1 | 3095 | |
| LOT 146 | 9/4/2018 | 28 | | | | | 5.8 | 6.4 | 5656 | 5289 |
| LOT 146 | 9/4/2018 | 28 | | | | | 5.6 | 6.2 | 5792 | 5260 |
| LOT 146 | 9/4/2018 | 90 | | | | | 16.2 | 17.8 | 6188 | |
| LOT 148 | 9/7/2018 | 3 | 86 | 68 | | 6 | | | 2750 | |
| LOT 148 | 9/7/2018 | 3 | | | | | 3.3 | 3.6 | 2941 | |
| LOT 148 | 9/7/2018 | 31 | | | | | 6.6 | 7.2 | 4984 | 4810 |
| LOT 148 | 9/7/2018 | 31 | | | | | 6.6 | 7.2 | 4915 | 4752 |
| LOT 148 | 9/7/2018 | 91 | | | | | 18.2 | 20.0 | 5977 | |
| LOT 149 | 9/7/2018 | 3 | 88 | 77 | 143.2 | 4.9 | 2.6 | 2.9 | 3373 | |
| LOT 149 | 9/7/2018 | 3 | | | | | 2.5 | 2.7 | 3637 | |
| LOT 149 | 9/7/2018 | 26 | | | | | 5.4 | 6.0 | 5521 | 5602 |
| LOT 149 | 9/7/2018 | 26 | | | | | 5.3 | 5.8 | 5599 | 5551 |
| LOT 149 | 9/7/2018 | 89 | | | | | 16.7 | 18.3 | 7231 | |
| LOT 150 | 9/10/2018 | 3 | 82 | 66 | 139.8 | 7.6 | 2.6 | 2.9 | 2762 | |
| LOT 150 | 9/10/2018 | 3 | | | | | 2.3 | 2.5 | 2960 | |
| LOT 150 | 9/10/2018 | 28 | | | | | 5.9 | 6.5 | 4462 | 4798 |
| LOT 150 | 9/10/2018 | 28 | | | | | 6.0 | 6.6 | 4226 | 4387 |
| LOT 150 | 9/10/2018 | 92 | | | | | 18.8 | 20.6 | 5932 | |
| LOT 151 | 9/10/2018 | 3 | 85 | 69 | 144.5 | 4 | 2.3 | 2.5 | 3443 | |

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| LOT 151 | 9/10/2018 | 3 | | | | | 2.2 | 2.4 | 3621 | |
| LOT 151 | 9/10/2018 | 28 | | | | | 5.8 | 6.4 | 5993 | |
| LOT 151 | 9/10/2018 | 28 | | | | | 5.5 | 6.0 | 6453 | 5525 |
| LOT 151 | 9/10/2018 | 92 | | | | | 21.1 | 23.2 | 7800 | 5794 |
| LOT 152 | 9/11/2018 | 6 | 86 | 70 | 142.8 | 5 | 3.1 | 3.4 | 4238 | |
| LOT 152 | 9/11/2018 | 6 | | | | | 2.9 | 3.2 | 4387 | |
| LOT 152 | 9/11/2018 | 28 | | | | | 6.5 | 7.2 | 6172 | 5253 |
| LOT 152 | 9/11/2018 | 28 | | | | | 6.6 | 7.2 | 6546 | 5231 |
| LOT 152 | 9/11/2018 | 91 | | | | | 23.7 | 26.1 | 8326 | |
| LOT 153 | 9/11/2018 | 6 | 88 | 73 | 141.7 | 5.5 | 2.9 | 3.2 | 4225 | |
| LOT 153 | 9/11/2018 | 6 | | | | | 2.8 | 3.1 | 4140 | |
| LOT 153 | 9/11/2018 | 28 | | | | | 6.5 | 7.2 | 5695 | 5223 |
| LOT 153 | 9/11/2018 | 28 | | | | | 6.7 | 7.4 | 6120 | 5204 |
| LOT 153 | 9/11/2018 | 91 | | | | | 23.8 | 26.2 | 7317 | |
| LOT 158 TTF | 10/22/2018 | 2 | 76 | 61 | 141.8 | 6.4 | | | 3083 | |
| LOT 158 TTF | 10/22/2018 | 2 | | | | | | | 2620 | |
| LOT 158 TTF | 10/22/2018 | 2 | | | | | | | 3086 | |
| LOT 158 TTF | 10/22/2018 | 28 | | | | | 5.9 | 6.4 | 6122 | 5383 |
| LOT 158 TTF | 10/22/2018 | 28 | | | | | 5.8 | 6.4 | 6140 | 5463 |
| LOT 159 | 10/24/2018 | 6 | 66 | 54 | 141.5 | 6.4 | 3.2 | 3.5 | 3766 | |
| LOT 159 | 10/24/2018 | 6 | | | | | 3.2 | 3.5 | 3708 | |
| LOT 159 | 10/24/2018 | 28 | | | | | 6.9 | 7.6 | 5568 | 5021 |
| LOT 159 | 10/24/2018 | 28 | | | | | 7.0 | 7.7 | 5609 | 4813 |
| LOT 160 | 10/29/2018 | 4 | 66 | 43 | | 4.4 | | | 5051 | |
| LOT 160 | 10/29/2018 | 4 | | | | | | | 4195 | |
| LOT 160 | 10/29/2018 | 28 | | | | | 5.9 | 6.4 | 6264 | 5390 |
| LOT 160 | 10/29/2018 | 28 | | | | | 6.2 | 6.8 | 6087 | 5962 |
| LOT 160 | 10/29/2018 | 28 | | | | | | | | |
| LOT 162 | 10/30/2018 | 3 | 72 | 64 | 142.4 | 5.5 | 2.3 | 2.5 | 3527 | |
| LOT 162 | 10/30/2018 | 3 | | | | | 2.3 | 2.5 | 3843 | |
| LOT 162 | 10/30/2018 | 28 | | | | | 6.4 | 7.0 | 6647 | 5874 |
| LOT 162 | 10/30/2018 | 28 | | | | | 6.3 | 6.9 | 6301 | 5890 |
| LOT 162 | 10/30/2018 | 28 | | | | | | | | |
| LOT 166 | 11/7/2018 | 5 | 65 | 72 | 142.7 | | 2.6 | 2.8 | 3496 | |
| LOT 166 | 11/7/2018 | 5 | | | | | 2.8 | 3.1 | 3537 | |
| LOT 166 | 11/7/2018 | 28 | | | | | 6.3 | 7.0 | 5641 | 4379 |
| LOT 166 | 11/7/2018 | 28 | | | | | 6.3 | 6.9 | 5614 | 5285 |
| LOT 167 | 11/7/2018 | 5 | 66 | 79 | 143.4 | 5.3 | 3.1 | 3.4 | 4278 | |
| LOT 167 | 11/7/2018 | 5 | | | | | 3.0 | 3.3 | 4165 | |
| LOT 167 | 11/7/2018 | 28 | | | | | 6.3 | 7.0 | 6455 | 5412 |
| LOT 167 | 11/7/2018 | 28 | | | | | 6.5 | 7.2 | 6389 | 5555 |
| LOT 168 TTF | 1/28/2019 | 2 | 60 | 50 | 145.3 | 5 | | | 3461 | |
| LOT 168 | 1/28/2019 | 2 | | | | | | | 3337 | |
| LOT 168 | 1/28/2019 | 2 | | | | | | | 3310 | |
| LOT 168 | 1/28/2019 | 28 | | | | | 6.7 | 7.4 | 7716 | 6153 |
| LOT 168 | 1/28/2019 | 28 | | | | | 6.8 | 7.5 | 7611 | 5959 |
| LOT 169 | 1/28/2019 | 3 | 60 | 53 | 145.5 | 4 | | | 3856 | |
| LOT 169 | 1/28/2019 | 3 | | | | | | | 4028 | |
| LOT 169 | 1/28/2019 | 28 | | | | | 6.4 | 7.1 | 7453 | 6529 |
| LOT 169 | 1/28/2019 | 28 | | | | | 6.6 | 7.2 | 7564 | 5900 |
| LOT 170 | 2/1/2019 | 3 | 52 | 47 | 144.3 | 5.5 | | | | |
| LOT 170 | 2/1/2019 | 3 | | | | | | | | |
| LOT 170 | 2/1/2019 | 28 | | | | | 6.5 | 7.2 | 5681 | 5921 |
| LOT 170 | 2/1/2019 | 28 | | | | | 6.7 | 7.3 | 5838 | 6043 |
| LOT 171 | 2/8/2019 | 3 | 70 | 63 | 142.6 | 6.4 | | | 3011 | |

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| LOT 171 | 2/8/2019 | 3 | | | | | | | 2904 | |
| LOT 171 | 2/8/2019 | 31 | | | | | 6.3 | 6.9 | 5836 | 5727 |
| LOT 171 | 2/8/2019 | 31 | | | | | 6.1 | 6.7 | 5657 | 5595 |
| LOT 171 | 2/8/2019 | 56 | | | | | | | | |
| LOT 176 TTF | 3/29/2019 | 3 | 65 | 42 | 146.9 | 4 | | | 3939 | |
| LOT 176 TTF | 3/29/2019 | 3 | | | | | | | 3971 | |
| LOT 176 TTF | 3/29/2019 | 3 | | | | | | | 3887 | |
| LOT 176 | 3/29/2019 | 28 | | | | | 5.3 | 5.8 | 6090 | 5660 |
| LOT 176 | 3/29/2019 | 28 | | | | | 5.5 | 6.0 | 6256 | 5985 |
| LOT 177 | 3/30/2019 | 3 | 75 | 62 | 143.2 | 5.4 | 2.4 | 2.6 | 3427 | |
| LOT 177 | 3/30/2019 | 3 | | | | | 2.4 | 2.6 | 3507 | |
| LOT 177 | 3/30/2019 | 27 | | | | | | | 5628 | 5952 |
| LOT 177 | 3/30/2019 | 27 | | | | | | | 6020 | 5615 |
| LOT 177 | 3/30/2019 | 55 | | | | | 9.9 | 10.9 | 6771 | |
| LOT 178 | 4/2/2019 | 3 | 60 | 37 | 138.7 | 7.4 | 5.3 | 5.8 | 3763 | |
| LOT 178 | 4/2/2019 | 3 | | | | | 5.2 | 5.8 | 3826 | |
| LOT 178 | 4/2/2019 | 28 | | | | | 7.1 | 7.8 | 5789 | 4833 |
| LOT 178 | 4/2/2019 | 28 | | | | | 7.2 | 7.9 | 5908 | 5500 |
| LOT 179 | 4/4/2019 | 4 | 70 | 72 | 141.2 | 6.8 | 2.7 | 2.9 | 3826 | |
| LOT 179 | 4/4/2019 | 4 | | | | | 2.7 | 3.0 | 3990 | |
| LOT 179 | 4/4/2019 | 28 | | | | | 5.7 | 6.3 | 5932 | 5510 |
| LOT 179 | 4/4/2019 | 28 | | | | | 6.0 | 6.6 | 6144 | 5464 |
| LOT 179 | 4/4/2019 | 56 | | | | | 9.9 | 10.9 | 7193 | |
| LOT 180 | 4/17/2019 | 2 | 67 | 57 | 145.0 | 5.2 | 2.5 | 2.7 | 3016 | |
| LOT 180 | 4/17/2019 | 2 | | | | | 2.4 | 2.6 | 2963 | |
| LOT 180 | 4/17/2019 | 2 | | | | | 2.1 | 2.3 | 3041 | |
| LOT 180 | 4/17/2019 | 28 | | | | | 7.3 | 8.0 | 5578 | 5805 |
| LOT 180 | 4/17/2019 | 28 | | | | | 7.1 | 7.8 | 6130 | 5724 |
| LOT 180 | 4/17/2019 | 56 | | | | | 12.8 | 14.1 | 184370 | |
| LOT 184 | 4/18/2019 | 4 | 68 | 67 | 144.6 | 5.2 | 2.8 | 3.1 | 3983 | |
| LOT 184 | 4/18/2019 | 4 | | | | | 2.9 | 3.2 | 3733 | |
| LOT 184 | 4/18/2019 | 28 | | | | | 6.7 | 7.4 | 5946 | 5471 |
| LOT 184 | 4/18/2019 | 28 | | | | | 7.0 | 7.6 | 6041 | 5490 |
| LOT 184 | 4/18/2019 | 56 | | | | | 13.7 | 15.1 | 6888 | |
| LOT 185 | 4/18/2019 | 4 | 72 | 71 | 144.9 | 4.5 | 2.6 | 2.8 | 4261 | |
| LOT185 | 4/18/2019 | 4 | | | | | 2.6 | 2.8 | 4050 | |
| LOT 185 | 4/18/2019 | 28 | | | | | 7.2 | 7.9 | 6622 | 5223 |
| LOT 185 | 4/18/2019 | 28 | | | | | 7.4 | 8.2 | 6575 | 5427 |
| LOT 185 | 4/18/2019 | 56 | | | | | 15.1 | 16.6 | 7696 | |
| LOT 186 | 4/18/2019 | 4 | 71 | 77 | 144.3 | 4.8 | 2.7 | 3.0 | 3939 | |
| LOT 186 | 4/18/2019 | 4 | | | | | 2.7 | 3.0 | 3613 | |
| LOT 186 | 4/18/2019 | 28 | | | | | 6.4 | 7.1 | 6077 | 5891 |
| LOT 186 | 4/18/2019 | 28 | | | | | 6.4 | 7.1 | 6611 | 5578 |
| LOT 186 | 4/18/2019 | 56 | | | | | 13.1 | 14.4 | 7659 | |
| LOT 187 | 4/22/2019 | 3 | 60 | 47 | 143.0 | 5 | 2.5 | 2.8 | 3502 | |
| LOT187 | 4/22/2019 | 3 | | | | | 2.4 | 2.7 | 3669 | |
| LOT 187 | 4/22/2019 | 28 | | | | | 6.6 | 7.2 | 6331 | 5525 |
| LOT 187 | 4/22/2019 | 28 | | | | | 6.7 | 7.4 | 6479 | 5870 |
| LOT 187 | 4/22/2019 | 56 | | | | | 12.3 | 13.5 | 6838 | |
| LOT 188 | 4/22/2019 | 3 | 66 | 60 | 145.6 | 4 | 2.5 | 2.8 | 3918 | |
| LOT 188 | 4/22/2019 | 3 | | | | | 2.6 | 2.8 | 3860 | |
| LOT 188 | 4/22/2019 | 28 | | | | | 6.3 | 7.0 | 6787 | 6433 |
| LOT 188 | 4/22/2019 | 28 | | | | | 6.4 | 7.0 | 6678 | 5908 |
| LOT 188 | 4/22/2019 | 56 | | | | | 12.6 | 13.8 | 7910 | |
| LOT 189 | 4/25/2019 | 4 | 67 | 57 | | 6.4 | 3.1 | 3.4 | 4632 | |

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| LOT 189 | 4/25/2019 | 4 | | | | | 3.1 | 3.4 | 4738 | |
| LOT 189 | 4/25/2019 | 28 | | | | | 7.2 | 7.9 | 7165 | 4728 |
| LOT 189 | 4/25/2019 | 28 | | | | | 7.2 | 8.0 | 7256 | 5095 |
| LOT 189 | 4/25/2019 | 56 | | | | | 14.0 | 15.4 | 7802 | |
| LOT 191 | 4/25/2019 | 4 | 72 | 69 | 140.2 | 6.5 | 2.9 | 3.2 | 4108 | |
| LOT 191 | 4/25/2019 | 4 | | | | | 2.9 | 3.2 | 4080 | |
| LOT 191 | 4/25/2019 | 28 | | | | | 7.1 | 7.8 | 6163 | 5885 |
| LOT 191 | 4/25/2019 | 28 | | | | | 6.8 | 7.5 | 6163 | 5282 |
| LOT 191 | 4/25/2019 | 56 | | | | | 14.1 | 15.5 | 6885 | |
| LOT 192 | 4/25/2019 | 4 | 73 | 74 | 144.6 | 4.6 | 2.6 | 2.9 | 4051 | |
| LOT 192 | 4/25/2019 | 4 | | | | | 2.7 | 3.0 | 4140 | |
| LOT 192 | 4/25/2019 | 28 | | | | | 5.9 | 6.5 | 6382 | 5960 |
| LOT 192 | 4/25/2019 | 28 | | | | | 6.0 | 6.5 | 6742 | 5506 |
| LOT 192 | 4/25/2019 | 56 | | | | | 12.8 | 14.1 | 7404 | |
| LOT 194 | 4/29/2019 | 4 | 67 | 60 | 143.2 | 5.1 | 2.4 | 2.6 | 3190 | |
| LOT 194 | 4/29/2019 | 4 | | | | | 2.4 | 2.6 | 3224 | |
| LOT 194 | 4/29/2019 | 29 | | | | | 5.3 | 5.9 | 5486 | 4892 |
| LOT 194 | 4/29/2019 | 29 | | | | | 5.5 | 6.1 | 5832 | 4821 |
| LOT 194 | 4/29/2019 | 56 | | | | | 10.5 | 11.5 | 6457 | |
| LOT 195 TTF | 4/29/2019 | 2 | 67 | 60 | 144.0 | 5.1 | 2.3 | 2.6 | 3484 | |
| LOT 195 TTF | 4/29/2019 | 2 | | | | | 2.4 | 2.6 | 3514 | |
| LOT 195 TTF | 4/29/2019 | 2 | | | | | 2.4 | 2.6 | 3685 | |
| LOT 195 | 4/29/2019 | 29 | | | | | 6.6 | 7.3 | 6790 | 6275 |
| LOT 195 | 4/29/2019 | 29 | | | | | 6.4 | 7.1 | 7154 | 6560 |
| LOT 195 | 4/29/2019 | 56 | | | | | 12.1 | 13.3 | 7929 | |
| LOT 195 | 4/29/2019 | 56 | | | | | 12.1 | 13.3 | 7929 | |
| LOT 196 | 4/29/2019 | 4 | 70 | 61 | 142.4 | 5.8 | 2.4 | 2.6 | 3889 | |
| LOT 196 | 4/29/2019 | 4 | | | | | 2.3 | 2.6 | 3847 | |
| LOT 196 | 4/29/2019 | 29 | | | | | 5.6 | 6.2 | 6544 | 6608 |
| LOT 196 | 4/29/2019 | 29 | | | | | 5.6 | 6.2 | 6532 | 6374 |
| LOT 196 | 4/29/2019 | 56 | | | | | 10.5 | 11.5 | 7180 | |
| LOT 197 | 4/30/2019 | 7 | 78 | 76 | 140.2 | 6.6 | 2.7 | 3.0 | 3761 | |
| LOT 197 | 4/30/2019 | 7 | | | | | 2.7 | 3.0 | 3923 | |
| LOT 197 | 4/30/2019 | 28 | | | | | 4.9 | 5.4 | 5920 | 5474 |
| LOT 197 | 4/30/2019 | 28 | | | | | 5.1 | 5.6 | 5787 | 5950 |
| LOT 197 | 4/30/2019 | 56 | | | | | 9.8 | 10.8 | 6471 | |
| LOT 200 | 5/1/2019 | 28 | | | | | 5.8 | 6.4 | 5827 | 5675 |
| LOT 200 | 5/1/2019 | 56 | | | | | 10.5 | 11.6 | 6814 | |
| LOT 201 | 5/2/2019 | 4 | 77 | 68 | 143.0 | 4.2 | 2.8 | 3.1 | 3410 | |
| LOT 201 | 5/2/2019 | 4 | | | | | 2.8 | 3.1 | 3719 | |
| LOT 201 | 5/2/2019 | 28 | | | | | 6.2 | 6.8 | 5481 | 5156 |
| LOT 201 | 5/2/2019 | 28 | | | | | 6.0 | 6.6 | 5231 | 4821 |
| LOT 201 | 5/2/2019 | 56 | | | | | 11.5 | 12.6 | 6832 | |
| LOT 202 | 5/2/2019 | 4 | 79 | 79 | 142.8 | 4.7 | 2.3 | 2.5 | 3519 | |
| LOT 202 | 5/2/2019 | 4 | | | | | 2.3 | 2.6 | 3542 | |
| LOT 202 | 5/2/2019 | 28 | | | | | 5.3 | 5.8 | MISREAD | 4733 |
| LOT 202 | 5/2/2019 | 28 | | | | | 4.9 | 5.4 | 5423 | 4949 |
| LOT 202 | 5/2/2019 | 56 | | | | | 10.1 | 11.1 | 6455 | |
| LOT 203 | 5/6/2019 | 3 | 78 | 63 | 144.3 | 5.5 | 2.5 | 2.7 | 3321 | |
| LOT 203 | 5/6/2019 | 3 | | | | | 2.5 | 2.8 | 3459 | |
| LOT 203 | 5/6/2019 | 28 | | | | | 5.7 | 6.3 | 5748 | 4525 |
| LOT 203 | 5/6/2019 | 28 | | | | | 6.0 | 6.6 | 5949 | 5394 |
| LOT 203 | 5/6/2019 | 56 | | | | | 12.6 | 13.9 | 7114 | |
| LOT 204 | 5/6/2019 | 3 | 84 | 75 | 141.7 | 6.2 | 2.5 | 2.8 | 3077 | |
| LOT 204 | 5/6/2019 | 3 | | | | | 2.5 | 2.7 | 3094 | |

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| LOT 204 | 5/6/2019 | 28 | | | | | 5.7 | 6.3 | 5629 | 5242 |
| LOT 204 | 5/6/2019 | 28 | | | | | 5.6 | 6.2 | 5464 | 5307 |
| LOT 204 | 5/6/2019 | 56 | | | | | 12.0 | 13.2 | 6375 | |
| LOT 205 | 5/8/2019 | 5 | 84 | 74 | | 4.9 | 2.8 | 3.1 | 4174 | |
| LOT 205 | 5/8/2019 | 5 | | | | | 2.8 | 3.1 | 3969 | |
| LOT 205 | 5/8/2019 | 28 | | | | | 6.8 | 7.5 | 6160 | 5967 |
| LOT 205 | 5/8/2019 | 28 | | | | | 7.2 | 7.9 | 6535 | 5967 |
| LOT 205 | 5/8/2019 | 56 | | | | | 12.8 | 14.0 | 6863 | |
| LOT207 TTF | 5/23/2019 | 5 | 80 | 72 | 145.4 | 4.5 | 2.9 | 3.2 | 4702 | |
| LOT207 TTF | 5/23/2019 | 5 | | | | | 2.8 | 3.1 | 4477 | |
| LOT207 TTF | 5/23/2019 | 5 | | | | | 2.8 | 3.1 | 4621 | |
| LOT207 | 5/23/2019 | 28 | | | | | 6.7 | 7.4 | 6787 | |
| LOT207 | 5/23/2019 | 28 | | | | | 6.5 | 7.1 | 6762 | |
| LOT207 | 5/23/2019 | 56 | | | | | 13.0 | 14.2 | 7203 | |
| LOT 208 | 5/24/2019 | 4 | 82 | 70 | 145.4 | 4.5 | 3.0 | 3.3 | 4095 | |
| LOT 208 | 5/24/2019 | 4 | | | | | 3.0 | 3.3 | 4155 | |
| LOT 208 | 5/24/2019 | 28 | | | | | 7.4 | 8.2 | 6143 | 5781 |
| LOT 208 | 5/24/2019 | 28 | | | | | 7.1 | 7.8 | 6244 | 5666 |
| LOT 208 | 5/24/2019 | 56 | | | | | 14.8 | 16.3 | 6973 | |
| LOT 209 | 5/24/2019 | 4 | 88 | 82 | 144.1 | 4.9 | 3.0 | 3.3 | 3992 | |
| LOT209 | 5/24/2019 | 4 | | | | | 2.9 | 3.2 | 4059 | |
| LOT 209 | 5/24/2019 | 28 | | | | | 7.4 | 8.2 | 6093 | 5957 |
| LOT 209 | 5/24/2019 | 28 | | | | | 7.8 | 8.6 | 6412 | 5773 |
| LOT 209 | 5/24/2019 | 56 | | | | | 15.7 | 17.3 | 6999 | |
| LOT 210 | 5/24/2019 | 4 | 88 | 90 | | 5.4 | 3.0 | 3.2 | 3546 | |
| LOT 210 | 5/24/2019 | 4 | | | | | 2.9 | 3.2 | 3543 | |
| LOT 210 | 5/24/2019 | 28 | | | | | 7.0 | 7.7 | 5729 | 5560 |
| LOT 210 | 5/24/2019 | 28 | | | | | 6.9 | 7.6 | 5722 | 4930 |
| LOT 210 | 5/24/2019 | 56 | | | | | 13.3 | 14.7 | 6181 | |
| LOT 211 | 5/28/2019 | 3 | 80 | 65 | | 4.9 | 2.7 | 3.0 | 4067 | |
| LOT 211 | 5/28/2019 | 3 | | | | | 2.7 | 3.0 | 4024 | |
| LOT 211 | 5/28/2019 | 28 | | | | | 7.3 | 8.0 | 6514 | 5636 |
| LOT 211 | 5/28/2019 | 28 | | | | | 7.1 | 7.8 | 6374 | 5614 |
| LOT 211 | 5/28/2019 | 56 | | | | | 15.4 | 16.9 | 7040 | |
| LOT 212 | 5/28/2019 | 3 | 84 | 75 | | 5.4 | 2.7 | 3.0 | 3755 | |
| LOT 212 | 5/28/2019 | 3 | | | | | 2.7 | 3.0 | 3716 | |
| LOT 212 | 5/28/2019 | 28 | | | | | 6.2 | 6.8 | 5989 | 5017 |
| LOT 212 | 5/28/2019 | 28 | | | | | 5.9 | 6.5 | 5924 | 5702 |
| LOT 212 | 5/28/2019 | 56 | | | | | 11.9 | 13.1 | 6752 | |
| LOT 213 | 5/28/2019 | 3 | 88 | 88 | | 6 | 2.6 | 2.9 | 3370 | |
| LOT 213 | 5/28/2019 | 3 | | | | | 2.7 | 3.0 | 3084 | |
| LOT 213 | 5/28/2019 | 28 | | | | | 6.4 | 7.0 | 4801 | 4946 |
| LOT 213 | 5/28/2019 | 28 | | | | | 5.7 | 6.3 | 5326 | 4452 |
| LOT 213 | 5/28/2019 | 56 | | | | | 11.6 | 12.8 | 5824 | |
| LOT 214 | 5/28/2019 | 3 | 88 | 90 | | 6.6 | 2.6 | 2.9 | 3494 | |
| LOT 214 | 5/28/2019 | 3 | | | | | 2.7 | 3.0 | 3318 | |
| LOT 214 | 5/28/2019 | 28 | | | | | 5.9 | 6.5 | 5488 | 4987 |
| LOT 214 | 5/28/2019 | 28 | | | | | 5.9 | 6.5 | 5458 | 5083 |
| LOT 214 | 5/28/2019 | 56 | | | | | 11.6 | 12.7 | 6538 | |
| LOT 215 | 5/29/2019 | 5 | 82 | 66 | | 4.4 | 2.9 | 3.2 | 4546 | |
| LOT 215 | 5/29/2019 | 5 | | | | | 2.9 | 3.1 | 4322 | |
| LOT 215 | 5/29/2019 | 28 | | | | | 6.8 | 7.5 | 5690 | 5604 |
| LOT 215 | 5/29/2019 | 28 | | | | | 6.2 | 6.8 | 6229 | 5999 |
| LOT 215 | 5/29/2019 | 56 | | | | | 11.1 | 12.3 | 7543 | |
| LOT 216 | 5/29/2019 | 5 | 84 | 79 | | 5.4 | 2.7 | 3.0 | 3559 | |

