TRANSPORTATION POOLED FUND PROGRAM
QUARTERLY PROGRESS REPORT

Lead Agency (FHWA or State DOT): ____IOWA DOT____________________________________

INSTRUCTIONS:
Project Managers and/or research project investigators should complete a quarterly progress report for each calendar quarter during which the projects are active. Please provide a project schedule status of the research activities tied to each task that is defined in the proposal; a percentage completion of each task; a concise discussion (2 or 3 sentences) of the current status, including accomplishments and problems encountered, if any. List all tasks, even if no work was done during this period.

Transportation Pooled Fund Program Project # *TPF-5(117)*	**Transportation Pooled Fund Program - Report Period:** Quarter 1 (January 1 – March 31) X Quarter 2 (April 1 – June 30), 2012 ☐Quarter 3 (July 1 – September 30) ☐Quarter 4 (October 4 – December 31)

Project Title:
Development of Performance Properties of Ternary Mixtures: Field Demonstration Projects

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Lead Agency Project ID:	**Other Project ID (i.e., contract #):**	**Project Start Date:**
RT 0149	**Addendum 241**	12/01/05
Original Project End Date:	**Current Project End Date:**	**Number of Extensions:**
8/25/11	7/25/2012	Pooled fund project; interim funding

Project schedule status:

☐ On schedule X On revised schedule ☐ Ahead of schedule ☐ Behind schedule

Overall Project Statistics:

Total Project Budget	Total Cost to Date for Project	Total Percentage of Work Completed
$675,000	$648,834.78	80%

Quarterly Project Statistics:

Total Project Expenses This Quarter	Total Amount of Funds Expended This Quarter	Percentage of Work Completed This Quarter
$30,417.69	$30,417.69	15%

Project Description:

This phase of the project is intended to provide states and contractors with the use and field management of ternary mixtures. The National CP Tech Center will provide its state-of-the-art 44-foot long mobile laboratory equipped for on-site cement and concrete testing. The mobile lab will be made available for testing at each project site to demonstrate the tests and procedures available for field management of ternary mixtures. Contractors will be provided with a list of potential mixture designs that encompass the optimum properties identified in earlier phases and the materials available in the local market. The contractors would be able to make minor adjustments in a selected mixture design to meet the needs of their equipment and crews.

Progress this Quarter (includes meetings, work plan status, contract status, significant progress, etc.):

- Final report was submitted to panel for review

Anticipated work next quarter:

- Finish project

Significant Results:

See attached report

Circumstance affecting project or budget (Describe any challenges encountered or anticipated that might affect the completion of the project within the time, scope, and fiscal constraints set forth in the agreement, along with recommended solutions to those problems).

Progress Statement for
Development of Performance Properties of Ternary Mixtures

1. Scope of Project

Supplementary cementitious materials (SCMs) such as fly ash, ground granulated blast-furnace slag (GGBFS), calcined kaolinite, natural pozzolans, and silica fume, have become common parts of modern concrete practice. The blending of two or three cementitious materials to optimize durability, strength, or economics provides owners, engineers, materials suppliers, and contractors with substantial advantages over mixtures containing only portland cement (PC). However, these advances in concrete technology and engineering have not been adequately captured in the specification of concrete. Usage is often curtailed because of prescriptive concerns or historical comparisons about how such materials should perform. Users need specific guidance to assist them in defining the performance requirements for a concrete application and the selection of optimal proportions of the cementitious materials needed to produce the required durable concrete.

The goal of this project is to provide the quantitative information needed to make sound engineering judgments pertaining to the selection and use of supplementary cementitious materials in conjunction with portland or blended cement. This will lead to a more effective utilization of supplementary materials and/or blended cements enhancing the life-cycle performance and cost of transportation pavements and structures. The efforts of this project will be directed at producing test results that support the following specific goals:

- Provide quantitative guidance for ternary mixtures that can be used to enhance the performance of structural and pavement concrete.
- Provide a solution to the cold weather issues that are currently restricting the use of blended cements and/or supplementary cementitious materials.
- Identify how to best use ternary mixes when rapid strength gain is needed.
- Develop performance based specifications for concrete used in transportation pavements and structures

2. Funding

The work covered by this project has been funded from a number of sources including a Transportation Pooled Fund TPF-5(117), FHWA DTFH61-06-H-00011 Work Plan 12, Portland Cement Association, American Coal Ash Association, Slag Cement Association, and Headwaters Resources. Materials were also donated by a number of manufacturers.

