# Performance Engineered Concrete Paving Mixtures

**Study Description:**

Background

Concrete for pavements has historically been specified and field controlled around acceptance criteria that do not relate well to durability (slump, air content, strength). Paving concrete specifications need to be built upon engineering properties that directly relate to good field performance. With the recent advancements in research knowledge on failure mechanisms, and the paralleled development of better tests, this is possible.

A review of many current and new specifications has found that they are still largely based on strength, slump, and air, which provide limited correlation with the mechanisms of pavement failure currently observed. The need for change in the way we specify concrete, especially concrete for paving mixtures, is becoming increasingly apparent as mixtures become more complex with a growing range of chemical admixtures and supplementary cementitious materials. Traffic loadings continue to increase, more aggressive winter maintenance practices are implemented, and demand increases to build systems more quickly, cheaply, and with increased longevity.

The Federal Highway Administration, through their Cooperative Agreement with the National Concrete Pavement Technology Center, has been working with the 30 member-state departments of transportation of the National Concrete Consortium to identify the specification approach and key testing technologies that are needed for paving concrete to have increased durability, including in the presence of wet freeze thaw and winter deicing materials. The testing technologies have been developed, and the next critical activities are deployment of the new testing technologies, development of practical specifications and QA/QC recommendations, and correlating specification limits with durable field performance. It is proposed that a TPF supported financially and technically by FHWA, DOTs, and industry be advanced as the best approach to accelerating the implementation and benefits associated with durability based specifications.

To date two significant milestones have been accomplished:

1. During the late summer of 2015 and the 2016 paving season, agencies (Illinois, Indiana, Iowa, Nebraska, Michigan, Minnesota, Wisconsin, South Dakota, Manitoba, and the Illinois Tollway) have started using and evaluating new testing technologies that support the design and testing of performance engineered concrete paving mixtures (PEMs).

2. A proposed AASHTO provisional specification and commentary has been submitted for balloting by the member states.

   The specification seeks to provide agencies with the tools to prepare a specification for concrete mixtures for pavements that moves closer to measuring and basing acceptance on the parameters that are truly critical to the long-term performance of the system.

   The commentary is provided to support each relevant section of the specification to provide background information and the rationale behind the recommended approach. Discussion is provided in this commentary regarding how desired performance requirements are typically sought in a prescriptive specification for comparison between the recommendations in this

document and current practice. It is recommended that mixing performance and prescriptive approaches be avoided, to the degree possible, because of the risk of making it impossible to meet all of the demands on the system.

The intent of this TPF is to build upon these two critical steps and provide technical assistance and training to participants, validate the AASHTO provisional specification based upon actual field performance, and continue the developmental work of measuring and relating early age concrete properties to pavement performance.

The Iowa DOT will serve as the lead state for the accomplishment of the pooled fund project described in this proposal. The Iowa DOT, through the National Concrete Pavement Technology Center (CP Tech Center) at Iowa State University, will handle all administrative and technical duties associated with the project. The CP Tech Center will serve as the lead research institution for the project, with Oklahoma State University and Oregon State University as contributing institutions. The Co-Principle investigators will be Dr. Peter Taylor for Iowa State University, Dr. Tyler Ley for Oklahoma State University, and Dr. Jason Weiss for Oregon State University.

**Objectives:**

The objective of this study is to focus on the successful deployment of performance engineered mixtures. This will involve building off the foundational work that FHWA and the "PEM Champion States" have done, with emphasis on implementation, education and training, adjusting the specification values to relate accurately to good pavement performance in the field, and continued development of relating early age concrete properties to performance.

**Scope of Work:**

## Task 1: Implementing What We Know

This task is intended to provide support to study participants with implementation of performance engineered paving mixtures within their states. Implementation assistance will include:

- **Education and Technical Training** - The TAC will prioritize the desired technical products that will likely include web-based training, on-line videos, state-based workshops open to agency and industry, technical materials to assist field personnel and contractors, and project case examples.

