Pooled Fund Problem Statement for Implementation of Concrete Pavement Mixture Design and Analysis (MDA) Track of Concrete Pavement Road Map

1. Scope of Pooled Fund

The work to be covered by this pooled fund addresses focused activities under the Concrete Pavement Road Map (CP Road Map) Track 1, Mix Design and Analysis. The activities are intended to meet some of the needs identified by the track. These include the need for:

- Verification tests that are easier to perform or better characterize materials and mixtures, both for uniformity control and for acceptance.
- Relationships and models that predict the performance of a mixture based on knowledge of the characteristics and proportions of the materials in it.
- Guides and Specifications that help users make good decisions, and make clear who is responsible for what and how it will be measured and paid for.
- Communication and education tools that help practitioners stay abreast of innovations being developed under this pooled fund.

Other activities under the mix track, that are not part of the pooled fund, are discussed in the attached Framing Report for Track 1 of the CP Road Map.

This pooled fund is being set up to address specific tasks within the Road Map, notably those tasks that can, and should, be addressed in the short term, with high probability of achieving significant improvements in the quality and uniformity of concrete mixtures.

2. Funding

- Pooled fund - $500,000 ($15,000 per year for 3 years from at least 11 states)
- National Concrete Pavement Technology Center (CP Tech Center), Iowa State University, Center for Transportation and Research contribution - $500,000

It is planned that work will be phased so that work can begin as soon as $165,000 has been raised from states (see Section 10 Budget). Details of priority activities will be agreed with the Technical Advisory Committee (TAC) after it is formed. Work is planned to begin in fall 2008.

3. Introduction

Increasing numbers of materials are being included in concrete mixtures, and higher demands are being made on the concrete, thereby significantly increasing the complexity of the pavement systems. Decreasing availability of ideal materials and increasing pressure to take a sustainable approach to construction means that mix designs cannot be based on a "business as usual" approach. With a diminishing number of experienced personnel able to address these needs, it is critical that tools and resources be provided to guide users through the process of selecting the pavement parameters required to meet the demands, including proportioning the available materials efficiently while still able to provide the required performance. In addition, tools and tests are needed to allow verification that the concrete delivered is in compliance with the specifications – particularly as pressure increases to move away from mostly prescriptive specifications to mostly performance based specifications.

The vision behind the work described in the Mix Design and Analysis (MDA) Track of the CP Road Map is to develop tools to help specify and make mixtures for concrete pavements that are consistently long-lasting, constructible, and cost efficient. The aim of the track is to develop:

- Clear guidelines on the characteristics of a good mixture, i.e. what properties are needed to satisfy the needs of the owner for a pavement that will last a given time in a given environment.
- Clear guidelines on the properties needed to satisfy the needs of the contractor for mixtures that can be reliably and consistently placed and finished.
- Appropriate limits for the various parameters based on the environment and construction conditions.
- Appropriate test methods for determining the properties of a mix; both for quality control and quality assurance.
- Guidance on what and how materials properties affect the final mixture.
- Calculation tools for determining mix proportions.
- Communications tools so that there is a feedback loop from design, through specification, mix proportioning, construction, placing, maintenance and back to design for the next pavement.

4. Overview

This pooled fund is intended to address the following needs identified in the CP Road Map, Mix Design and Analysis (MDA) Track:

- Tests
    - There is an over-arching need for cost effective, fast, reliable tests that measure the properties we are really interested in, both for incoming materials and for the mixture itself. Some are for Quality Control (contractor internal work) and some are for Quality Assurance (client acceptance) as discussed below.

- The first tests needed are those that assess the acceptability of a given material. Many of these are currently used based on existing ASTM and AASHTO methods. However, some parameters are still not resolved such as methods to assess acceptability of an aggregate or uniformity of a supplementary cementitious material.
- Tests are needed to monitor the variability of materials coming into a mixture, so that adjustments can be made on the fly to ensure that the delivered mixture is uniform and appropriate for the conditions in which it is being used.
- The other tests required are those that assess the quality and / or performance of the mixture as it is placed. Tied to this is the need for appropriate limits that allow unambiguous decisions to be made regarding the acceptability of a given material or mixture. Without these tests, it is impossible to develop good performance based specifications, because it is impossible to measure the concrete performance.

