Concrete Pavement Innovation and Technology Transfer Workshop

Emerging Technologies for Concrete Pavement Construction

Presented by
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Past President, International Society for Concrete Pavements

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Acknowledgements

• Mr. Gary Fick, Trinity Construction Management
• SHRP2
• Dr. Tyler Ley, Oklahoma State University
• Mr. Nadarajah Sivaneswaran, FHWA
• Federal Highway Administration, Office of Infrastructure R&D
Real-Time Smoothness

What is it?
An integrated system of profile data collection sensors and processing software that provides real-time profile feedback to the contractor.
Real-Time Smoothness

Background 2010 and 2011

• SHRP2 R06E
  ▪ Evaluation of GOMACO GSI and Ames Engineering RTP
  ▪ Georgia, Arkansas, Texas, Michigan and New York
Real-Time Smoothness

• Laser enabled smoothness measurement system monitors profile and calculates smoothness indices directly behind the paver.
• Calculates and displays profile as concrete is placed
• Instantly calculates and displays Profile Index (PI) and International Roughness Index (IRI)
• Locates areas of localized roughness and must grind locations
Real-Time Smoothness

The GSI includes: GSI computer assembly, real-time graphic display, media storage card, two sonic sensors, slope sensor, distance counter wheel assembly, and cables.
Benefits

The decision making feedback loop is tightened, thus process changes and construction artifacts are identified earlier

- Conventional profiling ≈ 12 to 24 hours
- Real-time profiling ≈ 1 minute to 1 hour
Real-Time Smoothness

Benefits of identifying construction artifacts in real-time

Opportunity to correct objectionable profile features caused by:

- Stringline disturbance
- Padline variability
- Non-uniformity of concrete
- …
Benefits of identifying the impact of process changes in real-time

Validation of adjustments in 1 hour vs. 12 to 24 hours:

- Hydraulic sensitivity relative to machine control input (stringline and stringless)
- Vibrator frequencies
- Paving speed
- Concrete head
- Concrete mixture proportions
- …
Real-Time Smoothness

Conclusions from R06E

RTS is applicable for:
• Evaluating concrete pavement smoothness in real time
• Quality control
• Process improvements as a result of timely feedback
• Understanding how construction artifacts can affect smoothness

RTS is not:
• A replacement for conventional profiling for acceptance
• A replacement for better practices to construct smoother pavements
Real-Time Smoothness
SHRP2 Implementation Support

RTS Implementation Support Activities
Objective: Routine use of RTS technology by agencies and contractors who routinely construct PCC pavement.
Real-Time Smoothness
SHRP2 Implementation Support

RTS Implementation Support Activities

Task 1: Equipment Loan Program (2015 and 2016)

- Full use of an RTS system for two weeks
- On-site technical support and training
- Budget allows for eleven equipment loans
- Projects with a minimum of 10 consecutive mainline paving days (more is preferable)
- Contractor or agency should commit to providing daily QA profiles during the equipment loan
- Contact gfick@trinity-cms.com if interested
RTS Implementation Support Activities

Task 2: Regional Showcase (Open House)

- One day classroom presentations with an on-site demonstration
- In conjunction with an equipment loan project
- Travel expenses are covered for up to 10 agency participants
Real-Time Smoothness
SHRP2 Implementation Support

RTS Implementation Support Activities

Task 3: Workshops

- Four hour workshops (8) – contact gfick@trinity-cms.com
- Tentative agenda
  - Importance of Pavement Smoothness
  - Fundamentals of Pavement Smoothness Measurement
  - Fundamentals of Ride Quality and Pavement Profile Analysis
  - Current Practices for Concrete Pavement IRI Specifications
  - Best Practices for Concrete Paving Operations
  - Using RTS Technology to Improve Concrete Pavement Smoothness
  - Q & A and Discussion
Real-Time Smoothness
SHRP2 Implementation Support

RTS Implementation Support Activities

Task 4: Documentation of Results/Case Studies

- Synthesis of contractors’ experience
- Case study – Comparing real-time measurements to QA results
- Case study – Long-term performance of RTS
- Documentation of equipment loans and lessons learned
Real-Time Smoothness
SHRP2 Implementation Support

RTS Implementation Support Activities

Task 5: Specification Refinement

- QC approach
- Process improvement
RTS Implementation Support Activities

Task 6: Outreach Materials

- Quick field reference guide (pocket reference?)
- Brochures
- Project updates (30 minute briefings)
Real-Time Smoothness
SHRP2 Implementation Support

Questions and Discussion
Using the Super Air Meter

Braden Tabb, Robert Felice, John Michael Freeman, Robert Frazier, David Welchel, Morteza Khatibmasjedi, Jake LeFlore

Tyler Ley, P.E., Ph. D
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• Concrete Pavement Technology Center
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- Iowa DOT
- Minnesota DOT
- Idaho DOT
- North Dakota DOT
- Pennsylvania DOT
- Connecticut DOT
- Illinois DOT
- Indiana DOT
- Michigan DOT
- Wisconsin DOT
- New Jersey DOT
- RMC Foundation
Why Do We Add Air to Concrete?