  While the PEM educational program is very large, this will be managed by the CP Tech Center with the Oregon State team focusing on aspects of formation factor, calcium oxychloride, drying/wetting, and time to critical saturation and the Oklahoma State team focusing on implement the Super Air Meter, Box Test, and Tarantula Curve.

- **Project level support** – On-call technical assistance will be provided to agencies as needed to assist with PEMs guidance and questions. This will be available throughout the project development and construction phases.
  - The **FHWA Mobile Concrete Trailer** (MCT) will be available to assist DOTs with shadow testing of the specification on projects to help field personnel gain firsthand experience

with the PEM and associated quality plan requirements. It is anticipated that the MCT will be able to support 3 to 5 projects per year and the intent is to schedule their work with the DOTs so all participants of the study will have the benefit of this support.
    - CP Tech Center staff will be available to provide on-site training at the project level to assist agencies and contractors run the suite of tests required for their location, as well as modify mixtures to achieve required limits as required.
    - Assist DOTs with evaluating and implementing the dual ring test method for concrete to better understand the probability of random cracking.

- Quarterly TAC meetings one of which will be an annual two-day TAC meeting to focus on lessons learned and on implementation support.

### Task 2: Performance Monitoring and Specification Refinement

With any new specification it is critical to monitor the requirements and be sure that they are optimized to consistently produce good performing pavements. As necessary, the specification values and testing limits should be adjusted to represent the optimal balance between cost and performance. This task will provide field performance data for use in making decisions on specification limits in the areas of salt damage, transport and freeze-thaw damage. To accomplish this successfully, an organized process of pavement monitoring and evaluation is intended in this task. It is proposed that the projects built under PEM specification requirements also continue to be monitored in the future Phase 2 of the study. Critical activities will include:

- Working with the TAC to determine the desired data to collect.

  A database will be developed that can be used throughout this study and beyond to track the tests, materials and properties used by the individual DOTS for the purpose of building a database that can provide inputs on the data to be collected, type of data to be collected, and the typical results. It is anticipated that this data will be tied to field performance over time. It will be intended to tie this work with LTPP data.

- Developing a process for uniform data collection between the states over the five-year period of the study.
- LTPP database mining - Review the available information within the existing Long-Term Pavement Performance (LTPP) data to determine what conclusions and insights can be drawn that will help with the verifying PEM test value limits to field performance. The LTPP database contains detailed information including results of material testing, mixture designs, construction information, climatic information, and performance information for hundreds of sights located throughout the U.S. and Canada. In addition, the LTPP Materials Reference Library (MRL) maintains thousands of specimens from LTPP sites, including concrete constituent materials (cement, SCMs, and aggregates) as well as cores. Together, analysis of this data and results from testing of sample concrete may provide a means to calibrate the service life models to predict future durability-related performance.

This detailed investigation on mining the LTPP database will include additional testing of the binders (Oregon State will focus on calcium oxychloride and pore solution conductivity and Oklahoma State will focus on SCM characterization) and concrete cores (Oregon State to evaluate both formation factor, pore volume, reserve alkalinity, chloride binding, and calcium oxychloride damage and Oklahoma State to measure air void parameters and existing chloride ion penetration).

- Develop a website for making the data available to all participating states
- Analyze the results on an annual basis and propose adjustments to the Provisional AASHTO PEM Specification, if any.
- Continue to work with the states to build a database of typical materials, in two main areas. First the propensity of different binders to form calcium oxychloride and the resulting damage. Second the pore solution chemistry as well as thermal and moisture related aspects of electrical measurement for formation factor.
- Continue to develop and implement recent research that uses new methods of fly ash and slag classification that give strong insights into the performance of these materials and their ability to predict performance in concrete such as pore refinement, improved corrosion performance, strength, formation factor, resistance to drying, and ability to suppress ASR. This will be incorporated into the service life models to help improve their accuracy.

