Michigan DOT’s Implementation of Performance Engineered Mixtures (PEM) for Concrete Pavement

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Performance Related Specifications

• Efforts in Michigan to develop PRS’ in the 1990’s
• The challenge is…“How do we confidently measure long-term performance during real-time construction?”
• Performance Engineered Concrete Pavement Mixtures (PEM) Pooled-Fund project is focused toward establishing linkage between today’s process control/acceptance and longevity.
Some pavements in Michigan were not performing as expected

- Pavements constructed in the late 1990’s and early 2000’s were experiencing problems with joint deterioration
- Something was not right !!!
- Not an aggregate durability problem
- Rather, it appeared to be aggressive paste decomposition
Premature Joint Decay

• Is it being a caused by:
  – Deicer?
  – Inadequate air-void system?
  – Intermittent SCMs…contractor “option” ?
  – Poor subsurface drainage?
  – All of the above?

• Media barrage was brutal !!
In the “Relative” Beginning,

- Midwest Concrete Consortium (MCC)
  - Established 1997
  - State reports and meeting discussion topics:
    - Aggregate gradation and optimization
    - Aggregate quality
    - Alternative durability-based field tests
    - Alternative materials
  - Early 2000’s
    - Started rolling up our sleeves toward “Engineered” mixture concepts
Evolution of Optimized Concrete Paving Mixtures in Michigan

• 1996 – Took a step back…What are the basics of “Quality Concrete”?  
• 1997 – First generation three aggregate optimized aggregate blend, required 
  – 4A: 1 ½ inch nominal top size (between AASHTO No. 3 and No. 357)  
  – 6AA: ½ to ¾ inch nominal top size (similar to AASHTO No. 57)  
  – 2NS: Natural sand  
  – Enhanced freeze-thaw quality coarse aggregates  
  – Optional SCMs  
• 1998 – First interstate reconstruction projects using 40/60 blend  
• 1998 – 2003: A few projects with larger top size 2-inch nominal top size  
  – Created two valleys…not good…too harsh  
• 2004 –  
  – Abandoned required standard gradations  
  – Coarse, intermediate, and fine labels, with 5-15 and CF/WF criteria
Evolution of Optimized Concrete Paving Mixtures in Michigan

- 2010 – First version of current QC/QA special provision
  - Defined independent QC and QA sampling and testing protocol
  - High Performance Concrete Pavement Mixtures
    - Reduced cementitious material content
      - Total cementitious materials content: 470-564 lbs/cyd
      - Mandatory 25-40 percent SCM replacement
    - Mandatory optimization using CF/WF criteria (*with a few haystack rules*)
    - Percent within limits quality index analysis for pavements
    - Pay factor for air content
    - ASR requirements for fine aggregate (all concrete applications)
  - Significant emphasis on Contractor Quality Control Plans
- 2017 – Expanded HP mixture requirements to structures
Roads Innovation Task Force (RITF)

- SAM and Resistivity will be demonstrated on two concrete demo paving projects:
  - 50-year design life (75-year service life): Grand Region, US-131 from 10 Mile Road to 14 mile Road. Spring 2018 project letting. Summer 2018 paving
  - QC and QA informational shadow testing via “Special Provision for Durability Based Field Testing”
Current Pooled-Fund Project Participation

• 2014 - MDOT along with 18 other state DOTs: “Improving Specifications to Resist Frost Damage in Modern Concrete Mixtures”, TPF-5(297). Completion date: 2019
  – Lead state – Oklahoma DOT
  – This pooled fund initiative is focused on the development of the SAM

• 2017 - MDOT along with 15 other states and the FHWA: “Performance Engineered Concrete Paving Mixtures”, TPF-5(368). Completion date: 2021
  – Lead state – Iowa DOT
  – The National Concrete Consortium (NCC) will be the anchor organization for dissemination of research and outreach for this project (34 DOTs, FHWA, industry, academia)
  – This pooled effort will greatly aide toward developing Michigan-based specifications for incorporation of PEM protocol into the MDOT concrete quality assurance program
State Transportation Innovation Council

• Federal Grant for Deployment of Innovative Technologies
  – Two grants were awarded to MDOT in 2016
  – STIC Application – Implementation of SAM
    • Total: $90,000 ($72,000 Federal Funds, $18,000 State Funds)
      – SAM Acquisition
      – Training, Spec Development, Outreach
      – Implementation
Equipment Acquisition and Training

• Equipment
  – Acquired
    • 19 SAMs, to date
    • 3 Resistivity Meters

• Training 2017/2018
  – Brought Dr. Ley in for two Joint MDOT/MCA SAM training courses
    • Day-long event (classroom and practical laboratory setting) – 53 attendees
      – MDOT technicians
      – MDOT Supervisors
      – County Road Commission
      – Contractors
      – Concrete Suppliers
      – Consultants
      – MCA Staff (“Train the Trainer” prep)
Bringing the Contractor Expertise and Perspective to the Table

