U.S. Concrete Pavement Research & Innovations

Thursday, October 21, 2021

CONCRETE ONTARIO

Cement Association of Canada

CONCRETE Build for life™

Facilitators

Alen Keri, P.Eng.

Director of Technical Services

Concrete Ontario

Tim J Smith, P.Eng., MSc. Eng.

Senior Director, Built Environment,

Transportation and Public Works

Cement Association of Canada

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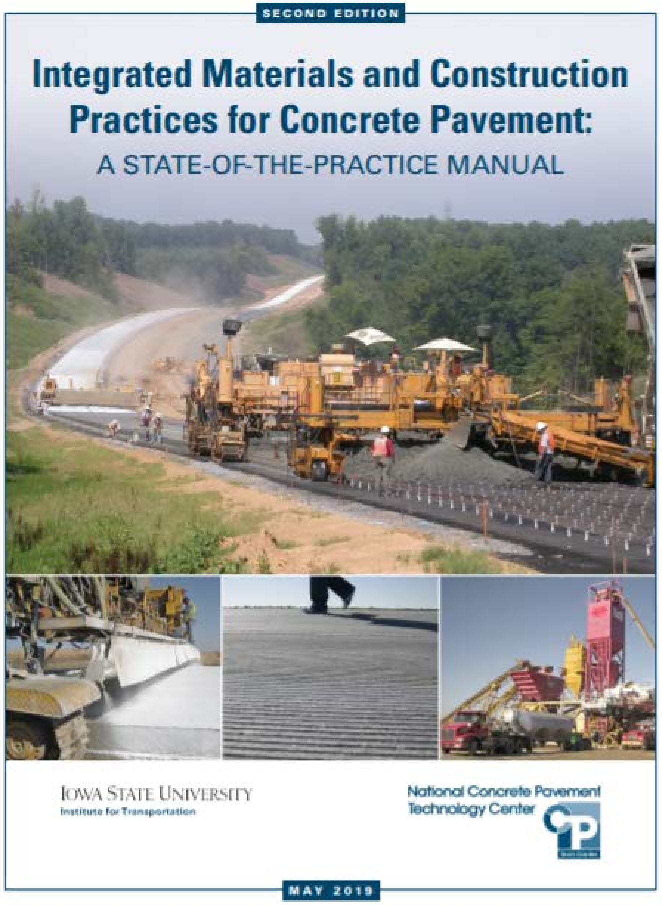
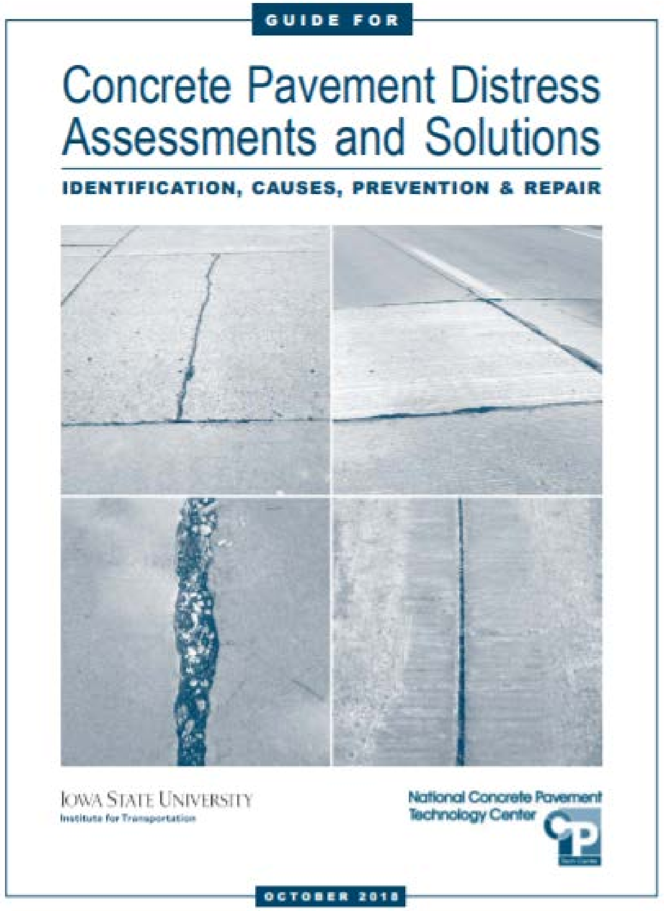
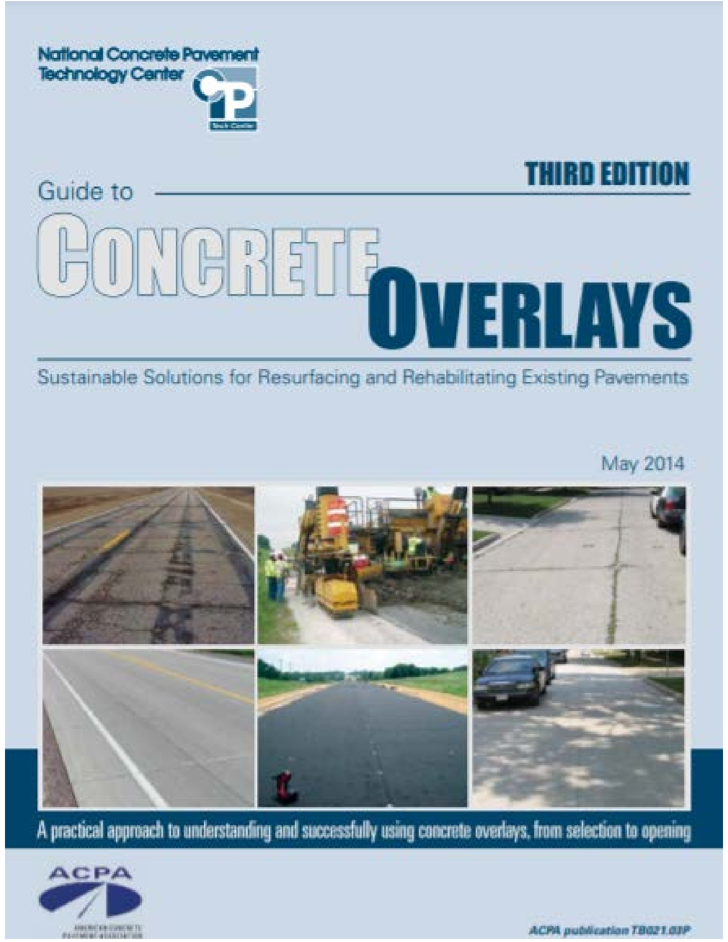
Housekeeping

- Approximately a 45-minute webinar with Q & A at the end
- All participants are muted
- Questions? Use the GoToWebinar 'Questions' Pane
- Webinar will be recorded and posted on the Concrete Ontario website along with a PDF copy of the presentation.
  - https://www.rmcao.org/publications/webinar-presentations/

CP Tech Center







Presenter

Dr. Peter C. Taylor P.E. (IL)

Director

CP Tech Center

Peter Taylor is the Director of the National Concrete Pavement Technology Center at Iowa State University. He is involved in conducting projects and programs investigating materials related aspects of concrete pavements. He also spends time helping agencies and contractors implement best practices in concrete pavement design, construction and maintenance. His research is focused on developing mixtures that are engineered to meet the requirements of the environment that will be used in.

He is a Professional Engineer, registered in Illinois and active in a number of professional societies.

Innovations in Concrete Pavements

Dr Peter Taylor

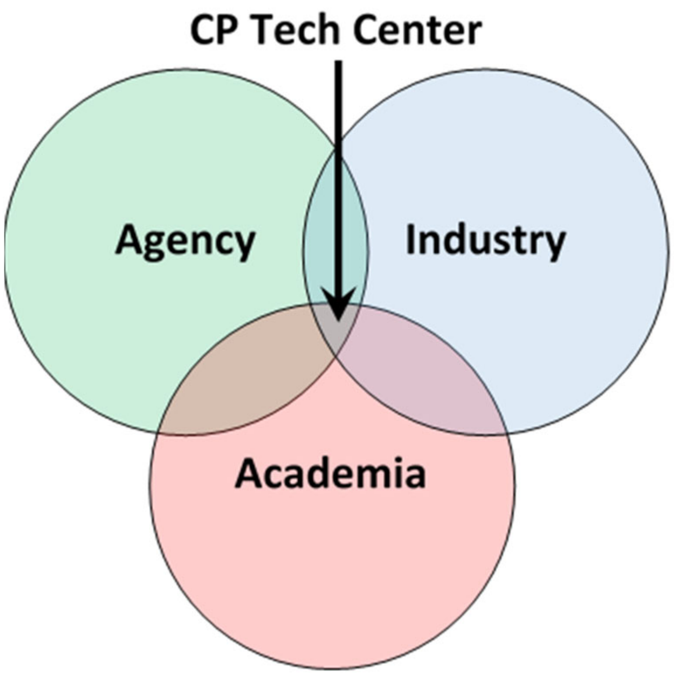
Iowa State University
Institute for Transportation

National Concrete Pavement Technology Center
Tech Center

CP Tech Center

"Making a difference"