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| LOT 216 | 5/29/2019 | 5 | | | | | 2.6 | 2.9 | 3667 | |
| LOT 216 | 5/29/2019 | 28 | | | | | 6.3 | 6.9 | 5203 | 4680 |
| LOT 216 | 5/29/2019 | 28 | | | | | 6.0 | 6.6 | 5515 | 4731 |
| LOT 216 | 5/29/2019 | 56 | | | | | 11.6 | 12.7 | 6493 | |
| LOT 217 | 5/29/2019 | 5 | 88 | 87 | | 4.8 | 3.0 | 3.3 | 4560 | |
| LOT 217 | 5/29/2019 | 5 | | | | | 2.9 | 3.2 | 4661 | |
| LOT 217 | 5/29/2019 | 28 | | | | | 6.8 | 7.4 | 5941 | 6018 |
| LOT 217 | 5/29/2019 | 28 | | | | | 6.9 | 7.6 | 6488 | 5821 |
| LOT 217 | 5/29/2019 | 56 | | | | | 13.1 | 14.5 | 7253 | |
| LOT 218 | 5/29/2019 | 5 | 88 | 90 | | 6.4 | 3.1 | 3.4 | 4527 | |
| LOT 218 | 5/29/2019 | 5 | | | | | 3.2 | 3.5 | 4410 | |
| LOT 218 | 5/29/2019 | 28 | | | | | 7.2 | 7.9 | 6371 | 4900 |
| LOT 218 | 5/29/2019 | 28 | | | | | 6.7 | 7.3 | 6551 | 6000 |
| LOT 218 | 5/29/2019 | 56 | | | | | 13.0 | 14.3 | 7604 | |
| LOT 219 | 5/30/2019 | 4 | 81 | 66 | | 3.6 | 2.4 | 2.7 | 4492 | |
| LOT 219 | 5/30/2019 | 4 | | | | | 2.5 | 2.8 | 4486 | |
| LOT 219 | 5/30/2019 | 28 | | | | | 6.6 | 7.2 | 6724 | 5844 |
| LOT 219 | 5/30/2019 | 28 | | | | | 6.9 | 7.5 | 6644 | 6733 |
| LOT 219 | 5/30/2019 | 56 | | | | | 14.1 | 15.5 | 7684 | |
| LOT 220 | 5/30/2019 | 4 | 80 | 72 | | 5.5 | 2.2 | 2.4 | 3341 | |
| LOT 220 | 5/30/2019 | 4 | | | | | 2.1 | 2.4 | 3486 | |
| LOT 220 | 5/30/2019 | 28 | | | | | 5.2 | 5.7 | 5300 | 5212 |
| LOT 220 | 5/30/2019 | 28 | | | | | 5.4 | 5.9 | 5643 | 5257 |
| LOT 220 | 5/30/2019 | 56 | | | | | 11.2 | 12.3 | 6581 | |
| LOT 221 | 6/3/2019 | 3 | 82 | 68 | 146.3 | 5 | 2.9 | 3.2 | 4069 | |
| LOT 221 | 6/3/2019 | 3 | | | | | 3.0 | 3.2 | 4134 | |
| LOT 221 | 6/3/2019 | 28 | | | | | 7.5 | 8.2 | 6747 | 5690 |
| LOT 221 | 6/3/2019 | 28 | | | | | 7.6 | 8.3 | 6869 | 5460 |
| LOT 221 | 6/3/2019 | 56 | | | | | 14.0 | 15.4 | 7631 | |
| LOT 222 | 6/3/2019 | 3 | 86 | 79 | 144.2 | 5.5 | 2.8 | 3.1 | 3434 | |
| LOT 222 | 6/3/2019 | 3 | | | | | 2.6 | 2.8 | 3471 | |
| LOT 222 | 6/3/2019 | 28 | | | | | 6.7 | 7.4 | 5642 | 5157 |
| LOT 222 | 6/3/2019 | 28 | | | | | 6.4 | 7.0 | 5511 | 5312 |
| LOT 222 | 6/3/2019 | 56 | | | | | 12.0 | 13.1 | 6183 | |
| LOT 223 | 6/3/2019 | 3 | 84 | 80 | 145.0 | 5.3 | 2.5 | 2.8 | 3351 | |
| LOT 223 | 6/3/2019 | 3 | | | | | 2.4 | 2.6 | 3472 | |
| LOT 223 | 6/3/2019 | 28 | | | | | 6.2 | 6.8 | 5811 | 5375 |
| LOT 223 | 6/3/2019 | 28 | | | | | 6.2 | 6.8 | 5420 | 4741 |
| LOT 223 | 6/3/2019 | 56 | | | | | 11.8 | 13.0 | 6390 | |
| LOT 224 | 6/4/2019 | 3 | 72 | 59 | 145.0 | 4.3 | 2.7 | 3.0 | 4223 | |
| LOT 224 | 6/4/2019 | 3 | | | | | 2.7 | 3.0 | 3827 | |
| LOT 224 | 6/4/2019 | 28 | | | | | 5.9 | 6.5 | 6527 | 6140 |
| LOT 224 | 6/4/2019 | 28 | | | | | 6.1 | 6.7 | 6574 | 5622 |
| LOT 224 | 6/4/2019 | 56 | | | | | 12.0 | 13.1 | 7207 | |
| LOT 225 TTF | 6/6/2019 | 4 | 80 | 73 | 140.2 | 6.8 | 2.5 | 2.7 | 3469 | |
| LOT 225 TTF | 6/6/2019 | 4 | | | | | 2.4 | 2.7 | 3374 | |
| LOT 225 TTF | 6/6/2019 | 4 | | | | | 2.5 | 2.7 | 3570 | |
| LOT 225 | 6/6/2019 | 29 | | | | | 7.5 | 8.3 | 5421 | 5240 |
| LOT 225 | 6/6/2019 | 29 | | | | | 6.2 | 6.8 | 5465 | 4765 |
| LOT 225 | 6/6/2019 | 56 | | | | | 12.6 | 13.9 | 6271 | |
| LOT 226 | 6/6/2019 | 4 | 86 | 78 | 140.3 | 6 | 2.6 | 2.9 | 3260 | |
| LOT 226 | 6/6/2019 | 4 | | | | | 2.6 | 2.9 | 3429 | |
| LOT 226 | 6/6/2019 | 29 | | | | | 5.7 | 6.3 | 5273 | 4910 |
| LOT 226 | 6/6/2019 | 29 | | | | | 6.0 | 6.6 | 4877 | 4602 |
| LOT 226 | 6/6/2019 | 56 | | | | | 12.7 | 14.0 | 5939 | |

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| LOT 227 TTF | 6/11/2019 | 2 | 80 | 69 | | 6.5 | 2.6 | 2.8 | 3022 | |
| LOT 227 TTF | 6/11/2019 | 2 | | | | | 2.8 | 3.0 | 2812 | |
| LOT 227 TTF | 6/11/2019 | 2 | | | | | 2.4 | 2.7 | 3008 | |
| LOT 227 | 6/11/2019 | 28 | | | | | 6.7 | 7.4 | 5590 | 5029 |
| LOT 227 | 6/11/2019 | 28 | | | | | 6.6 | 7.2 | 5706 | 5200 |
| LOT 227 | 6/11/2019 | 56 | | | | | 11.7 | 12.9 | 6106 | |
| LOT 228 | 6/11/2019 | 3 | 82 | 79 | 142.1 | 5.6 | 2.5 | 2.8 | 2718 | |
| LOT 228 | 6/11/2019 | 3 | | | | | 2.6 | 2.8 | 2882 | |
| LOT 228 | 6/11/2019 | 28 | | | | | 5.8 | 6.3 | 4658 | 4123 |
| LOT 228 | 6/11/2019 | 28 | | | | | 5.6 | 6.2 | 4717 | 4590 |
| LOT 228 | 6/11/2019 | 56 | | | | | 10.7 | 11.8 | 5444 | |
| LOT 229 | 6/13/2019 | 4 | 84 | 71 | 141.2 | 6.2 | 2.8 | 3.0 | 3649 | |
| LOT 229 | 6/13/2019 | 4 | | | | | 2.7 | 3.0 | 3457 | |
| LOT 229 | 6/13/2019 | 28 | | | | | 6.3 | 7.0 | 5605 | 4852 |
| LOT 229 | 6/13/2019 | 28 | | | | | 6.0 | 6.6 | 5420 | 5144 |
| LOT 229 | 6/13/2019 | 56 | | | | | 11.0 | 12.1 | 6338 | |
| LOT 231 | 6/13/2019 | 4 | 84 | 75 | 141.4 | 6.4 | 2.5 | 2.8 | 3081 | |
| LOT 231 | 6/13/2019 | 4 | | | | | 2.6 | 2.9 | 3001 | |
| LOT 231 | 6/13/2019 | 28 | | | | | 5.1 | 5.6 | 4673 | 4657 |
| LOT 231 | 6/13/2019 | 28 | | | | | 5.2 | 5.7 | 4781 | 4755 |
| LOT 231 | 6/13/2019 | 56 | | | | | 9.6 | 10.5 | 5437 | |
| LOT 232 | 6/14/2019 | 3 | 78 | 61 | 143.8 | 4.7 | 2.6 | 2.8 | 3965 | |
| LOT 232 | 6/14/2019 | 3 | | | | | 2.6 | 2.9 | 3925 | |
| LOT 232 | 6/14/2019 | 28 | | | | | 6.9 | 7.6 | 5735 | 5909 |
| LOT 232 | 6/14/2019 | 28 | | | | | 7.2 | 7.9 | 6285 | 5829 |
| LOT 232 | 6/14/2019 | 56 | | | | | 13.0 | 14.3 | 7037 | |
| LOT 233 | 6/18/2019 | 3 | 78 | 70 | 142.0 | 7 | 2.7 | 2.9 | 3026 | |
| LOT 233 | 6/18/2019 | 3 | | | | | 2.5 | 2.7 | 2940 | |
| LOT 233 | 6/18/2019 | 28 | | | | | 6.2 | 6.8 | 5235 | 4626 |
| LOT 233 | 6/18/2019 | 28 | | | | | 6.2 | 6.8 | 5219 | 4396 |
| LOT 233 | 6/18/2019 | 56 | | | | | 11.6 | 12.8 | 5786 | |
| LOT 234 | 6/18/2019 | 3 | 79 | 84 | | 4.6 | 2.3 | 2.5 | 3256 | |
| LOT 234 | 6/18/2019 | 3 | | | | | 2.3 | 2.5 | 3219 | |
| LOT 234 | 6/18/2019 | 28 | | | | | 5.3 | 5.8 | 5623 | 4892 |
| LOT 234 | 6/18/2019 | 28 | | | | | 5.0 | 5.5 | 5463 | 5119 |
| LOT 234 | 6/18/2019 | 56 | | | | | 10.7 | 11.8 | 6644 | |
| LOT 235 | 6/20/2019 | 4 | 84 | 78 | 142.1 | 5 | 2.5 | 2.8 | 3907 | |
| LOT 235 | 6/20/2019 | 4 | | | | | 2.4 | 2.7 | 4016 | |
| LOT 235 | 6/20/2019 | 28 | | | | | 5.4 | 5.9 | 5714 | 5758 |
| LOT 235 | 6/20/2019 | 28 | | | | | 5.4 | 5.9 | 5960 | 5573 |
| LOT 235 | 6/20/2019 | 56 | | | | | 9.8 | 10.8 | 6432 | |
| LOT 236 | 6/25/2019 | 3 | 84 | 70 | | 4.3 | 2.3 | 2.5 | 3969 | |
| LOT 236 | 6/25/2019 | 3 | | | | | 2.3 | 2.5 | 3948 | |
| LOT 236 | 6/25/2019 | 28 | | | | | 5.3 | 5.8 | 6408 | 5664 |
| LOT 236 | 6/25/2019 | 28 | | | | | 5.6 | 6.1 | 6630 | 5737 |
| LOT 236 | 6/25/2019 | 56 | | | | | 10.9 | 12.0 | 7209 | |
| LOT 238 | 6/25/2019 | 3 | 88 | 77 | 141.6 | 6 | 2.6 | 2.8 | 3622 | |
| LOT 238 | 6/25/2019 | 3 | | | | | 2.6 | 2.8 | 3716 | |
| LOT 238 | 6/25/2019 | 28 | | | | | 6.1 | 6.7 | 5614 | 5309 |
| LOT 238 | 6/25/2019 | 28 | | | | | 6.2 | 6.9 | 5744 | 5129 |
| LOT 238 | 6/25/2019 | 56 | | | | | 11.5 | 12.7 | 6440 | |
| LOT 239 | 6/25/2019 | 3 | 88 | 81 | 144.6 | 3.7 | 2.3 | 2.5 | 4074 | |
| LOT 239 | 6/25/2019 | 3 | | | | | 2.5 | 2.7 | 4057 | |
| LOT 239 | 6/25/2019 | 28 | | | | | 5.8 | 6.4 | 6438 | 5329 |
| LOT 239 | 6/25/2019 | 28 | | | | | 5.8 | 6.4 | 6764 | 5555 |

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| LOT 239 | 6/25/2019 | 56 | | | | | 11.2 | 12.3 | 7381 | |
| LOT 240 TTF | 6/25/2019 | 2 | 88 | 82 | 142.6 | 5 | 2.1 | 2.3 | 2591 | |
| LOT 240 TTF | 6/25/2019 | 2 | | | | | 2.2 | 2.4 | 2724 | |
| LOT 240 TTF | 6/25/2019 | 2 | | | | | 2.2 | 2.4 | 2770 | |
| LOT 240 | 6/25/2019 | 28 | | | | | 5.2 | 5.7 | 5420 | 5266 |
| LOT 240 | 6/25/2019 | 28 | | | | | 5.4 | 5.9 | 5661 | 5132 |
| LOT 240 | 6/25/2019 | 56 | | | | | 11.1 | 12.2 | 6371) | |
| LOT 241 TTF | 6/28/2019 | 1 | 80 | 67 | 142.1 | 5.3 | 1.8 | 2.0 | 2031 | |
| LOT 241 TTF | 6/28/2019 | 1 | | | | | 1.9 | 2.1 | 1929 | |
| LOT 241 TTF | 6/28/2019 | 3 | | | | | 2.3 | 2.6 | 3217 | |
| LOT 241 TTF | 6/28/2019 | 3 | | | | | 2.5 | 2.7 | 3022 | |
| LOT 241 TTF | 6/28/2019 | 7 | | | | | 2.8 | 3.1 | 3921 | |
| LOT 241 TTF | 6/28/2019 | 7 | | | | | 2.8 | 3.1 | 3973 | |
| LOT 241 TTF | 6/28/2019 | 14 | | | | | 3.4 | 3.7 | 4567 | |
| LOT 241 TTF | 6/28/2019 | 14 | | | | | 3.4 | 3.7 | 4465 | |
| LOT 241 TTF | 6/28/2019 | 28 | | | | | 5.9 | 6.4 | 5628 | 5306 |
| LOT 241 TTF | 6/28/2019 | 28 | | | | | 5.9 | 6.5 | 5635 | 5578 |
| LOT 241 TTF | 6/28/2019 | 56 | | | | | 12.2 | 13.4 | 6139 | |
| LOT 242 | 6/28/2019 | 3 | 88 | 82 | 141.1 | 5.5 | 2.6 | 2.8 | 2865 | |
| LOT 242 | 6/28/2019 | 3 | | | | | 2.6 | 2.8 | 2909 | |
| LOT 242 | 6/28/2019 | 28 | | | | | 5.4 | 5.9 | 5247 | 4444 |
| LOT 242 | 6/28/2019 | 28 | | | | | 5.4 | 5.9 | 5605 | 4664 |
| LOT 242 | 6/28/2019 | 56 | | | | | 11.0 | 12.1 | 5953 | |
| LOT 243 | 6/28/2019 | 3 | 90 | 88 | 143.8 | 4.5 | 2.4 | 2.7 | 2988 | |
| LOT 243 | 6/28/2019 | 3 | | | | | 2.4 | 2.6 | 3352 | |
| LOT 243 | 6/28/2019 | 28 | | | | | 5.3 | 5.9 | 5886 | |
| LOT 243 | 6/28/2019 | 28 | | | | | 5.3 | 5.8 | 5573 | |
| LOT 243 | 6/28/2019 | 56 | | | | | 11.1 | 12.2 | 6649 | |
| LOT 244 TTF | 7/9/2019 | 2 | 85 | 74 | 142.3 | 5 | 2.1 | 2.4 | 2368 | |
| LOT 244 TTF | 7/9/2019 | 2 | | | | | 2.2 | 2.4 | 2341 | |
| LOT 244 TTF | 7/9/2019 | 2 | | | | | 2.1 | 2.3 | 2465 | |
| LOT 244 | 7/9/2019 | 28 | | | | | 4.9 | 5.3 | 5424 | 4442 |
| LOT 244 | 7/9/2019 | 28 | | | | | 5.0 | 5.5 | 5127 | 4540 |
| LOT 244 | 7/9/2019 | 56 | | | | | 8.8 | 9.7 | 6273 | |
| LOT 245 | 7/10/2019 | 3 | 85 | 73 | 143.0 | 4.5 | 2.3 | 2.6 | 3129 | |
| LOT 245 | 7/10/2019 | 3 | | | | | 2.4 | 2.7 | 3238 | |
| LOT 245 | 7/10/2019 | 28 | | | | | 5.2 | 5.7 | 5469 | |
| LOT 245 | 7/10/2019 | 28 | | | | | 5.1 | 5.6 | 5335 | |
| LOT 245 | 7/10/2019 | 56 | | | | | 10.0 | 10.9 | 6258 | |
| LOT 246 | 7/10/2019 | 3 | 90 | 80 | | 6.6 | 2.7 | 2.9 | 2593 | |
| LOT 246 | 7/10/2019 | 3 | | | | | 2.7 | 3.0 | 2466 | |
| LOT 246 | 7/10/2019 | 28 | | | | | 4.8 | 5.3 | 4376 | 4441 |
| LOT 246 | 7/10/2019 | 28 | | | | | 4.9 | 5.4 | 4510 | 4171 |
| LOT 246 | 7/10/2019 | 56 | | | | | 9.5 | 10.5 | 5491 | |
| LOT 247 | 7/15/2019 | 3 | 80 | 74 | 142.4 | 5 | 2.5 | 2.7 | 3795 | |
| LOT 247 | 7/15/2019 | 3 | | | | | | | 3866 | |
| LOT 247 | 7/15/2019 | 28 | | | | | 6.0 | 6.5 | 6136 | |
| LOT 247 | 7/15/2019 | 28 | | | | | 5.8 | 6.3 | 6150 | |
| LOT 247 | 7/15/2019 | 56 | | | | | 12.4 | 13.7 | 7456 | |
| LOT 248 | 7/15/2019 | 3 | 83 | 84 | | 6 | 2.5 | 2.8 | 3342 | |
| LOT 248 | 7/15/2019 | 3 | | | | | 2.5 | 2.8 | 3316 | |
| LOT 248 | 7/15/2019 | 28 | | | | | 5.2 | 5.7 | 5516 | |
| LOT 248 | 7/15/2019 | 28 | | | | | 5.0 | 5.5 | 5127 | |
| LOT 248 | 7/15/2019 | 56 | | | | | 9.9 | 10.8 | 6494 | |
| LOT 249 | 7/15/2019 | 3 | 92 | 86 | | 3.7 | 2.6 | 2.9 | 4079 | |

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| LOT 249 | 7/15/2019 | 3 | | | | | 2.5 | 2.8 | 3876 | |
| LOT 249 | 7/15/2019 | 28 | | | | | 5.9 | 6.4 | 6451 | |
| LOT 249 | 7/15/2019 | 28 | | | | | 6.0 | 6.6 | 6592 | |
| LOT 249 | 7/15/2019 | 56 | | | | | 12.0 | 13.2 | 7721 | |
| LOT 250 | 7/15/2019 | 3 | 90 | 90 | | 5.4 | 2.7 | 2.9 | 3856 | |
| LOT 250 | 7/15/2019 | 3 | | | | | 2.7 | 3.0 | 3738 | |
| LOT 250 | 7/15/2019 | 28 | | | | | 5.8 | 6.4 | 6266 | |
| LOT 250 | 7/15/2019 | 28 | | | | | 5.9 | 6.5 | 6069 | |
| LOT 250 | 7/15/2019 | 56 | | | | | 11.0 | 12.1 | 7033 | |
| LOT 251 | 7/16/2019 | 3 | 86 | 74 | 143.8 | 5 | 3.0 | 3.2 | 4519 | |
| LOT 251 | 7/16/2019 | 3 | | | | | 3.0 | 3.3 | 4418 | |
| LOT 251 | 7/16/2019 | 28 | | | | | 6.5 | 7.1 | 6812 | |
| LOT 251 | 7/16/2019 | 28 | | | | | 6.4 | 7.0 | 6567 | |
| LOT 251 | 7/16/2019 | 56 | | | | | 12.2 | 13.4 | 7879 | |
| LOT 252 | 7/16/2019 | 3 | 88 | 77 | 142.0 | 5.6 | 2.7 | 3.0 | 3621 | |
| LOT 252 | 7/16/2019 | 3 | | | | | 2.9 | 3.2 | 3771 | |
| LOT 252 | 7/16/2019 | 28 | | | | | 5.6 | 6.1 | 5782 | |
| LOT 252 | 7/16/2019 | 28 | | | | | 6.1 | 6.7 | 5864 | |
| LOT 252 | 7/16/2019 | 56 | | | | | 11.5 | 12.6 | 6443 | |
| LOT 253 | 7/16/2019 | 3 | 90 | 84 | 143.4 | 4.6 | 2.5 | 2.8 | 3424 | |
| LOT 253 | 7/16/2019 | 3 | | | | | 2.6 | 2.8 | 3354 | |
| LOT 253 | 7/16/2019 | 28 | | | | | 5.2 | 5.7 | 5510 | |
| LOT 253 | 7/16/2019 | 28 | | | | | 5.5 | 6.1 | 5881 | |
| LOT 253 | 7/16/2019 | 56 | | | | | 11.1 | 12.2 | 6863 | |
| LOT 254 | 7/16/2019 | 3 | 92 | 88 | 144.2 | 5.6 | 2.4 | 2.6 | 3005 | |
| LOT 254 | 7/16/2019 | 3 | | | | | 2.4 | 2.7 | 3188 | |
| LOT 254 | 7/16/2019 | 28 | | | | | 5.4 | 5.9 | 5149 | |
| LOT 254 | 7/16/2019 | 28 | | | | | 5.3 | 5.8 | 5253 | |
| LOT 254 | 7/16/2019 | 56 | | | | | 9.7 | 10.7 | 6185 | |
| LOT 255 | 7/18/2019 | 4 | 84 | 72 | 141.8 | 5.4 | 2.9 | 3.2 | 3864 | |
| LOT 255 | 7/18/2019 | 4 | | | | | 2.9 | 3.2 | 3720 | |
| LOT 255 | 7/18/2019 | 28 | | | | | 5.2 | 5.7 | 5617 | |
| LOT 255 | 7/18/2019 | 28 | | | | | 5.4 | 5.9 | 5831 | |
| LOT 255 | 7/18/2019 | 56 | | | | | 10.4 | 11.5 | 6506 | |
| LOT 256 | 7/18/2019 | 4 | 86 | 80 | 144.0 | 5.1 | 2.8 | 3.0 | 3284 | |
| LOT 256 | 7/18/2019 | 4 | | | | | 2.8 | 3.0 | 3295 | |
| LOT 256 | 7/18/2019 | 28 | | | | | 4.9 | 5.3 | 5026 | |
| LOT 256 | 7/18/2019 | 28 | | | | | 5.2 | 5.7 | 4831 | |
| LOT 256 | 7/18/2019 | 56 | | | | | 8.8 | 9.7 | 5788 | |
| LOT 257 | 7/18/2019 | 4 | 92 | 89 | | 4.6 | 2.7 | 3.0 | 4082 | |
| LOT 257 | 7/18/2019 | 4 | | | | | 2.6 | 2.8 | 4358 | |
| LOT 257 | 7/18/2019 | 28 | | | | | 5.3 | 5.9 | 5474 | |
| LOT 257 | 7/18/2019 | 28 | | | | | 5.4 | 5.9 | 6036 | |
| LOT 257 | 7/18/2019 | 56 | | | | | 9.9 | 10.9 | 7149 | |
| LOT 258 TTF | 7/19/2019 | 3 | 88 | 73 | 140.2 | 5.7 | 3.0 | 3.3 | 3252 | |
| LOT 258 TTF | 7/19/2019 | 3 | | | | | | | 3258 | |
| LOT 258 TTF | 7/19/2019 | 3 | | | | | | | 3170 | |
| LOT 258 | 7/19/2019 | 28 | | | | | 5.6 | 6.2 | 4943 | |
| LOT 258 | 7/19/2019 | 28 | | | | | 5.7 | 6.3 | 5292 | |
| LOT 258 | 7/19/2019 | 56 | | | | | 10.4 | 11.4 | 5890 | |
| LOT 259 | 7/25/2019 | 4 | 80 | 64 | 144.8 | 4.6 | 2.8 | 3.1 | 4196 | |
| LOT 259 | 7/25/2019 | 4 | | | | | 2.9 | 3.2 | 4155 | |
| LOT 259 | 7/25/2019 | 28 | | | | | 6.2 | 6.8 | 6169 | 5581 |
| LOT 259 | 7/25/2019 | 28 | | | | | 6.1 | 6.7 | 6036 | 5582 |
| LOT 259 | 7/25/2019 | 56 | | | | | 10.5 | 11.6 | 6799 | |