- Military Airfield Paving
  - Experience with performance engineered mixtures
    - Optimized gradation really works
    - Support for gradation control specifications
- Looking Beyond PEM
  - Performance engineering is more than just the concrete mixture
  - The pavement structure is also important
    - Drainable
    - Stable
    - Long-term subgrade protections
Specialty Concrete Applications

- Stakeholders,
  - Owner/Specifier
  - Concrete producer
  - Contractor

- How do we translate between individual stakeholder requirements/limitations to produce an end product that is,
  - In compliance with specification requirements
  - Durable – long lasting
  - Aesthetically pleasing
  - Cost-effective
QC/QA Defined Roles

• Quality Control – Contractor Responsibility
  – Construct the project so that it complies with the project plans and specifications
  – Develop, operate and communicate a comprehensive plan to complete the work
  – Adjust plan as necessary to maintain control of the construction process
  – Testing so that only complying materials are incorporated in the work
  – A test of a batch of concrete – Utilize, Modify, Reject or Suspend Production

• Quality Acceptance – Owner Responsibility
  – Be in position to witness QC operations
  – Confirm compliance with plans and specifications
  – A test represents a sublot of concrete – not just one batch
  – Pay for acceptable completed work
PEM Value for Industry

• Super Air Meter (SAM)
  – Improve up front mix quality
    • Proper material selection…e.g. cheapest AEA may not be the best option
    • Batch sequencing
    • Mixing times and timely transport, discharge and finishing of concrete
  – Improve real time control of the concrete quality
    • Knowing your in-situ fresh concrete properties at all times
    • Modifying operations with changing ambient conditions
  – Could improve standard air testing precision
**PEM Value for Industry**

- **Box Test or V-Kelly**
  - Mix qualification
    - Are the materials suitable for the application
    - Are the materials properly proportioned
    - Will fresh concrete in the lab meet Box and V-Kelly criteria?
    - Changes in material properties, proportions or processes will prompt additional Box or V-Kelly field verification…is the mix still paver-friendly?
    - Note: Well graded mixes can be quicker to unload & easier to finish

- **Resistivity**
  - Proper material selection will dictate end result

- **Other PEM Initiatives**
PEM Value for DOT Agency

- **Super Air Meter (SAM)**
  - Addresses air quality not just total air content
  - Anticipate improved uniformity compared to status quo
  - Acceptance thresholds still need rugged validation
- **Resistivity**
  - Permeability of the concrete – long term performance measure
- **Box Test or V-Kelly**
  - Quality control tools – Value in terms of observing QC activities
  - Adaptability for acceptance is questionable
- **Other PEM initiatives**
Current Optimization versus Tarantula Curve
Initial SAM Data – 2018 Demo Project

SAM Number vs. Total Air Content
2018 30-year Demo Project

- 4.0 inch slump
- 4.5 inch slump
- 5.0 inch slump
- Production paving
  Slump: 0.75 to 1.75 inch

QA SAM Results (Mix# 527-1 unless otherwise noted):

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Initial SAM Data – 2018 Demo Project

SAM Numbers – 2018 30-year Demo Project

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Hardened Air Content (ASTM C457 – Procedure A)

Min. Specific Surface = 600 in\(^{-1}\)
Max Spacing Factor = 0.008 in.

- Total Fresh Air
- Total Hardened Air
- Effective Air (<250 um)

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### Initial SAM Data – 2018 Demo Project

#### Hardened Air Content (ASTM C457 – Procedure A)

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Lessons Learned

• Don’t attempt development and implementation “in a bubble”
• Work within “reasonable” material production and handling constraints
  – What’s good for paving may not work for ready-mix applications
  – Listen to the aggregate producers
• Incremental implementation of new tests…don’t force the issue!
• Consistency between Contractor QC and Agency QA
• Pilot and shadow demonstration projects recommended
• Need sound data prior to implementing for acceptance
• Need continual data collection for PWL calibration
Moving Forward

• Complete STIC obligations
• Partner with MCA to incorporate SAM training module into current MCA Level 1 certified concrete technician course – 2018
• Continue active participation in pooled-fund projects:
  – “Improving Specifications to Resist Frost Damage in Modern Concrete Mixtures”, TPF-5(297),
  – “Performance Engineered Concrete Paving Mixtures”, TPF-5(368)
  – Assist Dr. Weiss toward refining Resistivity, ”F-Factor”, ”Bucket Test”
• MCA is also a contributing partner in PEM project, TPF-5(368)
• Pooled-fund efforts will help steer future MDOT implementation of PEM
Questions?