National CP Tech Center

PROJECT BOOKLET

Research contributing to the CP Road Map

IOWA STATE UNIVERSITY
Institute for Transportation

Last updated May 2009
Introduction

The projects in this booklet are organized in accordance with the 13 tracks of the Long-Term Plan for Concrete Pavement Research and Technology—The Concrete Pavement Road Map (CP Road Map). The CP Road Map is a comprehensive and strategic plan for concrete pavement research that will guide the investment of research dollars for the next several years. It will result in technologies and systems that help the concrete pavement community meet the paving needs of today and the as-yet unimagined paving challenges of tomorrow.

The 13 tracks of the CP Road Map are organized as follows in this booklet:

- **Track 1: Performance-Based Concrete Pavement Mix Design Systems**
- **Track 2: Performance-Based Design Guide for New and Rehabilitated Concrete Pavements**
- **Track 3: High-Speed Nondestructive Testing and Intelligent Construction Systems**
- **Track 4: Optimized Surface Characteristics for Safe, Quiet, and Smooth Concrete Pavements**
- **Track 5: Concrete Pavement Equipment Automation and Advancements**
- **Track 6: Innovative Concrete Pavement Joint Design, Materials, and Construction**
- **Track 7: High-Speed Concrete Pavement Rehabilitation and Construction**
- **Track 8: Long-Life Concrete Pavements**
- **Track 9: Concrete Pavement Accelerated and Long-Term Data Collection**
- **Track 10: Concrete Pavement Performance**
- **Track 11: Concrete Pavement Business Systems and Economics**
- **Track 12: Advanced Concrete Pavement Materials**
- **Track 13: Concrete Pavement Sustainability**

Although many of the projects in this booklet can be included in more than one track of the CP Road Map, each project has been categorized based on the most dominant track into which it fits. The table on the following page lists the dominant and secondary tracks into which each project fits, illustrating the integrated nature of concrete pavement research.
<table>
<thead>
<tr>
<th>Page no</th>
<th>Project name</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>CP Road Map Administrative Support: Activities to Initiate the CP Road Map</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Concrete Pavement Mixture Design and Analysis (MDA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Investigation into Freezing-Thawing (F-T) Durability of Low-Permeability Concrete with and without Air Entraining Agent (AEA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Material &amp; Construction Optimization for Prevention of Premature Pavement Distress in Concrete Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Integrated Materials and Construction Practices for Concrete Pavement (IMCP): National Training</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Performance Properties of Ternary Mixtures for Concrete Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Improving Portland Cement Concrete Mix Consistency and Production through Two-Stage Mixing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Self-Consolidating Concrete Applications for Slip-Form Paving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Simple &amp; Rapid Test for Monitoring the Heat Evolution of Concrete Mixtures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Materials &amp; Mix Optimization for Concrete Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Coordination of Initial Meeting for Regional Mechanistic-Empirical Pavement Design Guide (MEPDG) User Groups</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Mechanistic-Empirical Pavement Design Guide: Iowa Implementation and Local Calibration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Improving the Variability &amp; Precision of AVA Test Results &amp; Developing Rational Specification Limits</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>In Situ Detection Methods for Materials-Related Distress in Concrete Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Real-Time Pavement Thickness Measurement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Nondestructive Evaluation of Iowa Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Concrete Pavement Surface Characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Impact to Concrete Pavement Smoothness from Curling, Warping, &amp; Other Early-Age Behaviors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Developing Smooth, Quiet Concrete Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Measuring Pavement Profile at the Slip-Form Paver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Stringless Concrete Paving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Dowel Bar Optimization</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Field Evaluation of Elliptical FRP Dowel Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Structural Behavior of Alternative Dowel Bars</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Field Evaluation of Elliptical Steel Dowel Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Effect of Admixtures on Roller-Compacted Concrete (RCC) Mixtures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Guide to Concrete Overlay Solutions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Concrete Overlay Field Application: Demonstration Projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Concrete Overlay Field Application: Research Projects</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Guide for Existing Concrete Overlay Design Methodology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Composite Pavement Unbonded Overlays</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Crack Development in Ternary Mix Concrete Utilizing Various Saw Depths</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Concrete Pavement Patching Techniques vs. Performance &amp; Traffic Delay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Design &amp; Construction Procedures for Concrete Overlay &amp; Widening of Existing Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Unbonded Ultrathin Whitetopping of Brick Streets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Improving the Foundation Layers for Concrete Pavements Track</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Scan Team Implementation Plan (STIP) for Long-Life Concrete Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Development of a Device for Analysis of Portland Cement Concrete and Composite Pavements, Phase I Feasibility Study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Attributes of Good In-Service Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Soil Stabilization of Non-Uniform Subgrade Soils</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Concrete Preservation and Rehabilitation Workshop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Effective Training Program for the Hispanic Construction Workforce</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Deicer Scaling Resistance of Concrete Pavements &amp; Bridge Decks Containing Slag Cement</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Improved Pavement Curing Materials &amp; Techniques</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Properties of Blended Cements for Concrete Pavements</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Two-Lift Concrete Pavements to Meet Public Needs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Pervious Concrete Mix Design for Wearing Course Applications, Phase 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Projects currently in progress are highlighted in blue
CP Road Map Administrative Support: Activities to Initiate the CP Road Map

NEED & OBJECTIVES
The CP Road Map is a comprehensive and strategic plan for concrete pavement research that will guide the investment of research dollars for the next several years. The CP Tech Center’s role in the CP Road Map is to provide the administrative support services needed for the efficient execution of the CP Road Map research and technology plan. This includes advance planning and implementation of the structures and systems necessary to initiate the CP Road Map program. The CP Tech Center is currently developing an updated research database to account for CP Road Map-related research studies. Work is also underway to develop track leaders and committees for the 13 research tracks in the CP Road Map.