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| LOT 260 | 7/25/2019 | 4 | 80 | 72 | 142.2 | 6.6 | 3.2 | 3.6 | 3820 | |
| LOT 260 | 7/25/2019 | 4 | | | | | 3.3 | 3.7 | 3700 | |
| LOT 260 | 7/25/2019 | 28 | | | | | 6.6 | 7.2 | 5524 | 4669 |
| LOT 260 | 7/25/2019 | 28 | | | | | 6.1 | 6.7 | 5624 | 4921 |
| LOT 260 | 7/25/2019 | 56 | | | | | 8.8 | 9.7 | 6128 | |
| LOT 261 | 7/25/2019 | 4 | 88 | 82 | 143.0 | 5.3 | 2.6 | 2.8 | 3301 | |
| LOT 261 | 7/25/2019 | 4 | | | | | 2.6 | 2.8 | 3171 | |
| LOT 261 | 7/25/2019 | 28 | | | | | 5.3 | 5.9 | 5370 | 4831 |
| LOT 261 | 7/25/2019 | 28 | | | | | 5.1 | 5.6 | 5063 | 4902 |
| LOT 261 | 7/25/2019 | 56 | | | | | 9.2 | 10.1 | 6125 | |
| LOT 262 | 7/25/2019 | 4 | 89 | 83 | 141.4 | 5.5 | 2.7 | 3.0 | 3894 | |
| LOT 262 | 7/25/2019 | 4 | | | | | 2.8 | 3.1 | 3469 | |
| LOT 262 | 7/25/2019 | 28 | | | | | 5.3 | 5.9 | 5527 | 4908 |
| LOT 262 | 7/25/2019 | 28 | | | | | 5.1 | 5.7 | 5971 | 5263 |
| LOT 262 | 7/25/2019 | 56 | | | | | 8.3 | 9.1 | 6228 | |
| LOT 263 | 7/26/2019 | 56 | | | | | 12.1 | 13.3 | 6577 | |
| LOT 263 | 7/26/2019 | 3 | 80 | 62 | 144.3 | 5 | 2.6 | 2.8 | 3765 | |
| LOT 263 | 7/26/2019 | 3 | | | | | 2.6 | 2.9 | 3868 | |
| LOT 263 | 7/26/2019 | 28 | | | | | 5.9 | 6.5 | 5827 | 5356 |
| LOT 263 | 7/26/2019 | 28 | | | | | 5.8 | 6.4 | 5990 | 5196 |
| LOT 264 | 7/26/2019 | 3 | 82 | 63 | 143.8 | 4.8 | 2.8 | 3.0 | 4007 | |
| LOT 264 | 7/26/2019 | 3 | | | | | 2.7 | 2.9 | 3925 | |
| LOT 264 | 7/26/2019 | 28 | | | | | 5.8 | 6.4 | 6287 | 5121 |
| LOT 264 | 7/26/2019 | 28 | | | | | 6.0 | 6.6 | 6248 | 5247 |
| LOT 264 | 7/26/2019 | 56 | | | | | 10.9 | 12.0 | 7106 | |
| LOT 265 | 7/26/2019 | 3 | 86 | 78 | 141.8 | 5.9 | 2.6 | 2.8 | 3749 | |
| LOT 265 | 7/26/2019 | 3 | | | | | 2.6 | 2.9 | 3600 | |
| LOT 265 | 7/26/2019 | 28 | | | | | 5.4 | 6.0 | 6009 | 4933 |
| LOT 265 | 7/26/2019 | 28 | | | | | 5.4 | 5.9 | 5870 | 5409 |
| LOT 265 | 7/26/2019 | 56 | | | | | 10.5 | 11.6 | 6594 | |
| LOT 266 | 7/26/2019 | 3 | 90 | 81 | 143.1 | 5.4 | 2.6 | 2.9 | 3314 | |
| LOT 266 | 7/26/2019 | 3 | | | | | 2.6 | 2.9 | 3106 | |
| LOT 266 | 7/26/2019 | 28 | | | | | 5.7 | 6.2 | 5641 | 5273 |
| LOT 266 | 7/26/2019 | 28 | | | | | 5.7 | 6.3 | 5540 | 4535 |
| LOT 266 | 7/26/2019 | 56 | | | | | 11.8 | 13.0 | 6722 | |
| LOT 267 | 7/26/2019 | 3 | 92 | 84 | 140.2 | 5.9 | 2.5 | 2.7 | 2981 | |
| LOT 267 | 7/26/2019 | 3 | | | | | 2.5 | 2.7 | 2981 | |
| LOT 267 | 7/26/2019 | 28 | | | | | 4.8 | 5.3 | 5053 | 4112 |
| LOT 267 | 7/26/2019 | 28 | | | | | 5.1 | 5.7 | 4937 | 4998 |
| LOT 267 | 7/26/2019 | 56 | | | | | 9.8 | 10.8 | 5860 | |
| LOT 268 | 7/29/2019 | 3 | 80 | 64 | 141.6 | 5.4 | 2.7 | 2.9 | 3795 | |
| LOT 268 | 7/29/2019 | 3 | | | | | 2.7 | 3.0 | 3997 | |
| LOT 268 | 7/29/2019 | 56 | | | | | 10.2 | 11.2 | 6842 | |
| LOT 269 TTF | 7/29/2019 | 3 | 84 | 73 | 142.4 | 6 | 2.3 | 2.5 | 3224 | |
| LOT 269 TTF | 7/29/2019 | 3 | | | | | 2.2 | 2.5 | 3293 | |
| LOT 269 TTF | 7/29/2019 | 3 | | | | | 2.3 | 2.5 | 3122 | |
| LOT 269 | 7/29/2019 | 56 | | | | | 8.6 | 9.4 | 5661 | |
| LOT 270 | 7/29/2019 | 3 | 88 | 84 | 143.0 | 5 | 2.6 | 2.8 | 3347 | |
| LOT 270 | 7/29/2019 | 3 | | | | | 2.4 | 2.6 | 3531 | |
| LOT 270 | 7/29/2019 | 56 | | | | | 9.2 | 10.1 | 6139 | |
| LOT 271 | 7/29/2019 | 3 | 92 | 88 | 142.4 | 4.8 | 2.5 | 2.7 | 3344 | |
| LOT 271 | 7/29/2019 | 3 | | | | | 2.6 | 2.8 | 3342 | |
| LOT 271 | 7/29/2019 | 56 | | | | | 9.3 | 10.2 | 6454 | |
| LOT 272 | 7/29/2019 | 3 | 92 | 88 | 141.8 | 5.4 | 2.2 | 2.4 | 3226 | |
| LOT 272 | 7/29/2019 | 3 | | | | | 2.2 | 2.4 | 3308 | |

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| LOT 272 | 7/29/2019 | 56 | | | | | 8.4 | 9.2 | 6158 | |
| LOT 273 | 8/1/2019 | 4 | 84 | 67 | 143.7 | 5 | 2.5 | 2.8 | 3668 | |
| LOT 273 | 8/1/2019 | 4 | | | | | 2.4 | 2.6 | 3469 | |
| LOT 273 | 8/1/2019 | 28 | | | | | 5.5 | 6.0 | 5353 | 5047 |
| LOT 273 | 8/1/2019 | 28 | | | | | 5.4 | 6.0 | 5159 | 5351 |
| LOT 273 | 8/1/2019 | 56 | | | | | 11.6 | 12.7 | 6083 | |
| LOT 274 | 8/1/2019 | 4 | 88 | 72 | 143.9 | 5 | 2.6 | 2.8 | 3076 | |
| LOT 274 | 8/1/2019 | 4 | | | | | 2.4 | 2.6 | 3222 | |
| LOT 274 | 8/1/2019 | 28 | | | | | 5.0 | 5.5 | 5022 | 4456 |
| LOT 274 | 8/1/2019 | 28 | | | | | 5.2 | 5.7 | 4873 | 4655 |
| LOT 274 | 8/1/2019 | 56 | | | | | 10.7 | 11.8 | 5673 | |
| LOT 275 | 8/1/2019 | 4 | 90 | 84 | 143.2 | 5.1 | 2.3 | 2.6 | 3465 | |
| LOT 275 | 8/1/2019 | 4 | | | | | 2.3 | 2.5 | 3434 | |
| LOT 275 | 8/1/2019 | 28 | | | | | 5.0 | 5.5 | 4886 | 4853 |
| LOT 275 | 8/1/2019 | 28 | | | | | 5.2 | 5.8 | 5054 | 4893 |
| LOT 275 | 8/1/2019 | 56 | | | | | 8.9 | 9.7 | 5926 | |
| LOT 276 | 8/1/2019 | 4 | 88 | 82 | 140.8 | 6 | 2.2 | 2.4 | 2842 | |
| LOT 276 | 8/1/2019 | 4 | | | | | 2.2 | 2.4 | 2932 | |
| LOT 276 | 8/1/2019 | 28 | | | | | 4.7 | 5.2 | 4061 | 4801 |
| LOT 276 | 8/1/2019 | 28 | | | | | 4.6 | 5.0 | 4035 | 4282 |
| LOT 277 | 8/2/2019 | 3 | 80 | 70 | 143.8 | 4.8 | 2.4 | 2.6 | 3406 | |
| LOT 277 | 8/2/2019 | 3 | | | | | 2.4 | 2.6 | 3476 | |
| LOT 277 | 8/2/2019 | 28 | | | | | 5.6 | 6.1 | 5379 | 5265 |
| LOT 277 | 8/2/2019 | 28 | | | | | 5.9 | 6.5 | 5635 | 5231 |
| LOT 277 | 8/2/2019 | 56 | | | | | 11.9 | 13.1 | 6003 | |
| LOT 278 | 8/2/2019 | 3 | 86 | 76 | 142.2 | 5.69 | 2.4 | 2.7 | 2947 | |
| LOT 278 | 8/2/2019 | 3 | | | | | 2.5 | 2.7 | 3077 | |
| LOT 278 | 8/2/2019 | 28 | | | | | 5.9 | 6.5 | 4618 | 4805 |
| LOT 278 | 8/2/2019 | 28 | | | | | 6.3 | 6.9 | 5184 | 4894 |
| LOT 278 | 8/2/2019 | 56 | | | | | 11.9 | 13.0 | 5556 | |
| LOT 279 | 8/5/2019 | 3 | 80 | 68 | 143.4 | 4.8 | 2.4 | 2.7 | 3615 | |
| LOT 279 | 8/5/2019 | 3 | | | | | 2.5 | 2.7 | 3860 | |
| LOT 279 | 8/5/2019 | 29 | | | | | 6.2 | 6.9 | 5935 | 5278 |
| LOT 279 | 8/5/2019 | 29 | | | | | 6.1 | 6.7 | 5875 | 5290 |
| LOT 279 | 8/5/2019 | 56 | | | | | 12.2 | 13.4 | 6472 | |
| LOT 280 | 8/5/2019 | 3 | 82 | 71 | 142.7 | 5.5 | 2.3 | 2.5 | 3269 | |
| LOT 280 | 8/5/2019 | 3 | | | | | 2.4 | 2.6 | 3452 | |
| LOT 280 | 8/5/2019 | 29 | | | | | 5.6 | 6.2 | 5265 | 5119 |
| LOT 280 | 8/5/2019 | 29 | | | | | 5.6 | 6.2 | 5281 | 5064 |
| LOT 280 | 8/5/2019 | 56 | | | | | 10.5 | 11.5 | 5837 | |
| LOT 281 | 8/5/2019 | 3 | 83 | 74 | 144.0 | 4 | 2.4 | 2.7 | 3750 | |
| LOT 281 | 8/5/2019 | 3 | | | | | 2.6 | 2.9 | 3710 | |
| LOT 281 | 8/5/2019 | 29 | | | | | 6.9 | 7.6 | 6121 | 5606 |
| LOT 281 | 8/5/2019 | 29 | | | | | 6.8 | 7.5 | 6267 | 5356 |
| LOT 281 | 8/5/2019 | 56 | | | | | 11.1 | 12.2 | 6970 | |
| LOT 282 | 8/5/2019 | 3 | 88 | 75 | 143.7 | 4.8 | 2.6 | 2.8 | 3642 | |
| LOT 282 | 8/5/2019 | 3 | | | | | 2.7 | 2.9 | 3670 | |
| LOT 282 | 8/5/2019 | 29 | | | | | 6.3 | 6.9 | 5841 | 5663 |
| LOT 282 | 8/5/2019 | 29 | | | | | 6.1 | 6.7 | 6238 | 5382 |
| LOT 282 | 8/5/2019 | 56 | | | | | 11.8 | 13.0 | 6427 | |
| LOT 283 | 8/5/2019 | 3 | 88 | 81 | 143.5 | 5.4 | 2.5 | 2.7 | 3454 | |
| LOT 283 | 8/5/2019 | 3 | | | | | 2.5 | 2.8 | 3301 | |
| LOT 283 | 8/5/2019 | 29 | | | | | 5.6 | 6.2 | 5685 | 4954 |
| LOT 283 | 8/5/2019 | 29 | | | | | 5.5 | 6.1 | 5570 | 4780 |
| LOT 283 | 8/5/2019 | 56 | | | | | 9.9 | 10.8 | 6422 | |

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| LOT 284 | 8/6/2019 | 3 | 82 | 67 | 144.2 | 5.4 | 2.6 | 2.9 | 3601 | |
| LOT 284 | 8/6/2019 | 3 | | | | | 2.8 | 3.1 | 3340 | |
| LOT 284 | 8/6/2019 | 28 | | | | | 5.9 | 6.5 | 5553 | 5475 |
| LOT 284 | 8/6/2019 | 28 | | | | | 6.1 | 6.7 | 5678 | 4909 |
| LOT 284 | 8/6/2019 | 56 | | | | | 13.2 | 14.5 | 6618 | |
| LOT 285 | 8/6/2019 | 3 | 88 | 75 | 143.5 | 5 | 2.4 | 2.6 | 3630 | |
| LOT 285 | 8/6/2019 | 3 | | | | | 2.3 | 2.6 | 3580 | |
| LOT 285 | 8/6/2019 | 28 | | | | | 4.7 | 5.2 | 5633 | 4719 |
| LOT 285 | 8/6/2019 | 28 | | | | | 4.6 | 5.1 | 5386 | 4958 |
| LOT 285 | 8/6/2019 | 56 | | | | | 10.3 | 11.3 | 6453 | |
| LOT 286 | 8/6/2019 | 3 | 88 | 82 | 143.8 | 5.2 | 2.7 | 3.0 | 3602 | |
| LOT 286 | 8/6/2019 | 3 | | | | | 2.6 | 2.8 | 3558 | |
| LOT 286 | 8/6/2019 | 28 | | | | | 5.5 | 6.0 | 5915 | 5700 |
| LOT 286 | 8/6/2019 | 28 | | | | | 5.4 | 5.9 | 5771 | 5150 |
| LOT 286 | 8/6/2019 | 56 | | | | | 11.1 | 12.2 | 6658 | |
| LOT 287 | 8/6/2019 | 3 | 90 | 86 | 144.3 | 4.2 | 2.6 | 2.8 | 3851 | |
| LOT 287 | 8/6/2019 | 3 | | | | | 2.7 | 2.9 | 3973 | |
| LOT 287 | 8/6/2019 | 28 | | | | | 5.7 | 6.3 | 6048 | 5049 |
| LOT 287 | 8/6/2019 | 28 | | | | | 5.7 | 6.2 | 6169 | 5338 |
| LOT 287 | 8/6/2019 | 56 | | | | | 11.1 | 12.2 | 6658 | |
| LOT 288 | 8/7/2019 | 5 | 86 | 74 | 144.2 | 4.8 | 2.8 | 3.1 | 4454 | |
| LOT 288 | 8/7/2019 | 5 | | | | | 2.7 | 2.9 | 4213 | |
| LOT 288 | 8/7/2019 | 28 | | | | | 5.8 | 6.4 | 5795 | 5025 |
| LOT 288 | 8/7/2019 | 28 | | | | | 6.0 | 6.6 | 6048 | 5632 |
| LOT 288 | 8/7/2019 | 56 | | | | | 12.0 | 13.2 | 7258 | |
| LOT 289 | 8/7/2019 | 5 | 86 | 78 | 146.2 | 3.7 | 2.8 | 3.1 | 4556 | |
| LOT 289 | 8/7/2019 | 5 | | | | | 2.9 | 3.2 | 4716 | |
| LOT 289 | 8/7/2019 | 28 | | | | | 6.7 | 7.3 | 6287 | 5864 |
| LOT 289 | 8/7/2019 | 28 | | | | | 6.7 | 7.4 | 6445 | 6030 |
| LOT 289 | 8/7/2019 | 56 | | | | | 14.4 | 15.8 | 7435 | |
| LOT 290 | 8/7/2019 | 5 | 90 | 82 | 143.2 | 4.9 | 2.8 | 3.1 | 3958 | |
| LOT 290 | 8/7/2019 | 5 | | | | | 2.8 | 3.0 | 3956 | |
| LOT 290 | 8/7/2019 | 28 | | | | | 6.2 | 6.8 | 5562 | 5280 |
| LOT 290 | 8/7/2019 | 28 | | | | | 6.2 | 6.8 | 5753 | 5088 |
| LOT 290 | 8/7/2019 | 56 | | | | | 11.7 | 12.9 | 6746 | |
| LOT 291 | 8/9/2019 | 3 | 88 | 85 | 142.8 | 5.5 | 2.8 | 3.0 | 3285 | |
| LOT 291 | 8/9/2019 | 3 | | | | | 2.6 | 2.9 | 3235 | |
| LOT 291 | 8/9/2019 | 28 | | | | | 6.8 | 7.5 | 5199 | 4593 |
| LOT 291 | 8/9/2019 | 28 | | | | | 6.9 | 7.6 | 5333 | 5050 |
| LOT 291 | 8/9/2019 | 56 | | | | | 13.7 | 15.1 | 5927 | |
| LOT 292 TTF | 8/9/2019 | 3 | 88 | 85 | 142.8 | 5.5 | 2.7 | 3.0 | 3180 | |
| LOT 292 TTF | 8/9/2019 | 3 | | | | | 2.6 | 2.8 | 3367 | |
| LOT 292 TTF | 8/9/2019 | 3 | | | | | 2.6 | 2.9 | 3076 | |
| LOT 292 | 8/9/2019 | 28 | | | | | 6.6 | 7.3 | 5476 | 4709 |
| LOT 292 | 8/9/2019 | 28 | | | | | 6.7 | 7.4 | 5067 | 5131 |
| LOT 292 | 8/9/2019 | 56 | | | | | 14.6 | 16.1 | 6143 | |
| LOT 293 | 8/12/2019 | 3 | 84 | 72 | 143.4 | 5 | 2.4 | 2.7 | 3196 | |
| LOT293 | 8/12/2019 | 3 | | | | | 2.4 | 2.6 | | |
| LOT 293 | 8/12/2019 | 28 | | | | | 6.1 | 6.7 | 5388 | 4948 |
| LOT 293 | 8/12/2019 | 28 | | | | | 5.5 | 6.0 | 5421 | 4934 |
| LOT 293 | 8/12/2019 | 56 | | | | | 12.9 | 14.2 | 6422 | |
| LOT 294 | 8/12/2019 | 3 | 90 | 84 | 141.2 | 5.7 | 2.5 | 2.7 | 3148 | |
| LOT 294 | 8/12/2019 | 3 | | | | | 2.4 | 2.6 | 3370 | |
| LOT 294 | 8/12/2019 | 28 | | | | | 5.6 | 6.2 | 5570 | 4735 |
| LOT 294 | 8/12/2019 | 28 | | | | | 5.8 | 6.3 | 5889 | 5256 |

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| LOT 294 | 8/12/2019 | 56 | | | | | 12.7 | 14.0 | 6389 | |
| LOT 295 | 8/12/2019 | 3 | 90 | 88 | 141.0 | 5.7 | 2.1 | 2.4 | 2939 | |
| LOT 295 | 8/12/2019 | 3 | | | | | 2.2 | 2.4 | 2907 | |
| LOT 295 | 8/12/2019 | 28 | | | | | 5.1 | 5.6 | 5271 | 4409 |
| LOT 295 | 8/12/2019 | 28 | | | | | 5.2 | 5.7 | 5076 | 4722 |
| LOT 295 | 8/12/2019 | 56 | | | | | 10.6 | 11.6 | 5870 | |
| LOT 296 | 8/14/2019 | 8 | 88 | 82 | 143.8 | 5.4 | 2.9 | 3.1 | 3966 | |
| LOT 296 | 8/14/2019 | 8 | | | | | 3.1 | 3.4 | 4044 | |
| LOT 296 | 8/14/2019 | 28 | | | | | 5.7 | 6.2 | 5209 | 4963 |
| LOT 296 | 8/14/2019 | 28 | | | | | 5.5 | 6.0 | 5195 | 4857 |
| LOT 297 | 8/22/2019 | 4 | 86 | 79 | 142.5 | 5.2 | 3.2 | 3.5 | 4196 | |
| LOT 297 | 8/22/2019 | 4 | | | | | | | 4210 | |
| LOT 297 | 8/22/2019 | 28 | | | | | 6.7 | 7.4 | 6325 | 5848 |
| LOT 297 | 8/22/2019 | 28 | | | | … | 6.7 | 7.4 | 6205 | 5629 |
| LOT 298 | 8/16/2019 | 3 | 84 | 75 | 141.6 | 5 | | | 3428 | |
| LOT 298 | 8/16/2019 | 3 | | | | | | | 3462 | |
| LOT 298 | 8/16/2019 | 28 | | | | | 7.2 | 7.9 | 5974 | |
| LOT 298 | 8/16/2019 | 28 | | | | | 6.5 | 7.2 | 5774 | |
| LOT 299 | 8/20/2019 | 3 | 84 | 75 | 143.0 | 5.4 | 2.3 | 2.6 | 3022 | |
| LOT 299 | 8/20/2019 | 3 | | | | | 2.3 | 2.5 | 2927 | |
| LOT 299 | 8/20/2019 | 3 | | | | | 2.3 | 2.6 | 3032 | |
| LOT 299 | 8/20/2019 | 28 | | | | | 5.9 | 6.5 | 5174 | 5459 |
| LOT 299 | 8/20/2019 | 28 | | | | | 5.6 | 6.1 | 5638 | 5810 |
| LOT 300 | 8/20/2019 | 3 | 86 | 83 | 141.6 | 5.4 | 2.2 | 2.4 | 2975 | |
| LOT 300 | 8/20/2019 | 3 | | | | | 2.3 | 2.5 | 2810 | |
| LOT 300 | 8/20/2019 | 28 | | | | | 5.1 | 5.6 | 5126 | |
| LOT 300 | 8/20/2019 | 28 | | | | | 5.2 | 5.7 | 5250 | |
| LOT 301 | 8/27/2019 | 3 | 78 | 66 | 142.3 | 5.5 | 2.4 | 2.6 | 3271 | |
| LOT 301 | 8/27/2019 | 3 | | | | | 2.4 | 2.7 | 3261 | |
| LOT 301 | 8/27/2019 | 28 | | | | | 5.8 | 6.4 | 5715 | 5389 |
| LOT 301 | 8/27/2019 | 28 | | | | | 5.9 | 6.5 | 5367 | 5391 |
| LOT 302 TTF | 9/3/2019 | 6 | 84 | 81 | 142.7 | 5.2 | 3.2 | 3.5 | 3318 | |
| LOT 302TTF | 9/3/2019 | 6 | | | | | 3.0 | 3.3 | 3843 | |
| LOT 302 TTF | 9/3/2019 | 6 | | | | | 3.0 | 3.3 | 3806 | |
| LOT 302TTF | 9/3/2019 | 28 | | | | | 6.9 | 7.6 | 5516 | |
| LOT 302TTF | 9/3/2019 | 28 | | | | | 6.6 | 7.2 | 5453 | |
| LOT 303 | 8/27/2019 | 3 | 80 | 68 | 142.2 | 5.3 | 2.6 | 2.8 | 3322 | |
| LOT 303 | 8/27/2019 | 3 | | | | | 2.5 | 2.8 | 3313 | |
| LOT 303 | 8/27/2019 | 28 | | | | | 6.7 | 7.3 | 5750 | 5579 |
| LOT 303 | 8/27/2019 | 28 | | | | | 6.8 | 7.5 | 5880 | 5462 |
| LOT 304 | 8/28/2019 | 6 | 80 | 70 | 142.3 | 5.8 | 3.1 | 3.4 | 4122 | |
| LOT 304 | 8/28/2019 | 6 | | | | | 3.2 | 3.5 | 4078 | |
| LOT 304 | 8/28/2019 | 28 | | | | | 7.1 | 7.8 | 5644 | 5447 |
| LOT 304 | 8/28/2019 | 28 | | | | | 6.9 | 7.6 | 5679 | 5164 |
| LOT 305 | 8/28/2019 | 6 | 82 | 71 | 140.9 | 5.8 | 2.8 | 3.1 | 3709 | |
| LOT 305 | 8/28/2019 | 6 | | | | | 2.9 | 3.1 | 3780 | |
| LOT 305 | 8/28/2019 | 28 | | | | | 6.5 | 7.1 | 5679 | 4605 |
| LOT 305 | 8/28/2019 | 28 | | | | | 6.4 | 7.1 | 5740 | 4442 |
| LOT 306 | 8/28/2019 | 6 | 85 | 75 | 143.3 | 4.6 | 2.8 | 3.0 | 4172 | |
| LOT 306 | 8/28/2019 | 6 | | | | | 2.8 | 3.0 | 4226 | |
| LOT 306 | 8/28/2019 | 28 | | | | | 6.4 | 7.1 | 6011 | 5487 |
| LOT 306 | 8/28/2019 | 28 | | | | | 6.4 | 7.0 | 6115 | 5002 |
| LOT 307 | 8/28/2019 | 6 | 90 | 79 | 143.7 | 5.2 | 2.8 | 3.1 | 3897 | |
| LOT307 | 8/28/2019 | 6 | | | | | 2.8 | 3.1 | 3826 | |
| LOT 307 | 8/28/2019 | 28 | | | | | 7.0 | 7.7 | 5720 | 4520 |