- Models
  - Tied to the need for tests, is a need to correlate test results with long term performance of a concrete system. At present, we lack the tools to be able to predict the potential life of a pavement based on accelerated or early age performance data.
  - Other models needed include development of more robust predictions of fresh concrete properties based on the properties, proportions and interactions of the ingredients. This is especially evidenced in the current approaches taken to addressing interactions between ingredients. It is known that class F fly ash may improve alkali silica reaction expansion, but this can only be quantified using slow or imprecise tests. At the same time the use of the ash will likely retard setting and early strength gain, thereby increasing the risk of plastic cracking. The decision then of "how much fly ash" is currently based on empirical estimates.

- Specifications
  - Specifiers and plant operators need effective guidelines on the effects and side effects that may be expected if they change the source, type or dosage of a given material.
  - Current contracts are built around lowest cost, therefore innovations impose high risk to the specifier and to the contractor. It is more conservative to continue with business as usual.
  - Prescriptive practices also allow little flexibility to accommodate variation in materials or environment, potentially leading to distress or unacceptable variation in the finished pavement.
  - The aim of a good specification is to ensure that the owner is given the highest probability of getting what they pay for, while affording suppliers and contractors a reasonable opportunity to optimize their decisions and minimize their risk.
  - As specifications become more performance based, there is a need for a guidelines addressing who should make what decisions – for instance, should

designers specify slump when they do not know what equipment the contractor will use, and what slumps will be optimum for that equipment?

- Communication
    - When changing the rules, we have to prove that they work, and teach all involved what the new rules are, and how to use them.
    - The need for education is growing because cement based systems are becoming increasingly complex with multiple admixtures and supplementary cementitious materials in most concrete mixtures made today. This is coupled with increasingly stringent demands being placed on the mixtures as budgets and time constraints become tighter.
    - The potential for problems is exacerbated as staffing levels are being reduced, leaving relatively inexperienced personnel being required to make decisions beyond their experience or training.

5. Detailed program

Following are the details of the four activities intended to address the above needs.

- **Evaluation of Emerging Testing Equipment**

This project involves the evaluation and implementation of promising tests currently under development, and new tests needed, that can be used to evaluate concrete ingredients and mixtures.

A task under this activity will be to monitor the findings generated by others, and to conduct supplementary work where needed, such as conducting ruggedness tests and round robins to develop precision and bias statements. Assistance will be provided in developing test protocols and preparing methods for submission to AASHTO and ASTM where necessary. Pilot investigations of innovative tests identified as being necessary will also be conducted.

Selection of the tests to be investigated will be in consultation with the TAC and with input from the states. At the April 2008 meeting of the Technology Transfer Concrete Consortium (TTCC) Pooled Fund, the tests discussed below were selected as having the highest priority.

The following tests may be considered to be in three different states of development, 1) Nearing implementation, 2) Under development, and 3) Conceptual. The actions needed for each test will vary and are described as appropriate for each test.

    - Rheology test. The slump test is currently the standard approach to determining workability of a mixture. However it is not always valid for use in mixtures needed for slipform paving, and it does not describe the parameters needed to be known by paver operators. There is a need to

develop a simple field test for measuring how much a paving mixture will move when vibrated (viscosity) and whether it will be prone to edge slump (yield stress). Some work has been conducted in this field in the past with limited success. A pilot investigation into alternative approaches to this issue is needed. It is planned that the results of the test will allow for a more definitive description of the workability of a mixture.

- AVA. The air void analyzer is a device intended to provide on-site evaluation of the air void system in fresh concrete. Work is being conducted by a number of researchers to evaluate the device and to develop guidelines on its use. The findings of these researchers need to be gathered and interpreted, and a formal method statement needs to be developed for submission to AASHTO and ASTM.
- If performance based specifications are to become more acceptable, there is a need to be able to verify that a mixture delivered to a given site contains the correct materials in the given proportions used in the verification testing during design stage. At present there is no good way to do this, but the topic is worth investigating.
- If the AVA does not prove to be useful, consideration should be given to investigating alternative methods of assessing the air void system in fresh concrete.
- Foam index test. Several versions of this test are used by fly ash producers and purchasers as a quality control tool. There is a need for this test to be standardized and submitted to AASHTO and ASTM.