### Task 3: Measuring and Relating Early Age Concrete Properties to Performance

This task will build upon the foundational work done to date in measurement technologies to design and control concrete pavement mixtures around key engineering properties. It is planned that work under this task will address Improved testing methods for improved accuracy and reduced cost. These include:

- **Accelerated tests to determine transport properties**. The team has been working on this for the last several years and feel now that they have an understanding of how to obtain long-term transport and performance properties at the time of placement and shortly thereafter. This will be useful both for materials qualification as well as materials acceptance. This will also include improved sensing technologies for the determination of pore solution composition and other parameters for use in rapid determination of formation factor.
- **Development of the thermodynamic model** with potential links to transport and overall performance. This will be useful in linking material characteristics, test methods and overall service life performance.
- **Development of a moisture movement model** that specifically targets the performance at joints with aspects of very detailed measurement on moisture movement from the application of salts/drying/wetting as well as capillary action from the subgrade. This information will be used to extend the formation factor, calcium oxychloride, and freeze-thaw work to improved predictions of service life.
- **Rapid method to determine water content.** A major parameter needed to determine the durability of concrete is the water to cementitious ratio (w/cm). A test is needed that is fast, reliable, and able to be run in the field to measure the water content in concrete accurately. Currently, the microwave oven test (AASHTO T 318) can be used to do this. However, the accuracy of the test has been questioned. A new approach is needed to make this measurement using fast and inexpensive measures. The test will also measure the amount and different types of binders

that are used in the mixture. This test can be used to give both industry and owners insights into their concrete before it is placed. The establishment of this test would give tremendous insights into the durability of the concrete before the material is placed and will be a useful tool for everyone in the concrete industry.

- **Impact of construction methods on field performance of concrete.** Construction methods play an important role in the long term performance of concrete. There is very little understanding that concrete curing and compaction has on the long term performance of the pavement. In this effort concrete will be produced with different levels of curing and compaction and the performance in freeze thaw, shrinkage, and mass transport will be quantified. The Box Test will be used to quantify the compaction of the materials. Techniques developed at Oklahoma State will also be used to place controlled amounts of curing compound on the surface of the concrete and investigate the impact on the resulting pore structure. Once the impact of these methods has been established then they can be used to modify the existing models and augment existing models to predict the long term durability of concrete.
- **VKelly Workability Test** – Work is needed to calibrate the test output against the needs of different types of paving equipment. It is planned to work with paver manufacturers as well as agencies to conduct the test on as wide a range of sites and mixture types as possible to refine the recommended values for different applications.

  There is also a need to conduct a round robin to determine the repeatability of the test to write into a formal method statement. This will be conducted at a central location at which a number of operators will be asked to test a range of mixtures. This session will also act as an opportunity to train operators as needed.

  At all of these sites, data will also be collected to validate the mixture proportioning methodology being recommended by determining mixture properties and the aggregate gradations.

**Schedule, Budget and Sponsorship:**

Schedule:

- Proposed start: January 1, 2017
- TPF length: 5 years (Phase 1)*

Phase 1 – 5 years @ $3m

Proposed Funding Sources

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|---|---|
| • DOT's: $15,000 per year for 5 years ($75,000) from 14 states. | $1,050,000 |
| • FHWA: $200,000 per year for 5 years = | $1,000,000 |
| • Industry: $200,000 per year for 5 years = | $1,000,000** |
| | $3,050,000*** |

*Phase 2 (2022-2026) Future

- The specific scope will be developed in detail in year 4 of the Phase 1 study, but at a minimum it is envisioned that Phase 2 will have continued emphasis on Tasks 2 and 3 of Phase 1.

**Industry commitments will be made through a dedicated fund established by the CP Tech Center to support this project.

***Work on the project is anticipated to start once the first-year funding of $600,000 is committed.

**Summary of Requirements for Project Sponsors:**

1. Financial support
2. Participation in quarterly TAC meetings, three of which will be web based and one physical meeting per year. DOT travel support will be provided through the TPF.
3. Participate in implementation of a PEM specification through test evaluation, shadow projects, and pilot projects.
4. Assistance with performance monitoring data collection to ensure specification limits reflect actual field performance.