ANTICIPATED BENEFITS
The CP Road Map will result in technologies and systems that help the concrete pavement community meet the paving needs of today and the as-yet unimagined paving challenges of tomorrow. In short, the CP Road Map will result in a new generation of concrete pavements for the 21st century.

SPONSOR
FHWA (TPF-5[185])

RESEARCH LEAD
Tom Cackler, National CP Tech Center

FUNDING
$945,000

STATUS
In progress
**NEED & OBJECTIVES**
Research has revealed that high-density and low-permeability concrete rarely becomes saturated, and the water in the very fine capillary voids of the concrete hardly freezes in field exposure conditions. Therefore, theoretically, there is no need to require use of air-entraining agent (AEA) in the high-density and low-permeability concrete for freezing-thawing (F-T) durability. Use of AEA could cause notable strength reduction due to the existence of micro-air bubbles. The major objectives of this study are to investigate the F-T durability of low permeability concrete with and without AEA and to discover the value of the limiting permeability below which AEA is not necessary for good concrete F-T durability.

**FINDINGS TO DATE**
For non-air-entrained concrete made with given cementitious materials, there is a clear relationship between F-T durability and porosity, water-to-binder ratios, or permeability. However, such a relationship does not exist for air-entrained concrete. The F-T resistance of air-entrained concrete is largely dependent on the concrete air void structure. Generally, concrete with 6% of air content (measured with ASTM C231) and/or the spacing factor of 0.3 mm or less (measured with AVA) demonstrates desirable F-T resistance.

**ANTICIPATED BENEFITS**
While confirming the beneficial effect of reduced permeability on concrete F-T durability, this research also demonstrates the need of AEA for low-permeability, normal strength concrete. The results provide the concrete industry with an insight into quality control of concrete containing supplementary cementitious materials.
Material & Construction Optimization for Prevention of Premature Pavement Distress in Concrete Pavements

NEED & OBJECTIVES
The objective of this project was to evaluate new and conventional technologies and procedures used in testing concrete materials and pavements in order to prevent material and construction problems that could lead to premature concrete pavement distress.

FINDINGS & CONCLUSIONS
After evaluation, this project recommended 21 tests that have the potential to advance concrete pavement technology in two specific ways. First, some tests can be used as field quality control measures. These tests allow contractors to determine whether the concrete they are placing has the desired performance-related properties and if not, to make real-time modifications to the mix or to construction practices. The tests also allow contractors to meet requirements for incentives more efficiently. Second, some of the tests can be used by agency representatives to measure pavement properties during field inspection.

PRODUCTS & BENEFITS
The following products were developed through this project. These products are available online, and more than 2,000 hard copies have been distributed.

- The Testing Guide for Implementing Concrete Pavement Quality Control Procedures helps users execute and interpret the suite of tests developed and vetted during the project.
- Test summaries for each of the 21 tests are included in the guide and available as individual summaries.
- The Air-Void Analyzer (AVA) Hyperdocument, a multimedia training document, walks technicians through AVA testing using video clips, photos, and illustrations.
- A video demonstrating the “coffee cup test,” or cementitious heat generation test, which helps contractors monitor the uniformity of their cementitious materials.

SPONSORS
FHWA; Pooled fund (TPF-5[066]): Georgia, Indiana, Iowa (lead state), Kansas, Louisiana, Michigan, Minnesota, Missouri, Nebraska, New York, North Carolina, North Dakota, Ohio, Oklahoma, South Dakota, Texas, and Wisconsin; American Concrete Pavement Association; Iowa Concrete Paving Association

RESEARCH LEAD
Jim Grove, National CP Tech Center

FUNDING
$3,150,000

STATUS
Completed (2007)


NEED & OBJECTIVES
Today’s complex road building environment has led to increased specialization in pavement design and construction procedures. However, specialization has not eliminated the need for every individual involved in any stage of a project to understand concrete pavements as integrated systems and pavement construction as an integrated process. With this in mind, the CP Tech Center developed the Integrated Materials & Construction Practices for Concrete Pavement (IMCP): State-of-the-Practice Manual, which will help users understand the integrated nature of concrete pavement materials and construction practices and apply that understanding to the design and construction of concrete pavements.

PRODUCTS & BENEFITS
- Nearly 13,000 copies were distributed free of charge to state and local highway agencies, FHWA offices, and the industry via state and regional paving association chapters.
- One- and two-day regional workshops were held in Denver, Kansas City, Albany, Raleigh, Dallas, the Twin Cities, and four locations in California. Several state DOTs and concrete paving association chapters—Pennsylvania, Michigan, Wisconsin, and Iowa—also hosted workshops.
- Training materials are available through the FHWA. The package includes 10 one-hour modules, each with slide presentations, instructor notes, and participant handouts, including a brief, four-page technical summary.