Other tests that may be considered include (if funding is available):

- Coefficient of Thermal Expansion (CTE), is a measure of the change in dimension of a concrete sample due to changes in temperature. The parameter has a direct impact on the risk of temperature related cracking in newly placed concrete pavements. A test has been developed at FHWA and needs to be field tested and validated, and a formal method statement based on the AASHTO provisional method needs to be developed for submission to ASTM.
- Field Temperature Monitoring. Monitoring the rise in temperature due to hydration of a fresh mixture provides a tool to assess the uniformity between material and concrete batches, as well as indicating setting times useful for saw-cutting operations. A project is nearing completion investigating the various devices available including some field tests. A formal method statement needs to be developed for submission to AASHTO and ASTM.
- Permeability. European specifications are using a permeability test developed by Torrent. There is a need to investigate the applicability of this test to US pavement construction. Recommendations have also been made to use the ASTM C 642 boiled water test as a simple measure of potential durability. This test has been the subject of a brief investigation in Minnesota and Kansas. The test warrants further investigation. Work under this task would be coordinated with the Indiana Pooled Fund Permeability work.

- Foam Drainage Test. This test shows promise as a means of assessing the risk of air void loss based on the ingredients in the mix. The correlation between lab data and field performance needs to be established.

- **Modeling**

It is also planned that under this project some immediate issues such as "How much air is really necessary?" and "How do I specify a good grading" can be addressed.

The models discussed below include tools or methods to correlate different parameters, and to help users select appropriate materials and proportions. At the April 2008 meeting of the TTCC, the models discussed below were selected as having the highest priority.

- Seminal work conducted by Klieger in the 50's on which we base our current limits on air content and air void system parameters was conducted using no supplementary cementitious systems and a single type of air entraining admixture. Some of the recommendations of this work need to be verified as still appropriate for current cements, SCM's and air entraining admixtures, all of which have changed significantly over time. Work will be coordinated with a recent project being initiated at Michigan Technological University on a similar topic.
- There is a need to correlate paste content with mixture shrinkage and cracking risk, for all types of binders.
- There is a need to set out standard information to be recorded and stored at the time of construction so that in later years, the performance of pavements can be compared with the construction data, thus allowing development of durability models based on field performance rather than extrapolation of laboratory data.

Other tests that may be considered, if funding is available, include:

- Current specifications impose limits on minimum working temperatures for concrete pavements. The validity of these limits needs to be verified.
- Current tools used to assess the combined aggregate grading are empirical in nature, and are difficult to impose specified requirements around. It is accepted that while a good combined grading increases the probability of an acceptable mixture, it is still possible to make good concrete pavement with a poor grading and bad pavement with good grading. This topic needs further investigation.
- Interaction Hyperdoc – it is planned to develop an interactive electronic document, based on the IMCP, that will enable users to observe the effects that their decisions on materials type and dosage will have on properties of the concrete.

- **Mixture Testing and Analysis Guidelines (Specifications)**

Changes and innovations to the way we do things can only be achieved within the context of specifications. It is therefore critical that appropriate guides and specifications be developed and implemented.

This project consists of developing tools to assist with all stages of mixture design, proportioning and analysis. It is planned that work will start with assimilating knowledge currently available (including that developed in the recently completed Materials and Construction Optimization Pooled Fund, MCO Project, and FHWA Task 64) to develop worksheets and guidelines for decision making by designers, specifiers, contractors, mixture suppliers, and inspectors. These documents can then be computerized and integrated with other available packages. As new tests and protocols are developed these products can be updated and refined. Selection of the topics to be investigated will be in consultation with the TAC and with input from the states.