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| LOT 307 | 8/28/2019 | 28 | | | | | 7.1 | 7.8 | 5815 | 5018 |
| LOT 308 | 8/28/2019 | 6 | 90 | 79 | 144.1 | 4.6 | 2.7 | 3.0 | 4122 | |
| LOT 308 | 8/28/2019 | 6 | | | | | 2.6 | 2.9 | 4068 | |
| LOT 308 | 8/28/2019 | 28 | | | | | 6.7 | 7.4 | 5820 | 5077 |
| LOT 308 | 8/28/2019 | 28 | | | | | 6.3 | 6.9 | 6059 | 5300 |
| LOT 309 | 8/28/2019 | 6 | 90 | 86 | 144.6 | 4.1 | 2.8 | 3.1 | 4464 | |
| LOT 309 | 8/28/2019 | 6 | | | | | 3.0 | 3.3 | 4577 | |
| LOT 309 | 8/28/2019 | 28 | | | | | 7.1 | 7.8 | 6226 | 5508 |
| LOT 309 | 8/28/2019 | 28 | | | | | 7.2 | 7.9 | 6599 | 5858 |
| LOT 310 | 8/29/2019 | 5 | 80 | | 143.5 | 5.4 | 2.7 | 3.0 | 3867 | |
| LOT 310 | 8/29/2019 | 5 | | | | | 2.8 | 3.0 | 3952 | |
| LOT 310 | 8/29/2019 | 28 | | | | | 6.8 | 7.5 | 5822 | 5156 |
| LOT 310 | 8/29/2019 | 28 | | | | | 7.3 | 8.0 | 5777 | 4929 |
| LOT 311 | 8/29/2019 | 5 | 85 | 74 | 144.3 | 4.4 | 2.8 | 3.0 | 4113 | |
| LOT 311 | 8/29/2019 | 5 | | | | | 2.7 | 3.0 | 4445 | |
| LOT 311 | 8/29/2019 | 28 | | | | | 7.1 | 7.9 | 5709 | 5255 |
| LOT 311 | 8/29/2019 | 28 | | | | | 6.4 | 7.0 | 6100 | 5656 |
| LOT 312 | 8/29/2019 | 5 | 84 | 77 | 143.7 | 5.5 | 2.9 | 3.1 | 3725 | |
| LOT 312 | 8/29/2019 | 5 | | | | | 2.8 | 3.1 | 3789 | |
| LOT 312 | 8/29/2019 | 28 | | | | | 6.2 | 6.8 | 5527 | 4630 |
| LOT 312 | 8/29/2019 | 28 | | | | | 6.4 | 7.1 | | 5236 |
| LOT 313 | 8/29/2019 | 5 | 89 | 87 | 144.2 | 4.9 | 2.7 | 2.9 | 4187 | |
| LOT 313 | 8/29/2019 | 5 | | | | | 2.6 | 2.9 | 3914 | |
| LOT 313 | 8/29/2019 | 28 | | | | | 7.0 | 7.7 | 6091 | 5547 |
| LOT 313 | 8/29/2019 | 28 | | | | | 7.4 | 8.1 | 6196 | 5285 |
| LOT 314 | 8/29/2019 | 5 | | | | | 2.8 | 3.0 | 3699 | |
| LOT 314 | 8/29/2019 | 5 | | | | | 2.7 | 2.9 | 3855 | |
| LOT 314 | 8/29/2019 | 28 | | | | | 6.3 | 6.9 | 5865 | 4649 |
| LOT 314 | 8/29/2019 | 28 | | | | | 6.1 | 6.7 | 6004 | 5150 |
| LOT 315 | 9/5/2019 | 4 | 83 | 73 | 143.9 | 5.5 | 2.6 | 2.9 | 3597 | |
| LOT 315 | 9/5/2019 | 4 | | | | | 2.5 | 2.7 | 3636 | |
| LOT 315 | 9/5/2019 | 28 | | | | | 6.3 | 6.9 | 5535 | |
| LOT 315 | 9/5/2019 | 28 | | | | | 6.5 | 7.1 | 5974 | |
| LOT 316 | 9/6/2019 | 3 | 88 | 82 | 145.3 | 5.1 | 3.1 | 3.4 | 3326 | |
| LOT 316 | 9/6/2019 | 3 | | | | | 3.1 | 3.4 | 3346 | |
| LOT 316 | 9/6/2019 | 28 | | | | | 6.9 | 7.6 | 5437 | |
| LOT 316 | 9/6/2019 | 28 | | | | | 6.8 | 7.5 | 5656 | |
| LOT 317 | 9/5/2019 | 4 | 85 | 77 | 145.2 | 5 | 2.5 | 2.8 | 3540 | |
| LOT 317 | 9/5/2019 | 4 | | | | | 2.6 | 2.9 | 3753 | |
| LOT 317 | 9/5/2019 | 28 | | | | | 6.7 | 7.3 | 5604 | |
| LOT 317 | 9/5/2019 | 28 | | | | | 6.1 | 6.8 | 5991 | |
| LOT 318 | 9/9/2019 | 3 | 82 | 73 | 143.9 | 4.6 | 2.5 | 2.7 | 2780 | |
| LOT 318 | 9/9/2019 | 3 | | | | | 2.3 | 2.5 | 2901 | |
| LOT 318 | 9/9/2019 | 28 | | | | | 5.9 | 6.5 | 4787 | |
| LOT 318 | 9/9/2019 | 28 | | | | | 6.2 | 6.8 | 4816 | |
| LOT 319 | 9/6/2019 | 3 | 86 | 88 | 144.5 | 5.2 | 2.6 | 2.9 | 3128 | |
| LOT 319 | 9/6/2019 | 3 | | | | | 2.5 | 2.8 | 3141 | |
| LOT 319 | 9/6/2019 | 28 | | | | | 6.2 | 6.8 | 5218 | |
| LOT 319 | 9/6/2019 | 28 | | | | | 6.2 | 6.8 | 5415 | |
| LOT 320 | 9/11/2019 | 5 | 84 | 73 | 145.4 | 4.8 | 3.2 | 3.6 | 4126 | |
| LOT 320 | 9/11/2019 | 5 | | | | | 3.2 | 3.5 | 3892 | |
| LOT 322 | 9/11/2019 | 5 | 88 | 81 | 144.7 | 4.6 | 2.5 | 2.8 | 3324 | |
| LOT 322 | 9/11/2019 | 5 | | | | | 2.4 | 2.7 | 3023 | |
| LOT 323 | 9/23/2019 | 3 | 84 | 88 | 144.1 | 5.8 | 2.5 | 2.8 | 3090 | |
| LOT323 | 9/23/2019 | 3 | | | | | 2.4 | 2.6 | 3298 | |

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|---|---|---|---|---|---|---|---|---|---|---|
| LOT 325 | 9/13/2019 | 10 | 82 | 75 | 144.6 | 4.3 | 3.2 | 3.5 | 4437 | |
| LOT 325 | 9/13/2019 | 10 | | | | | 3.2 | 3.6 | 4574 | |
| LOT 326 | 9/13/2019 | 10 | 84 | 73 | 144.4 | 5.8 | 3.3 | 3.6 | 4155 | |
| LOT 326 | 9/13/2019 | 10 | | | | | 3.3 | 3.6 | 3949 | |
| LOT 327 | 9/14/2019 | 9 | 82 | 73 | 142.9 | 6.4 | 3.0 | 3.3 | 3784 | |
| LOT 327 | 9/14/2019 | 9 | | | | | 2.8 | 3.1 | 3744 | |
| LOT 328 | 9/19/2019 | 4 | 76 | 55 | 142.8 | 5.8 | 2.7 | 2.9 | 3619 | |
| LOT 328 | 9/19/2019 | 4 | | | | | 2.8 | 3.0 | 3642 | |
| LOT 331 | 9/19/2019 | 4 | 80 | 70 | | 6.2 | 2.7 | 2.9 | 3251 | |
| LOT 331 | 9/19/2019 | 4 | | | | | 2.4 | 2.7 | 3212 | |
| LOT 332 | 9/19/2019 | 4 | 82 | 73 | 142.8 | 5.2 | | | | |
| LOT 333 | 9/19/2019 | 4 | | | | | 2.2 | 2.4 | 3539 | |
| LOT 333 | 9/19/2019 | 4 | | | | | 2.2 | 2.4 | 3333 | |
| LOT 334 | 9/20/2019 | 3 | 77 | 51 | 142.8 | 5.6 | | | 3742 | |
| LOT 334 | 9/20/2019 | 3 | | | | | | | 3745 | |
| LOT 335 | 9/20/2019 | 3 | 82 | 73 | 144.2 | 5.5 | | | 3354 | |
| LOT 335 | 9/20/2019 | 3 | | | | | | | 3307 | |
| LOT 336 | 9/20/2019 | 3 | 82 | 70 | 144.1 | 5.8 | | | 3035 | |
| LOT 336 | 9/20/2019 | 3 | | | | | | | 3068 | |
| LOT 337 | 9/23/2019 | 3 | 78 | 61 | 142.7 | 5.5 | 2.8 | 3.0 | 3573 | |
| LOT 337 | 9/23/2019 | 3 | | | | | 2.6 | 2.8 | 3568 | |
| LOT 338 | 9/23/2019 | 3 | 84 | 83 | 143.4 | 4.6 | 2.3 | 2.5 | 2925 | |
| LOT 338 | 9/23/2019 | 3 | | | | | 2.4 | 2.6 | 3102 | |
| LOT 339 | | 0 | | | | | | | | |
| LOT 339 | | 0 | | | | | | | | |
| LOT 339 | | 0 | | | | | | | | |
| LOT 339 | | 0 | | | | | | | | |
| LOT 339 | | 0 | | | | | | | | |
| LOT 340 | 9/25/2019 | 3 | 80 | 70 | 145.3 | 4.7 | 2.6 | 2.8 | 3160 | |
| LOT 340 | 9/25/2019 | 3 | | | | | 2.4 | 2.7 | 3257 | |
| LOT 341 | 9/26/2019 | 4 | 82 | 72 | 141.1 | 5.7 | 2.4 | 2.7 | 3500 | |
| LOT 341 | 9/26/2019 | 4 | | | | | 2.5 | 2.7 | 3600 | |
| LOT 342 | 9/26/2019 | 4 | 84 | | 143.6 | 4.4 | 2.4 | 2.6 | 2956 | |
| LOT 342 | 9/26/2019 | 4 | | | | | 2.3 | 2.5 | 3326 | |
| LOT 343 | 9/28/2019 | 6 | 82 | 73 | 142.0 | 5.2 | 3.0 | 3.3 | 3992 | |
| LOT 343 | 9/28/2019 | 6 | | | | | 3.0 | 3.2 | 4213 | |
| LOT 344 | 9/30/2019 | 3 | 82 | 72 | 141.6 | 5.7 | 2.6 | 2.8 | 2947 | |
| LOT 344 | 9/30/2019 | 3 | | | | | 2.7 | 2.9 | 2966 | |
| LOT 345 | 10/3/2019 | 4 | 84 | 79 | 140.2 | 5.6 | 3.0 | 3.3 | 3361 | |
| LOT 345 | 10/3/2019 | 4 | | | | | 2.9 | 3.2 | 3508 | |
| LOT 346 | 10/3/2019 | 4 | | | | | 2.9 | 3.2 | 3435 | |
| LOT 346 | 10/3/2019 | 4 | | | | | 3.0 | 3.3 | 3333 | |
| LOT 348 | 10/7/2019 | 3 | 76 | 71 | 141.1 | 5.8 | | | | |

## Appendix D:  Data used for Analysis of Resistivity Test Results for Mixture 496HPNS

| LOT # | Sample Made | Test Age | Concrete Temp | Ambient Temp | Unit Weight | Air | Surface Resistivity | Resistivity adj. x1.1 | Compressive Strength | NCDOT 28-day Comp Str |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (days) | (°F) | (°F) | (pcf) | (%) | k-ohm*cm | k-ohm*cm | (psi) | PSI |
| LOT32 | 5/7/2018 | 2 | 80 | 79 | 142.4 | 6.0 | 2.6 | 2.8 | 3287 | |
| LOT32 | 5/7/2018 | 2 | 80 | 79 | 142.4 | 6.0 | 2.8 | 3.0 | 3036 | |
| LOT32 | 5/7/2018 | 2 | 80 | 79 | 142.4 | 6.0 | 2.6 | 2.8 | 3107 | |
| LOT32 | 5/7/2018 | 28 | 80 | 79 | 142.4 | 6.0 | 7.6 | 8.3 | 5935 | 5962 |
| LOT32 | 5/7/2018 | 28 | 80 | 79 | 142.4 | 6.0 | 7.4 | 8.1 | 6113 | 5522 |
| LOT32 | 5/7/2018 | 91 | 80 | 79 | 142.4 | 6.0 | 20.9 | 23.0 | 7223 | |
| 496HP TTF | 5/31/2018 | 2 | 84 | 80 | 143.2 | 6.0 | 2.5 | 2.7 | 2818 | |
| 496HP TTF | 5/31/2018 | 2 | 84 | 80 | 143.2 | 6.0 | 2.6 | 2.9 | 2757 | |
| 496HP TTF | 5/31/2018 | 2 | 84 | 80 | 143.2 | 6.0 | 2.5 | 2.7 | 3030 | |
| 496HP TTF | 5/31/2018 | 28 | 84 | 80 | 143.2 | 6.0 | 5.8 | 6.3 | 5723 | |
| 496HP TTF | 5/31/2018 | 28 | 84 | 80 | 143.2 | 6.0 | 5.8 | 6.4 | 5599 | |
| 496HP TTF | 5/31/2018 | 28 | 84 | 80 | 143.2 | 6.0 | | | | |
| 496HP TTF | 6/11/2018 | 2 | 85 | 72 | 143.8 | 4.5 | 2.1 | 2.3 | 3420 | |
| 496HP TTF | 6/11/2018 | 2 | 85 | 72 | 143.8 | 4.5 | 2.3 | 2.5 | 3292 | |
| 496HP TTF | 6/11/2018 | 2 | 85 | 72 | 143.8 | 4.5 | 2.3 | 2.6 | 3345 | |
| 496HP TTF | 6/11/2018 | 2 | 85 | 72 | 143.8 | 4.5 | | | | |
| 496HP TTF | 6/11/2018 | 2 | 85 | 72 | 143.8 | 4.5 | | | | |
| 496HP TTF | 6/11/2018 | 2 | 85 | 72 | 143.8 | 4.5 | | | | |
| LOT 69 | 6/18/2018 | 3 | | | | | 2.7 | 3.0 | 3232 | |
| LOT 69 | 6/18/2018 | 3 | 90 | 85 | 143.2 | 6.2 | 2.8 | 3.1 | 3617 | |
| LOT 69 | 6/18/2018 | 29 | | | | | 5.7 | 6.2 | 5807 | |
| LOT 69 | 6/18/2018 | 29 | | | | | 5.6 | 6.2 | 6014 | |
| LOT 69 | 6/18/2018 | 91 | | | | | 14.6 | 16.1 | 7396 | |
| LOT 84 TTF | 7/9/2018 | 2 | 82 | 71 | 138.6 | 6.0 | 2.5 | 2.7 | 3198 | |
| LOT 84 TTF | 7/9/2018 | 2 | | | | | 2.3 | 2.5 | 3033 | |
| LOT 84 TTF | 7/9/2018 | 2 | | | | | 2.3 | 2.5 | 3170 | |
| LOT 84 TTF | 7/9/2018 | 28 | | | | | 5.1 | 5.6 | 5736 | 4932 |
| LOT 84 TTF | 7/9/2018 | 28 | | | | | 5.1 | 5.6 | 5762 | 5297 |
| LOT 84 TTF | 7/9/2018 | 91 | | | | | 14.0 | 15.4 | 7306 | |
| LOT 86 | 7/12/2018 | 4 | 92 | 88 | | 6.5 | 2.6 | 2.8 | 3458 | |
| LOT 86 | 7/12/2018 | 4 | | | | | 2.7 | 2.9 | 3275 | |
| LOT 86 | 7/12/2018 | 28 | | | | | 4.8 | 5.3 | 5338 | 4450 |
| LOT 86 | 7/12/2018 | 28 | | | | | 4.7 | 5.2 | 5077 | 4844 |
| LOT 86 | 7/12/2018 | 92 | | | | | 15.3 | 16.8 | 6519 | |
| LOT 89 | 7/16/2018 | 3 | 86 | 73 | 147.8 | 5.5 | 2.9 | 3.2 | 3189 | |
| LOT 89 | 7/16/2018 | 3 | | | | | 2.7 | 3.0 | 3435 | |
| LOT 89 | 7/16/2018 | 28 | | | | | 5.3 | 5.8 | 5704 | 5421 |
| LOT 89 | 7/16/2018 | 28 | | | | | 5.5 | 6.1 | 5498 | 5240 |
| LOT 89 | 7/16/2018 | 91 | | | | | 16.1 | 17.7 | 6785 | |
| LOT 137 | 8/23/2018 | 3 | 86 | 73 | 143.8 | 6.5 | 2.3 | 2.5 | 3050 | |
| LOT 137 | 8/23/2018 | 3 | | | | | 2.3 | 2.5 | 3124 | |
| LOT 137 | 8/23/2018 | 3 | | | | | 2.4 | 2.6 | 3272 | |
| LOT 137 | 8/23/2018 | 28 | | | | | 5.4 | 5.9 | 5289 | 4794 |
| LOT 137 | 8/23/2018 | 28 | | | | | 5.3 | 5.8 | 5165 | 5102 |
| LOT 137 | 8/23/2018 | 90 | | | | | 19.0 | 20.8 | 6744 | |

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| LOT 147 | 9/4/2018 | 3 | 88 | 82 | | 5 | 2.6 | 2.9 | 3467 | |
| LOT 147 | 9/4/2018 | 3 | | | | | 2.9 | 3.2 | 3570 | |
| LOT 147 | 9/4/2018 | 28 | | | | | 5.6 | 6.1 | 6038 | 5891 |
| LOT 147 | 9/4/2018 | 28 | | | | | 5.6 | 6.2 | 6580 | 5671 |
| LOT 147 | 9/4/2018 | 90 | | | | | 15.4 | 17.0 | 7881 | |
| LOT 154 | 9/11/2018 | 6 | 91 | 84 | | 5.8 | 2.4 | 2.7 | 4275 | |
| LOT 154 | 9/11/2018 | 6 | | | | | 2.4 | 2.6 | 4172 | |
| LOT 154 | 9/11/2018 | 28 | | | | | 5.3 | 5.8 | 6147 | 4660 |
| LOT 154 | 9/11/2018 | 28 | | | | | 5.0 | 5.4 | 6153 | 4777 |
| LOT 154 | 9/11/2018 | 91 | | | | | 18.4 | 20.2 | 7769 | |
| LOT 155 | 9/24/2018 | 3 | 80 | 69 | 141.2 | 6.2 | | 0.0 | 2998 | |
| LOT 155 | 9/24/2018 | 28 | | | | | 6.6 | 7.2 | 5233 | 5004 |
| LOT 155 | 9/24/2018 | 28 | | | | | 6.5 | 7.2 | 5690 | 4960 |
| LOT 155 | 9/24/2018 | 87 | | | | | 17.9 | 19.7 | 6837 | |
| LOT 155 | 9/24/2018 | 87 | | | | | | | 2987 | |
| LOT 161 | 10/23/2018 | 2 | 70 | 63 | 142.1 | 6.2 | 2.3 | 2.5 | 2826 | |
| LOT 161 | 10/23/2018 | 2 | | | | | 2.2 | 2.5 | 2787 | |
| LOT 161 | 10/23/2018 | 2 | | | | | 2.2 | 2.4 | 2857 | |
| LOT 161 | 10/23/2018 | 28 | | | | | 5.4 | 6.0 | 5180 | 4777 |
| LOT 161 | 10/23/2018 | 28 | | | | | 5.4 | 5.9 | 5027 | 5459 |
| LOT 163 | 10/29/2018 | 3 | 70 | 62 | 143.1 | 5.2 | 2.2 | 2.4 | 3399 | |
| LOT 163 | 10/29/2018 | 3 | | | | | 2.1 | 2.3 | 3351 | |
| LOT 163 | 10/29/2018 | 28 | | | | | 4.8 | 5.3 | 5973 | 5817 |
| LOT 163 | 10/29/2018 | 28 | | | | | 4.6 | 5.0 | 6132 | 5658 |
| LOT 163 | 10/29/2018 | 28 | | | | | | | | |
| LOT 165 | 11/1/2018 | 3 | 66 | 61 | 139.4 | 7 | 2.8 | 3.1 | 3182 | |
| LOT 165 | 11/1/2018 | 3 | | | | | 2.6 | 2.9 | 2984 | |
| LOT 165 | 11/1/2018 | 28 | | | | | 5.4 | 5.9 | 4972 | 5006 |
| LOT 165 | 11/1/2018 | 28 | | | | | 5.5 | 6.0 | 4896 | 5030 |
| LOT 165 | 11/1/2018 | 28 | | | | | | | | |
| LOT 172 | 2/5/2019 | 2 | 58 | 43 | 144.2 | 5.5 | | | 2712 | |
| LOT 172 | 2/5/2019 | 2 | | | | | | | 2704 | |
| LOT 172 | 2/5/2019 | 2 | | | | | | | 2719 | |
| LOT 172 | 2/5/2019 | 28 | | | | | 4.2 | 4.6 | 5108 | 5254 |
| LOT 172 | 2/5/2019 | 28 | | | | | 4.3 | 4.7 | 5674 | 5002 |
| LOT 174 TTF | 2/8/2019 | 3 | 74 | 62 | 144.2 | 5 | | | 2756 | |
| LOT 174 | 2/8/2019 | 3 | | | | | | | 2759 | |
| LOT 174 | 2/8/2019 | 3 | | | | | | | 2882 | |
| LOT 174 | 2/8/2019 | 3 | | | | | 4.9 | 5.4 | 6097 | 5351 |
| LOT 174 | 2/8/2019 | 3 | | | | | 4.9 | 5.4 | 6120 | 5770 |
| LOT 181 | 4/8/2019 | 2 | 70 | 71 | 142.8 | 5 | | | 3665 | |
| LOT 181 | 4/8/2019 | 2 | | | | | | | 4060 | |
| LOT 181 | 4/8/2019 | 2 | | | | | | | 3709 | |
| LOT 181 | 4/8/2019 | 28 | | | | | 5.8 | 6.3 | 6547 | 5893 |
| LOT 181 | 4/8/2019 | 28 | | | | | 5.9 | 6.5 | 6913 | 5832 |
| LOT 181 | 4/8/2019 | 56 | | | | | 10.1 | 11.1 | 7956 | |
| LOT 190 | 4/23/2019 | 2 | 72 | 72 | 139.9 | 6.5 | 2.2 | 2.4 | 2610 | |
| LOT 190 | 4/23/2019 | 2 | | | | | 2.2 | 2.4 | 2707 | |
| LOT 190 | 4/23/2019 | 2 | | | | | 2.2 | 2.4 | 2621 | |
| LOT 190 | 4/23/2019 | 28 | | | | | 5.0 | 5.5 | 5501 | 6951 |
| LOT 190 | 4/23/2019 | 28 | | | | | 5.2 | 5.7 | 5830 | 6451 |

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| LOT 190 | 4/23/2019 | 56 | | | | | 9.6 | 10.5 | 5933 | |
| LOT 230 TTF | 6/13/2019 | 2 | 72 | 61 | 140.6 | 6.5 | 2.1 | 2.3 | 2606 | |
| LOT 230 TTF | 6/13/2019 | 2 | | | | | 2.0 | 2.2 | 2745 | |
| LOT 230 TTF | 6/13/2019 | 2 | | | | | 2.2 | 2.5 | 2558 | |
| LOT 230 | 6/13/2019 | 28 | | | | | 5.5 | 6.0 | 5349 | 4228 |
| LOT 230 | 6/13/2019 | 28 | | | | | 5.9 | 6.5 | 5160 | 5143 |
| LOT 230 | 6/13/2019 | 56 | | | | | 10.3 | 11.3 | 5489 | |
| LOT 237 TTF | 6/24/2019 | 2 | 76 | 67 | 143.3 | 7 | 2.2 | 2.4 | 2564 | |
| LOT 237 TTF | 6/24/2019 | 2 | | | | | 2.0 | 2.2 | 2626 | |
| LOT 237 TTF | 6/24/2019 | 2 | | | | | 2.1 | 2.3 | 2594 | |
| LOT 237 | 6/24/2019 | 28 | | | | | 5.0 | 5.5 | 4977 | 4363 |
| LOT 237 | 6/24/2019 | 28 | | | | | 5.1 | 5.6 | 4825 | 3975 |
| LOT 237 | 6/24/2019 | 56 | | | | | 9.3 | 10.2 | 5465 | |
| LOT 268 | 7/29/2019 | 28 | | | | | 5.9 | 6.5 | 6182 | 5671 |
| LOT 268 | 7/29/2019 | 28 | | | | | 6.3 | 6.9 | 6010 | 5505 |
| LOT 269 | 7/29/2019 | 28 | | | | | 5.4 | 5.9 | 5569 | 4372 |
| LOT 269 | 7/29/2019 | 28 | | | | | 5.6 | 6.2 | 5067 | 5020 |
| LOT 270 | 7/29/2019 | 28 | | | | | 5.6 | 6.1 | 5982 | 5456 |
| LOT 270 | 7/29/2019 | 28 | | | | | 5.7 | 6.3 | 5736 | 5467 |
| LOT 271 | 7/29/2019 | 28 | | | | | 6.0 | 6.6 | 5300 | 4872 |
| LOT 271 | 7/29/2019 | 28 | | | | | 5.8 | 6.4 | 5863 | 5356 |
| LOT 272 | 7/29/2019 | 28 | | | | | 5.1 | 5.6 | 5412 | 5522 |
| LOT 272 | 7/29/2019 | 28 | | | | | 5.3 | 5.8 | 5443 | 5611 |
| LOT 496 HP | 8/22/2019 | 3 | | | | | 2.2 | 2.5 | 3183 | |
| LOT 496 HP | 8/22/2019 | 3 | | | | | 2.3 | 2.5 | 3164 | |
| LOT 496 HP | 8/22/2019 | 3 | | | | | 2.2 | 2.4 | 3204 | |
| LOT 496 HP | 8/22/2019 | 7 | | | | | 2.5 | 2.8 | 4052 | |
| LOT 496 HP | 8/22/2019 | 7 | | | | | 2.5 | 2.7 | 3755 | |
| LOT 496 HP | 8/22/2019 | 14 | | | | | 3.1 | 3.4 | 4726 | |
| LOT 496 HP | 8/22/2019 | 14 | | | | | 3.2 | 3.5 | 4590 | |
| LOT 496 HP | 8/22/2019 | 28 | | | | | 4.8 | 5.3 | 5447 | |
| LOT 496 HP | 8/22/2019 | 28 | | | | | 4.9 | 5.4 | 5644 | |
| LOT 496 HP | 8/22/2019 | 28 | | | | | | | | |
| LOT 496 HP | 8/22/2019 | 28 | | | | | | | | |
| LOT 2P HP | 9/6/2019 | 3 | 78 | 72 | 143.2 | 5.6 | 2.8 | 3.1 | 3177 | |
| LOT 2P HP | 9/6/2019 | 3 | | | | | 2.8 | 3.1 | ?? | |
| LOT 2P HP | 9/6/2019 | 3 | | | | | | | | |
| LOT 2P HP | 9/6/2019 | 3 | | | | | | | | |
| LOT 2P HP | 9/6/2019 | 3 | | | | | | | | |
| LOT 321 HP | 9/9/2019 | 3 | 82 | 73 | 144.2 | 5.5 | 2.2 | 2.5 | 2758 | |
| LOT 321 HP | 9/9/2019 | 3 | | | | | 2.3 | 2.5 | 3279 | |
| LOT 321 HP | 9/9/2019 | 28 | | | | | 6.2 | 6.8 | 5573 | |
| LOT 321 HP | 9/9/2019 | 28 | | | | | 6.5 | 7.2 | 5711 | |
| LOT 321 HP | 9/9/2019 | 28 | | | | | | | | |
| LOT 324 HP | 9/11/2019 | 5 | 90 | 84 | 141.6 | 5.3 | 2.6 | 2.8 | 2961 | |
| LOT 324 HP | 9/11/2019 | 5 | | | | | 2.5 | 2.8 | 2794 | |
| LOT 324 HP | 9/11/2019 | 5 | | | | | | | | |
| LOT 324 HP | 9/11/2019 | 5 | | | | | | | | |
| LOT 324 HP | 9/11/2019 | 5 | | | | | | | | |
| LOT 329 | 9/16/2019 | 3 | 88 | | 142.4 | 5.2 | 2.4 | 2.7 | 3677 | |
| LOT 329 | 9/16/2019 | 3 | | | | | 2.5 | 2.7 | 3627 | |

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|---|---|---|---|---|---|---|---|---|---|---|
| LOT 329 | 9/16/2019 | 3 | | | | | | | | |
| LOT 329 | 9/16/2019 | 3 | | | | | | | | |
| LOT 329 | 9/16/2019 | 3 | | | | | | | | |
| LOT 330 | 9/25/2019 | 3 | 72 | | 141.0 | 5.5 | 2.5 | 2.7 | 3050 | |
| LOT 330 | 9/25/2019 | 3 | | | | | 2.3 | 2.5 | 3039 | |
| LOT 330 | 9/25/2019 | 3 | | | | | | | | |
| LOT 330 | 9/25/2019 | 3 | | | | | | | | |
| LOT 330 | 9/25/2019 | 3 | | | | | | | | |
| LOT 5P HP | 10/3/2019 | 4 | 78 | 64 | 139.0 | 5.9 | 2.9 | 3.1 | 2940 | |
| LOT 5P HP | 10/3/2019 | 4 | | | | | 2.8 | 3.1 | 3080 | |
| LOT 5P HP | 10/3/2019 | 4 | | | | | | | | |
| LOT 5P HP | 10/3/2019 | 4 | | | | | | | | |
| LOT 5P HP | 10/3/2019 | 4 | | | | | | | | |
| LOT 347 HP | 10/4/2019 | 3 | 86 | 88 | 140.8 | 5.8 | | | 3197 | |
| LOT 347 HP | 10/4/2019 | 3 | | | | | | | 3166 | |
| LOT 347 HP | 10/4/2019 | 3 | | | | | | | | |
| LOT 347 HP | 10/4/2019 | 3 | | | | | | | | |
| LOT 347 HP | 10/4/2019 | 3 | | | | | | | | |

# APPENDIX B –

# PEM TEST PROCEDURES

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To: Brian Hunter, P.E.
State Laboratory Engineer
Materials and Tests Unit

From: Tara Cavalline, Ph.D., P.E.
Brett Tempest, Ph.D., P.E.
University of North Carolina at Charlotte

Date: March 31, 2021

Re: Guides for PEM Testing Technologies

Dear Mr. Hunter,

As outlined in NCDOT RP 2019-41, "Performance Engineered Concrete Mixtures – FHWA Implementation Funds," UNC Charlotte has developed technology transfer documents including guides for performance engineered concrete mixture (PEM) testing technologies of interest to NCDOT. Attached are test procedures, developed in a manner compatible with the format used in NCDOT's Concrete Field Study Guide. In particular, the format of Section V: Field Test Procedures and Standards was used as a model for development of the attached documents.