SPONSOR
FHWA

RESEARCH LEAD
Peter Taylor, National CP Tech Center

FUNDING
$425,000

STATUS
Completed (2006)
Integrated Materials and Construction Practices for Concrete Pavement (IMCP): National Training

NEED & OBJECTIVES
The IMCP manual describes concrete pavement construction as an integrated system in which materials selection, mix design, and construction practices all affect each other in ways that influence critical mix properties and the overall quality of the final product. The Technical Advisory Subcommittee and FHWA, who provided oversight and input regarding the development of the IMCP manual, have maintained throughout the project that the end users (state DOTs, engineering consultants, materials suppliers, contractors, quality control personnel, and technicians) must have proper training regarding the contents of the manual. The primary objective of this project was to provide training and materials that will help participants understand the integrated nature of concrete pavement materials and construction practices and apply that understanding to the design and construction of concrete pavements. A second goal was to introduce participants to the content of the IMCP manual so they can effectively use it as a resource and reference.

PRODUCTS & BENEFITS
- One-and-a-half day workshops were held in eight additional states.
- A train-the-trainer workshop was held in 2008. The 48 attendees included ACPA state chapter executives, industry representatives, and state DOT representatives from across the country. The program provided the individuals with the skills necessary to conduct effective IMCP training sessions.
- Training-on-demand webinar modules are being created and will be available through NHI’s interactive training website in 2009.

Performance Properties of Ternary Mixtures for Concrete Pavements

NEED & OBJECTIVES
The existing literature contains contradictory and inadequate information concerning the optimal use of supplementary cementitious materials (SCMs) in concrete. Users need specific guidance to help them define the performance requirements for a concrete application and select optimal proportions of the cementitious materials needed. The objectives of this project include (1) determining how SCMs and/or blended cements can improve the performance and cost of concrete applications and (2) addressing the cold weather issues that restrict the use of blended cements and SCMs.

FINDINGS TO DATE
Phase I of this study consisted of laboratory experiments that examined the influence of multiple combinations and proportions of cement and SCMs on specific performance properties. To date, the team has not identified any combinations of materials that would prohibit them from use in concrete for pavements, bridges, or other structures.

PRODUCTS & BENEFITS
- SCMs, such as pozzolans and slag, have the potential to dramatically improve the overall performance and lower the long-term cost of concrete. In properly formulated concrete mixes, fly ash and slag have been shown to enhance long-term strength, decrease permeability, increase durability, and reduce cracking.
- Contractors will be provided with a list of potential mix designs that encompass the optimum properties and the materials available in the local market.
- A software decision support tool and proposed specifications for using ternary mixes will be developed.
Improving Portland Cement Concrete Mix Consistency and Production through Two-Stage Mixing

NEED & OBJECTIVES
Concrete ingredients must be thoroughly mixed to produce a homogeneous mixture with sufficiently hydrated and uniformly distributed cement particles. However, modern concrete contains fine cementitious materials, low water-to-binder ratios, and high binder contents. This allows fine particles to agglomerate, prevents cementitious materials from hydrating uniformly, and reduces workability. The objective of this research was to investigate effective methods for coating aggregate particles with cement slurry, study the effect of two-stage mixing on concrete properties, and characterize the pastes produced.

FINDINGS & CONCLUSIONS
- Increasing mixing energy during two-stage mixing produces a more thoroughly mixed slurry. Pastes containing fly ash generally require lower mixing energy to reach optimum uniformity than pastes containing only cement.
- High-shear mixing produces a slightly greater degree of hydration than normal mixing, and high-shear mixing produces the earliest hydration reactions.
- Two-stage mixes have lower permeability than conventionally mixed concrete.
- Air entrainment is less effective in two-stage mixing when the air-entraining admixture (AEA) is added in the slurry.
- For a given AEA type and dosage, concrete produced using two-stage mixing contains lower air content than concrete mixed conventionally.

PRODUCTS & BENEFITS
- Based on this research, two-stage mixing can significantly improve concrete uniformity.
- Two-stage mixes generally show a reduced slump and increased concrete strength.

Self-Consolidating Concrete Applications for Slip-Form Paving

NEED & OBJECTIVES
Overconsolidation is often visible as longitudinal vibrator trails in the surface of concrete pavements constructed using slip-form paving. Overconsolidation and inconsistent consolidation lead to an inadequate and non-uniform air-void system that reduces concrete freeze-thaw durability. The objective of this research was to develop a new type of concrete that can self-consolidate without vibration and hold its shape after slip-form paving.

FINDINGS TO DATE
- Well-designed self-consolidating concrete (SCC) mixtures used in slip-form paving can attain a desirable balance between flowability and self-consolidation by tailoring concrete materials and mix design.
- The new slip-form SCC is workable enough for machine placement, self-compacting with minimum segregation, shape-containing after extrusion from a paver, and has strength and set time comparable with standard pavement concrete.
- The general properties of slip-form SCC (such as strength, set time, heat evolution, and freeze-thaw durability) are comparable to conventional concrete pavement.

ANTICIPATED BENEFITS
- This product will provide recommended design methods for using SCC for slip-form paving and will provide an assessment of equipment modifications needed to adapt to the new paving technology.
- Potential benefits include elimination of vibration required for conventional concrete slip-form paving, a more uniform air-void system that improves freeze-thaw durability, increased construction speed and decreased costs for labor and energy, and solutions to consolidating thin pavement sections where vibration is difficult to apply properly.
Simple & Rapid Test for Monitoring the Heat Evolution of Concrete Mixtures

NEED & OBJECTIVES
Currently, no standard method practically and accurately monitors the hydration process of field concrete, an influential property for early-age behavior and long-term performance. While various tests measure heat of cement hydration, most require expensive equipment, complex procedures, and/or extensive time. The objective of this project was to identify, develop, and evaluate a more practical standard test procedure for characterization and quality control of pavement concrete mixtures using calorimetry.