- Problem solving
- Implementing the latest and greatest
- Saving money by doing good things
- Building better concrete pavements

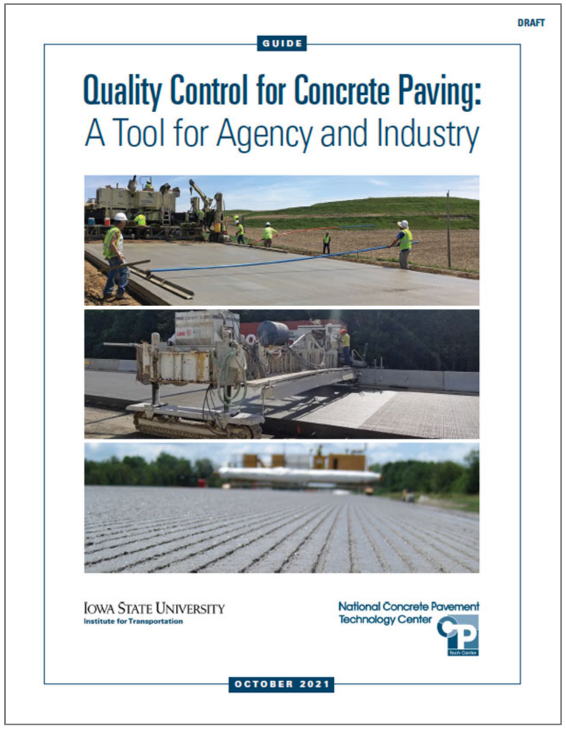


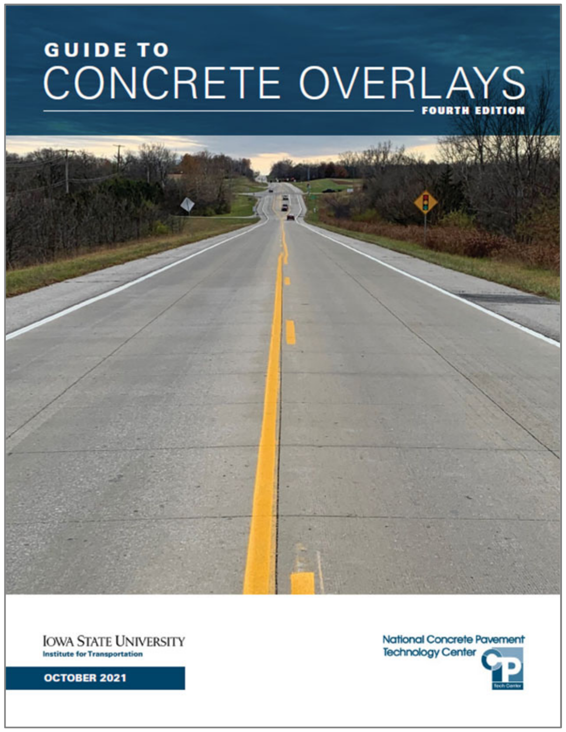
How do we do this?

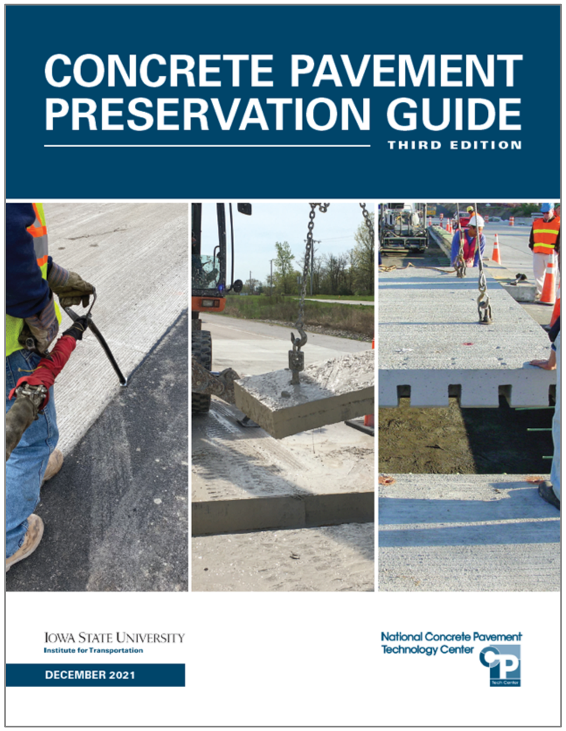
- Technical products
- Education
- Independent expertise
- Professional presence
- Applied research and implementation

Our goal:
to be top-of-mind of anyone needing concrete pavement information

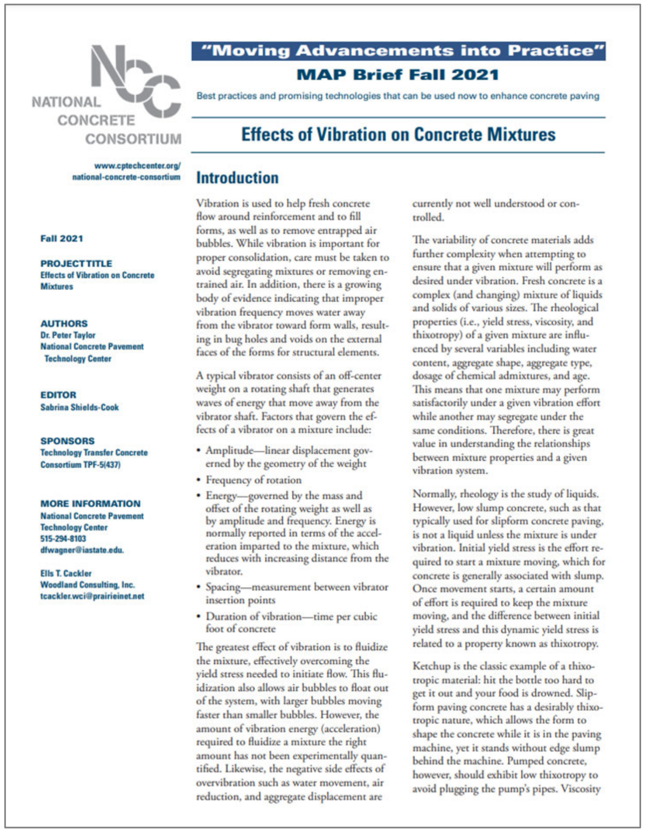
Technical Products







Technical Products



NATIONAL CONCRETE CONSORTIUM

www.cptechcenter.org/national-concrete-consortium

"Moving Advancements into Practice"

MAP Brief Fall 2021

Best practices and promising technologies that can be used now to enhance concrete paving

Effects of Vibration on Concrete Mixtures

Fall 2021

PROJECT TITLE
Effects of Vibration on Concrete Mixtures

AUTHORS
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SPONSORS
Technology Transfer Concrete Consortium TPF-5(437)

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Introduction

Vibration is used to help fresh concrete flow around reinforcement and to fill forms, as well as to remove entrapped air bubbles. While vibration is important for proper consolidation, care must be taken to avoid segregating mixtures or removing entrained air. In addition, there is a growing body of evidence indicating that improper vibration frequency moves water away from the vibrator toward form walls, resulting in bug holes and voids on the external faces of the forms for structural elements.

A typical vibrator consists of an off-center weight on a rotating shaft that generates waves of energy that move away from the vibrator shaft. Factors that govern the effects of a vibrator on a mixture include:

- Amplitude—linear displacement governed by the geometry of the weight
- Frequency of rotation
- Energy—governed by the mass and offset of the rotating weight as well as by amplitude and frequency. Energy is normally reported in terms of the acceleration imparted to the mixture, which reduces with increasing distance from the vibrator.
- Spacing—measurement between vibrator insertion points
- Duration of vibration—time per cubic foot of concrete

The greatest effect of vibration is to fluidize the mixture, effectively overcoming the yield stress needed to initiate flow. This fluidization also allows air bubbles to float out of the system, with larger bubbles moving faster than smaller bubbles. However, the amount of vibration energy (acceleration) required to fluidize a mixture the right amount has not been experimentally quantified. Likewise, the negative side effects of overvibration such as water movement, air reduction, and aggregate displacement are currently not well understood or controlled.

The variability of concrete materials adds further complexity when attempting to ensure that a given mixture will perform as desired under vibration. Fresh concrete is a complex (and changing) mixture of liquids and solids of various sizes. The rheological properties (i.e., yield stress, viscosity, and thixotropy) of a given mixture are influenced by several variables including water content, aggregate shape, aggregate type, dosage of chemical admixtures, and age. This means that one mixture may perform satisfactorily under a given vibration effort while another may segregate under the same conditions. Therefore, there is great value in understanding the relationships between mixture properties and a given vibration system.

Normally, rheology is the study of liquids. However, low slump concrete, such as that typically used for slipform concrete paving, is not a liquid unless the mixture is under vibration. Initial yield stress is the effort required to start a mixture moving, which for concrete is generally associated with slump. Once movement starts, a certain amount of effort is required to keep the mixture moving, and the difference between initial yield stress and this dynamic yield stress is related to a property known as thixotropy.