  - A guide specification and commentary will be prepared that lays out current state of the art thinking with respect to materials and mixture selection, proportioning and acceptance. This document will take into account the different environments, practices and materials in use across the US, and will allow optional inputs for local application. The specification will be developed based on existing documents including the recent IPRF Draft P501.
  - As a supplement to the Integrated Materials and Construction Practices for Concrete Pavement Manual (IMCP), it is planned to develop check-sheets for different parties involved in the development of a mix design. They will help inexperienced practitioners make appropriate selections for the tasks they are conducting (e.g. preparing a specification or selecting aggregates). It is also intended that decisions are made at the correct location (e.g. slump is selected by the contractor rather than the specifier).

- **Training, and Outreach**

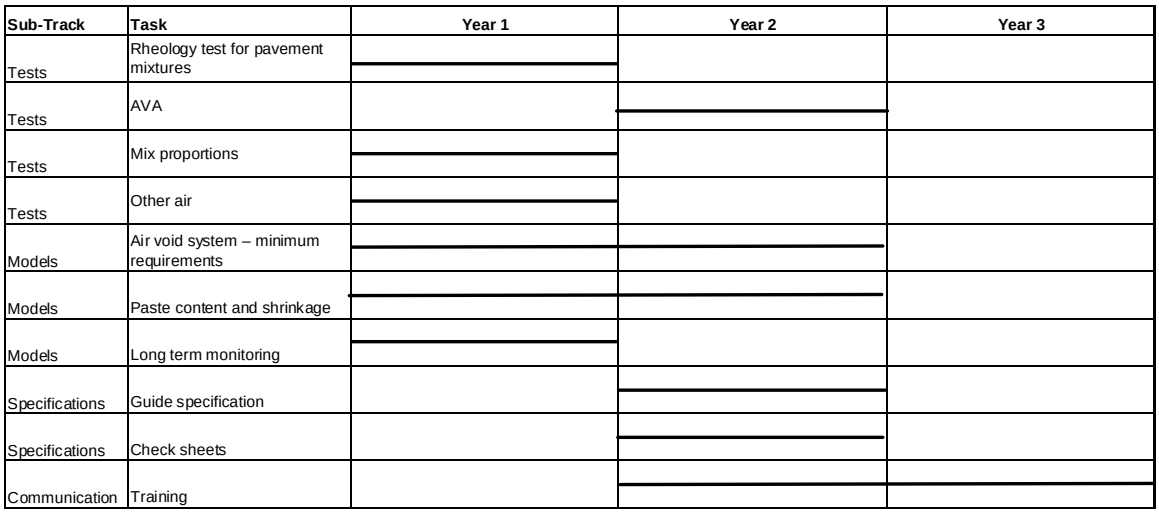
This project provides a mechanism for industry and state DOTs to conduct field evaluations of test methods and protocols developed in the previous project and to facilitate training in their application. Work will include using the Iowa State University Mobile Laboratory trailer built under the MCO Pooled Fund project in field trials or demonstrations, and workshops to disseminate the results and provide technical training. Selection of the work to be conducted will be in consultation with the TAC and with input from the states.

An integral part of any significant change to the methods or process of mix design is education. Users from all parties have to be made familiar with what has changed, why it was necessary, and how it affects the way they do things.

Activities that will be required to support the other tasks in this project include the following. Details of when and how these will be implemented will depend on progress in the other tasks.

- Field trials to demonstrate and validate new tests
- Field trials to demonstrate and validate new models
- Field trials to demonstrate and validate new specifications
- Training materials as needed

Timing of the tasks described above is shown in the following figure.



6. Cooperative features

This pooled fund project includes collaboration between various funding agencies (federal and state public agencies, and industry) and various research entities (academia and consultants) all working to the same end, with funds being leveraged through multiple funding sources.

The pooled fund will be funded by a number of states and by the CP Tech Center.

Other projects being conducted as part of the Track, but outside of this Pooled Fund will contribute to, and leverage the findings of this work. Examples of such work include development of a manual by ACPA/PCA, refinement of computer models by FHWA, and development of a permeability test by Indiana DOT. It is planned that additional projects will be developed under the Track in the near future.