FINDINGS & CONCLUSIONS
• There is no consensus on how to use the heat evolution curves to characterize concrete materials and how to effectively relate the characteristics of heat evolution curves to concrete pavement performance.
• The concrete heat evolution process is influenced by the configuration of the calorimeter device, sample size, mixing procedure, and testing environment temperature.
• Concrete heat evolution test results can also be used to forecast concrete setting time, specify curing period, estimate risk of thermal cracking, assess pavement sawing/finishing time, identify incompatibility of cementitious materials, verify concrete mix proportions, and select materials and mix designs for given conditions.

PRODUCTS & BENEFITS
• A relatively simple, inexpensive device and a prototype test procedure for measuring the heat of hydration of field concrete has been developed.
• A more practical standard calorimetry technique will provide higher quality control at a lower cost than existing tests.

Materials & Mix Optimization for Concrete Pavements

NEED & OBJECTIVES
Severe environmental conditions, coupled with the routine use of deicing chemicals and increasing traffic volume, place extreme demands on concrete pavements. While in most instances engineers have been able to specify and build concrete pavements that met these challenges, some reports of premature deterioration could not be specifically attributed to a single cause. The objective of this project included the evaluation of the important variables that impact the homogeneity of concrete mixtures.

FINDINGS & CONCLUSIONS
• Ternary mixtures show significant promise for improving the performance of concrete mixtures.
• The presence of bassanite causes cements to exhibit premature stiffening problems (false sets).
• Fly ash helps to reduce the impact of premature stiffening because it behaves as a low-range water reducer in most instances.
• The premature stiffening problem can also be alleviated by increasing the water-cement ratio of the mixture and providing a remix cycle.

PRODUCTS & BENEFITS
Since no evidence of premature distress has been observed in the last decade, it appears that the development and implementation of the current quality assurance concrete mixture program in Iowa has resolved previous problems.
Coordination of Initial Meetings for Regional Mechanistic-Empirical Pavement Design Guide (M-EPDG) User Groups

NEED & OBJECTIVES
Implementation of the Mechanistic-Empirical Pavement Design Guide (M-EPDG) is proceeding nationwide. The development of regional user groups to share expertise and experience is needed to expedite national implementation of the guide. The objective of this project is to coordinate and facilitate four user group meetings across the country to share M-EPDG implementation efforts, identify implementation components that could benefit from regional collaboration, and consult with national experts and lead states on the design guide.

ANTICIPATED BENEFITS
The development of the regional user groups will create the opportunity for interagency and intra-agency networking to share the expertise and experience needed to successfully use the M-EPDG.

Mechanistic-Empirical Pavement Design Guide: Iowa Implementation and Local Calibration

NEED & OBJECTIVES
The Iowa Department of Transportation (Iowa DOT) will significantly benefit by implementing the Mechanistic-Empirical Pavement Design Guide (M-EPDG) as a reliable pavement performance prediction tool. Research projects are underway across the state to accelerate implementation of the M-EPDG in Iowa. The National CP Tech Center is spearheading five tasks:
- Testing Iowa Portland Cement Concrete Mixtures for the M-EPDG
- Characterization of Unbound Materials (Soil/Aggregates) for the M-EPDG
- Material Thermal Input for Iowa Materials for the M-EPDG
- Existing Pavement Input Information for the M-EPDG
- Validation of Pavement Performance Models for the M-EPDG

ANTICIPATED BENEFITS
The benefits for the Iowa DOT of implementing the M-EPDG include (1) more appropriate designs focusing on minimizing or mitigating the predominant distress types that occur in Iowa, (2) better performance predictions resulting in significant long-term savings by eliminating the possible premature failures and over-designing the pavement sections, (3) better materials-related research reducing the need to conduct extensive, lengthy, and costly field trials, and (4) the use of M-EPDG software as a powerful forensic tool for analyzing the condition of existing pavements.
**High-Speed Nondestructive Testing and Intelligent Construction System**

### Track 3. Nondestructive Testing

**Improving the Variability & Precision of AVA Test Results & Developing Rational Specification Limits**

**NEED & OBJECTIVES**
An adequate air-void system is essential for concrete resistance to freeze-thaw damage. Measuring air voids in hardened concrete core samples cannot provide information that is timely enough for field concrete quality control. The air-void analyzer (AVA) has been shown to provide accurate and timely measurements of the entrained air content, specific surface area, and spacing factors in fresh concrete. The objective of this project was to improve the variability and precision of AVA test results and to develop rational specification limits for controlling concrete freeze-thaw damage.

**FINDINGS & CONCLUSIONS**
- AVA is a useful tool for determining the air-void parameters in fresh concrete, and it has significant advantages over conventional air-void test methods, providing not only air content but also air-void spacing factor and specific surface.
- AVA is a time- and cost-effective tool for field concrete quality control. However, AVA equipment and test methods need further improvement for proper implementation in concrete practice.

**PRODUCTS & BENEFITS**
- Future research is needed to modify the AVA test procedure and specifications through a series of systematic experiments in the laboratory. The experimental results of this project will be used to modify, calibrate, and/or validate the test procedures.

**SPONSOR**
FHWA

**RESEARCH LEADS**
Jim Grove, National CP Tech Center; Kejin Wang, Iowa State University

**FUNDING**
$130,000

**STATUS**
Completed (December 2008)

---

**In Situ Detection Methods for Materials-Related Distress in Concrete Pavements**

**NEED & OBJECTIVES**
Materials-related distress in concrete pavements includes concrete failures caused by the materials' properties and their interaction with the environment. Effective methods are needed for evaluating and quantifying the amount of distress or deterioration present in existing pavement slabs. Petrographic examination of core sections is routinely used; however, this technique is time-consuming and often opinion-based, and site selection depends on observations of surface features. The objective of this project was to evaluate nondestructive testing methods that can enhance the in situ detection of materials-related distress.