Ketchup is the classic example of a thixotropic material: hit the bottle too hard to get it out and your food is drowned. Slipform paving concrete has a desirably thixotropic nature, which allows the form to shape the concrete while it is in the paving machine, yet it stands without edge slump behind the machine. Pumped concrete, however, should exhibit low thixotropy to avoid plugging the pump's pipes. Viscosity

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"Moving Advancements into Practice"

MAP Brief Summer 2021

Best practices and promising technologies that can be used now to enhance concrete paving

Improving the Foundation Layers for Concrete Pavements: Lessons Learned and a New Framework for Mechanistic Assessment

Summer 2021

PROJECT TITLE
Improving the Foundation Layers for Concrete Pavements: Lessons Learned and a New Framework for Mechanistic Assessment

AUTHOR
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EDITOR
Sabrina Shields-Cook

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Introduction

State Highway Agencies (SHAs) are facing a tremendous technical and financial challenge in how to not only improve the condition of their transportation infrastructure but modernize it for future needs with the constrained funding available. The disparity between need and available funding is not new, as funding historically has not been sufficient to keep up with the demands on the nation's roadway network. As a result, many agencies have had to delay needed improvements on portions of their network as funding is channeled to address the most pressing infrastructure needs.

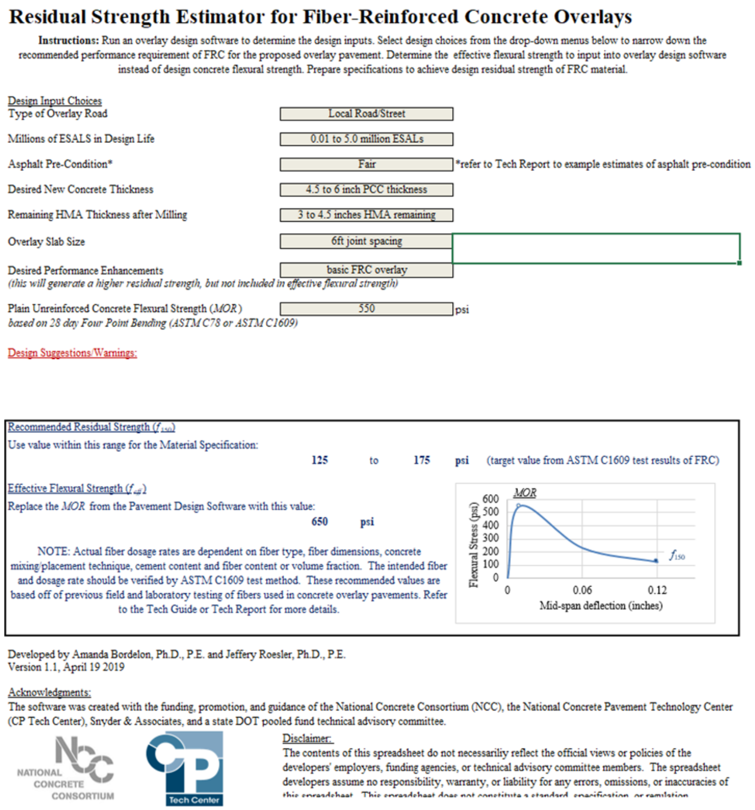
The American Society of Civil Engineers (ASCE) Committee on America's Infrastructure recently released their 2021 infrastructurereport card. Their cumulative grade for all infrastructure categories was C-, which was a modest improvement over the D and D+ scores of the past 20 years. Specifically for the roads category, however, the assessment continued to assign a D grade that has remained unchanged from the 2017 and 2013 report cards, was a D- in 2009, and was a D again in the 2005 report. The bottom line is that the nation is continuing to struggle just to maintain the condition of our roadway network.

What can be done to improve the condition of our roadways and address future needs? How do we get to a sustainable scenario where pavement condition can be consistently maintained with available funding? This is not an easy problem to solve. However, as a practical matter, there are two strategies that need to be addressed simultaneously to help address this dilemma. The first is to attempt to secure additional local, state, and federal funding for infrastructure. This is currently a national focus area, in addition to ongoing efforts at local and state levels. It is unlikely, however, that sufficient additional investment will be secured to fully address the needs. Therefore, the second strategy that must be pursued concurrently with seeking additional infrastructure investment is to cost-effectively build roadways that will last longer, thus relieving the funding demand.

The second strategy is receiving significant attention from the engineering community. However, the budget gap is so large that instead of the traditional 20-to-40-year pavement design life, agencies are increasingly discussing what is needed to achieve very long-life pavement systems, in terms of double or triple present performance. This represents a tremendous engineering challenge.

Where do we start? Where are the opportunities to improve— not incrementally, but significantly—pavement performance? Many SHAs would identify two major causes of pavement performance problems

Technical Products



Residual Strength Estimator for Fiber-Reinforced Concrete Overlays

Instructions: Run an overlay design software to determine the design inputs. Select design choices from the drop-down menus below to narrow down the recommended performance requirement of FRC for the proposed overlay pavement. Determine the effective flexural strength to input into overlay design software instead of design concrete flexural strength. Prepare specifications to achieve design residual strength of FRC material.

Design Input Choices

Type of Overlay Road	Local Road/Street	
Millions of ESALS in Design Life	0.01 to 5.0 million ESALs	
Asphalt Pre-Condition*	Fair	*refer to Tech Report to example estimates of asphalt pre-condition
Desired New Concrete Thickness	4.5 to 6 inch PCC thickness	
Remaining HMA Thickness after Milling	3 to 4.5 inches HMA remaining	
Overlay Slab Size	6ft joint spacing	
Desired Performance Enhancements	basic FRC overlay	
Plain Unreinforced Concrete Flexural Strength (*MOR*)	550	psi

(this will generate a higher residual strength, but not included in effective flexural strength)

based on 28 day Four Point Bending (ASTM C78 or ASTM C1609)

Design Suggestions/Warnings:

Recommended Residual Strength (f_{150})

Use value within this range for the Material Specification:

125 to **175** **psi** (target value from ASTM C1609 test results of FRC)

Effective Flexural Strength (f_{eff})

Replace the *MOR* from the Pavement Design Software with this value:

650 **psi**

NOTE: Actual fiber dosage rates are dependent on fiber type, fiber dimensions, concrete mixing/placement technique, cement content and fiber content or volume fraction. The intended fiber and dosage rate should be verified by ASTM C1609 test method. These recommended values are based off of previous field and laboratory testing of fibers used in concrete overlay pavements. Refer to the Tech Guide or Tech Report for more details.

Developed by Amanda Bordelon, Ph.D., P.E. and Jeffery Roesler, Ph.D., P.E.

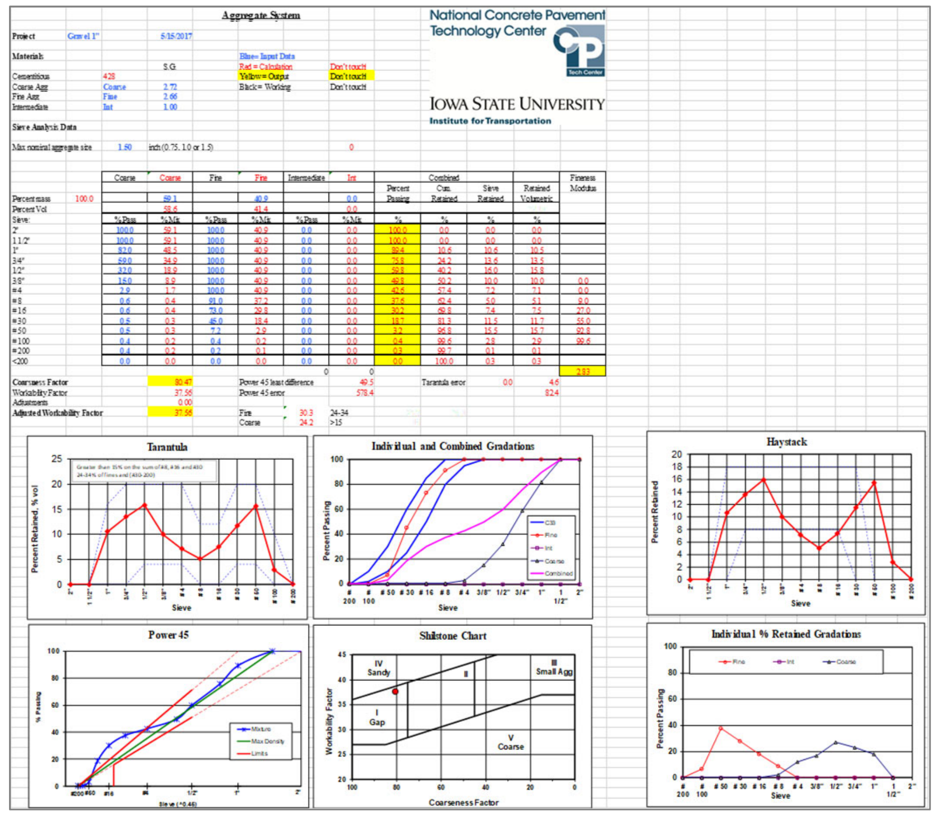
Version 1.1, April 19 2019

Acknowledgments:

The software was created with the funding, promotion, and guidance of the National Concrete Consortium (NCC), the National Concrete Pavement Technology Center (CP Tech Center), Snyder & Associates, and a state DOT pooled fund technical advisory committee.