Each entity involved will realize information valued at many times the amount of their financial contribution due to the leveraging of different dollars. The information and data from all parts of this study will prove to be very valuable as the completed information will allow highway officials to more effectively design and specify long-lasting constructible, sustainable and affordable concrete pavement mixtures.

7. Technical Advisory Committee

A Pooled Fund Technical Advisory Committee (TAC) will be established comprising representatives of states contributing funds to the project. The committee will meet every six months in conjunction with the Technology Transfer Concrete Consortium (TTCC) pooled fund TAC meetings. Travel for these meetings will be provided by the TTCC pooled fund. If any MDA pooled fund state is not a member of TTCC, contributions to this MDA pooled fund must be increased by $5,000 to permit travel to MDA TAC meetings twice a year. The TAC committee will review and provide input to the work as it progresses.

8. Deliverables

It is planned that the following deliverables will be provided as a result of conducting this work:

- Tests
  - A report describing a potential rheology test for slipform pavement concrete along with recommendations for future validation and implementation.
  - Draft versions of the AVA test method in a form ready for submission to ASTM and AASHTO.
  - A review of potential tools to determine mix proportions in fresh and hardened concrete along with recommendations for future validation and implementation.
  - A report describing potential methods of assessing the air void system in fresh concrete
  - Draft versions of the Foam index test method in a form ready for submission to ASTM and AASHTO.

- Models
  - Recommendations on requirements for an effective air-void system.
  - A report correlating paste content with mixture shrinkage and cracking risk.
  - A document that lays out standard information that should be recorded in order that long term performance can be correlated with mix parameters in the future.

- Specifications
  - A guide specification and commentary for mixtures.
  - Check-sheets to guide for different parties involved in the development of a mix design.

- Training
  - Field trial reports
  - Training materials as needed

9. Team

The lead state for this pooled fund will be Iowa. The CP Tech Center will act as administrators and coordinators of the project under an existing "Basic Management Agreement" with Iowa DOT.

The Center will subcontract research work with the best qualified researchers as appropriate and as approved by the lead state.

Some field work will be conducted using the Field Laboratory trailer built under the MCO Pooled Fund, TPF-5(066).

10. Budget – Three phases over three years

	Phase 1 /Yr 1	Phase 2/Yr 2	Phase 3/Yr 3	Total
Tests	$150,000	$50,000		$200,000
Models	$210,000	$90,000		$300,000
Specifications		$200,000		$200,000
Communication		$50,000	$150,000	$200,000
Project oversight	$40,000	$40,000	$20,000	$100,000
TOTAL COST	$400,000	$430,000	$170,000	$1,000,000
CP Tech Center contribution	$235,000	$265,000		$500,000
Pooled fund	$165,000	$165,000	$170,000	$500,000
TOTAL FUNDING	$400,000	$430,000	$170,000	$1,000,000

($15,000 per year for 3 state fiscal years for at least 11 states)

The National Concrete Pavement Technology Center has committed to contribute up to $500,000 to the total project from their FHWA Cooperative Agreement funds.

It is planned that work will be phased so that work can begin as soon as $165,000 has been raised from states. Details of priority activities will be agreed with the TAC after it is formed. Work is planned to begin in fall 2008.

11. State Project Responsibility

Participation in the pooled fund will require that a representative from each state be available for TAC meetings, conference calls and to review draft deliverables.

Participation in the pooled fund does not require involvement in field site activities. States involved with the project that choose to participate in field experiment sites may be

asked to provide staff and resources for activities such as traffic control assistance and sample collection.

12. Pooled Fund Project Contacts:

Administrative Contact:

Sandra Q. Larson, P.E.
Research and Technology Bureau Director
Iowa Department of Transportation
Sandra.Larson@dot.iowa.gov
515-239-1205

Technical Contact:

Todd Hanson, P.E.
PCC Engineer, Materials Office
Iowa Department of Transportation
Todd.Hanson@dot.iowa.gov
515-239-1226

CP Tech Center Contact:

Dr. Peter C. Taylor, P.E. (IL)
Associate Director
National Concrete Pavement Technology Center
Center for Transportation Research and Education
Iowa State University
515-294-9333
ptaylor@iastate.edu
www.cptechcenter.org