**FINDINGS & CONCLUSIONS**
- While both the ground-penetrating radar (GPR) and visual inspection systems passed the proof-of-concept trials, neither method can diagnose the presence of materials-related distress. Instead, both techniques can detect the symptoms of materials-related distress.
- High-frequency GPR antennas can detect subsurface distress.
- Pavement profile scanner surveys show an excellent capability of detecting surface cracking on pavement slabs.

**PRODUCTS & BENEFITS**
The GPR and visual inspection systems enhance the ability of pavement engineers to detect distress and are thus considered to have passed proof-of-concept testing.

**SPONSORS**
FHWA; Iowa DOT; Iowa Highway Research Board (HR-1081)

**RESEARCH LEAD**
Scott Schlorholtz, Iowa State University

**FUNDING**
$270,000

**STATUS**
Completed (August 2005)
Real-Time Pavement Thickness Measurement

NEED & OBJECTIVES
Taking core samples of concrete pavement is essential to the quality assurance process and helps determine pavement pay factors for contractors. This labor-intensive process requires that the resulting holes be patched. The objective of this project was to identify and test innovative and efficient approaches to quality assurance for concrete pavements.

FINDINGS & CONCLUSIONS
• Two approaches are viable for measuring concrete pavement thickness during the paving operation: laser scanning and electromagnetic eddy current sensors.
• Laser scanning has proved to be a reliable technique in terms of its ability to provide virtual core thickness and its low variability.

PRODUCTS & BENEFITS
• A nondestructive evaluation (NDE) device that measures pavement thickness in real time will eliminate the need for state DOTs to assess thickness by taking cores after the paving process is complete and then patching the resulting holes.
• This device can also be considered for in-process paver control since real-time pavement depths will be calculated. Such a real-time method may eliminate the need for the owner or contractor to measure depth during paving.
• Having real-time feedback on actual pavement thickness means that the contractor does not need to pave at a higher than specified thickness to ensure that specifications are met. This will result in savings to the contractor by reducing the amount of concrete used.
• Scanning lasers may be used to determine concrete yield quantities and perhaps smoothness.

Nondestructive Evaluation of Iowa Pavements

NEED & OBJECTIVES
In the last decade, interest has increased in a new class of computational intelligence systems, known as artificial neural networks (ANNs), for rapid and accurate predictions of layer parameters. Transportation agencies are interested in rapid models of backcalculating for pavement structural properties, including the use of ANNs. The objective of this project is to develop an easy-to-use method to evaluate existing pavement structural conditions using ANNs that will interpret routinely collected nondestructive test data for rapid and accurate predictions of pavement layer parameters.

FINDINGS TO DATE
• ANNs were capable of successfully predicting pavement layer moduli values using FWD field deflection measurements.
• ANN-based backcalculation models successfully predicted pavement layer moduli values.
• The adoption of an ANN-based approach resulted in a drastic reduction in computation time and a simplification of the backcalculation approach from the viewpoint of a pavement designer/analyst.

ANTICIPATED BENEFITS
• The rapid prediction ability of the ANN models, capable of analyzing 100,000 FWD deflection profiles in less than a second, provides a tremendous advantage to pavement engineers by allowing them to nondestructively assess the condition of the transportation infrastructure system in real time.
• Phase II of this project will focus on developing guidelines for the Iowa DOT that clearly define FWD testing requirements, data analysis approaches, and reporting requirements.
Concrete Pavement Surface Characteristics

**NEED & OBJECTIVES**
Surface characteristics represent a critical issue facing pavement owners and the concrete paving industry. The traveling public expects smoother, quieter, and better drained pavements without compromised safety. The surface characteristics issue is complex because all pavement surface characteristics, including texture, noise, friction, splash/spray, rolling resistance, reflectivity/illuminance, and smoothness, are interrelated. The objectives of this multi-part project include developing a strategic plan for improving concrete pavement surface characteristics, measuring the relationship of conventional concrete pavement surface textures to tire-pavement noise and friction in the field, and field evaluating conventional practices and innovative solutions for concrete pavement surface characteristics.

**FINDINGS TO DATE**
- Data collection in Part 2 of this project involved 1,012 test sections, totaling 240,000 feet and representing 395 unique pavement textures.
- Initial data analysis shows an apparent relationship between some characteristics of texture and the corresponding tire-pavement noise. For example, more aggressive texturing of fresh concrete can lead to latent deposits of concrete on the surface that increase noise.
- Data also suggests that nominal texture geometry—width, depth, and spacing—does not relate to the corresponding tire-pavement noise.

**ANTICIPATED BENEFITS**
This project will result in fully field-tested and validated concrete pavement designs and construction methods that produce consistent surface characteristics that meet or exceed highway user requirements.

Impact to Concrete Pavement Smoothness from Curling, Warping, & Other Early-Age Behaviors

**NEED & OBJECTIVES**
The objective of this project was to obtain detailed information affecting concrete pavement smoothness during the critical time immediately following construction.