NATIONAL CONCRETE CONSORTIUM

Tech Center



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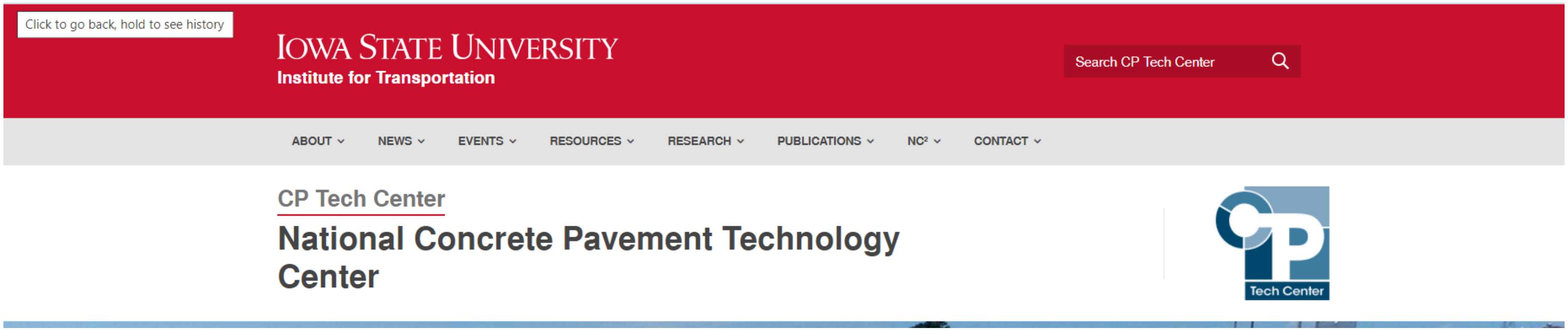
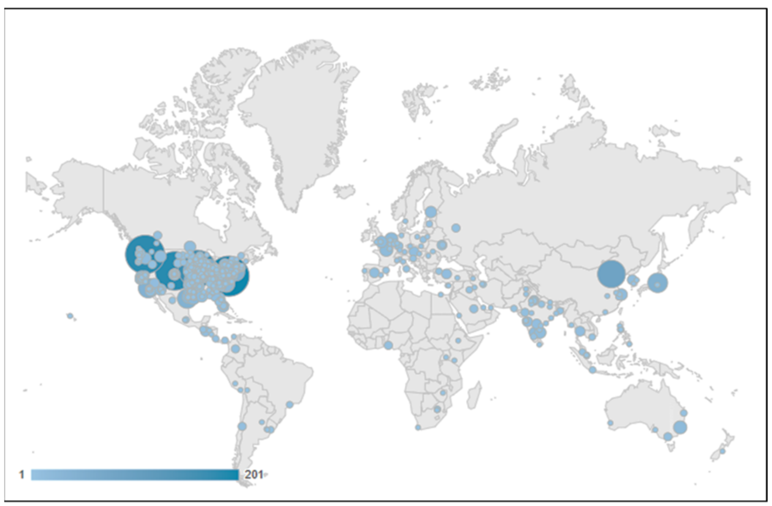
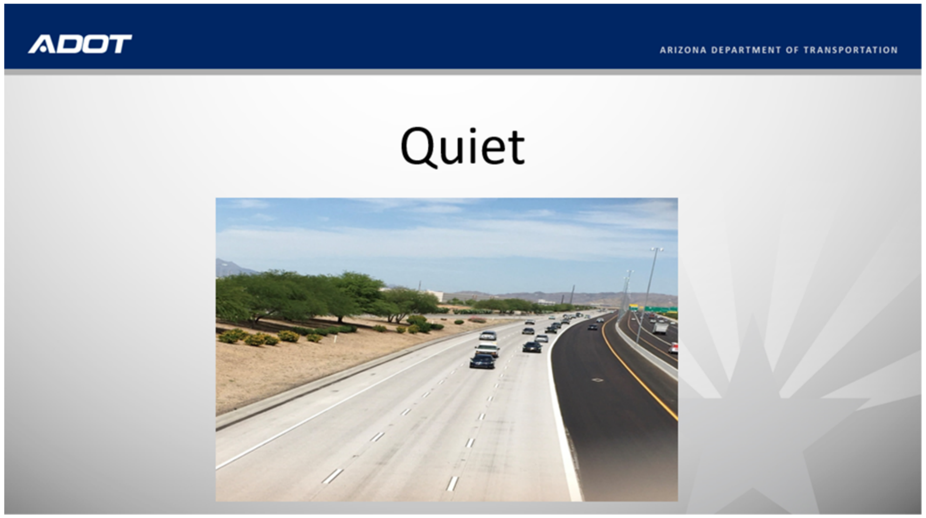




cptechcenter.org

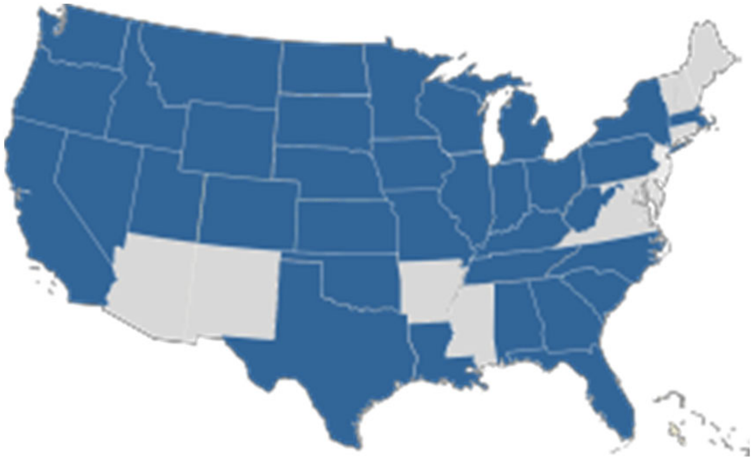
Education

- Concrete Pavement Technology Tuesday
  - In collaboration with ACPA
  - Monthly
  - Topics
    - RCC
    - Overlays Innovations
    - Resiliency
    - Man vs Machine…
  - Recordings online



Education

- National Concrete Consortium (NC2)
  - Web meeting 2020
  - Strengths:
    - 350 attendees every day for three days
      - cf ~150 in-person
    - Focused presentations
  - Weaknesses
    - Discussion is hard
  - Where next?
    - Spring meeting April 13-15, 2021 Virtual



Education

- Workshops (when Covid permits)
  - IMCP
  - Inspectors
  - Preservation
  - Overlays
  - PEM
  - Proportioning
  - RCA

Implementation

- Performance Engineered Mixtures (PEM)
  - Specifications that call for what we really need
    - Transport properties (permeability)
    - Aggregate stability
    - Cold weather resistance
    - Strength
    - Shrinkage
    - Workability

Implementation

- Performance Engineered Mixtures (PEM)
  - Test methods that assess those properties
  - Appropriate limits
  - Run at the right time
  - Tools to proportion mixtures that comply

Implementation

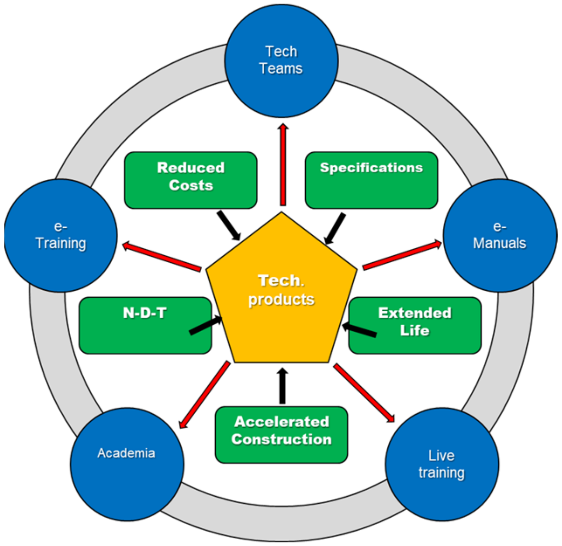
- Test methods (for those critical properties)
  - VKelly / Box
  - Resistivity (Formation factor)
  - SAM

Implementation

- Real Time Smoothness
  - Guidelines for Building Smooth Concrete Pavements
    - On-site Demonstrations
    - Guide Specifications
    - Webinar
    - On-Call Technical Support

Implementation

- FHWA Cooperative Agreement
    - Extending pavement life and performance
    - Reducing initial and lifecycle costs
    - Accelerating construction techniques
    - Design criteria and specifications
    - Non-destructive testing
    - Technology transfer



U.S. Department of Transportation
Federal Highway Administration

Implementation

- FAA Cooperative Agreement
  - $6.5M for research
  - CP Tech is acting as research manager
  - Priority topics being collected:
    - ASR
    - Mixture proportioning
    - Rapid rehabilitation
    - Quality manual