3. Work Plan

The work was conducted in three parts:

- Laboratory tests of pastes and mortars
- Laboratory tests of concretes

- Field demonstration projects

Laboratory tests of paste and mortar

This phase focused on the paste and mortar properties of 114 ternary mixtures. The results quantify the shrinkage, sulfate resistance, alkali silica reaction (ASR) mitigation, strength development, chemical and physical properties of SCMs, heat signature, and sensitivity to sucrose-based water-reducing admixtures. The result of this work was the identification of 48 cementitious combinations for use in the next phase of the project.

This phase of the study created the baseline for a broad array of ternary cementitious material combinations for concrete. The work shows that ternary cementitious combinations have no as yet-identified technical barriers to their wider use in pavements, bridges and other structures. The results show that compressive strength potential at all ages for ternary combinations is excellent. Nearly all combinations of materials were able to meet general transportation use and concrete strength requirements. The heat of hydration and setting time of all mixtures were acceptable. The lower heat of hydration of some of the mixtures may be especially valuable in hot weather applications. Setting time was delayed by the use of a sucrose-based water reducing admixture. The work shows that use of polycarboxylate-based water reducers was effective in reducing compatibility issues.

Shrinkage generally increased for ternary combinations incorporating Type I/II cement when compared to the Type I/II cement control, but decreased for many combinations with Type I cement and blended cements. This would indicate that the cement plays a major role in shrinkage reduction. Sulfate resistance testing is ongoing. The key component of this testing is the effect of a third pozzolan to cementitious combinations containing Class C fly ash. It will take some months before it can be determined if sulfate attack exacerbated by Class C fly ash can be mitigated by the combination of other pozzolans. The effectiveness of ternary combinations in mitigating ASR is also a result that will be known in the coming weeks.

The major result of Phase I is that no combinations of materials were identified that would prohibit them from use in concrete for pavements, bridges, or other structures. Depending on the technical requirements of the application, some have preferential properties, but all performed well in the screening tests in this phase. Some compatibility issues were identified, but solutions were also identified.

Laboratory tests of concrete

This phase used mixtures containing 564 lbs/yd3 containing 48 different cementitious combinations. The combinations included

- Type I cement with binary combination controls and 26 ternary combinations (31 total combinations with TI cement),
- Type IP with six SCM combinations (seven total),
- Type IPM with four SCM combinations (five total),
- and Type ISM with four SCM combinations (five total).

Each of these combinations is technically advantageous for highway applications, economical, and represents potential combinations that the project could use in Phase III. At least 11 of these ternary mixtures have the potential to have maturity in cold weather concrete operations (measured as greater than 3,500 psi at three days), and at least 11 of these mixtures have the maturity characteristics for hot weather concrete (measured as less than 2,500 psi at three days).

The efforts of this work were directed at producing test results to support the following specific goals:

- Provide quantitative guidance for ternary mixtures that can be used to enhance the performance of structural and pavement concrete
- Provide a solution to the cold weather issues that are currently restricting the use of blended cements and/or SCMs
- Identify how to best use ternary mixes when rapid strength gain is needed
- Develop performance-based specifications for concrete used in transportation pavements and structures

This phase of the study used the information obtained from the paste and mortar work to select a range of materials and dosages to investigate the effects of cold, hot, and ambient environmental conditions for use in laboratory concrete mixtures. The thrust of this phase was to build on the data from the paste and mortar work, and test concrete mixtures to evaluate the performance characteristics of pavement and structural mixtures.