**FINDINGS TO DATE**
- This study shows that early-age curling and warping behaviors are influenced not only by temperature variation but also by environmental effects such as moisture variation, drying shrinkage, and temperature conditions during pavement construction.
- Even though measurable changes in early-age pavement smoothness occur between morning and afternoon, these variations are not statistically significant.
- A linear relation was observed between the actual measured temperature difference and the equivalent temperature difference associated with actual slab displacement under pure environmental loading.
- The measured smoothness index values were different at different measurement locations within a test section.

**PRODUCTS & BENEFITS**
- This project has developed a database that contains a wealth of information related to early-age behavior of concrete pavements under pure environmental loading.
- With the recognition that the early-age response significantly affects the long-term performance, researchers can help solidify this connection in years to come.
- This project provides a better understanding of the complex relationship between concrete pavement curling and warping and pavement smoothness.
- This information can be used by researchers and practitioners to design and build smoother, better-performing pavements.
Developing Smooth, Quiet Concrete Pavements

NEED & OBJECTIVES
The concrete paving industry has spent large amounts of time working to provide safe, quiet, and smooth pavements for the traveling public as their needs and driving habits have changed since the advent of the automobile. During that time, the efforts of research, design, and construction were directed at one of the problems at a time. Current public surveys indicate that the traveling public wishes to have safe, quiet, and smooth pavements. The goal of this research was to suggest ways for future research to find methods of providing each of these desirable qualities without sacrificing any of the others.

PRODUCTS & BENEFITS
- This research identified the problems remaining in developing smooth, quiet, and safe portland cement concrete pavement.
- The project team developed a research framework that can be used to bring existing information together with additional research in each area.
- This project suggested future research that is now being conducted under the Concrete Pavement Surface Characteristics project (see p. 12).

Measuring Pavement Profile at the Slip-Form Paver

NEED & OBJECTIVES
Operational highway profiles are typically measured with high-speed inertial profilers, but new highway profiles are usually measured with profilographs in order to establish incentives or disincentives for pavement construction. These two processes usually do not measure the same value throughout the life of pavements. To correct the inconsistency between measuring techniques, several lightweight profilers are being made that can measure pavement profile at the slip-form paver during construction. The objective of this project was to evaluate equipment and methods to measure pavement profile at the paver.

FINDINGS & CONCLUSIONS
- The profilers evaluated can adequately detect roughness in the final profile, including localized roughness and roughness at joints.
- Dowel basket ripple is a significant source of pavement surface roughness. The evaluated profilers are able to detect dowel basket ripple with enough clarity to warn the paving crew.
- The profilers evaluated are not currently able to detect the same absolute IRI values on the plastic concrete that can be measured by inertial profilers on the hardened concrete.

PRODUCTS & BENEFITS
- The findings from this project expand our understanding of the causes of and solutions to common pavement profile problems.
- The profilers evaluated in this study can provide real-time warnings for most surface roughness problems so that corrective action can be taken prior to set of concrete.
- The evaluated profilers can measure pavement thickness, which reduces or eliminates the need for quality assurance coring to determine pavement depth.
Stringless Concrete Paving

NEED & OBJECTIVES
Conventional concrete pavement construction uses a string line on one or both sides of the paving train to ensure proper pavement thickness and alignment. This approach requires space on each side of the paving machine to set the string line. Placing and verifying the string line is time-intensive and limits access to the area in front of the slip-form paver. The objective of this project was to evaluate the potential of new stringless paving control methods compared to the conventional string-line method of paving control.

FINDINGS & CONCLUSIONS
- Stringless global positioning system (GPS) control can successfully guide the slip-form paver and adequately control the concrete yield quantity, pavement depth, and surface elevations.
- GPS control can provide a reasonably smooth-riding pavement surface.

PRODUCTS & BENEFITS
- Stringless GPS control has the potential to provide the required guidance without the need for string lines.
- Elimination of string lines shortens construction periods that disrupt traffic, reducing contractors' move in/move out times and preventing project delays caused by time-intensive staking of string lines.
- Labor costs are reduced since string lines do not need to be placed.
- The risks of setting and removing string lines in hazardous areas are eliminated.
- Removal of string-line sensors from paving machines decreases the overall width of the machines. This provides greater work access to the slip-form paver and surrounding area, especially on county roads where the shoulders are limited.

Dowel Bar Optimization

NEED & OBJECTIVES
This project synthesized research on dowel bars for highway pavements in order to identify and document knowledge gaps. The research objectives of the project were to (1) investigate the static behavior and failure modes of steel elliptical and round epoxy-coated dowel bars, (2) evaluate elliptical dowel bars for load transfer, (3) determine the effect of dowel bar spacing on load transfer efficiency, and (4) evaluate whether variable spacing with dowel bar shape and size can optimize costs and constructability.

FINDINGS & CONCLUSIONS
- Large elliptical steel dowel bars produce greatly reduced bearing stresses on the concrete, while the increase in relative deflection is minimal.
- Round steel dowel bars have a slight advantage in stiffness over elliptical dowel bars.
- For most pavements, a 12-inch spacing is sufficient for traffic loads. Decreased pavement thickness and poor subgrade material lower the number of dowel bars available for load transfer, and smaller spacing may be required.
- Knowledge gaps include aging of fiber reinforced polymer (FRP) dowels, investigation of uneven dowel bar placement, standardized testing procedures and ASTM tests for dowel bars, and development of a universal design procedure.