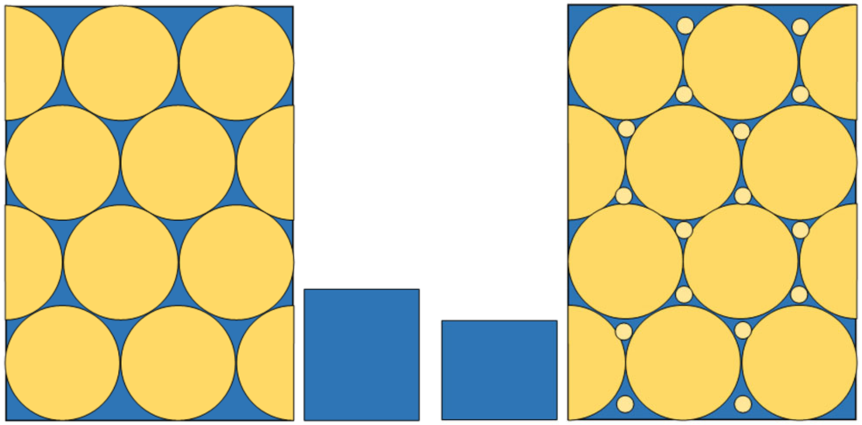
Research Activities

- Mixture proportioning
  - Supporting PEM program
  - Cutting carbon footprint
  - Delivering performance

		Workability	Transport	Strength	Cold weather	Shrinkage	Aggregate stability
Aggregate System	Type, gradation	✓✓	-	-	-	-	✓✓
Paste quality	Air, w/cm, SCM type and dose	✓	✓✓	✓✓	✓✓	✓	✓
Paste quantity	Vp/Vv	✓	-	-	-	✓✓	-

Research Activities

- Mixture proportioning
  - Tool available based on voids between aggregates

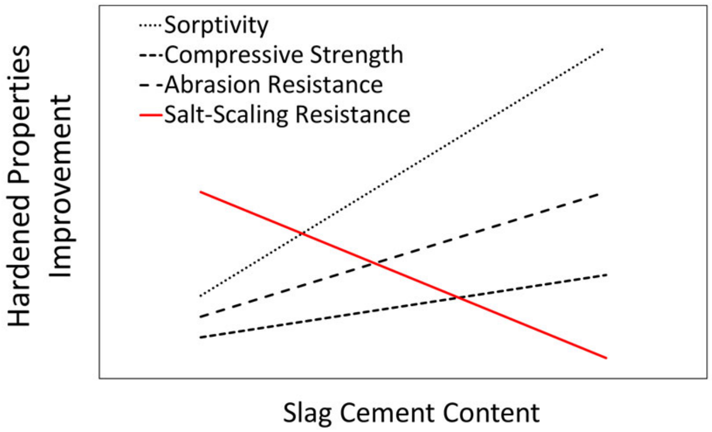


Research Activities

- Mixture proportioning
  - Work is ongoing to understand effects of:
    - Aggregate shape
    - Aggregate mineralogy

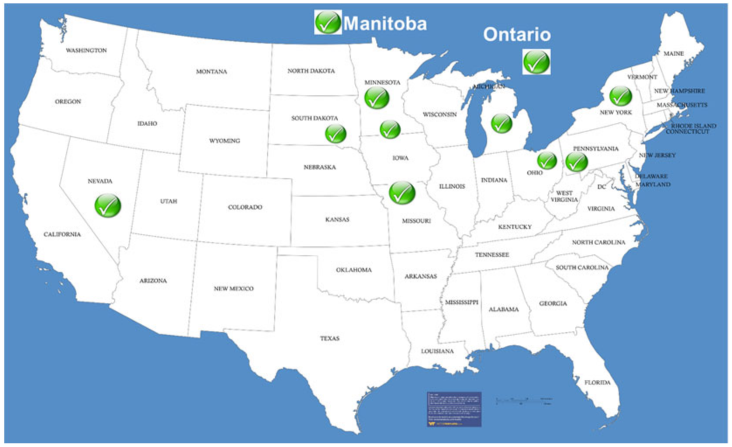
Research Activities

- Salt scaling – effect of system chemistry
  - Increasing slag cement content improves mechanical performance
  - While reducing salt scaling resistance
  - Therefore likely a chemical effect
  - Investigating interactions of minor compounds with chloride salts



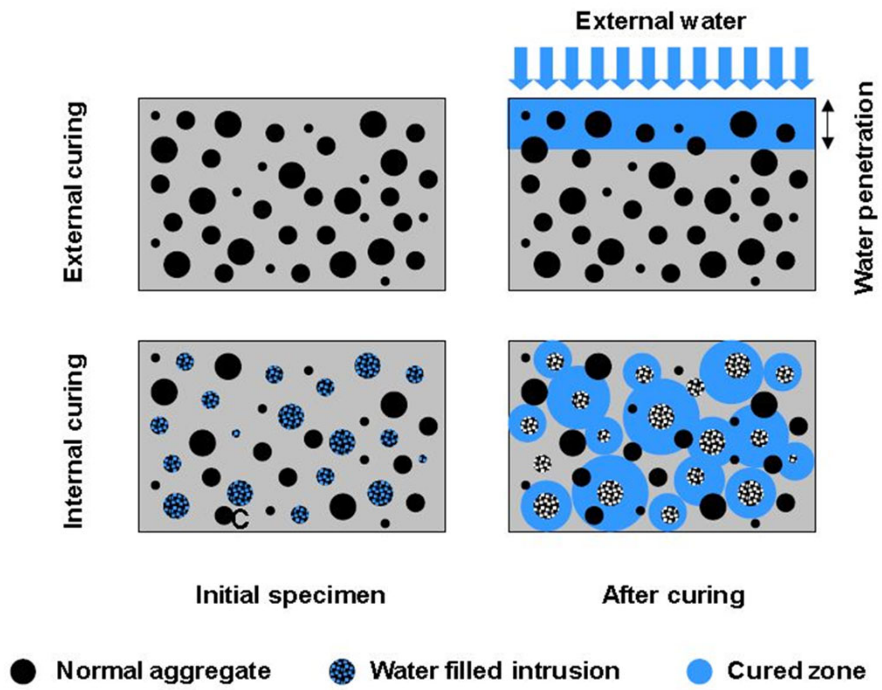
Research Activities

- Air Void System Requirements
  - Properties of the pavements exhibiting good, marginal, and poor durability
  - Correlations between fresh and hardened air void system
  - Compare to performance in different accelerated F-T tests
- Findings
  - Rare to find failure due to air only
  - Current limits are conservative