Thank you for the opportunity to assist NCDOT with research supporting performance engineered concrete mixtures.

Sincerely,

Tara L. Cavalline
Associate Professor

Attachments:
Procedures for the following PEM technologies:

- Surface Resistivity (AASHTO T 358)
- Volumetric Shrinkage (ASTM C157)
- Super Air Meter (AASHTO TP 118)
- Box Test (procedure developed by Oklahoma State University)

**SURFACE RESISTIVITY (AASHTO T 358)**

1. The equipment needed to run the test include:
   - Four-point Wenner array probe complying with AASHTO T 358 capable of having a probe tip spacing of 1.5 inches (38.1 mm).
   - Specimen holder to prevent specimen rotation during the test. See AASHTO T 358 for an example specimen holder. One approach is wood pieces with v-notches, as shown in Figure 2.
   - Saturated sponge or towel

2. The following information should be known and reported:
   - Source of cylinder or core
   - Identification number of cylinder or core
   - Type of concrete, including cementitious material types and contents, water cement ratio, and other pertinent mixture design information.
   - Curing conditions

3. Tests should be performed on 4in by 8in or 6in by 12in concrete cylinders cured in accordance with the appropriate requirements for compressive strength testing.

4. Cylinders or cores of other diameters may be tested with appropriate changes (per AASHTO T 358) to the Wenner probe tip spacing and use of the correction factor in the calculating equation. Specimens should not contain reinforcing steel, wire, or other metals which interfere with the electrical measurements.

5. Immediately after removing the cylinder from the mold, permanent marks should be made on the top finished circular face of the cylinder at the quarter points of the circumference (0, 90, 180, and 270 degrees). One mark should be assigned 0, and the other markings proceeding counterclockwise around the circumference of the cylinder. Marks should be extended to the longitudinal sides of the sample. The center of the sample length should also be marked on the longitudinal side of the sample for visual reference (Figure 1).

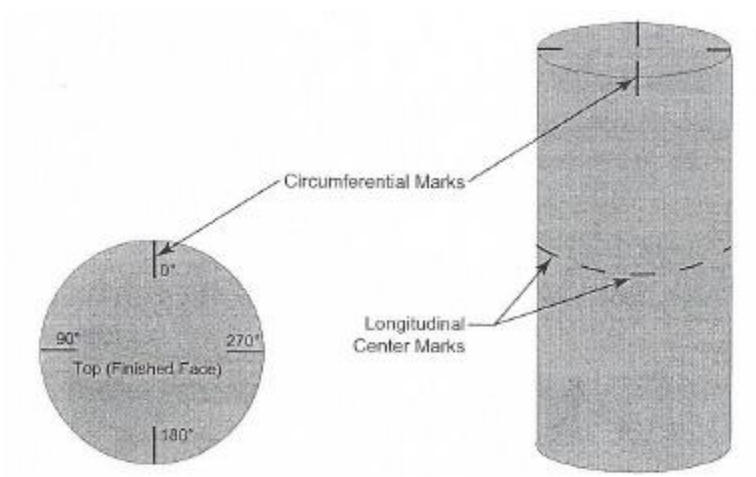


Figure 1: Sample marking (from AASHTO T 358-17)

6. Cure cylinders until the appropriate age for testing. The curing condition of cylinders to be tested can be either limewater bath or moist room. If specimens have been cured in a lime water bath, a correction factor of 1.1 should be applied to the readings.

7. Resistivity measurements are sensitive to the saturation condition and temperature of the specimen. The standardized conditioning procedure presented in AASHTO T 358 must be followed.

8. The air temperature in the vicinity of the test should be maintained between 68 to 77°F (20 to 25°C).

9. The specimen should be removed from the moist room or limewater bath and placed in the specimen holder with the 0° marking at the top. The sample should be wiped clean using a saturated sponge or towel, and the surface should remain wet before and during testing. Testing should be competed within 5 minutes of removal from the moist room or limewater bath.

10. Place the Wenner probe on the longitudinal side of the specimen, ensuring that the longitudinal center mark is equidistant from the center probe pins (Figure 2).

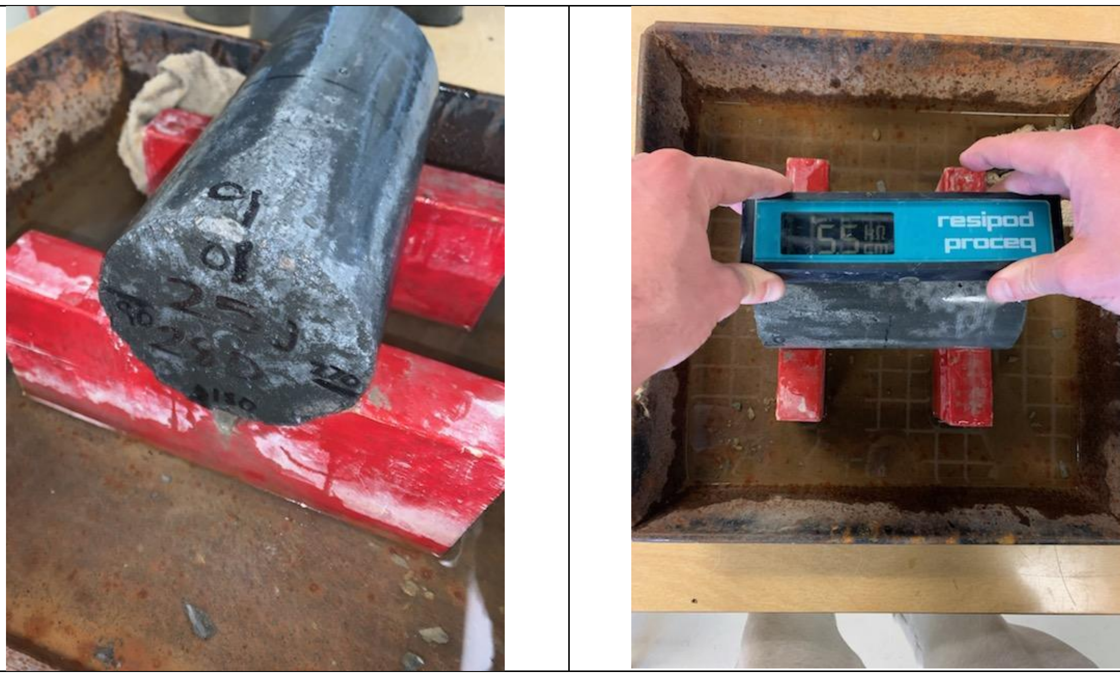


Figure 2: Surface resistivity measurement

11. Activate the Wenner probe (typically by pressing downward) and record the measurement once it becomes stable. The sample data table is provided in Table 1.

Table 1: Sample data table for surface resistivity test

| | Surface resistivity readings (kΩ•cm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample | 0° | 90° | 180° | 270° | 0° | 90° | 180° | 270° | Average | %RSD |
| A | | | | | | | | | | |
| B | | | | | | | | | | |
| C | | | | | | | | | | |
| Set average | | | | | | | | | | |
| Curing condition correction (×1.1 for lime water bath, ×1.0 for moist room) | | | | | | | | | | |
| Corrected average | | | | | | | | | | |

12. Rotate the specimen so the 90° mark is upward, align and activate the Wenner probe, and record the measurement once it becomes stable.

13. Rotate the specimen so the 180° mark is upward, align and activate the Wenner probe, and record the measurement once it becomes stable.

14. Rotate the specimen so the 270° mark is upward, align and activate the Wenner probe, and record the measurement once it becomes stable.

15. Repeat the process described in the previous five steps to take a second set of readings from the 0°, 90°, 180°, and 270° marks.

16. Calculate the average resistivity for each specimen in the set. Also, compute the percent relative standard deviation for each sample in the set (% RSD). The %RSD can be computed as follows:

$$\%RSD = (\text{standard deviation of readings} \times 100) / \text{average of readings}$$

If the %RSD is greater than 7.5%, the specimen should be immersed into a water bath maintained between 68 to 77°F (20 to 25°C) for two hours, and then the test should be repeated. If the %RSD on the second set of measurements is less than 7.5%, then the second set of measurements should be used to compute the average for the specimen. If the %RSD on the second set of measurements is greater than 7.5%, then the average of all 16 measurements (both the first set and second set of measurements) should be used.

17. Compute the average resistivity for the set of specimens.

18. If specimens were cured in lime water bath, multiply the set average by 1.1 to correct for the curing condition. If specimens were cured in a moist room, the set average is multiplied by 1.0.

19. AASHTO T 358 provides a qualitative assessment of chloride ion penetration as shown in Table 2. It is noted that these qualitative ratings were developed using concrete of a variety of types containing a variety of materials. NCDOT has also supported research correlating surface resistivity to chloride permeability (ASTM C1202) using local mixtures and materials.

Table 2: Qualitative Assessment of Chloride Ion Penetration from AASHTO T 358-17.

| Chloride Ion Penetration | Surface Resistivity Test Result (kΩ•cm) | |
|---|---|---|
| | 4in by 8in cylinder, probe spacing 1.5in | 6in by 12in cylinder, probe spacing 1.5in |
| High | <12 | <9.5 |
| Moderate | 12-21 | 9.5-16.5 |
| Low | 21-37 | 16.5-29 |
| Very Low | 37-254 | 29-199 |
| Negligible | >254 | >199 |

## VOLUMETRIC SHRINKAGE (ASTM C157)

1. The equipment needed to run the test include:
    - Molds per ASTM C157, 4in by 4in square cross-section and 11¼ inch in length.
    - Gauge studs (ensure they are positioned appropriately in the molds)
    - Length comparator

2. The following information should be known and reported:
    - Type of concrete, including cememtitious material types and contents, water cement ratio, and other pertinent mixture design information.
    - Identification of specimens
    - Size of specimens
    - Description of consolidation method
    - Curing conditions, if different from specified
    - Any other pertinent information on specimen preparation, storage, curing, or measurement.

3. Prepare concrete in accordance with ASTM C192/C192M. Ensure slump is approximately 3½ ± ½ in.

4. Concrete should be placed in molds in two approximately equal layers in accordance with ASTM C192/C192M. Layers should be consolidated by rodding, unless the slump is less than 3 in, in which case the specimens should be consolidated using external vibration. Use the same method of consolidation for all specimens that will be compared. Ensure concrete is worked around the gauge studs using fingers (Figure 1). The top layer of concrete should slightly overfill the mold. After consolidation of the top layer, it should be struck off with a straightedge.

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Figure 1:  Preparation of beam specimens.

5.  Specimens should be cured in the molds in a moist cabinet or room, protected from dripping water.

6. Specimens should be removed from the molds at 23½ ± ½ hour after the addition of water to the cement during mixing.  Specimens should be labeled in indelible ink and then placed in a lime-saturated water bath maintained at 73 ± 1°F (23 ± 0.5°C) for a minimum of 30 minutes to stabilize the temperature. At an age of 24 ± ½ hours after the addition of water to the cement during mixing, the specimens should be removed from the bath one at a time, wiped with a damp cloth, and measured using the length comparator.  This is the initial reading.

7. Once the initial reading is made, the specimens should be stored in a lime-saturated water bath maintained at 73 ± 1°F (23 ± 0.5°C) until they reach an age of 28 days (including the time period in the molds).  Ensuring the temperature is controlled, take another length comparator reading at 28 days. Specimens should be removed from the bath one at a time, wiped with a damp cloth, and measured using the length comparator.

8.  At the end of the curing period, specimens should be stored in a drying rom in a manner that allows them to have a clearance of at least 1 inch on all sides.  The drying room should be maintained at a temperature of 73 ± 3°F (23 ± 2°C) with a relative humidity is 50 ± 4%.

9.  Readings should be taken using the length comparator after the specimens have been stored in air in the drying room for 4, 7, 14, and 28 days.  Preferably, these readings should be taken in a room with a relative humidity is 50 ± 4% while the specimens are at a temperature of 73 ± 3°F (23 ± 2°C) (Figure 2).

Figure 2: Measurement using length comparator in drying room.

10. The length change of each specimen can be computed at any age using the formula below. The length change of specimens at 28 days of storage in the drying room is of particular interest.

$$\Delta L_x = \frac{CRD - initial\ CRD}{G} \times 100$$

Where: $\Delta L_x$ = length change of specimen at any age, %
CRD = difference between the length comparator reading of the specimen and the reference bar (this is the length comparator reading, if the digital readout is zeroed using the reference bar)
G = gage length, 10 in

11. The length change in microstrain (με) can be computed by multiplying the length change (in percent) by 10,000.

## SUPER AIR METER (SAM) (AASHTO TP 118)

Note: much of this procedure was developed by FHWA's Mobile Concrete Technology Center (MCTC) using input from various state agencies, and shared by Robert Conway, PE, FHWA Senior Pavement & Materials Engineer on March 10, 2021.

1. The equipment needed to run the test include:
   - Super Air Meter (SAM) device
   - Cali-can
   - 5/8 inch diameter by 24 inch long steel tamping rod with round hemispherical tips
   - Strike-off plate: A flat 14 inch by 14 inch by ½ inch straight, squre plate of steel, acrylic, or other suitable material.
   - A #2 (8.25 inch by 5.25 inch by 3 inch) concrete scoop
   - Sponges with straight edges for cleaning the rim of the bowl
   - 16 oz. rubber-head mallet with a wooden handle, with a weight between 1.2 and 1.25 pounds
   - Plastic funnel with fitted brass adaptor tip matching petcock screw threads
   - Water pail – approximately 1 gallon filled with clean water for use during filling and burping the SAM bowl.
   - Wash bucket – 5-gallon plastic bucket with wash water for cleanup after the test.
   - Scale – field scale accurate to NCDOT specifications
   - Optional: Air cape: portable air vessel capable of delivering air to the SAM, metered approximately for each of the sequential pressure steps.
   -

2. The following information should be known and reported:
   - Type of concrete, including cementitious material types and contents, water cement ratio, and other pertinent mixture design information.

3. Before using a SAM, obtain the Calibration Sheet and perform the following checks (from Oklahoma State University):

   a) Check the clamp arms spacing:
   The clamps arms tension must be uniform and at a constant value for all six clamps. This can be checked by measuring the distance from the bucket rim to the tip of the clamp lever before tightening the clamps. This is done by placing the lid on the bucket and resting the clamp tab under the beveled lip of the bucket but not pressing the clamp arms down. This is shown in Figure 1. The recommended distance from the edge of the bucket to the free end of the clamp arm is 3.50 in +/- 0.25 in. If the clamp arm is further than 3.75 in from the bucket then the clamp tab should be loosened by one turn. If the clamp arm is closer than 3.25 in from the bucket, it is recommended that the clamp arm be tightened by one turn. The meter must be recalibrated if the clamp tabs are adjusted.

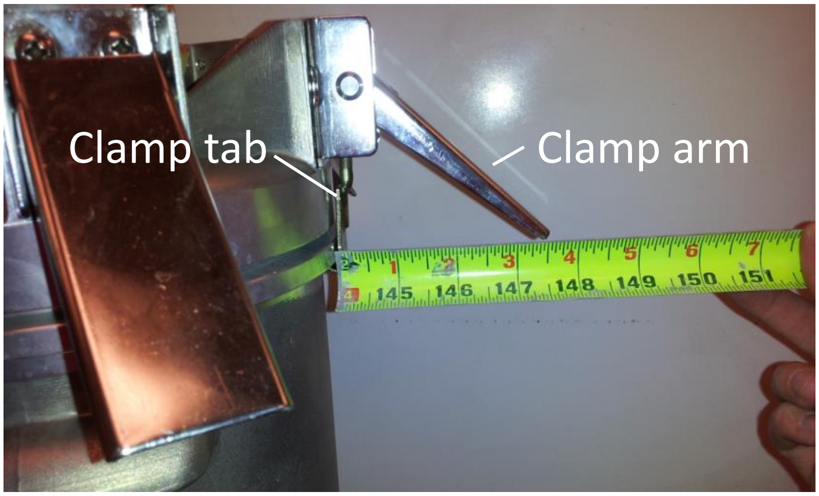


Figure 1: Checking clamp arm spacing (from Oklahoma State University)

b) Perform a SAM test with just water in the bottom chamber:
Record and compare all test equilibrium pressures to the corresponding equilibrium pressures from the provided calibration sheet or the most recent calibration. All values should be within 0.15 psi of the calibration value. The air should display at 0.2% or lower. The lower the SAM number the more consistent the test has been run.

c) Perform a Type B test with one Pro Cali can:
Run the Type B air meter test with one Pro Cali Can in the bottom chamber. The displayed results should be between 4.8% to 5.0% air. If you can perform all the above tests with correct values, it is a good indicator that you are performing the Super Air Meter tests correctly.

4. Standardization / Calibration Check / Annual Maintenance

- The SAM meter should be maintained annually, which includes a full inspection of all parts and components.
- The SAM meter should be standardized every three months. A standardization of the SAM updates the settings inside the gauge to account for changes in the device (part replacement, wear and tear). The SAM meter should be standardized per the manufacturer's procedure utilizing the provided Standardization Vessel at the start of production while correlating Quality Control and Agency Verification devices. If the SAM meter is being utilized on multiple projects or by multiple technicians, the SAM meter should be Standardized once a month during production.
- Once a week during production, when performing the daily start up water run insert the Standardization Vessel with the known volume as a calibration check. The air content in this case should be 4.9% ±0.2%. If the SAM is outside of 4.9% ±0.2% check for leaks and/or Standardize the device.
- Replacement or maintenance of the lower bowl, upper unit gasket (O-ring), clamps, needle valve, ultra pump, gauge fittings or gauge batteries will also require a re-calibration of the SAM meter. Ensure the correct O-ring is used with each gauge version; if the version number ends with a 6 or 7, use a 70 durometer O-ring (black). If it ends with an 8, use a 50 durometer O-ring (orange).
- Calibration records shall be kept with the device.

5. Operation of SAM

a) Daily Start Up Procedure:

- Note the mix designs planned for the day's production, confirm that the designs have been approved and that the Aggregate Correction Factor for the mix design sources has been verified by the Agency. Record the mix design designation and Aggregate Correction Factor.

- Inspect lower bowl rim for major dings or damage that would cause the rim to leak. Inspect the bottom of the bowl for concrete buildup that would change the volume of the bowl. Inspect the lid O-ring seating gasket for material caught under the ring or tears to the ring. Inspect clamp arms for incorrect arm tension or damage (recommended distance from the edge of the bucket to the free end of the clamp arm should be 3.5 inches ±0.2). Inspect the batteries in the back of the gauge to ensure they are not corroded, or that no moisture has accumulated inside the gauge from the machine being put away wet. Inspect the Pressure Adjustment valve nut to ensure it has not become loose. Check battery levels in SAM gauge, and the portable scale to ensure they are not low. When arriving onsite, allow SAM to acclimate to the ambient temperature prior to testing and take care not to leave the gauge in direct sunlight throughout the day. Storing the SAM in direct sunlight or taking it from an air conditioned or heated vehicle into the ambient environment can cause erroneous readings.

- Turn on SAM meter by pressing 'Enter' (support the back of the gage when pressing any button). Give it about 5 pumps, then release – inspect to ensure no water was released onto the surface below, and has not accumulated into the upper chamber from condensation or improper use (if water was released or you can hear water in the upper chamber, disassemble and dry it out). Open and close the Pressure Adjustment value nut a few times, then close it to see that the gauge returns to less than 0.03 psi. and is stable after 8 seconds. If not zeroed, long press of menu button to abort. After the gauge is aborted, long press of zero button until the gauge is zeroed. Exercise care when pressing buttons on the SAM gauge not to generate excessive force that might crack the neck of stem gauge prematurely.

- Arrange portable air vessel ('cape') (if using), hammer, rod, scoop, strike-off plate, water funnel ('shotgun') (if using), sponges, clean water pail, and wash water. Ensure the work surface is level, and free from any secondary motion or vibration. Turn bowl handle so it is facing operator, as to not interfere with mallet strikes. Check battery level. Check to make sure nut on top of pressure lever is not loose.

- Prior to performing the first concrete test of the day, check the SAM with a WATER RUN to check and document that meter is operating correctly, pressurizes O-rings, and checks for leaks. For the Water Run, follow the same meter operation instructions after filling the bowl with clean water and gently scraping the inside of the bowl with the tamping rod to release any air bubbles on the inside of the bowl. Record the time and results of the water run daily meter check.

- *Technician Tip: When running the test, wait for gage prompts to continue with the process. Proceeding ahead of the prompts could result in an invalid test, requiring you to start over. Use extreme care at the end of pressure steps to always release the bowl / lower chamber petcocks first, before releasing the upper chamber pressure, or water will be drawn back up into the upper chamber requiring it to be drained, dried out and re-standardized.*

- Open the pressure adjustment valve, then close it seating it sufficiently closed that it won't leak. Give it a few pumps, then lift the lever to air it out. See that it returns to zero after 8 seconds. If gauge does not return to zero, or less than 0.05 psi, re-zero. --> Long press Menu button until gauge reads 'PSI'. Long press Zero button until gauge resets (support the back of the gage when pressing any button).

- The target air content should be less than 0.05. The SAM # should be near zero, or possibly N-Err. If it is larger than 0.03 the machine needs to be inspected for water in the upper chamber or a leak. Any air content greater than 0.03 indicates a leak or an error during testing. Run the test again after repairing any leaks to ensure all seals are closed.

- *Technician Tip: Once a week during production, when performing the daily start up water run insert the Standardization Vessel with the known volume as a calibration check. The air content in this case should be 4.9% ±0.2%. If the SAM is outside of 4.9% ±0.2% check for leaks and/or Standardize the device. Always shake the Standardization Vessel itself prior to use to check if any moisture or debris has gotten inside which would affect the known volume of air, clean it out as necessary.*

6. Running a Quality Control and Verification Test:

**A. Sampling:** Use the same sampling and consolidation procedure for each SAM meter on the project. Obtain the random sample of concrete for the test in accordance with the applicable provisions of ASTM Designation: C 172. Complete the other required plastic concrete tests and prepare strength specimens prior to beginning SAM test. Begin the SAM test within 30 minutes of sampling. Begin the SAM test by dampening the inside and outside of bowl, underside of the lid, strike-off plate and rod. Record empty weight of Bowl (W1 Empty) for the unit weight calculation.

**B. Rodding and Tapping:** Using the scoop, fill the base with freshly mixed concrete in three layers of equal depth. (Insert State's Vibratory procedure for sample consolidation if applicable in this section) Rod each layer 25 times with the tamping rod, distributing the strokes evenly over the surface of the layer. After rodding each layer, tap the sides of three layers of equal depth. Rod each layer 25 times with the tamping rod, distributing the strokes evenly over the surface of the layer. After rodding each layer, strike the sides of the base 12 times with a mallet, 3 strikes per quadrant, during each lift. The strikes from the mallet, should be of sufficient energy to close the voids left after rodding, and release any entrapped air around the bowl periphery. (This should become the same energy used throughout the remainder of the test when striking the bowl.) In rodding the first layer, penetrate nearly full depth into the layer, but avoid striking the bottom of the base. In rodding the second and third layers, penetrate slightly into the layer below with each stroke. The last lift should overfill the bowl by approximately 1/8" after rodding and mallet striking.

**C. Striking Off:** Strike-off the measure by pressing the strike-off plate on the top surface of the measure to cover about two thirds of the surface and withdraw the plate with a sawing motion to finish only the area originally covered. Then place the plate on the top of the measure to cover the original two thirds of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure and continue to advance it until it slides completely off the measure. Incline the plate at a 45-degree angle and perform final strokes with the edge of the plate to produce a smooth surface free of voids.

**D. Clean and Weigh:** Rough clean lower rim and upper rim clean-- but not meticulous-clean at this point because the sample is going to be disturbed slightly when moved to the scale for weighting. Wipe clean

the handle and outside of the bowl any concrete that may remain from after the strike-off process. Weigh the bowl and Record sample + weight of Bowl (W2 Full) for the unit weight calculation.
After weighing, using the damp sponges, make a careful second cleaning of the top seating rim and lower outer rim. Inspect visually or with the check of a finger, ensure that no sand grains remain on the seating rim.

**E. Assemble the SAM:** Without disturbing the bowl and with both petcocks open, carefully place the upper portion of the SAM onto the lower bowl seating rim. (A large rubber band can be easily placed around all the clamp arms to hold them up during this step. After the upper portion has been seated, each of the arms can be freed, and the clamping sequence began.) Clamp down the arms in sequence, 2 at a time-- opposite sides in unison, working around the bowl until all arms are down securely. (Each should go down with equal pressure. If any grinding sound is noted during this step, removed the upper chamber, and re-clean the bowl seating rim. Repeat as necessary until no grinding or differential pressure is observed.) Petcocks should be open, and pressure adjustment valve is closed. If the SAM is not already on, turn it on by pressing 'Enter' (Support the back of the gage when pressing any button) to begin SAM Test and record Start Time.

**F. Sequential Pressure Test:**

- Screw funnel assembly into a petcock port and close the petcock valve. Fill the funnel with water using sponge or water pail. Open the petcock valve and allow water to drain into the bottom bowl. Burp the device by SLOWLY rocking meter away from the open petcock until the base is inclined to approximately 45 degrees from the ground. Repeat this until no more bubbles are observed escaping from the bottom chamber. Close the petcock at the funnel.

- Close the needle valve and pressurize to 15.5 psi, then let the device pressure stabilize between 15.5-14.5 psi. Adjust pressure valve until the pressure is 14.5 psi. The closer to 14.5psi., 30psi. and 45psi. the less variability will be introduced into the test. (While pumping, observe if any remaining bubbles escape from the open petcock, and if this happens repeatedly, abort the test and inspect the needle valve to ensure it is set correctly then resume testing.)