PRODUCTS & BENEFITS
- The knowledge generated in this project provides pavement designers with better guidance regarding steel elliptical and round epoxy-coated dowel bars and the optimal spacing of dowel bars for various conditions and designs.
- The summary of knowledge gaps in dowel bar research can help conserve research funds and resources, guide the future of dowel bar research for highway pavements, and help researchers challenge and revise old research.
Field Evaluation of Elliptical FRP Dowel Performance

NEED & OBJECTIVES
The most commonly used load transfer devices in transverse concrete pavement joints are epoxy-coated steel dowels, which are usually round with a diameter of 1.25 or 1.5 inches. These dowels can cause corrosion and oblong joints, leading to chipping and spalling in the surrounding concrete, freezing or locking of the joint, and loosening of the connection between the dowel and the pavement. The objective of this project was to evaluate elliptical-shaped fiber reinforced polymer (FRP) dowels as an alternative to steel dowels.

FINDINGS & CONCLUSIONS
• FRP dowel bars provide adequate load transfer across the joints.
• FRP dowels provide adequate rider comfort for vehicles crossing joints.
• Faulting and joint opening measurements demonstrated that the joints with FRP dowels operate properly.

PRODUCTS & BENEFITS
FRP dowels have the potential to reduce or eliminate the corrosion and resulting deterioration often associated with conventional steel dowels.

SPONSOR
FHWA
RESEARCH LEAD
Max Porter, Iowa State University
FUNDING
$160,000
STATUS
Completed (June 2005)

Structural Behavior of Alternative Dowel Bars

NEED & OBJECTIVES
Many problems have been associated with round steel dowels, including corrosion of the dowel and erosion of the surrounding concrete. This erosion reduces the bar’s ability to handle load transfer. In order to determine the optimal bar shape and material for the design of concrete pavements, the modulus of dowel support must be accurately determined. The objective of this project was to compare two different shear load laboratory test methods to determine modulus of dowel support: a modified version of the American Association of State Highway and Transportation Officials (AASHTO) T253 method and an experimental cantilevered dowel test.

FINDINGS & CONCLUSIONS
• The modified AASTHO T253 test method demonstrates improvement over the traditional AASHTO method.
• The experimental cantilever test is not a satisfactory test method to replace or verify the AASHTO test.
• The fatigue test was inconclusive in demonstrating which dowel bar will cause the least amount of deterioration over time.

PRODUCTS & BENEFITS
The cantilever test has been effectively ruled out as a method of evaluating dowel bar performance. Although further refinement of the modified AASHTO T253 method may continue to improve its accuracy, the modified test demonstrates better accuracy than the traditional method.

SPONSORS
FHWA; Iowa Highway Research Board (TR-510)
RESEARCH LEAD
Max Porter, Iowa State University
FUNDING
$178,000
STATUS
Completed (May 2006)
Field Evaluation of Elliptical Steel Dowel Performance

NEED & OBJECTIVES
Joints are always a concern in the construction and long-term performance of concrete pavements. Research has shown that some type of positive load transfer is needed across transverse joints. The same research has directed pavement designers to use round dowels spaced at regular intervals across the transverse joint to distribute the vehicle loads both longitudinally and transversely across the joint. The objectives of this project were to evaluate the performance of elliptical steel dowels as compared to round dowels and to evaluate the impact of joint spacing on the relative performance of elliptical and round dowels in the field.

FINDINGS & CONCLUSIONS
• The medium and large elliptical steel dowels performed equal to or better than the conventional steel dowels in terms of deflection, visual distress, and joint faulting. No conclusions could be reached on the relative performance in terms of joint openings.
• The medium-sized elliptical steel dowels can be spaced up to 15 inches (381 mm), center to center, and perform as well as or better than conventional round bars.

PRODUCTS & BENEFITS
The results of this project indicate that changes can be made in the Iowa Department of Transportation specifications to allow for the use of elliptical shaped steel dowels as an alternative to the standard round steel bars currently in use.

Effect of Admixtures on Roller-Compacted Concrete (RCC) Mixtures

NEED & OBJECTIVES
Admixtures are ingredients in the form of powder or liquid added to the concrete matrix during mixing. Very little documentation exists today on the effect of concrete admixtures on the behavior of roller-compacted concrete (RCC) mixes. The objective of this project is to develop an understanding of the effect of concrete admixtures on RCC mixes, and to prepare recommendations for their appropriate use. The project emphasis will be on retarders and water reducers and will not include the study of air-entraining agents.

ANTICIPATED BENEFITS
The results from this project will be utilized as guidelines for producers and contractors in the use of admixtures for RCC mixes. A set of recommended guidelines will be developed for producers and contractors for the use of admixtures based on the detailed literature review and laboratory investigation results; the documents could be used by any agency working on RCC.
Guide to Concrete Overlay Solutions

NEED & OBJECTIVES
The objective of this project was to develop the Guide to Concrete Overlay Solutions to help pavement owners and contractors understand, design, and build various types of concrete overlays. The guide was designed to emphasize that concrete overlays can serve as cost-effective maintenance and rehabilitation solutions for almost any combination of existing pavement type and condition, desired service life, and anticipated traffic loading.

PRODUCTS & BENEFITS
The first edition of the Guide to Concrete Overlay Solutions was published in January 2007. The 28-page guide provides detailed information on the six major types of concrete overlays, along with specifics on materials, typical sections, and important construction elements.

The CP Tech Center printed and distributed 10,000 copies of the first edition of the guide. Copies were delivered to state and regional concrete paving chapters, state DOTs participating in the field application program, and other potential training venues.

In September 2008, a second edition of the guide was published to address additional topics not included in the first edition and to clarify terminology. The National CP Tech Center distributed 7,500 copies of the second edition.