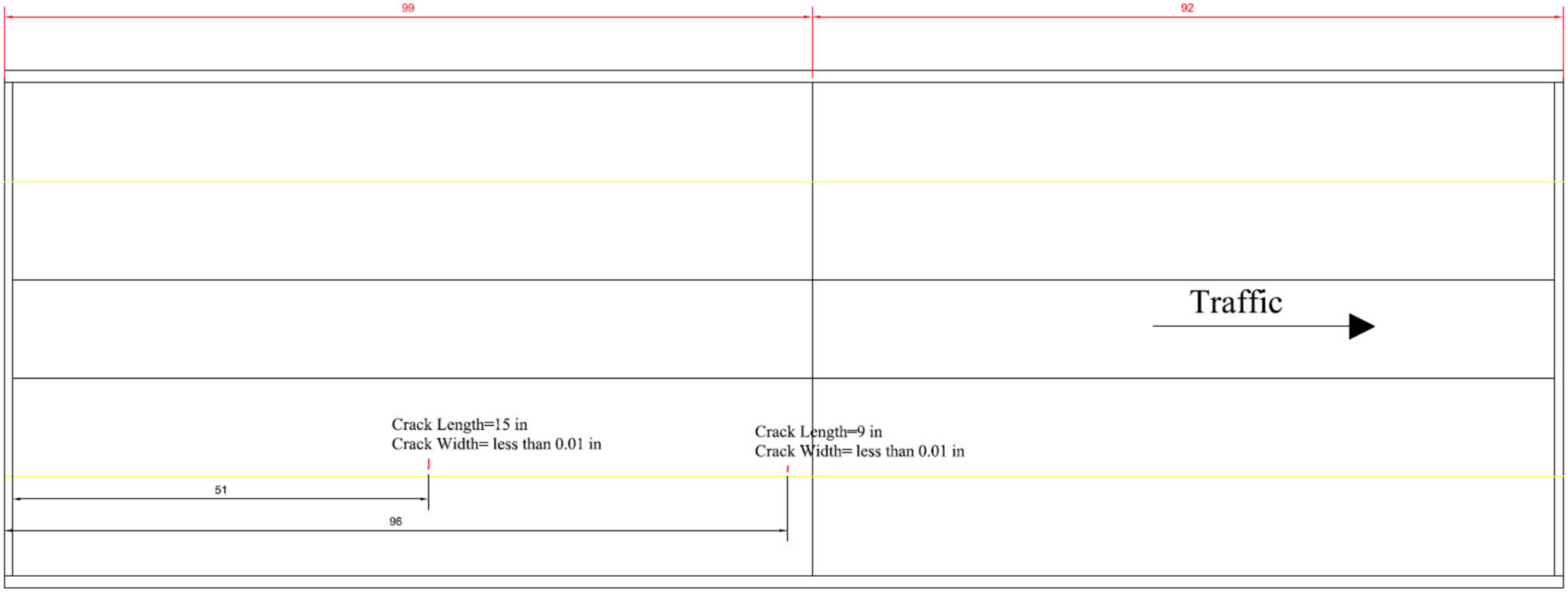
Research Activities

- Internal curing
  - Improved hydration
  - Reduced differentials



Research Activities

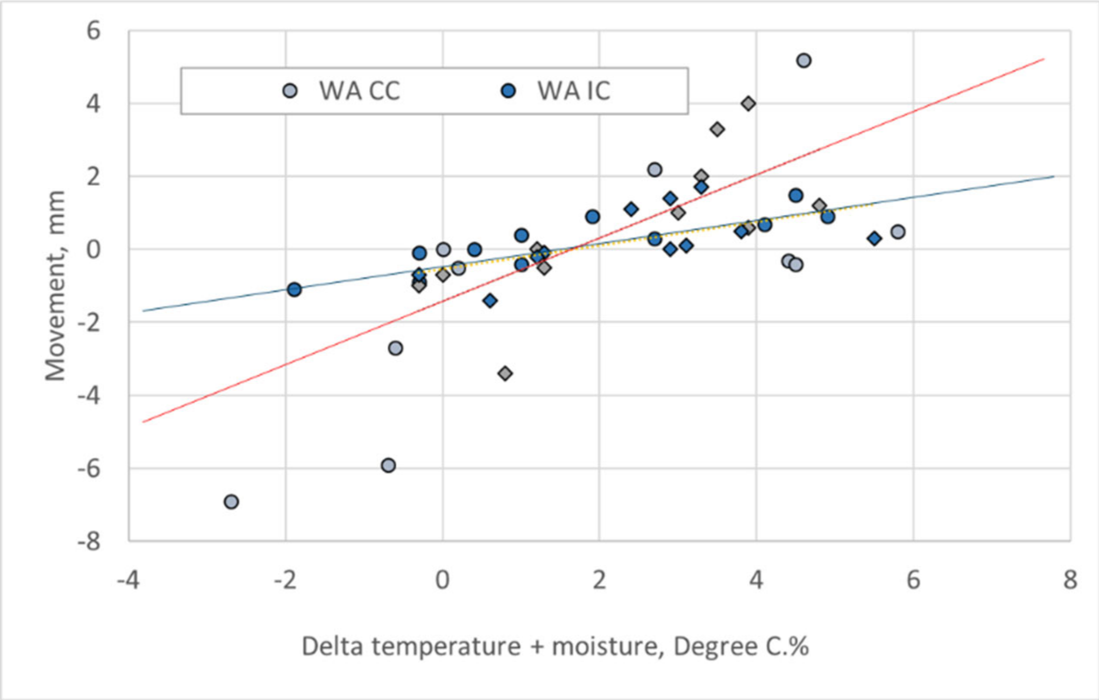
- Internal curing
  - Bridge decks – no cracking



IC Deck

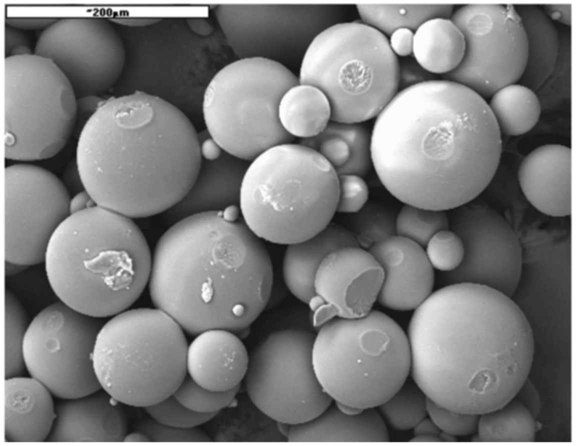
Research Activities

- Internal curing
  - Pavements – less warping



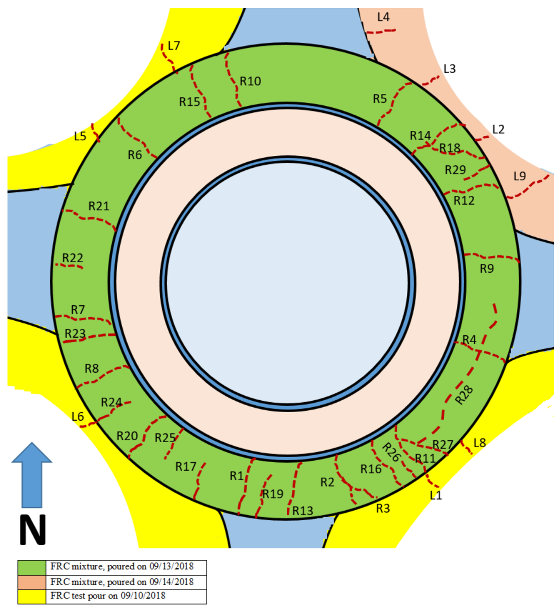
Research Activities

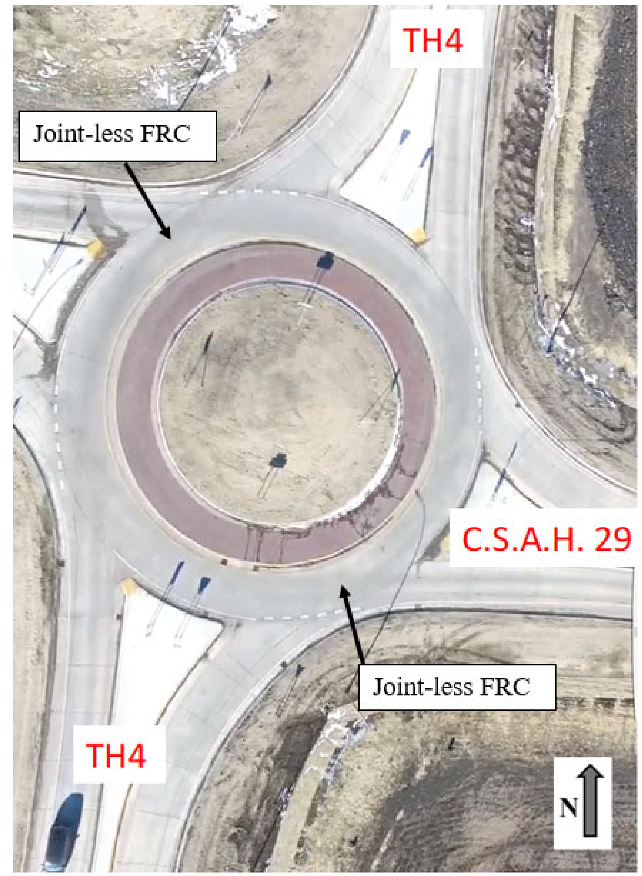
- Internal curing
  - Constructability is challenging with LWFA
    - Extra stockpile
    - Moisture control
  - Looking at super-absorbent polymers



Research Activities

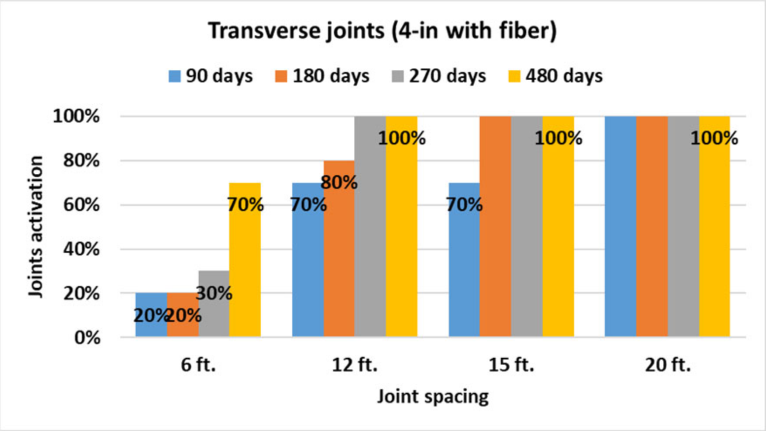
- Overlay performance – fibers!
  - Circle with no joints – MN
  - Crack widths up to 5 mm





Research Activities

- Overlay performance – fibers!
  - Mitchell County Overlays
  - Most of the joints are cracking as intended
  - Fibers slowed activation
  - Need data on faulting…