- *Technician Tip: Over pressurize 1 psi, let it naturally bleed off and stabilize, then slowly use the Pressure Adjustment valve to tick down, timing to close the valve on the target pressure. This gives good precision. If the pressure does not stabilize, troubleshoot the following; either the Pressure Adjustment valve is worn (not tight), the nut on the lever is too tight (pulling up the lever a tad), or air is leaking around the base of the upper chamber (test with water). If troubleshooting does not stabilize, switch to the backup SAM device.*

- After reaching 14.5 accurately, close the second petcock. Check both petcocks to make sure that they are closed.

- Once at 14.5, press enter on the gauge. It will flash "Read" and then say OK if the pressure is stable. Then display will read "Hold Lever, Hit and press Enter". (Support the back of the gage when pressing any button)

- Continue holding the lever open, strike the bowl using the same energy when consolidating the sample 3 times, then press enter. (Take care to avoid hitting the clamps during this step) (Support the back of the gage when pressing any button) Continue holding the lever through the ten second countdown on the digital gage, and while the display shows "Read," then release it when the display shows "Ok."

- Press Enter to view Air. Record Apparent Air %. Press Enter to return to running the SAM procedure. (Support the back of the gage when pressing any button)

- Subtract Aggregate Correction Factor from Apparent Air %. Record result as Total Air%. Example: 6.3 - 0.3 = 6.0 %
- Proceed in the same manner through the 30 and 45 pressure steps. Do not pressurize above 55 psi or the gauge will invalidate the test.

- After the final "Read" of the 45-pressure step is complete, cover both petcocks with hands while purging them slowly.

- Then slowly open the dial value to release the remaining pressure in the Upper Chamber.

- *Technician Tip: NEVER release the Upper Chamber pressure before lower, as this will draw water into the Upper Chamber from reverse pressurization. (If this happens disassemble the upper chamber, drain and clean it out as shown in Figure 2.)*

- After depressurization is complete, place shotgun, re-fill with water, burp and record the initial 'Starting Pressure' again.

- **Repeat each of the 14.5, 30 and 45 pressure steps again.**
- Record each beginning and ending pressures of each 10 second countdown.
- Press Enter (Support the back of the gage when pressing any button) to view SAM #. Record. Example = 0.18
- Open petcocks slowly, and then dial valve slowly.
- Clean Air out by pressurizing upper chamber, then lifting lever to blow out a few times, to rid the can of any condensation moisture.

**G. Clean the Device:** Clean all concrete thoroughly from inside of the bowl and from upper lid of the meter. Special attention should be paid to keep all valves and openings free of concrete residue buildup. Take care to prevent damage to the top rim of the bowl or rough handling of the gauge stem during placement or retrieval from the case that may cause it to crack. A tight seal is necessary for proper operation, so care should be taken to avoid buildup around the lid gasket. Always keep the gauge out of water. *DO NOT use soap when cleaning. The soap could leave a residue behind which can result in an inaccurate reading.*

**H. Care and Storage:** When storing the device, always completely dry the device to avoid and buildup of mold or mildew. Do not store an air meter with the lid clamped tightly to the base. Allow the upper unit to air dry as much as possible before securing in the case to prevent condensation from accumulating in the gauge. *Condensation left on the device when stored can result in a fouled gage, possible damaging the digital screen and making it unreadable and sulfation at the battery terminals. Keep the gauge out of direct sunlight in-between tests and avoid excessive temperature changes prior to testing (storing SAM in AC vehicle just prior to test).* Ensure that the pressure valve is open for storage to avoid any pressure buildup in the upper chamber. When closing the lid of the storage container, take care to avoid causing damage to the flanges and gage by forcefully closing the lid.

| | Process | Frequency |
| --- | --- | --- |
| Standardization | Standardize the SAM using a Cali-can. We are calibrating the device with a known volume (Cali-can volume is 4.9%. per altitude) | • Start of Production<br>• Minimum of every three months during production.<br>• Whenever maintenance is performed |
| Calibration Check | Verify that the SAM is within calibration. A Cali-can of known volume (4.9%) is used for this purpose. In this process, the device is checked by measuring the volume of the Cali-can. The measurement should be within 4.9%±0.2% to satisfy the calibration. | Once a week |
| Annual Maintenance | • Tension of the clamps*<br>• Weigh the air pot<br>• Check the volume of the lower chamber<br>• Schrader Valve<br>• Pet cocks*<br>• One way valve on the pump*<br>• Check the gaskets<br>• Check the gasket mating surface | At a minimum, once a year.<br><br>* Items will require more frequent maintenance throughout production |

**BOX TEST (Cook et al. 2014)**

1. The equipment needed to run the test include:
    - 12 in high box form constructed to hold 12 in by 12 in square of fresh concrete
    - L-brackets to hold form together
    - Surface beneath the box test can be plywood or other material
    - 1 inch square head vibrator operating at 12,500 vibrations per minute

2. The following information should be known and reported:
    - Type of concrete, including cementitious material types and contents, water cement ratio, and other pertinent mixture design information.
    - Visual rating of voids
    - Edge or bottom slump

3. Prepare concrete in accordance with ASTM C192/C192M or obtain concrete from field source.

4. Construct the box and ensure clamps hold the sides together tightly.

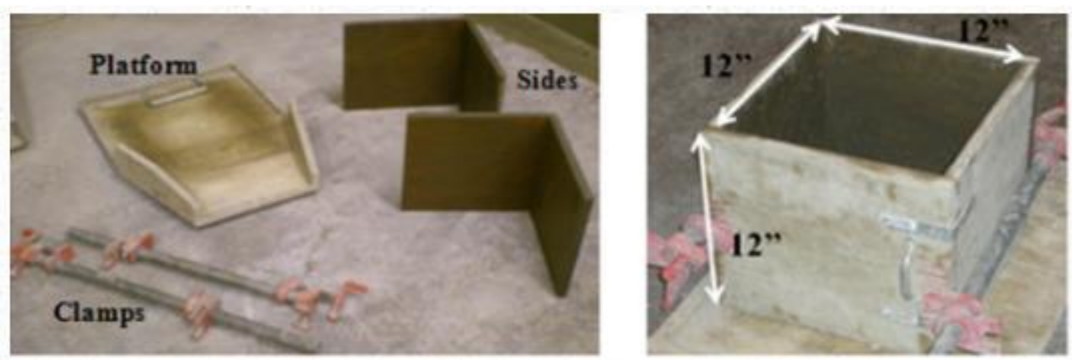


Figure 1: Box test components and dimensions (from www.tarantulacurve.com)

5. Scoop the concrete into the box form until the height is 9.5 inches (241.3 mm)

6. Insert the vibrator into the center of the concrete, moving downward for 3 seconds and upward for 3 seconds, removing it from the concrete (Figure 2).

Figure 2: Insertion and removal of vibrator from concrete (from www.tarantulacurve.com)

7. Remove the clamps from the forms and inspect the sides of the concrete for surface voids and edge slumping.

8.  The surface voids can be evaluated by visual ranking, using the following images, showing estimated percent of overall surface voids (Figure 1).

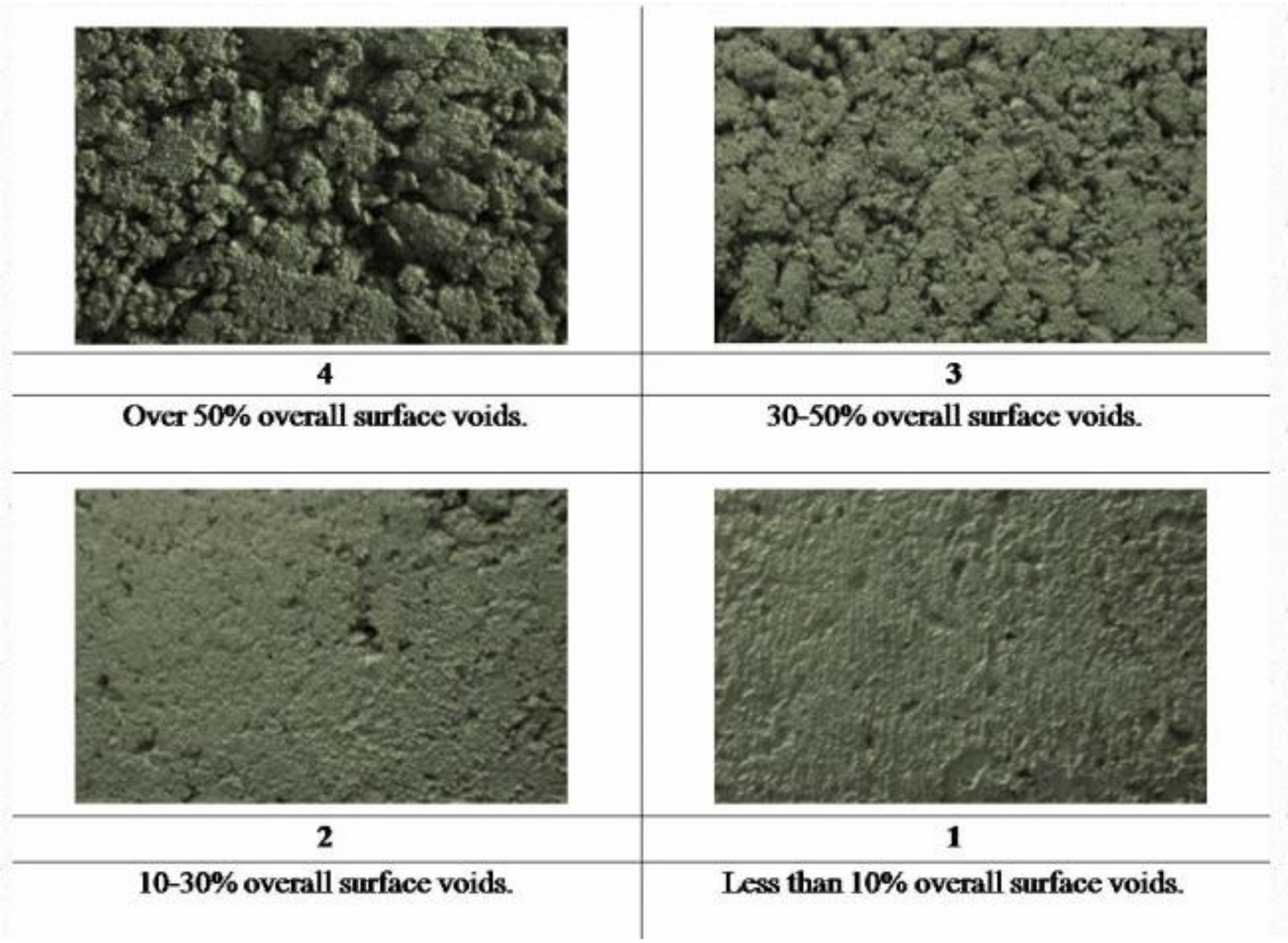


Figure 3: Estimated surface void percentages and ranking system (from www.tarantulacurve.com)

9. Bottom or edge slumping can be measured using a straightedge. Place the straightedge at the corner of the concrete and extend a tape measure horizontally to find the length at the greatest extruding point of concrete.

Note: The Box Test procedure is described in detail in:
Cook, M.D., Ley, M.T., and Ghaeezadah, A. (2014). “A workability test for slip formed concrete pavements.” Construction and Building Materials. 68, 376-383.

## APPENDIX C –

## PRESENTATIONS SLIDES FOR WORKSHOP/SEMINAR on PEM

**Note: Presentations for three modules are provided**

**Workshop Module 1:**
**Overview of the Performance Engineered Mixtures (PEM) Initiative**

Module 1:

# Overview of the Performance Engineered Mixtures (PEM) Initiative

Tara Cavalline, PhD, PE
Brett Tempest, PhD, PE
University of North Carolina at Charlotte

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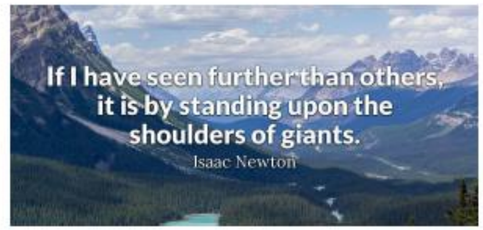
## Acknowledgements


- Cecil L. Jones, PE – Diversified Engineering Services, Inc.
- Peter Taylor, PhD, PE - National Concrete Pavement Technology Center
- Gordon L. Smith, PE – National Concrete Pavement Technology Center
- Tyler Ley, PhD, PE - Oklahoma State University
- Jason Weiss, PhD, PE – Oregon State University
- Tom Van Dam, PhD, PE - NCE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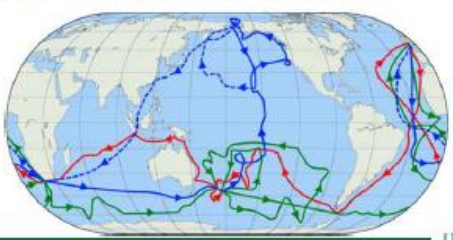
## PEM - The Path to Implementation

- What are Performance Engineered Mixtures (PEM) for concrete infrastructure?
- Why do we need to move towards PEM?
- Brief history of PEM initiative
- PEM specification basics
- Future plans for PEM - nationally
- Moving towards implementation in North Carolina



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## Concrete Technology Has Progressed

A very rough timeline:

- 1824 – 1900 – Portland cement invented, testing developed, early structures constructed
- 1913 – First ready-mixed concrete delivered
- 1920's – 1:2:3 mixtures
- 1930/40's – advances in equipment, mixture proportioning, major structures constructed
- 1940's – w/c ratio controlling water, slump test, entrained air
- 1950's – Advances in construction, equipment, admixtures
- 1980's – Supplementary cementitious materials
- 1990's – High-performance concrete
- 2000's – Increased emphasis on durability and sustainability

BUT – we have also seen:
Changes in construction delivery systems, accelerated construction, funding, TRAFFIC

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## How did we get here?

Concrete materials/mixtures have evolved slowly
BUT
construction has changed

Tests for specification and acceptance of concrete typically center around three criteria:

- Slump
- Air content
- Strength

These test results historically do not correlate well with durable performance over the service life

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Joint issues, early age cracking, incremental cracking, cold-weather durability issues... and more

"We keep measuring the same old things, and we still get cracking and other durability problems arising."

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## Current specifications typically:

- Do <u>not</u> measure critical engineering parameters associated with durability
- Make changing materials and proportions difficult
- Result in mixtures that are often:
  - Over-cemented
  - High paste contents
- Are often built around previous failures – thereby introducing unintended consequences.

For the contractor and supplier: innovation is often stifled

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## Why are PEM specifications needed?

- Concrete infrastructure has not always performed as designed.
- Premature distress in concrete elements has become more severe with changes in cements, SCMs, and winter maintenance practices.
- Economic and policy environment has driven the need to shift to more durable infrastructure
  - Must reduce maintenance cost and frequency
  - Reduce replacement costs
  - MAP-21 legislation focus on performance, sustainability

PEM specifications foster: durability, innovation, and sustainability

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## Progress over the last 30+ years

- Improvements in materials selection/use selection
- Better understanding of deterioration mechanisms and mitigation strategies
- New testing technologies

We have a gained a far better understanding of the:

Materials
Mixture proportions, and
Tests

required to specify and construct durable concrete.

... but specifications have not kept up.

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## What is Performance-Engineered Concrete?

1) Is workable / constructable
2) Provides adequate strength
3) Provides the desired durability performance

4) Achieves other desired special properties or performance requirements

   – Sustainability goals
   – Service life / maintenance goals
   – Addresses construction challenges
     - Pumpable
     - Flowable
     - Temperature issues

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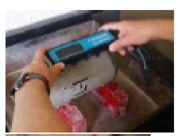
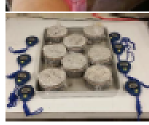
## What does Performance-Engineered Concrete need?

**Appropriate material selection/proportioning**

- Appropriate cement contents
- Lower paste contents
- Use of SCMs
  - fly ash
  - portland limestone cement
  - slag
- Stable (non-reactive) aggregates
- Optimized aggregate gradation
- Materials/mixtures that provide:
  - workability/strength
  - reduced permeability
  - reduced cracking/curling
  - freeze-thaw durability

**Tests for enhanced acceptance criteria**





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## PEM Goals

**PEM initiative <u>challenges</u> state agencies to:**

- Identify the performance characteristics and properties that are desired
- Specify, measure, and accept based on these characteristics
- Measure the right things at the right times

Don't specify/test for everything – just the <u>right</u> things...

What performance do you need from this element?

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## Preventing issues, rather than spending money/efforts monitoring or addressing them

Drilled powder samples tested for chloride content

vs.

Resistivity testing for mixture acceptance

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*Moving towards performance specifications, an agency lets the contractor know what is needed for a particular concrete element, and allows the contractor to innovate and meet the performance test requirements with minimal prescriptive direction.*


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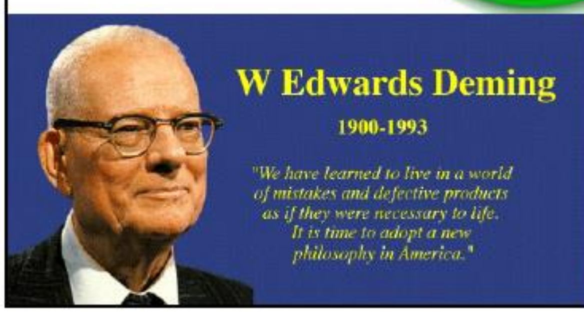
PEM initiative also includes an increased emphasis on Quality Control

**Deming Cycle**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## Prescriptive Specifications

Sometimes called:

- methods specifications
- materials and methods specifications
- "recipe" specifications (for construction materials)


Tells contractor what to do, or how to do something

- Method specifications

Tells contractor what to use.

- Materials specifications

"Specifications that direct the contractor to use specified materials in definite proportions and specific types of equipment and methods to place the material." - from NCHRP Synthesis 346.

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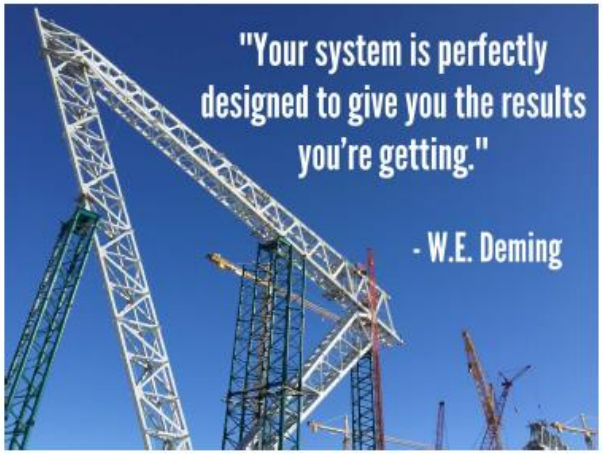


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## Performance Specifications

Also called:

- Performance-based specifications (PBS)
- End result specifications (ERS)

Instead of telling contractor (or material supplier, etc.) how to do something or what to do, provides minimum standard of performance for completed product/service.

"Specifications that describe how the finished product should perform over time." - NCHRP Synthesis 346

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## P2P Initiative

P2P INITIATIVE

National Ready Mixed Concrete Association (NRMCA)

P2P = Prescriptive Specifications to Performance Specifications

"A shift to performance-based specifications for concrete focuses on innovation, quality and customer satisfaction."

www.nrmca.org/p2p



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## PEM Specifications for Concrete

Require the things that matter:

- fluid transport properties (low permeability/diffusion)
- aggregate stability
- strength
- freeze-thaw resistance
- resistance to shrinkage cracking
- workability

The needed performance for these characteristics varies by application...

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## This can seem a bit scary…

- Where would an agency even start?
- We aren't familiar with some of these tests…
- Agencies and industries will be learning at the same time…
- What will be the attitudes of the stakeholders?
- How can we balance the risk?
- Ongoing advances in research, testing, performance evaluation…

How about an example of another state agency's path towards PEM


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## Minnesota Paving Specifications

| Pre 1995 | Post 1995 |
|---|---|
| Typical w/c ratio – 0.46 | w/c ratio ≤ 0.40 |
| Min Cement – 450 lb | Min Cement – 400 lb |
| Min Cementitious – 530 lb | Min Cementitious – 530 lb |
| 15% fly ash allowed | Max Cementitious – 600 lb |
| No admixtures allowed | 30% max fly ash allowed |
| Air Content – 5.5% ± 1.5% | Admixtures allowed |
| | Air Content – 7.0% ± 1.5% (≥ 5.0 behind paver) |

(from Maria Masten, MnDOT 2016)

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## GOALS OF WATER/CEMENTITIOUS INCENTIVES

- Make concrete more durable by reducing permeability and thus make it more freeze-thaw resistant and less susceptible to aggregate deteriorations.
- Reduce w/c by taking out water, not by increasing cementitious content.

(from Maria Masten, MnDOT 2016)

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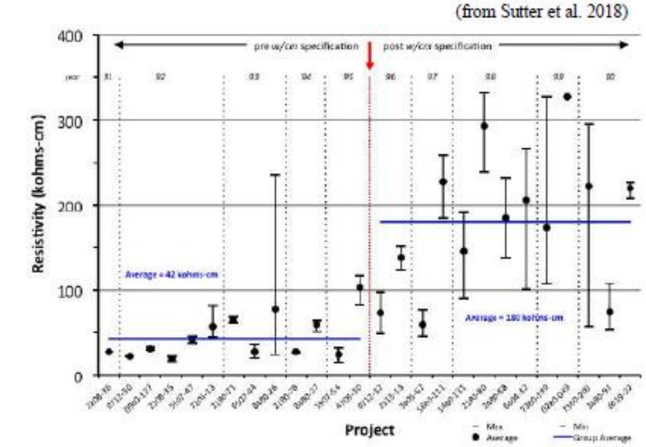
Change successfully implemented can bring great benefits…

(from Sutter et al. 2018)

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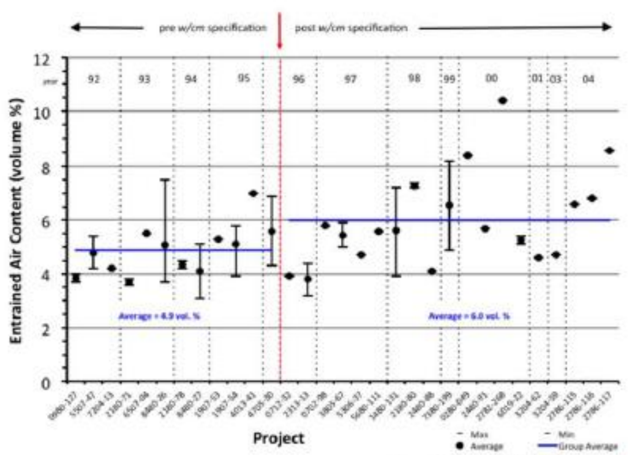


(from Sutter et al. 2018)

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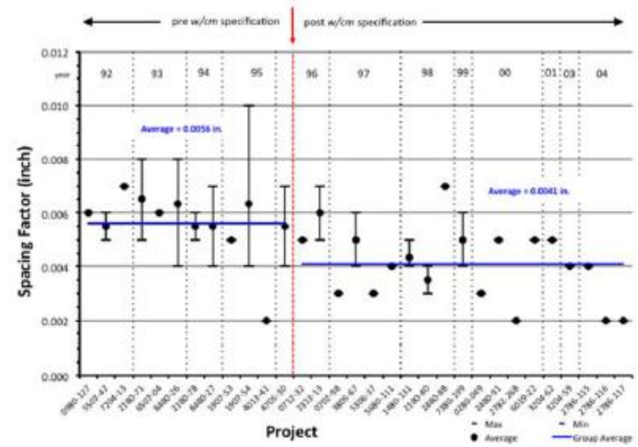


(from Sutter et al. 2018)

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## PEM - Partners in Implementation

Development Team

- Dr. Peter Taylor, Director CP Tech Center
- Cecil Jones, Diversified Engineering Services, Inc.
- Dr. Jason Weiss, Oregon State University
- Dr. Tyler Ley, Oklahoma State University
- Dr. Tom VanDam, NCE
- Mike Praul, FHWA
- Tom Cackler, CP Tech Center

PEM Expert Task Group formed in 2013 through National Concrete Consortium

Industry Participants/Reviewers

- Champion States & ACPA Chapter Execs
- ACPA National
- PCA
- NRMCA
- Others

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## PEM Initiative – The Vision

Concrete Mixtures that are **engineered** to meet or exceed the design requirement, are predictably durable, with increased sustainability.

Keys:

- Design and field control of mixtures around engineering properties related to performance
- Development of practical specifications
- Incorporating this knowledge into an implementation system (Design, Materials, Construction, Maintenance).
- Is validated and refined by performance monitoring

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## FHWA's PEM Initiative
## - The Path to Implementation

### What has been accomplished:

1. New testing technologies that measure properties related to critical engineering properties have been integrated into a specification framework – AASHTO PP 84
2. Ongoing evaluation of new test methods has been supported
3. Transportation Pooled Fund (TPF) established to assist DOTs with implementation
4. AASHTO voted to approve a PEM standard, serving as a guide specification for PEM (since revised twice)
5. FHWA Implementation Funds to support states
6. Many state agencies moving forward with a variety of approaches

YOU ARE HERE

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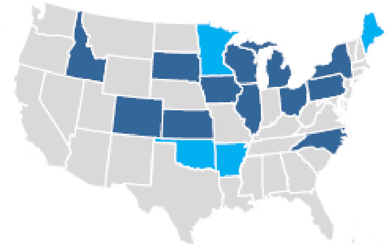
## PEM Pooled Fund - TPF-5(368)
## The Path to Implementation

Provide technical support for performance approach to concrete

- Introduce PEM and a performance approach to concrete acceptance programs
- Provide additional guidance on new PP 84 tests/implementation
- Develop quality control guidance (aimed at industry)
- Incentive Fund Program
- Support PEM with Mobile Concrete Trailer

12 States + FHWA & Industry
(August 2017)



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## PEM Pooled Fund Work Tasks

**Phase 1**

- 5 years (2017-2021)
- $3 million
  - FHWA $200k/year = $1M
  - DOTs 14@$15k/year = $1.05M
  - Industry $200k/year = $1M

- Implementing what we know: Education, Training & Technical Support
- Performance monitoring and specification refinement
- Measuring and relating early age concrete properties to performance

**Phase 2**

to support performance monitoring

- 5 years (2022-2026)
- $ TBD

New products/tools:

- Guidance on use of QC programs, QC plans, QC test data
- Model QC plan and implementation tools
- PEM Tech Tools – videos, one-pagers
- E-training and live training
- More

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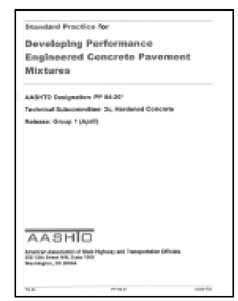
## AASHTO PP 84-20(+)

### Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures

- Guide Specification
- A "sufficient start" in 2017
- Revised 2018/2019/2020...
- Provisional = meaning we can modify as we learn things
- Evolving as we speak...