• Air-entrained bubbles are the key to the freeze-thaw resistance of concrete

Air volume ≠ freeze-thaw performance

• Smaller bubbles are more effective in providing freeze-thaw resistance than larger bubbles
Hardened Air Void Analysis

From Hover
What Do You Want in an Air-Void System?

- Volume of air provided is the same for both circumstances.
- Case B has a lower spacing factor and a higher specific surface.
• Spacing Factor – \( \frac{1}{2} \) of the average distance of an average sized void uniformly distributed in the paste

• Desired Value < 0.008 in (ACI 201)

real concrete

idealized concrete

from Hover

Spacing factor

from Hover
Why Can’t We Just Use Air Volume?
Mixtures with AEA and HRWR

Mixtures with just AEA

ACI 201.2R

WROS .45

WROS .45 + PC1

Yes!

No!
Mixtures with AEA and HRWR

Mixtures with just AEA

Freeman et al., 2012
Mixtures with just AEA
Mixtures with AEA and HRWR

Freeman et al., 2012
Summary

• It is common to require a certain volume of air in concrete in order to obtain freeze thaw durability

• The volume of air does not equal air void system quality

• Although, a hardened air void analysis (ASTM C457) can measure the air-void quality it is not practical to run regularly
What do we need?

- We need a test that can quantify air-void systems quickly in fresh concrete.
- Investigate a sample of significant size.
- Economical.
- Field ready.
Super Air Meter (SAM)

- We have modified a typical ASTM C 231 pressure meter so that it can hold larger pressures
- We have replaced the dial gage with a digital one
- The test takes 8 - 10 minutes with the hand pump
- 5-6 minutes with a new accessory!!
digital gauge
different bleeder valve
six clamps!
How does it work?

- Use ASTM C231 procedures to fill the measurement bowl
- Secure the lid
- Add water through the petcocks
release pressure in both chambers

- **Top Chamber, \( P_c \)**
- **Bottom Chamber, \( P_a \)**
- **Equilibrium Pressure**
Pressure (psi) vs. Time graph showing the pressure in the Top Chamber, $P_c$, and the Bottom Chamber, $P_a$, with an indicated SAM number and equilibrium pressure.
How does it work?

• We use an algorithm to find a **SAM number**.
• The SAM number correlates to air void size distribution
• The meter also measures air volume
How can we prove it?

- We made a lot of concrete mixtures
- Different AEAs
- Combinations of AEAs and PCs
- Different w/cm (0.39 - 0.53)
- Slumps from 0.25” to 10”
- Air contents from 1.25% to 10%
- **Hardened air void analysis (ASTM C 457) was completed on each mixture**
- Values were compared to the SAM number
92% Agreement

- Lab Data OSU
- Field Data
- LAB Data FHWA
Discussion

• There is over 90% agreement between the lab, field, and 3rd party lab data

• A SAM number of 0.20 corresponds well with a spacing factor of 0.008”

• While spacing factor is great we really want to know freeze thaw performance.
80% agreement w/ 0.20 limit
89% agreement w/ 0.25 limit
Discussion

• The SAM number of 0.20 does a good job correlating to ASTM C666 testing.

• A SAM number of 0.25 may give us better agreement but the 0.20 limit is conservative.

• The SAM is useful to investigate admixture compatibility!
Why is this useful?

- It could be a useful tool during the mixture design stage to help understand how your admixture combinations impact air void size distribution.
- In some cases we will use less and some cases we will use more air than current specifications.
The following states have a SAM

- Michigan (5)
- Kansas (4)
- Utah
- Colorado (2)
- Iowa (2)
- Illinois (3)
- Indiana (2)
- Wisconsin (2)
- Massachusetts
- Oregon
- Tennessee
- Georgia

- Pennsylvania
- Missouri (2)
- N. Carolina (2)
- N. Dakota
- Oklahoma (9)
- Nebraska (2)
- Ohio (2)
- Minnesota (2)
- Texas (2)
- FHWA (4)
- Manitoba (3)
- Ottawa (2)
AASHTO TP 118

www.superairmeter.com
Conclusion

• Data has been presented that shows that air volume is not enough to determine the air void system quality with some admixture combinations and that air void size distribution is much more useful.