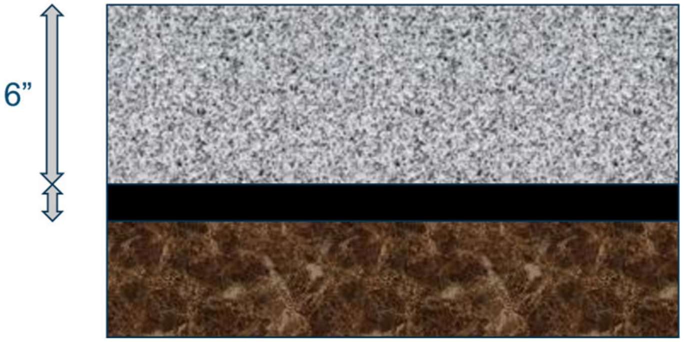


Research Activities

- Overlay performance – fibers!
  - Worth County Overlay – no sawn joints
    - Control - 6 inch FRC overlay, typical 4 lbs/cy and 12 ft x 12 ft joint spacing
    - Test
      - 7.5 lbs/cy fibers – no saw cuts
      - Increased cementitious content
      - Average crack spacing = 26.5 ft
      - Average crack width = ~1/32 inch
      - Widest cracks = ~1/12 inch

Research Activities

- Geotextiles
  - Textile vertical movement <0.05” (~1 mm)
  - System stiffness is reduced with thicker textile
  - Using specific heat capacity from published data
    - For 6” concrete overlay
    - Start with separator layer at 120°F and concrete at 70°F
    - Concrete temperature increase
      - 1” Asphalt – 8.0°F
      - 3 mm Textile – 0.3°F
  - Measuring insulation benefit

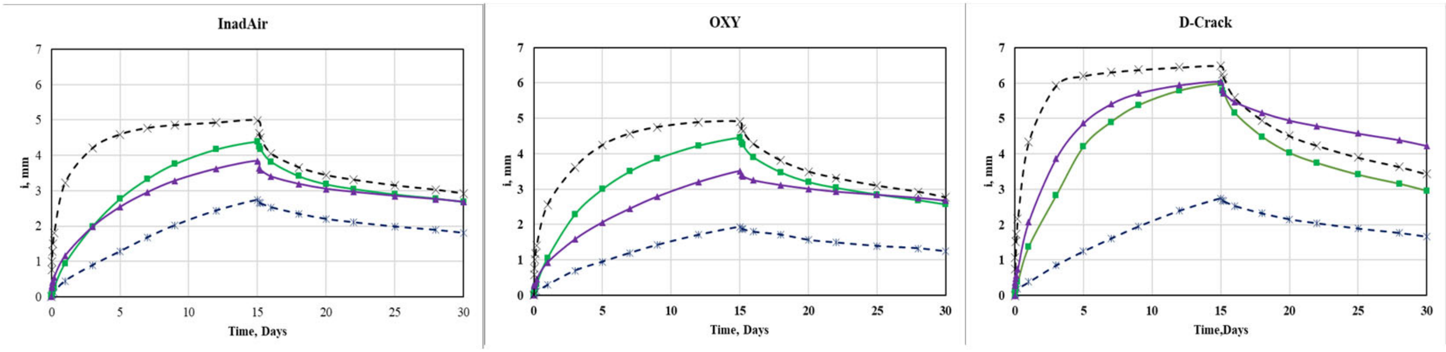


Research Activities

- Geotextiles
  - Resilient Modulus values were higher in the geotextile fabric sections than in AC interlayer sections

Research Activities

- Penetrating sealants – developing a protocol
  - All sealers are not the same and should not be applied equally to all concretes.
  - We recommend absorption/desorption, and saturation/desaturation testing.
  - Pore blocking sealers should be considered with caution.
  - Field tests just started

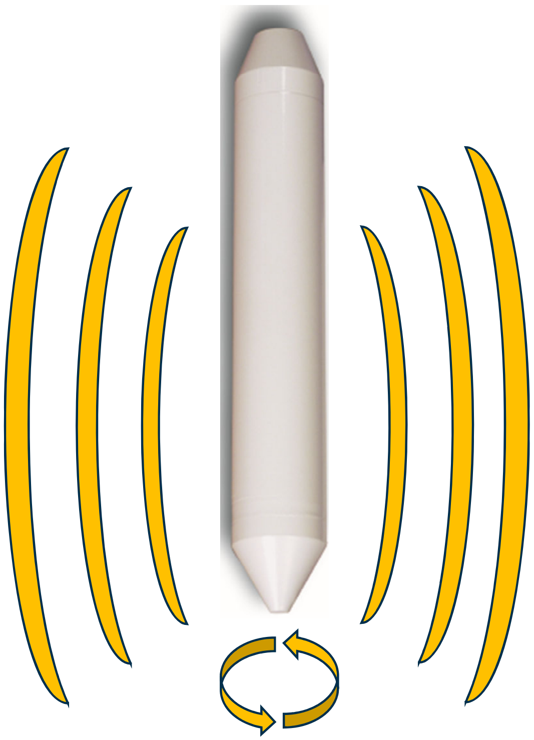


Research Activities

- Good vibration ensures
  - No segregation
  - No entrapped air
  - Retain entrained air
  - No water movement

But how?

Research Activities



Shaft oscillates in a circle sending out P and S waves

What Is Happening under Vibration?

Acceleration drops viscosity and allows air to float up and out

Water moves horizontally

Solids wobble And maybe rotate

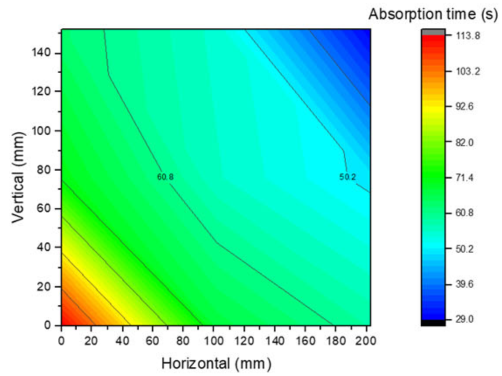
What is a good vibration?

- Missing is fundamental understanding of the “how to” details
  - Energy
  - Frequency
  - Amplitude
  - Duration
  - Spacing
- For a given
  - Workability
  - Air void system
  - Bleed / segregation
  - …

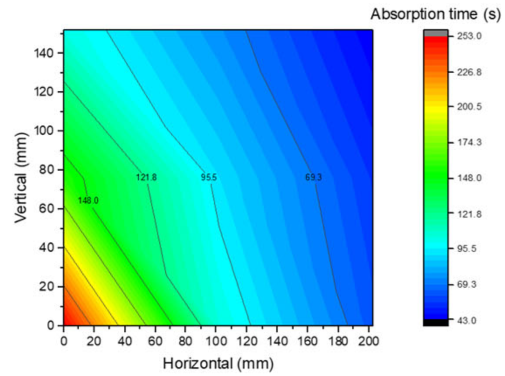
Research Activities

- Increased frequency
  - Moves water sideways

- Excess vibration
  - Impacts air void system



(a) Mixture 1 - slump 10cm



(b) Mixture 3 - slump 2.5cm

Research Activities

- Pooled fund being prepared to dig into the details
  - How much vibration
  - A vibrator proof mixture
  - Feedback from paver to batch plant

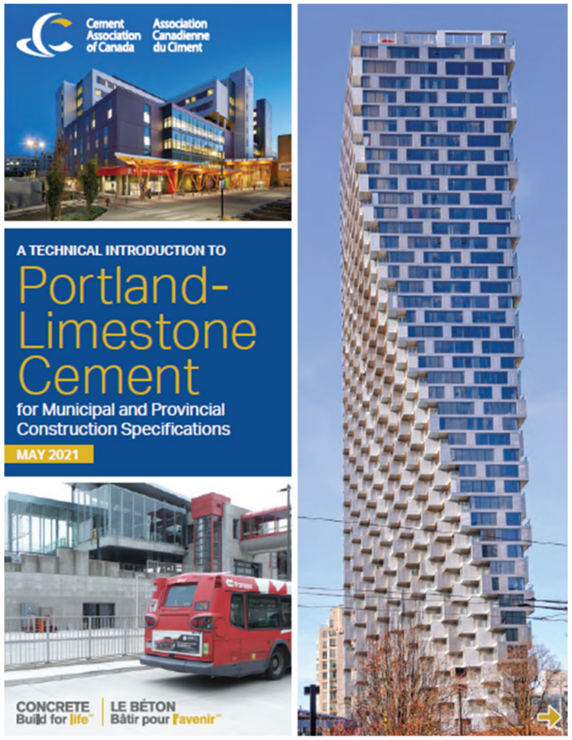
Research Needs

- Achieving uniformity load to load
- Machine control
- Moisture content
- Carbonation rates
- Buckling
- Alternative SCMs

- Paving in cold weather
- Chains

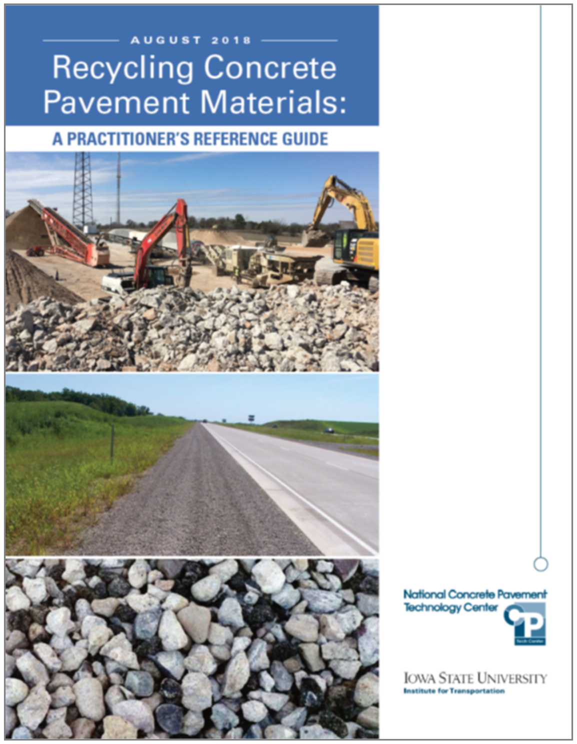
Innovations

- Portland limestone cements
  - Up to 15% limestone added at the grinding mill
  - Small effects on performance
  - Synergy with fly ash
  - Cuts CO_2 footprint