Provides guidance to move towards better, more performance-related specifications

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## Closing Thoughts

- Movement towards PEM will help us specify and construct the infrastructure we need for the 21st century and beyond.
- Everyone can benefit from PEM
  - Agency, contractor, industry, public
  - "concrete that delivers what is needed"
    - efficiently (cost, environmental impact)
    - reliably
- Balancing risk / reward
- QC is big part of PEM Implementation

Quantifying benefits of PEM implementation is a key goal
- Benefits to contractor
- Benefits to agency

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## PEM Resources

Tech Center

PEM Resource Repository at
National Concrete Pavement Technology Center Website
https://cptechcenter.org/performance-engineered-mixtures-pem/

FHWA video on PEM
https://www.youtube.com/watch?v=tXb4f7bCYs8

UNC Charlotte Research Reports
https://connect.ncdot.gov/projects/research/
RP 2011-06, 2015-03, 2016-06, 2018-14

NCDOT PEM Implementation Project – I-85 Widening
https://intrans.iastate.edu/app/uploads/sites/7/2020/05/Post-Construction-Report-for-North-Carolina-DOT-Demonstration-Project-05-14-2020.pdf

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## Acknowledgements

- Chris Peoples, Brian Hunter, Aaron Earwood and many others at NCDOT
- Steering and Implementation Committees for RP 2011-06, RP 2015-03, RP 2016-06, RP 2018-14, RP 2019-17, and several technical assistance programs
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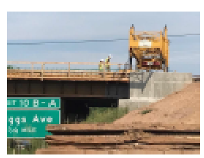
- Blake Biggers, Austin Lukavsky, Ross Newsome, Memoree McEntyre
- Peter Theilgard, Joe OCampo, Allison Summers
- Wes Maxwell, Research Operations Manager
- CP Tech Center and PEM Pooled Fund Study Team
- Cecil Jones
- Chris Ange and Fred White, Lane Construction
- Sam Lenoble, Blythe Construction
- Adam Neuwald, Concrete Supply
- Gina Ahlstrom and Mike Praul, FHWA
- Many folks who continue to donated materials
  - a continued THANK YOU!!!



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**Workshop Module 2:**
**Overview of AASHTO PP 84 for Performance Engineered Concrete Mixtures (PEM)**

Module 2:

# Overview of AASHTO PP 84

## for Performance Engineered Concrete Mixtures (PEM)

Tara Cavalline, PhD, PE
Brett Tempest, PhD, PE
University of North Carolina at Charlotte

1

## What is Performance Engineered Concrete?

- Concrete that does what you want it to do:
  - during construction (workable and constructable)
  - over the service life (adequate strength and good durability performance)
- Meets other needs
  - construction challenges
    - pumpable
    - highly flowable
    - high early strength
    - many other kinds of project-specific needs
  - sustainability goals
    - lower emissions/carbon footprint
    - use of recycled materials
    - use of local materials

Moving specifications away from slump, strength, and air content...

and towards materials and tests that support long term performance.

2

## What does Performance-Engineered Concrete need?

**Appropriate material selection/proportioning**

- Appropriate cement contents
- Lower paste contents
- Use of SCMs
  - fly ash
  - portland limestone cement
  - slag
- Stable (non-reactive) aggregates
- Optimized aggregate gradation
- Materials/mixtures that provide:
  - workability/strength
  - reduced permeability
  - reduced cracking/curling
  - freeze-thaw durability

**Tests for enhanced acceptance criteria**

3

## PEM Goals

**PEM initiative <u>challenges</u> state agencies to:**

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What performance do you need from this element?

4

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# AASHTO PP 84-20(+)

## Standard Practice for Developing Performance Engineered Concrete Pavement Mixtures

- Guide Specification
- A "sufficient start" in 2017
- Revised 2018/2019/2020…
- Provisional = meaning we can modify as we learn things
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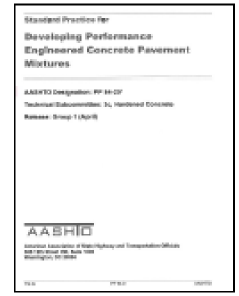


Provides guidance to move towards better, more performance-related specifications

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# PEM starts with a Better Specification

Specification framework:

Measure the right things at the right time

- Prequalification
- Process control
- Acceptance

A "buffet" or "menu" of approaches for agency to chose from

- Intended to work for SHAs and local agencies
- Intended to respect organizational traditions while offering performance options

Table 2 – Specification Worksheet of AASHTO PP 84

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# AASHTO PP 84 (2020)

## Table 2 – Specification Worksheet for Mixture Proportioning

| Section | Property | Specified Test | Specified Value | | Mixture Qualification | Acceptance | Selection Details | Special Notes |
|---|---|---|---|---|---|---|---|---|
| 6.3 Concrete Strength | | | | | | | | |
| 6.3.1 | Flexural Strength | T 97 | 4.1 MPa | 600 psi | Yes | Yes | Choose either or both | — |
| 6.3.2 | Compressive Strength | T 22 | 27.5 MPa | 4000 psi | Yes | Yes | | — |
| 6.4 Reducing Unwanted Slab Warping and Cracking Due to Shrinkage (if cracking is a concern) | | | | | | | | |
| 6.4.1.1 | Volume of Paste | — | ≤25% | | Yes | No | Choose only one | — |
| 6.4.1.2 | Unrestrained Volume Change | T 160 | 420 με | At 28 days | Yes | No | | |
| 6.4.2.2 | Unrestrained Volume Change | T 160 | 360, 420, 480 με | At 91 days | Yes | No | | — |
| 6.4.2.1.1 | Restrained Volume Change | T 334 | No cracking | At 180 days | Yes | No | | |
| 6.4.2.1.2 | Restrained Volume Change | T 363 | <60% f'r | At 7 Days | Yes | No | | |
| 6.5 Durability of Hydrated Cement Paste for Freeze–Thaw Durability | | | | | | | | |
| 6.5.1.1 | Water to Cementitious Ratio | — | 0.45 | — | Yes | Yes | a | — |
| 6.5.1.2 | Fresh Air Content | T 152, T 196, TP 118 | 5 to 8% | — | Yes | Yes | Choose only one | — |
| 6.5.1.3 | Fresh Air Content/SAM | T 152, T 196, TP 118 | ≥4%, ≤0.20 | — | Yes | Yes | | — |
| 6.5.2.1 | Time of Critical Saturation | ASTM C1585 | 30 | yr | Yes | No | a, b | Variation controlled with mixture proportion observation or $F_{app}$ and porosity measures |
| 6.5.3.1 | Deicing Salt Damage | — | 30% | SCM | Yes | Yes | Choose only one if concrete will be exposed to deicing salts | Are calcium or magnesium chloride used |
| 6.5.3.2 | Deicing Salt Damage | M 224 | — | Topical treatment | Yes | Yes | | Are calcium or magnesium chloride used, use specified sealers |
| 6.5.4.1 | Calcium Oxychloride Limit | T 365 | <0.15 g CaOXY/100g paste | | Yes | No | | Are calcium or magnesium chloride used |
| 6.6 Transport Properties | | | | | | | | |
| 6.6.1.1 | Water to Cementitious Ratio | — | ≤0.45 or ≤0.50 | 91 days | Yes | Yes | Choose only one | The required maximum water to cementitious ratio is selected based on the exposure conditions |
| 6.6.1.2 | Apparent F Factor ($F_{app}$) | TP 119, T 358 | ≥500 or ≥1000 | 91 days | Yes | Yes | | Based on the exposure conditions, other criteria could be selected |
| 6.6.2.1 | Apparent F Factor ($F_{app}$) | TP 119 | 25 mm at 30 yr | 91 days | Yes, F | Through ρ | | Determined using guidance provided in 6.6.2 |
| 6.7 Aggregate Stability | | | | | | | | |
| 6.7.1 | D-Cracking | ASTM C666, T 161 | — | — | Yes | No | | Procedure A |
| 6.7.2 | Alkali Aggregate Reactivity | R 80 | — | — | Yes | No | | — |
| 6.8 Workability | | | | | | | | |
| 6.8.1 | Box Test | AASHTO TP 137 | <6.25 mm, <30% surface void | | | No | | — |
| 6.8.2 | Modified VKelly Test | TP 129 | 15–30 mm/√s | | | No | | — |

Notes:

a Choose either 6.5.1.1 or 6.5.2.

b Choose either 6.5.1.2, 6.5.1.3, or 6.5.2.1.

c Note other ages can be used if desired however for SCM sufficient time should be provided for the pozzolanic reaction

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## PEM Mixture Design Parameters

Test the things that matter!

- Strength
- Cracking tendency (dimensional stability)
- Freeze-Thaw durability
- Resistance to Fluid Transport
- Aggregate stability
- Workability

Performance and prescriptive options for each, except strength

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## AASHTO PP 84-20 Scope

- Facilitates movement toward specifying the performance characteristics – shifting responsibility and providing opportunity for innovation.
- Highlights test methods and values
- Agency traditions of using prescriptive methods respected
- Intended to provide flexibility for agency
- Sets values at 30 years performance level
- Notes that inclusion of performance measures increases the importance of Quality Control (QC)

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## AASHTO PP 84 (2017, 2018, 2019, 2020...) Performance Engineered Concrete Pavement Mixtures

*"A group of senior experts representing agencies, industry and academia met at two FHWA sponsored events and agreed that the following parameters that should be addressed in a materials specification."*

- *Sufficient strength*
- *Low risk of cracking and warping due to drying shrinkage*
- *Durable (freeze-thaw resistance)*
- *Durable (resistance to chemical deicers)*
- *Durable (low absorption, diffusion, and other transport related properties)*
- *Durable (aggregate stability)*
- *Workable*

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## Specification Basics

- Specification describes process and choices
  - Includes acceptance requirements
  - Includes quality control provisions
- Requires contractor to submit a Quality Control Plan to be approved
  - Minimum requirements listed
- Provides guidance for QC
  - Requires QC testing and control charts
  - Testing targets, frequency, and action limits
  - Guidance expands on this

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## Various Approaches/Test Methods Included

| Section | Property | Specified Test | Specified Value | Mixture Qualification | Acceptance | Selection Details | Special Notes |
|---|---|---|---|---|---|---|---|
| 6.3 Concrete Strength | | | | | | | |
| | | | | | | | |
| 6.4 Reducing Unwanted Slab Warping and Cracking Due to Shrinkage (If Cracking is a Concern) | | | | | | | |
| | | | | | | | |
| 6.5 Durability of Hydrated Cement Paste for Freeze-Thaw Durability | | | | | | | |
| | | | | | | | |
| 6.6 Transport Properties | | | | | | | |
| | | | | | | | |
| 6.7 Aggregate Stability | | | | | | | |
| | | | | | | | |
| 6.8 Workability | | | | | | | |
| | | | | | | | |



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## Specification Basics - Strength

| Section | Property | Specified Test | Specified Value | Mixture Qualification | Acceptance | Selection Details | Special Notes |
|---|---|---|---|---|---|---|---|
| 6.3 Concrete Strength | | | | | | | |
| 6.3.1 | Flexural Strength | AASHTO T 97 | 4.1 MPa (600 psi) | Yes | Yes | Choose either or both | --- |
| 6.3.2 | Compressive Strength | AASHTO T 22 | 27.5 MPa (4000 psi) | Yes | Yes | | --- |

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## Specification Basics – Warping and Cracking

| Section | Property | Specified Test | Specified Value | Mixture Qualification | Acceptance | Selection Details | Special Notes |
|---|---|---|---|---|---|---|---|
| 6.4 Reducing Unwanted Slab Warping and Cracking Due to Shrinkage (If Cracking is a Concern) | | | | | | | |
| 6.4.1.1 | Volume of Paste | | ≤ 25% | Yes | No | Choose only one | |
| 6.4.1.2 | Unrestrained Volume Change | ASTM C157 | 420 με (28 days) | Yes | No | | |
| 6.4.2.1 | Unrestrained Volume Change | ASTM C157 | 360, 420 480 με (91 days) | Yes | No | | |
| 6.4.2.2 | Unrestrained Volume Change | AASHTO T 334 | No cracking (180 days) | Yes | No | | |
| 6.4.2.3 | Restrained Volume Change | AASHTO T363 | σ < 60% f'r (7 days) | Yes | No | | |

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## Specification Basics – Paste F-T Durability

| Section | Property | Specified Test | Specified Value | Mixture Qualification | Acceptance | Selection Details | Special Notes |
|---|---|---|---|---|---|---|---|
| 6.5 Durability of Hydrated Cement Paste for Freeze-Thaw Durability | | | | | | | |
| 6.5.1.1 | Water to Cementitious Ratio | --- | 0.45 | Yes | Yes | Choose Either 6.5.1.1 or 6.5.2.1 | --- |
| 6.5.1.2 | Fresh Air Content | AASHTO T 152, T 196, TP 118 | 5 to 8 | Yes | Yes | Chose only one | |
| 6.5.1.3 | Fresh Air Content/SAM | AASHTO T 152, T 196, TP 118 | ≥ 4% Air; SAM ≤ 0.2 | Yes | Yes | | |
| 6.5.2.1 | Time of Critical Saturation | ASTM C1585 | 30 | Yes | No | Choose either 6.5.1.2, 6.5.1.3, or 6.5.2.1 | Variation controlled w/several measures |
| 6.5.3.1 | Deicing Salt Damage | --- | 35% | Yes | Yes | Choose only one | Ca/Mg Cl used? |
| 6.5.3.2 | Deicing Salt Damage | AASHTO M 224 | --- | Yes | Yes | | Ca/Mg Cl used? Sealers |
| 6.5.4.1 | Calcium Oxychloride Limit | AASHTO T365 | < 0.15g CaOXY/g paste | Yes | No | | Ca/Mg Cl used? |

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## Specification Basics – Transport Properties

| Section | Property | Specified Test | Specified Value | Mixture Qualification | Acceptance | Selection Details | Special Notes |
|---|---|---|---|---|---|---|---|
| 6.6 Transport Properties | | | | | | | |
| 6.6.1.1 | w/cm ratio | --- | ≤ 0.45 or ≤ 0.50 | Yes | Yes | Choose only one | based on F/T conditions |
| 6.6.1.2 | Formation Factor | Table 1 | ≥ 500 or ≥ 1000 | Yes | Yes | | F/T conditions, others possible |
| 6.6.2.1 | Ionic Penetration, F Factor | Appendix X2 | 25 mm at 30 yr | Yes, F | Through ρ | | Appendix X2 guidance |

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## Specification Basics – Aggregate Stability

| Section | Property | Specified Test | Specified Value | Mixture Qualification | Acceptance | Selection Details | Special Notes |
|---|---|---|---|---|---|---|---|
| 6.7 Aggregate Stability | | | | | | | |
| 6.7.1 | D-Cracking | AASHTO T 161, ASTM C 1646 | --- | Yes | No | --- | --- |
| 6.7.2 | Alkali-Aggregate Reactivity | AASHTO R 80 | --- | Yes | No | | --- |

Standard Practice for

**Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction**

AASHTO Designation: ~~PP 65-11~~ → AASHTO R 80-17

AASHTO

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## Specification Basics – Workability

| Section | Property | Specified Test | Specified Value | Mixture Qualification | Acceptance | Selection Details | Special Notes |
|---|---|---|---|---|---|---|---|
| 6.8 Workability | | | | | | | |
| 6.8.1 | Box Test | Appendix X3 | <6.25 mm, < 30% Surf. Void | --- | Yes | --- | --- |
| 6.8.2 | Modified V-Kelly Test | AASHTO TP 129 | 15-30 mm per root seconds | --- | Yes | | --- |

Hey! Where is slump?

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## New and Emerging Test Methods

- Information in the Appendices of AASHTO PP 84
  - Cracking and volume change
  - Formation factor and pore solution resistivity
  - Box test
  - V-Kelly test
  - Bucket test
  - Transport and pore structure… and more!

Simplified procedures for NCDOT's targeted PEM technologies have been prepared

along with…
- Commentary
- Detailed discussion of each section
- References for more detailed background

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# PEM Resources

PEM Resource Repository at
National Concrete Pavement Technology Center Website

https://cptechcenter.org/performance-engineered-mixtures-pem/

FHWA video on PEM

https://www.youtube.com/watch?v=tXb4f7bCYs8

UNC Charlotte Research Reports

https://connect.ncdot.gov/projects/research/
RP 2011-06, 2015-03, 2016-06, 2018-14

NCDOT PEM Implementation Project – I-85 Widening
https://intrans.iastate.edu/app/uploads/sites/7/2020/05/Post-Construction-Report-for-North-Carolina-DOT-Demonstration-Project-05-14-2020.pdf

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# Acknowledgements

- Chris Peoples, Brian Hunter, Aaron Earwood and many others at NCDOT
- Steering and Implementation Committees for RP 2011-06, RP 2015-03, RP 2016-06, RP 2018-14, RP 2019-17, and several technical assistance programs
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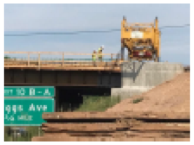
- Sam Lenoble, Blythe Construction
- Adam Neuwald, Concrete Supply
- Gina Ahlstrom and Mike Praul, FHWA
- Many folks who continue to donated materials
  - a continued THANK YOU!!!



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**Workshop Module 3:**
**NCDOT’s Initial Steps Towards Performance Engineered Concrete Mixtures (PEM)**

Module 3:

# NCDOT's Initial Steps Towards Performance Engineered Concrete Mixtures (PEM)

Tara Cavalline, PhD, PE
Brett Tempest, PhD, PE
University of North Carolina at Charlotte

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## What is Performance Engineered Concrete?

- Concrete that does what you want it to do:
  - during construction (workable and constructable)
  - over the service life (adequate strength and good durability performance)
- Meets other needs
  - construction challenges
    - pumpable
    - highly flowable
    - high early strength
    - many other kinds of project-specific needs
  - sustainability goals
    - lower emissions/carbon footprint
    - use of recycled materials
    - use of local materials

Moving specifications away from slump, strength, and air content...

and towards materials and tests that support long term performance.

2

## What does Performance-Engineered Concrete need?

Appropriate material selection/proportioning

- Appropriate cement contents
- Lower paste contents
- Use of SCMs
  - fly ash
  - portland limestone cement
  - slag
- Stable (non-reactive) aggregates
- Optimized aggregate gradation
- Materials/mixtures that provide:
  - workability/strength
  - reduced permeability
  - reduced cracking/curling
  - freeze-thaw durability

Tests for enhanced acceptance criteria

3

## FHWA's PEM Initiative - The Path to Implementation

•What has been accomplished:

1. New testing technologies that measure properties related to critical engineering properties have been integrated into a specification framework – AASHTO PP 84
2. Ongoing evaluation of new test methods has been supported
3. Transportation Pooled Fund (TPF) established to assist DOTs with implementation
4. AASHTO voted to approve a PEM standard, serving as a guide specification for PEM (since revised twice)
5. FHWA Implementation Funds to support states
6. Many state agencies moving forward with a variety of approaches

YOU ARE HERE

4

# This PEM thing sounds GREAT!

*But where (and how) would we even start?*

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## Background

- NCDOT specifications for concrete have changed little over the past 85 years
  - Prescriptive specification
  - Little room for innovation
  - Mixtures are often over-designed for strength, high cementitious/paste contents
- Resource reductions drive the need to reduce maintenance cost, increase service life
- NCDOT desires fly ash in most mixtures because of the benefits
  - Encounter fly ash shortage throughout the years
  - Need to find equivalent performance of mixtures without fly ash (in case of "what if" scenario)
- 2018 increased allowable fly ash substitution rate from 20% to 30%
  - Needed data to support/encourage use of higher substitution rate, account for slower early age strength gain
- Need data to support decision to allow use of portland limestone cement
  - PLC has lower carbon footprint (up to 15% reductions in GHG)

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TABLE 1000-1
REQUIREMENTS FOR CONCRETE

| Class of Concrete | Min. Comp. Strength at 28 days | Maximum Water-Cement Ratio | | | | Consistency Max. Slump | | Cement Content | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Air-Entrained Concrete | | Non Air-Entrained Concrete | | Vibrated | Non-Vibrated | Vibrated | | Non-Vibrated | |
| | | Rounded Aggregate | Angular Aggregate | Rounded Aggregate | Angular Aggregate | | | Min. | Max. | Min. | Max. |
| Units | psi | | | | | inch | inch | lb/cy | lb/cy | lb/cy | lb/cy |
| AA | 4,500 | 0.381 | 0.426 | - | - | 3.5 | - | 639 | 715 | - | - |
| AA Slip Form | 4,500 | 0.381 | 0.426 | - | - | 1.5 | - | 639 | 715 | - | - |
| Drilled Pier | 4,500 | - | - | 0.450 | 0.450 | - | 5-7 dry 7-9 wet | - | - | 640 | 800 |
| A | 3,000 | 0.488 | 0.532 | 0.550 | 0.594 | 3.5 | 4 | 564 | 677 | 602 | 682 |
| B | 2,500 | 0.488 | 0.567 | 0.559 | 0.630 | 2.5 | 4 | 508 | 600 | 545 | 654 |
| B Slip Formed | 2,500 | 0.488 | 0.567 | - | - | 1.5 | - | 508 | 600 | - | - |
| Sand Light-weight | 4,500 | - | 0.420 | - | - | 4 | - | 715 | 715 | - | - |
| Latex Modified | 3,000 7 day | 0.400 | 0.400 | - | - | 6 | - | 658 | 658 | - | - |
| Flowable Fill excavatable | 150 max. at 56 days | as needed | as needed | as needed | as needed | - | Flowable | - | - | 40 | 100 |
| Flowable Fill non-excavatable | 125 | as needed | as needed | as needed | as needed | - | Flowable | - | - | 100 | as needed |
| Pavement | 4,500 design, field 650 flexural, design only | 0.559 | 0.559 | - | - | 1.5 slip form 3.0 hand place | - | 526 | - | - | - |
| Precast | See Table 1077-1 | as needed | as needed | - | - | 6 | as needed | as needed | as needed | as needed | as needed |
| Prestress | per contract | See Table 1078-1 | See Table 1078-1 | - | - | 8 | - | 564 | as needed | - | - |

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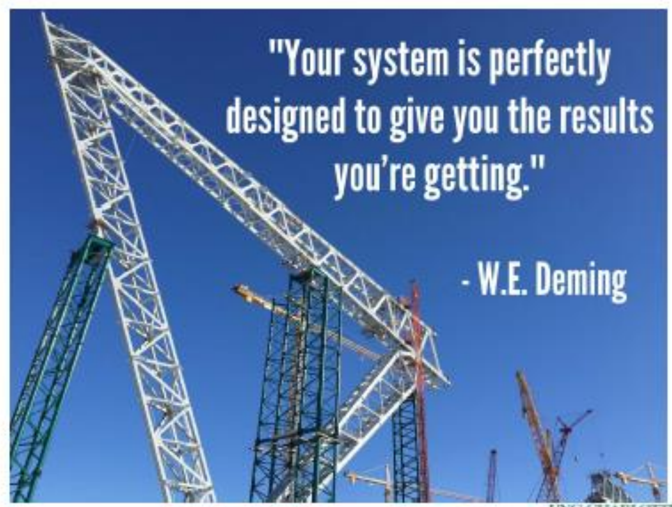


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## Implementation Considerations

- What concrete performance characteristic(s) do we want to improve?
- How much pushback (or support) from the industry can we expect?
- What are people willing to try?
- If we "put a toe in the water," what would that look like?

"The agency should make the choices that best fit their situation and willingness to share risk."

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## PEM for NCDOT

Motivations

- AASHTO PP 84 provides guidance for both prescriptive and performance options
- Emerging QA and QC testing technologies utilized in AASHTO PP 84 show promise when used as part of research projects

- Time for a change...

Changes in materials, need for flexibility and durable performance

- Moving towards use of portland limestone cements
- Increased use of fly ash
- Potential scarcity of fly ash
- Promising early age test results - resistivity / SAM

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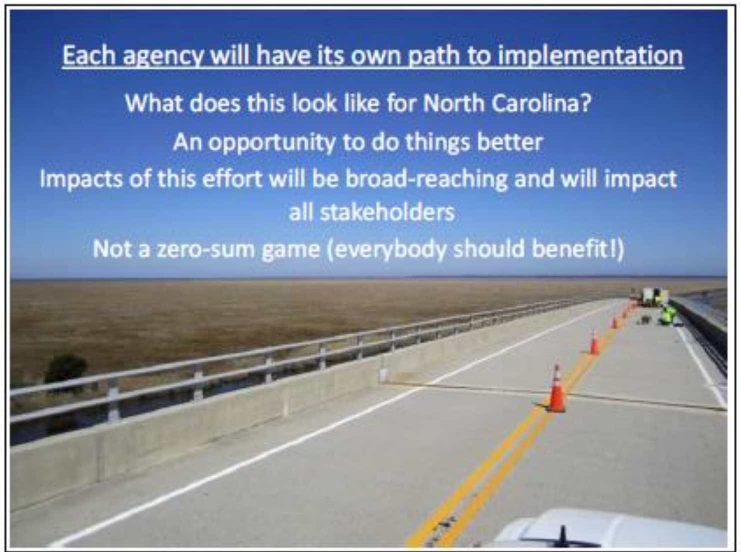


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## Overall Objectives – NCDOT's PEM initiatives

1. Establish preliminary specification recommendations, targets for selected PEM technologies and some prescriptive provisions
   - surface resistivity ✓
   - w/cm, cementitious content (prescriptive provisions) In progress
   - shrinkage ✓
   - SAM ✓
   - potentially other tests In progress
2. Explore ways to reduce paste/cement contents
   - optimized aggregate gradation
   - reduced cementitious contents In progress
3. Support pilot project implementation
   - pavement projects ✓
   - bridge projects
   - bridge deck overlay projects
4. Support technology transfer to NCDOT division/regional personnel as well as industry stakeholders

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## Projects Supporting PEM

**Previous/ongoing Research**

- Field study of bridge deck durability performance (RP 2011-06)
- Concrete inputs for MEPDG pavement design/analysis (RP 2015-03)
- Internal curing of concrete bridge decks (RP 2016-06)
- Technical Assistance Projects – SAM, pavement projects
- Corrosion policy evaluation for coastal bridges (RP 2019-22)

**Research Project 2018-14**

- Data analysis of current/past mixtures
- Laboratory evaluation to support identification of performance targets:
  - resistivity
  - SAM
  - shrinkage
- Develop shadow specifications/PSP
- Preliminary guidance on some prescriptive measures
- More data for 30% fly ash and PLC mixtures
- Developed "roadmap" for PEM

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## Projects Supporting PEM

**FHWA Implementation Funds**

- Supported contractor and NCDOT at pavement-focused PEM implementation project – I-85 in Rowan County
- Analyze QC/QA data from implementation project
- Developed tech transfer documents – test procedures for:
  - Surface resistivity
  - SAM
  - Shrinkage
  - Box Test
- development and delivery of seminar for NCDOT division/region personnel

**Research Project 2020-13**

- Laboratory evaluation to support identification and refinement of PEM performance targets:
  - increased SCM contents (up to 30% replacement)
  - optimized aggregate gradations (using intermediate aggregate)
  - carbon nanotubes (Edencrete)
- Guidance on prescriptive measures (w/cm, cementitious/paste contents)
- Pilot projects – bridge decks, other structural concrete, deck overlays
- Resources to support contractor QC

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## RP 2018-14 Project Objectives

1) Use existing data on concrete materials, mixtures, and field performance, to identify trends and link to unacceptable, acceptable, and excellent performance.