The materials used in both phases were identical, so that the mortar test results could be directly compared to the test results obtained from concrete test specimens. This comparison is needed to provide information pertaining to the selection of appropriate mixture design and performance tests for specification development. It was desirable to develop mixture design tests using the behavior of mortar specimens that translate well into the performance of concrete. The results of this phase were performance-based measures for concrete in transportation applications.

This work investigated the age-related distress mechanisms in ternary blended cementitious materials in concrete and any related barriers to using ternary blended cementitious materials in ready mix concrete. Findings included:

- There are few technical barriers to using most ternary blended cement mixtures. The mixtures can be designed to meet state requirements and outperform ordinary portland cement concrete (PCC) mixtures.

- Ternary blended cement concrete mixtures greatly reduce the carbon dioxide and other greenhouse gas emissions related to the concrete industry. These mixtures can save more than 10,000 tons of carbon dioxide from being emitted into the atmosphere for just 10 miles of a six-lane concrete pavement.
- The initial cost of a ternary blended cement concrete pavement is dependent on the SCMs used and their proximity to the project location. The initial cost can generally be lowered if fly ash or GGBFS is used. Life cycle costs of ternary blended cement mixtures containing these materials, as well as silica fume, metakaolin and other pozzolans are also reduced.
- The interaction between SCMs varies depending on different materials that are used. Optimum combinations will vary with the selection of materials and relative quantities of each constituent in the concrete mixture. The most efficient means of optimizing a ternary concrete mixture is through trial batching using the mixture designs in this report as a starting point.
- Ready mix plants can receive a return of their investment of adding additional silos for storage of SCMs if they provide fly ash. If they blend on site, the investment in the silo and associated equipment can be recovered in less than 10,000 yd^3 of concrete.
- Pre-blended cements can be beneficial because the SCMs are well distributed and the gypsum content has been optimized during the cement production. These cements also meet all applicable standards. There is no capital investment by the ready mix producers from using pre-blended cements.
- States should update their specification to remove limitations on total SCMs and use performance-based tests to determine acceptable concrete mixture properties.
- Different SCMs are appropriate for general use and others for special projects. Different SCMs are also appropriate for different environments. Each state should use SCMs that best suit the project and its environment.

Field Demonstrations

A mobile laboratory was used to assess the properties of ternary mixtures used in construction sites in 8 states. Data and samples were collected from 8 sites including 3 pavements, 5 bridge decks and 1 bridge structure between July 2009 and September 2011. The states visited were: UT, KS, MI, IA, PA, NH, NY, and CA.

Fresh and hardened properties were measured for all of the mixtures, and commentary obtained from construction crews and agency staff.

All of the mixtures performed as required and no mixture related distress has been reported.

4. Deliverables and Tech Transfer

Full reports have been prepared based on the work conducted in the laboratory based phases. Individual data reports have been prepared for each field demonstration project.

A number of presentations have been made around the country summarizing the findings.

In addition it should be noted that a number of graduate students have completed their advanced degrees working on this project and are now employed as faculty or in Departments of Transportation. Other benefits including evaluation and implementation of innovative assessment tools, such as the Wenner probe, were initiated through this project. A full list of graduates, technical papers and innovations is being developed.

The full report summarizing the findings of the whole project and a guide specification has been submitted to the panel.

5. Findings

At the last TAC meeting the following summary of findings was developed:

- Performance will be different depending on system.
- Every mixture has to be designed for the purpose.
- Use all the materials intended for the field in the lab trials – don't substitute admixtures of SCMs.
- Check for setting compatibility with calorimetry. Need protocol for air.
- Activities are driven by incentives – reconsider what we really want and when we want it.
- Increasing SCM decreases environmental impact.
- Recommended performance limits have been developed.
- Education and demonstration projects are critical to moving forward. Need to get in front of everyone involved.
- Systems have to be competitive in the market place.

6. Technical Advisory Committee

The Technical Advisory Committee (TAC) held a wrap up meeting in Chicago in February 2012.