• A novel test method was presented that can measure the air void volume and size distribution in fresh concrete.
Conclusion

• A SAM number of 0.20 seems to correspond to a spacing factor of 0.008” for over 300 lab and field mixtures

• Over 90% of the lab and field data is correctly separated with this limit

• The SAM number also correlates with about 60 ASTM C666 results
Questions???
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CA4PRS

Construction Analysis for Pavement Rehabilitation Strategies

Nadarajah Sivaneswaran
Federal Highway Administration
Office of Infrastructure R&D
The Challenge

• Highway infrastructure needs to be renewed
  – Many pavements have reached their design life
  – We must maintain, rehabilitate, and reconstruct highways under live traffic

• Impacts of construction to the general public must be minimized
  – Lane closures create adverse impacts to traveling public, local communities, and businesses
  – Work zones responsible for about 12 percent of highway traffic delay
  – Safety: 40,000 injuries, 1028 fatalities in work zones in USA in 2003
CA4PRS Purpose

- Integrated analysis approach to balance and optimize competing objectives
  - Longer lasting pavements
  - Faster delivery of construction
  - Tolerable traffic delays
  - Within agency budget and scope
CA4PRS Development

- Pooled Fund (CA, MN, TX, WA, FHWA)
- FHWA 2008 Market-ready Technology Product
- Arranged Free Group-License for all State DOTs
- Provided on-site training
- Distributed to 22 states and trained 1,000 engineers
CA4PRS Modules

STEP 1

**SCHEDULE**
- Constructable?
  - Yes: Closure Numbers
    - Project Duration
    - Construction Staging
  - No: Queue & Delay
    - Road User Cost
    - Demand control

STEP 2

**TRAFFIC**
- Tolerable?
  - Yes: Project Cost
    - Agency, Traffic, Support
    - Life-cycle (LCCA)
  - No: Yes

STEP 3

**COST**
- Budget?
  - Yes: TMP
  - No: PS&E
CA4PRS Options

- JPCP Rehabilitation
- CRCP Rehabilitation
- HMA Overlay
- HMA Mill and Fill
- Full Depth HMA
- Precast Concrete
- Roadway Widening

- Deterministic
- Probabilistic
CA4PRS Implementation Projects

- Validation: I-10 (CA), I-710 (CA), I-5 (WA), I-494 (MN)
  - TWO 8-day non-stop construction closures, would have taken 10 month of nighttime conventional closures => Public Perception Change!
  - 10 lane-mile scope ($25M), savings $8M agency cost, $2M delay cost
- I-5 Olive to James PCC Rehabilitation (Seattle, WA) (2005)
  - 1st analysis during early scoping and design evaluation, refined 2nd analysis post-award preconstruction evaluation; probabilistic analysis.
  - Four 55-hour weekend closures
  - One direction full-closure instead of conventional one-lane closure
## CA I-15 Devore Analysis

<table>
<thead>
<tr>
<th>Construction Scenario</th>
<th>Construction Schedule</th>
<th>WZ Traffic Delay</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Total Closures</td>
<td>Closure Hours</td>
<td>Max. Delay (Min)</td>
</tr>
<tr>
<td>One Roadbed Continuous (24/7)</td>
<td>2</td>
<td>400</td>
<td>80</td>
</tr>
<tr>
<td>72-Hour Weekday Non-stop</td>
<td>8</td>
<td>576</td>
<td>50</td>
</tr>
<tr>
<td>55-Hour Weekend Extended</td>
<td>16</td>
<td>880</td>
<td>80</td>
</tr>
<tr>
<td>9-Hour Nighttime Closures</td>
<td>230</td>
<td>2,100</td>
<td>50</td>
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<tr>
<td>8-Hour Nighttime Closures</td>
<td>300</td>
<td>2,400</td>
<td>20</td>
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<tr>
<td>7-Hour Nighttime Closures</td>
<td>410</td>
<td>2,900</td>
<td>10</td>
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WA I-5 Olive to James PCC Rehab

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Estimated</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane-miles Paved Per Weekend Closure</td>
<td>0.47</td>
<td>0.52</td>
<td>0.57</td>
</tr>
<tr>
<td>Number of Required Weekend Closures</td>
<td>4.72</td>
<td>4.28</td>
<td>3.89</td>
</tr>
</tbody>
</table>
CA4PRS Implementation Benefits

- Identify most effective design alternative and closure strategy balancing schedule, traffic impact and agency cost
- Optimizes production and identifies constraining resources to accelerate construction
- Allows comprehensive what-if and trade-off analysis considering resource constraints, traffic impacts and agency costs
- Effective tool for communicating impacts competing alternatives among stakeholders and for public outreach.
- Cost savings through optimized work-zone closures that balances competing demands. Example – CA I-15 Devore Project - $8 M cost savings (Project cost $25 M)
- INFORMED AND COST EFFECTIVE DECISIONS
Application of CA4PRS in Planning, Design and Construction Stages

- Integration Analysis: Schedule – Traffic - Cost
- Planning Stage (PSR/PA&ED)
  - Project Scope and Priority
  - Value Analysis and Life-Cycle Cost Analysis
- Design Stage: PS&E & TMP packages
  - Working-Days (CPM); Construction staging-plans
  - WZ Traffic: TMP and Lane-closure charts
- Construction Stage
  - Formulate Incentives/Disincentives Baseline
  - Validate contractor’s work-plans and Change-order Request
  - Optimized production rates and identification critical path resources
CA4PRS Future Plans

• Software and training upgrade
  – Web-based application
  – Online training, to include case studies
  – On-demand classroom training

• Schedule – 12 months
In Conclusion...

• CA4PRS can help agencies:
  – Integrate schedule, cost, and traffic impacts
  – Improve decision making

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