2) Perform laboratory testing of a broad matrix of conventional highway concrete mixtures, to establish performance-related criteria for selected tests + evaluate some existing prescriptive provisions:
   1) - Range of w/cm, range of cementitious materials contents
   2) - Representative materials for Piedmont region
   3) - Consistency in materials from previous studies to leverage data already obtained

3) Produce additional performance data on concrete containing PLC and fly ash
   - support a better understanding the potential enhanced durability and economy
   - provide additional justification for use.

4) Develop specification provisions for:
   - surface resistivity
   - shrinkage
   - early age strength for opening of pavements and bridge components

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## Data Analysis

Mixture Materials/Proportions (HiCAMS) → Link mixtures to Projects (HiCAMS) → Test Results (HiCAMS) → Field Performance (BMS/PMS Data)

- Identify trends in materials and proportions, and link to unacceptable, acceptable, and excellent QA/QC test performance
- Link mixture characteristics and QA/QC test results with field performance and observed condition data

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## What concrete are we placing and how is it doing?

1) Approved mixtures database: 18+ years (33,000+ mixtures)
- Focus on Class A/AA (structural) and pavement concrete
- Possibly precast/prestressed

2) Early age test data: strength, air content, slump

3) Asset management databases:
- Bridge Management System (BMS)
  - 36 years of NBI inspection data, plus some additional
  - 3 years of element-level data
- Pavement management system (PMS) – 25+ years of condition data

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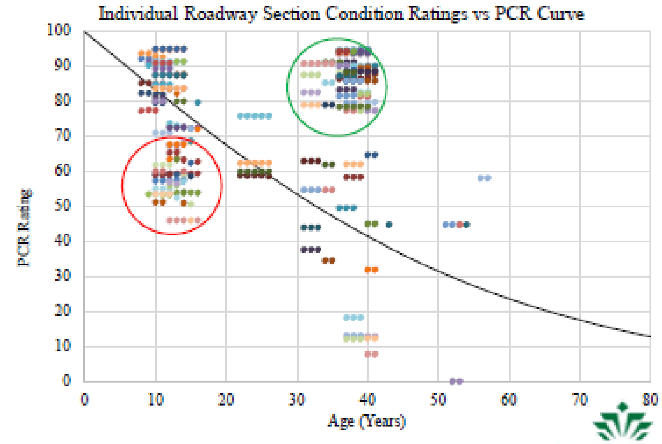
## Rigid pavement performance data

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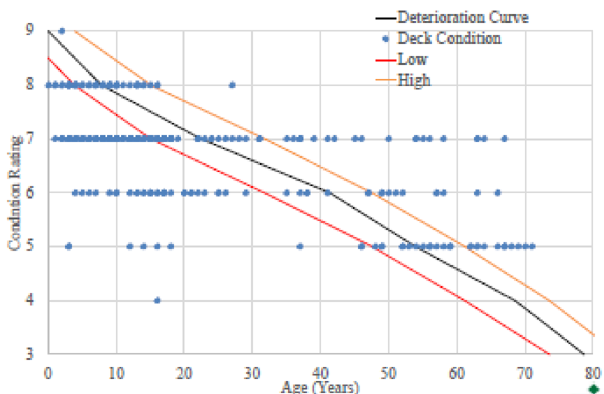
## Bridge performance data

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## Mixture Analysis Conclusions

- Within construction tolerances, the majority of mixes are within the required ranges for air content, slump, compressive strength, and/or flexural strength
- For the long-term performance of the bridge decks, the following are important:
  - Increased fly ash content
    - Over-performing bridges have higher mean and higher overall values
  - Increased Water Content and Paste Content were associated with better performance, however these are most likely proxy indicators of improved workability. Improving workability with reduced water and paste should be explored as a performance enhancement.
- Modifications to the pavement data gathering and storage are necessary to accurately conduct similar analysis for pavements

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## Targeted Laboratory Testing/Evaluation

Goal 1:

Establish performance-related criteria using several rapid, early age QA/QC tests to assess durability currently of interest to NCDOT.

Surface Resistivity, SAM

Goal 2:

Produce additional performance data on concrete containing PLC and fly ash (0%, 20%, 30%)

- better understanding the potential enhanced durability/economy
- provide additional justification for use.

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## PEM Laboratory Program

Differences in:

- Materials
- Exposure conditions
- Construction

Strategic selection of materials/mixture proportions

- Review of approved mixtures/sources
- Representative cement/fly ash sources
- Piedmont coarse aggregate, natural and/or manufactured sand

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## Mixture Matrix

| Mixture ID W-XXX-YYY, where W is w/cm ratio, XXX is cement content, YYY is fly ash content | Mixture Characteristics | | | Mixture Proportions, pcy | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mixture type | Cement type | w/cm | Fly ash replacement (%) | Cement | Fly ash | Coarse aggregate | Fine aggregate | Water |
| H-700-0 | AA (high and medium cm content) | OPC | 0.47 | 0 | 700 | 0 | 1659 | 1072 | 329.0 |
| H-560-140 | | | | 20 | 560 | 140 | 1659 | 1022 | 329.0 |
| H-650-0 | | | | 0 | 650 | 0 | 1659 | 1175 | 305.5 |
| H-520-130 | | | | 20 | 520 | 130 | 1659 | 1129 | 305.5 |
| H-600-0 | | | | 0 | 600 | 0 | 1659 | 1277 | 282.0 |
| H-480-120 | | | | 20 | 480 | 120 | 1659 | 1235 | 282.0 |
| H-420-180 | | | | 30 | 420 | 180 | 1659 | 1214 | 282.0 |
| M-700-0 | | | 0.42 | 0 | 700 | 0 | 1659 | 1163 | 294.0 |
| M-560-140 | | | | 20 | 560 | 140 | 1659 | 1114 | 294.0 |
| M-650-0 | | | | 0 | 650 | 0 | 1659 | 1259 | 273.0 |
| M-520-130 | | | | 20 | 520 | 130 | 1659 | 1214 | 273.0 |
| M-600-0 | | | | 0 | 600 | 0 | 1659 | 1356 | 252.0 |
| M-480-120 | | | | 20 | 480 | 120 | 1659 | 1313 | 252.0 |
| M-420-180 | | | | 30 | 420 | 180 | 1659 | 1292 | 252.0 |
| M-600P-0 | | PLC | | 0 | 600 | 0 | 1659 | 1356 | 252.0 |
| M-480P-120 | | | | 20 | 480 | 120 | 1659 | 1313 | 252.0 |
| M-420P-180 | | | | 30 | 420 | 180 | 1659 | 1292 | 252.0 |
| L-700-0 | AA (low cm content) and Pavement | OPC | 0.37 | 0 | 700 | 0 | 1659 | 1254 | 259.0 |
| L-560-140 | | | | 20 | 560 | 140 | 1659 | 1205 | 259.0 |
| L-650-0 | | | | 0 | 650 | 0 | 1659 | 1344 | 240.0 |
| L-520-130 | | | | 20 | 520 | 130 | 1659 | 1298 | 240.0 |
| L-600-0 | | | | 0 | 600 | 0 | 1659 | 1434 | 222.0 |
| L-480-120 | | | | 20 | 480 | 120 | 1659 | 1392 | 222.0 |
| L-420-180 | | | | 30 | 420 | 180 | 1659 | 1370 | 222.0 |

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## Testing Program

| | Test name | Standard | Testing age(s) in days | Replicates |
|---|---|---|---|---|
| Fresh | Air content | ASTM C231 | Fresh | 1 |
| | SAM number | AASHTO TP 118 | Fresh | 2 |
| | Slump | ASTM C143 | Fresh | 1 |
| | Fresh density (unit weight) | ASTM C138 | Fresh | 1 |
| | Temperature | AASHTO T 309 | Fresh | 1 |
| Hardened | Compressive strength | ASTM C39 | 3, 7, 28, 56, 90 | 3 each age |
| | Modulus of rupture (MOR, or flexural strength) | ASTM C78 | 28 | 2 |
| | Modulus of elasticity (MOE) and Poisson's ratio | ASTM C469 | 28 | 2 |
| | Resistivity | AASHTO T 358 | 3, 7, 28, 56, 90 | 3 each age |
| | Formation factor (via Bucket Test) | Protocol by J. Weiss, Oregon State University (Weiss 2018) | 35 | 2 |
| | Shrinkage | ASTM C157 | Per standard | 3 |
| | Rapid chloride permeability | ASTM C1202 | 28, 90 | 2 |

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## RP 2018-14 Outcomes

This project provided:

- Insight into "what concrete mixtures are being used, how they are doing"
  - Statistical analysis identifying mixture parameters that are linked to performance
- Data to support increased use of fly ash at higher rates, PLC
- Data to support identification of performance targets for:
  - surface resistivity
  - early age strength for opening to traffic
  - shrinkage
- Recommended specification provisions for:
  - surface resistivity
  - early age strength for opening to traffic
  - shrinkage
- Additional data to support SAM specification recommendations

Ready for use as shadow specifications in upcoming pilot projects

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## Surface Resistivity (AASHTO T 358)

- Quick, easy durability measurement on cylinders you're already making and testing
- Strongly correlates to the rapid chloride permeability test (AASHTO T 277, ASTM C 1202)
- Several states already specify (Louisiana DOTD, NYSDOT, others)
- AASHTO PP 84 suggests use of Formation Factor
  - F = resistivity of bulk concrete / resistivity of pore solution
  - helps account for pore solution chemistry
  - "Bucket test" – trials ongoing

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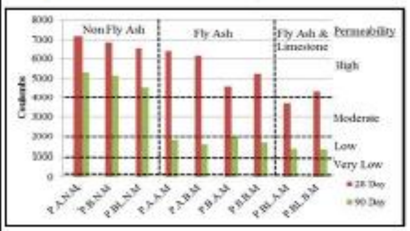
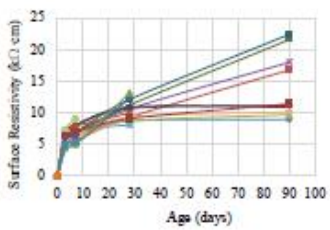
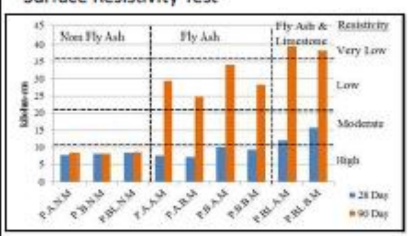
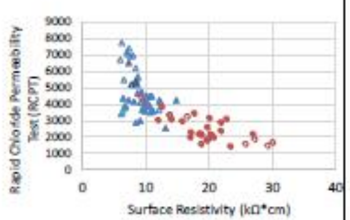
Rapid Chloride Permeability Test




Surface Resistivity Test

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## Development of a Surface Resistivity Specification

- Surface resistivity (left) highly correlated to Rapid Chloride Permeability Test (right), a more time/labor intensive test historically been linked to field performance

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## Review of Existing State Specifications

- Virginia, Florida, Louisiana, New Hampshire, Kansas, New Jersey, New York, Rhode Island, Texas, Utah, West Virginia, and Montana have specification provisions on resistivity
- A variety of approaches, with targets generally linked to the type(s) of mixtures and importance/exposure of element
- Many states have 28-day targets. Some states have 56-day targets.
  - Trade off between ease of use at earlier age (28-days) vs. capturing value of fly ash on permeability reduction (56-days)
- Virginia DOT provides RCPT targets for pavements (3,500 coulomb) and bridges (2,500 coulomb)
  - Field performance of these targets verified in similar climate/traffic conditions
  - Use 28-day values, but use of same targets at 56-days could also show promise

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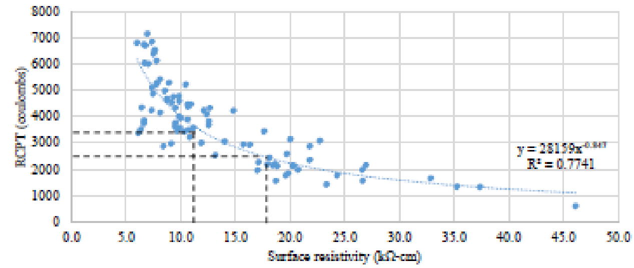
## Surface Resistivity




- Pavement target of 3,500 coulombs RCPT corresponds to ~ 10.5 kΩ-cm resistivity
- Bridge target of 2,500 coulombs RCPT corresponds to ~ 18.8 kΩ-cm resistivity
- VDOT uses these targets at 28 days which would preclude many NC mixtures with lower w/cm, fly ash, good performance
- Use of targets at 56 days is recommended (NJDOT and NHDOT use 56-day targets)
- Alternatively, could identify 28-day target that correlates to 56-day value (mixture specific)

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## Suggested Specification for Resistivity

- Suggested revision to Section 1000-4C "Portland Cement Concrete for Structures and Incidental Construction"

(C) Strength and Surface Resistivity of Concrete

The compressive strength *and surface resistivity* of the concrete will be considered the average test results of two 6 inch x 12 inch cylinders, or two 4 inch x 8 inch cylinders if the aggregate size is not larger than size 57 or 57M. Make cylinders in accordance with AASHTO T 23 from the concrete delivered to the work. Make cylinders at such frequencies as the Engineer may determine and cure them in accordance with AASHTO T 23 as modified by the Department. Copies of these modified test procedures are available upon request from the Materials and Tests Unit. Testing for compressive strength should be performed in accordance with AASHTO T 22. *Testing for surface resistivity should be performed in accordance with AASHTO T 358.* When the average compressive strength or surface resistivity of the concrete test cylinders is less than the minimum targets specified in Table 1000-1 and the Engineer determines it is within reasonably close conformity with design requirements, these properties will be considered acceptable. *When the Engineer determines average cylinder strength or surface resistivity is below the specification, the in-place concrete will be tested.* Based on these test results, the concrete will either be accepted with no reduction in payment or accepted at a reduced unit price or rejected as set forth in Article 105-3.

Suggested addition to Table 1000-1

| Class of Concrete | Minimum surface resistivity at 56 days (kΩ-cm) |
|---|---|
| AA | 15.0* |
| Pavement | 11.0 |

*A 56 day minimum of 16.0 kΩ-cm can be required at the engineer's discretion for applications where risk of chloride ion penetration is high.

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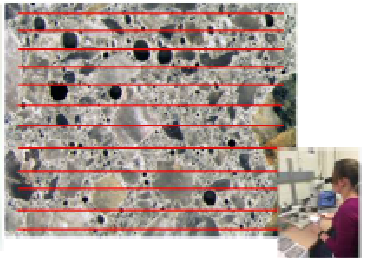
## Super Air Meter (SAM)


- SAM (left) correlated to hardened air void analysis (middle), ASTM C666 freeze-thaw test (right), time/labor intensive tests historically linked to freeze-thaw durability
- AASHTO TP 118
- Performed on fresh concrete, similar to ASTM C231 pressure method
- Test takes about 15 minutes to do
- Assesses air void dispersion (size/spacing of bubbles) rather than total %
  - air void quality rather than air void quantity
- Current target for NC mixtures is SAM number of 0.30

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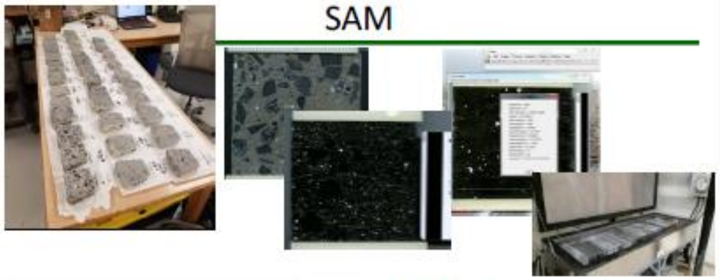
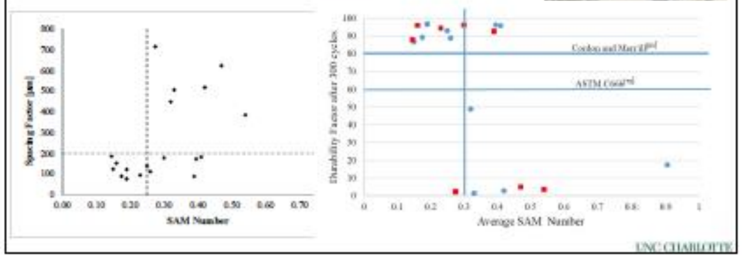
## SAM



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## Development of a Volumetric Shrinkage Specification

Photo: Humboldt

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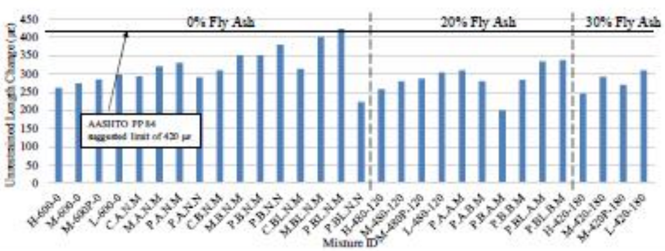
## Review of Existing State Specifications

- Louisiana, Minnesota, New York, Florida, Virginia, and West Virginia have specification provisions on volumetric shrinkage
- Many shrinkage specifications are for repair materials, some for bridge decks, superstructure elements.
- AASHTO PP 84 suggests 420 µε at 28 days
- Mokarem et al. (2003) suggest 400 µε at 28 days for crack-resistant concrete
- Only 1 mixture from RP 2015-03 (w/cm 0.48) didn't meet target.
- 350 µε at 28 days was reasonable for almost all mixtures (even w/cm 0.47)

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## Suggested Specification for Shrinkage

- Suggested revision to Section 1000-4A Portland Cement Concrete for Structures and Incidental Construction"

(A) Composition and Design

Table of laboratory tests to be submitted with Form 312U for mixture approval

| Property | Test Method |
|---|---|
| Aggregate Gradation | AASHTO T 27 |
| Air Content | AASHTO T 152 |
| Slump | AASHTO T 119 |
| Compressive Strength | AASHTO T 22 and T23 |
| Shrinkage | AASHTO T 160 |

Additional information could be provided in a new Section (E) Shrinkage requirements or added to Project Special Provisions for use at acceptance.

(E) Shrinkage Requirements

Concrete should be tested for unrestrained length change at 28 days using AASHTO T 160. For typical concrete pavement and bridge applications, the length change is limited to 420 µε. For concrete applications where enhanced provisions against cracking are desired, length change can be limited to 350 µε at the engineer's discretion.

Table below should be added or incorporated into Table 1000-1 with the following note:

| Class of Concrete | Shrinkage Limit (µε) at 28 days |
|---|---|
| AA | 420* |
| Pavement | 420* |
| *For concrete where a reduction in cracking due to shrinkage is desirable, 350µε could be used. | |

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# Development of a Specification for Early Age Opening to Traffic

Photo: concreteconstruction.net

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# Review of Existing State Specifications

- Florida, Illinois, Iowa, Louisiana, Minnesota, New York, Virginia, West Virginia specifications summarized.
- A variety of approaches, with targets generally linked to the type(s) of mixtures (conventional bridge or pavement, repair, VHES)
- Many states have 7-day or 14-day targets for conventional mixtures.

Current NCDOT Specifications:

- Pavements
  - 3,000 psi for opening to traffic
  - 4,500 psi compressive (650 psi flex) for acceptance
- Bridge substructures
  - 2,400 psi prior to placement of beams/girders
- Bridge Decks
  - 4,500 psi to open to vehicles of construction traffic

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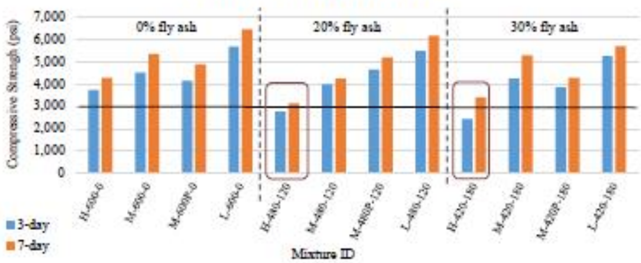
# Pavement Mixtures




- Current target appears appropriate for most mixtures, provided a reasonable w/cm ratio is utilized.
- Use of fly ash will provide durability benefits, but delay in strength gain may impact time required to meet 3,000 psi target.

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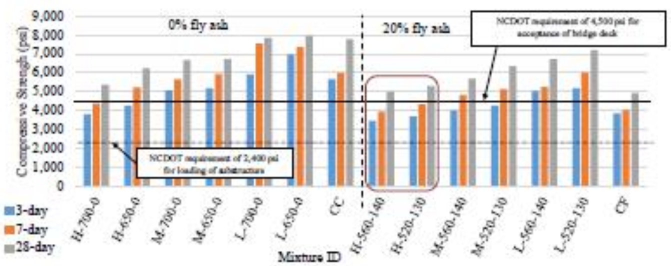
# Structural Mixtures




- Current targets appear appropriate for most mixtures, provided a reasonable w/cm ratio is utilized.
- Use of fly ash will provide durability benefits, but delay in strength gain may impact time required to meet 2,400/4,500 psi targets.
- Some states open bridge decks to traffic at 4,000 psi. NCDOT could investigate use of this target if desired. Lowering the target to 4,000 psi could promote additional use of SCMs.

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## Recommendations

- NCDOT should promote use of fly ash, particularly at higher replacement rates.
- NCDOT should promote use of PLC
- Promote use of resistivity as a readily implementable tool to promote construction of durable infrastructure
- Consider implementing shrinkage targets for applications were reduced cracking is desirable.
- Engage contractors in PEM initiatives through pilot projects, technology transfer, other avenues.
- Remain engaged with FHWA activities related to PEM.
  - Findings of other states Implementation Studies
  - Use of PEM tools in QC (QC Guidance)

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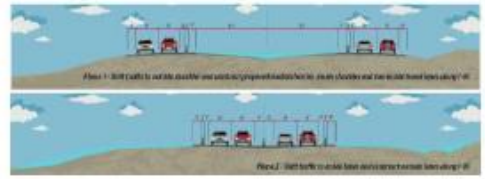
## PEM Implementation Site in North Carolina

- I-85 widening project north of Charlotte – 8 miles in length
- Addition of 4 travel lanes (2 each direction)
- 12-inch thick mainline JPCP
- Two phases



- Contractor-led involvement
- Motivated staff
  - "We know PEM is coming, and we want to get on board."
  - "We already do some of this QC but want to do more."
  - "How can we help?"

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## Implementation site: PEM Tests and QC activities

<u>Mixture design and approval</u>

- Resistivity test results
- SAM test results
- Box test results

<u>Acceptance tests</u>

- NCDOT standard requirements
  - 28-day compressive strength (4,500 psi)
  - Air content (6.0% ± 1.5%)
  - Max slump 1.5 in
- Shadow Tests
  - SAM test results
  - Resistivity test results

VKelly may be utilized on a trial basis

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## PEM Tests and QC activities

<u>QC/Control Charts</u>

- Air content, slump, unit weight, concrete temperature
  - One test per lot
  - PEM tests
  - SAM – once per day target
  - Resistivity – all cylinders tested for compressive strength
  - Bucket test – performed at UNC Charlotte
- Other control charts may be developed
  - Moisture content of aggregates
  - Fly ash LOI

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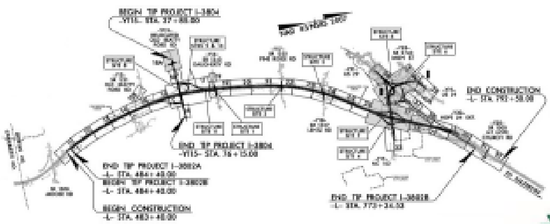
## FHWA Implementation Project

- I-85 widening project north of Charlotte, NC
  - 5.3 miles long
  - Existing 4-lane interstate widened to provide 4 additional travel lanes (2 lanes in each direction)
  - 500,000 SY of concrete pavement construction (12" thick JPCP)
  - Two phases:
    - April 2018 to September 2018
    - April 2019 to October 2019



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## FHWA Implementation Project Outcomes

This project resulted in:

- Engagement of a contractor to implement PEM tests for QC on a pavement project:
  - Box Test
  - SAM
  - surface resistivity
- Technology transfer to regional/divisional NCDOT personnel
- Data collection during FHWA Mobile Concrete Technology Center visit (April/May 2019)
- Technology transfer to NC stakeholders during Open House hosted at the Implementation Site

★ Support of a contractor and commitment to use of PEM tools on their next project ★

Report available at:
https://intrans.iastate.edu/app/uploads/sites/7/2020/05/Post-Construction-Report-for-North-Carolina-DOT-Demonstration-Project-05-14-2020.pdf

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## RP 2020-13 Objectives

1) Supplemental laboratory evaluation to expand the catalog of data to support development and refinement of PEM specifications
   - same mixture matrix as RP 2018-14, with optimized aggregate gradations
   - refine QA/QC protocol for resistivity, shrinkage, and SAM
   - expand specification guidance to include w/cm ratios, aggregate gradations and/or paste contents
   - Use of surface resistivity meter as a QA tool for overlay quality

2) Implementation of PEM tests and shadow specifications at additional pilot projects
   - bridge project
   - bridge deck overlay project
   - additional pavement project through Lane Construction (*bonus*)

3) Development of guidance to support contractor QC plans
   - refine technology transfer tools for NCDOT personnel developed as part of RP 2019-41 for QC use

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## Structural Concrete PEM Implementation Project I-485 Widening (I-5507 Design Build)

- I-485 widening project south of Charlotte, NC
  - 18.2 miles long
  - High-occupancy toll (HOT) lanes along entire stretch of roadway
  - 17 structures, 15.3 miles of new sound wall
  - 3 year duration
- Concrete Supply Co. is providing most structural mixtures
  - AA, Drilled Pier, A
- PEM Shadow Testing
  - SAM, surface resistivity, shrinkage
  - Ongoing Spring/Summer 2020

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## More to come…
## Movement towards PEM is continues

- RP 2020-13 project will provide additional insight into
  - optimized gradations
  - higher volumes of fly ash
  - carbon nanotubes
- QC guidance coming out from FHWA
  - "Quality Control for Concrete Paving: A Tool for Agency and Industry"
  - PEM tests are integrated
- QC guidance targeted towards NCDOT from RP 2020-13
- Increased and continued engagement of contractors and industry
  - Additional shadow testing for pavement concrete
  - Ready-mix concrete suppliers are obtaining and using the tests

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## PEM Resources

PEM Resource Repository at
National Concrete Pavement Technology Center Website
https://cptechcenter.org/performance-engineered-mixtures-pem/

FHWA video on PEM
https://www.youtube.com/watch?v=tXb4f7bCYs8

UNC Charlotte Research Reports
https://connect.ncdot.gov/projects/research/
RP 2011-06, 2015-03, 2016-06, 2018-14

NCDOT PEM Implementation Project – I-85 Widening
https://intrans.iastate.edu/app/uploads/sites/7/2020/05/Post-Construction-Report-for-North-Carolina-DOT-Demonstration-Project-05-14-2020.pdf

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- Chris Peoples, Brian Hunter, Aaron Earwood and many others at NCDOT
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- Many folks who continue to donated materials
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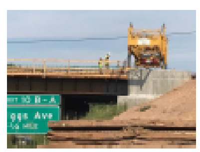

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