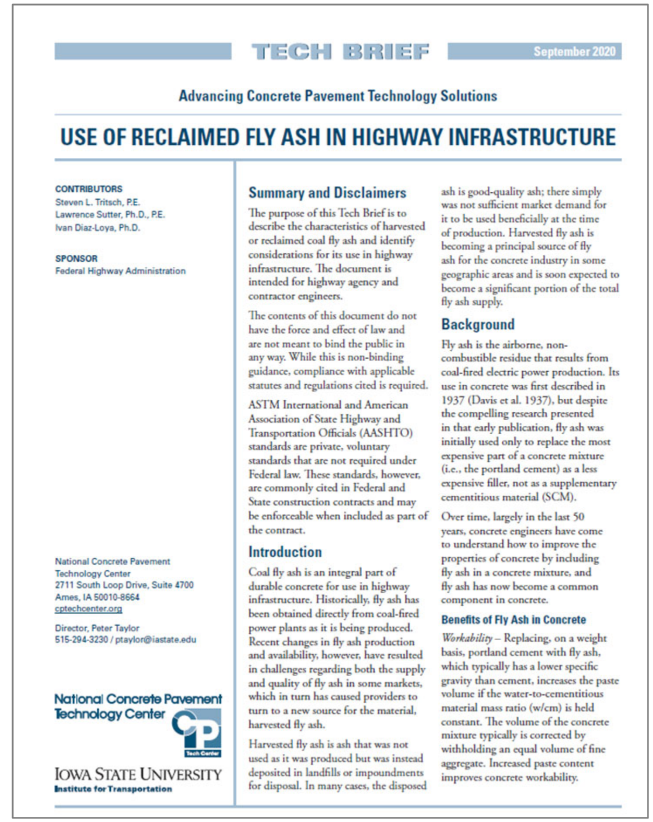
Aggregates

- Recycled concrete aggregates



Innovations

- Reclaimed fly ash
- SCMs from other industries
- …



TECH BRIEF September 2020

Advancing Concrete Pavement Technology Solutions

USE OF RECLAIMED FLY ASH IN HIGHWAY INFRASTRUCTURE

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Summary and Disclaimers

The purpose of this Tech Brief is to describe the characteristics of harvested or reclaimed coal fly ash and identify considerations for its use in highway infrastructure. The document is intended for highway agency and contractor engineers.

The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. While this is non-binding guidance, compliance with applicable statutes and regulations cited is required.

ASTM International and American Association of State Highway and Transportation Officials (AASHTO) standards are private, voluntary standards that are not required under Federal law. These standards, however, are commonly cited in Federal and State construction contracts and may be enforceable when included as part of the contract.

Introduction

Coal fly ash is an integral part of durable concrete for use in highway infrastructure. Historically, fly ash has been obtained directly from coal-fired power plants as it is being produced. Recent changes in fly ash production and availability, however, have resulted in challenges regarding both the supply and quality of fly ash in some markets, which in turn has caused providers to turn to a new source for the material, harvested fly ash.

Harvested fly ash is ash that was not used as it was produced but was instead deposited in landfills or impoundments for disposal. In many cases, the disposed ash is good-quality ash; there simply was not sufficient market demand for it to be used beneficially at the time of production. Harvested fly ash is becoming a principal source of fly ash for the concrete industry in some geographic areas and is soon expected to become a significant portion of the total fly ash supply.

Background

Fly ash is the airborne, non-combustible residue that results from coal-fired electric power production. Its use in concrete was first described in 1937 (Davis et al. 1937), but despite the compelling research presented in that early publication, fly ash was initially used only to replace the most expensive part of a concrete mixture (i.e., the portland cement) as a less expensive filler, not as a supplementary cementitious material (SCM).

Over time, largely in the last 50 years, concrete engineers have come to understand how to improve the properties of concrete by including fly ash in a concrete mixture, and fly ash has now become a common component in concrete.

Benefits of Fly Ash in Concrete

Workability – Replacing, on a weight basis, portland cement with fly ash, which typically has a lower specific gravity than cement, increases the paste volume if the water-to-cementitious material mass ratio (w/cm) is held constant. The volume of the concrete mixture typically is corrected by withholding an equal volume of fine aggregate. Increased paste content improves concrete workability.

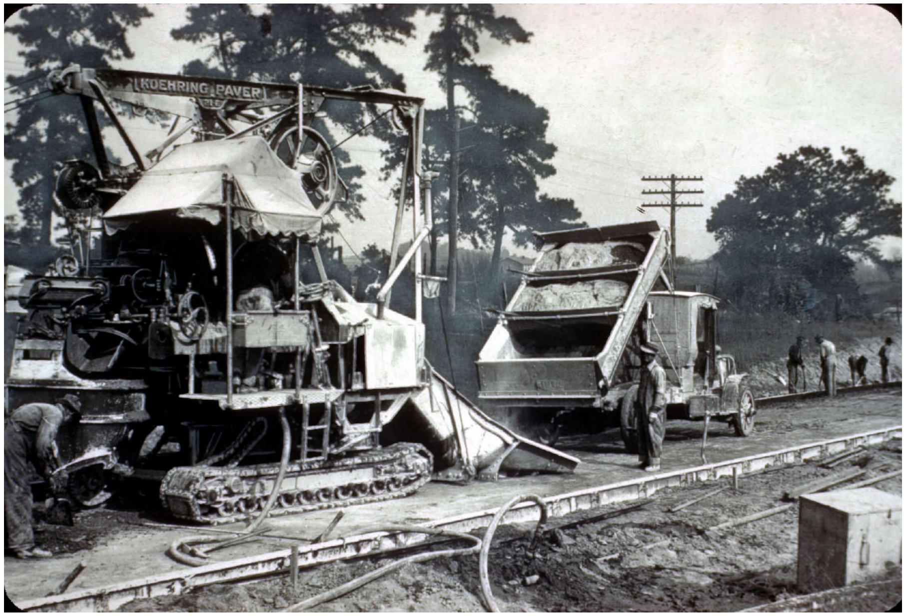
Innovations





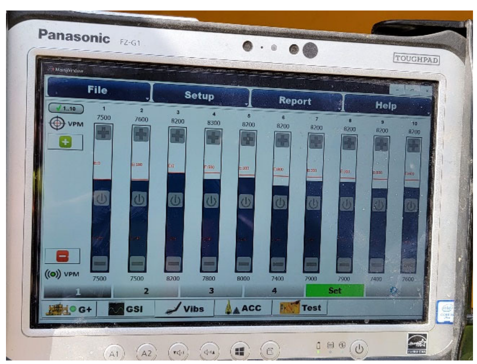

Innovations

- First slipform paver was in Iowa 1950's



Innovations

- Current machines
  - Wide and heavy
  - Controlled vibrators
  - Adjustable pans
  - Stringless
  - Real time smoothness

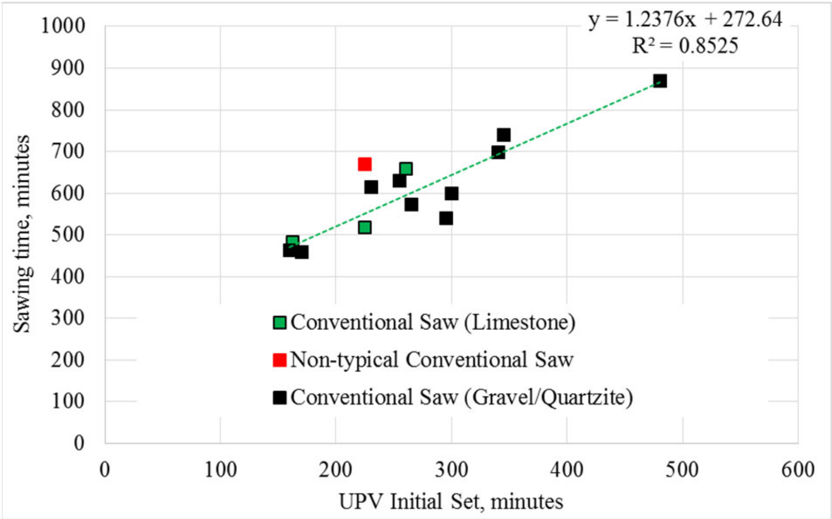


Innovations

- Tining
- Curing

Innovations

- Crack free
  - UPV to guage timing



Are we there yet?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Questions?

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