Concrete Overlay Field Application: Demonstration Projects

NEED & OBJECTIVES
The FHWA/CP Tech Center’s Field Application Program is a two- to three-year effort, begun in 2007, to apply concrete overlays in the field in 20 states and to develop a comprehensive manual on concrete overlay solutions. The objective of this project is to support the Field Application Program by guiding six state departments of transportation (DOTs) through the concrete overlay design and construction process. These demonstration projects will draw from the Field Application Program’s multi-state research projects to teach, demonstrate, and document various concrete overlay applications. The Guide to Concrete Overlay Solutions, Second Edition will serve as the primary source document for these demonstrations.

ANTICIPATED BENEFITS
The results of the demonstration projects will be used to develop improved design and construction guidelines for concrete overlays. These guidelines will allow government agencies to use concrete overlays with confidence and will help agencies meet traffic, construction time, and performance requirements during overlay construction.

In addition, informal open houses will be held during each project to showcase important research activities, and the results of the demonstration projects will be presented in tech notes to provide the background and standards that designers can use to evaluate overlay projects.
Concrete Overlay Field Application: Research Projects

NEED & OBJECTIVES
The objective of this project is to increase awareness of and confidence in concrete overlay applications by demonstrating improved concrete overlay construction techniques on different types of concrete overlay projects. Techniques will include stringless paving, fabric stress relief layers, GPS control for grades, different traffic control strategies, and comparisons of strength versus opening time.

ANTICIPATED BENEFITS
Research will focus on four locations in Iowa, including two state routes and two county facilities. The research results will be compared to existing construction techniques and project design elements to identify changes that can be implemented to speed construction of quality concrete overlays. The information from this research project will be included with the items learned from the six-state demonstration projects conducted for the FHWA/CP Tech Center’s Field Application Program and will be included in modifications to the design guide for concrete overlays.

SPONSORS
FHWA; Iowa DOT

RESEARCH LEAD
Paul Wiegand, National CP Tech Center

FUNDING
$500,000

STATUS
In progress (completion estimated May 2010)

Guide for Existing Concrete Overlay Design Methodology

NEED & OBJECTIVES
Guidance for concrete overlay thickness design has been published by several national agencies and state departments of transportation. Much of this guidance has been used for over 15 years to help agencies design and construct numerous pavement projects. However, these design methodologies have limitations, such as a tendency to generate conservative design approaches, relatively non–user–friendly design tools, and the significant amounts of input needed to arrive at a reliable and reasonable pavement thickness. The result is often a design that does not fully use the advantages inherent to concrete overlays. The objective of this project is to develop straightforward guidance that will help pavement engineers use the design procedures commonly practiced today.

ANTICIPATED BENEFITS
This project will result in a guide that outlines the existing concrete overlay design process, defines the key inputs, and provides numerous design examples and typical cross sections. Both existing and state-of-the-art analytical design methods will be cited, many based on mechanistic principles, and the methods’ most sensitive variables will be identified. The guide will also describe the underlying design philosophies so that users may modify the inputs to suit their project-specific values while adhering to the overall process.
Composite Pavement Unbonded Overlays

NEED & OBJECTIVES
Previous asphalt resurfacing efforts have extended the design lives of many aging concrete pavements. Now, engineers need concrete alternatives that provide longer life at a lower life-cycle cost. The goal of this research project was to investigate the stability and durability of thin unbonded concrete overlays over time. This project evaluated many independent design variables to gain information regarding the most cost-effective thin overlay designs for composite pavement.

FINDINGS & CONCLUSIONS
• Overlay depths of 3.5 inches or greater can be built without the use of fiber inclusion. Adding fibers to overlay depths of 4 inches or less will provide insurance against loss of materials in the event of an individual slab loss-of-support or multiple cracking. In overlays of 4.5 inches or less, structural fibers can provide an opportunity for larger slab sizes without subsequent loss of load transfer or increased cracking rates.
• Minimal scarification of the base asphalt surface is shown to be the most efficient way to control overlay quantities, ensure proper cross slope, and minimize overlay thickness design while placing additional concrete in the rutted areas of existing surface.
• Maintenance personnel with normal materials and equipment can maintain the concrete surface when isolated panels fail under this design system.

PRODUCTS & BENEFITS
• Understanding the design variables of thin unbonded overlays can help engineers design concrete pavement revitalization projects with optimum cost-effectiveness.

Crack Development in Ternary Mix Concrete Utilizing Various Saw Depths

NEED & OBJECTIVES
Early-entry sawing, which uses a lightweight machine to apply earlier and shallower cuts than conventional sawing, is believed to increase sawing productivity and reduce costs. However, some early-entry saw joints in Iowa have experienced delayed cracking, including delays of weeks or months after sawing. An urgent concern is whether early-entry sawing could lead to late-age random cracking. This study was designed to investigate whether delayed random cracking may occur in pavements constructed using early-entry sawing. Because cracking is related to stress development in concrete, the specific objective was to examine the stress levels that develop at pavements' early-entry sawing joints.

FINDINGS & CONCLUSIONS
• Although most joints made using the early-entry sawing method cracked later than the joints made with conventional sawing, all 30 joints examined in this study cracked within 25 days after paving.
• No random cracking was observed in the test section two months after construction.
• The average joint cracking time for early-entry sawing was 12.3 days. The average joint cracking time for the joints made with the conventional sawing method was 2.2 days.

PRODUCTS & BENEFITS
• With the results of this study, agencies and the paving industry can identify potential late-age random cracking problems in pavements constructed with early-entry sawing.
• The results may also help the Iowa DOT and paving contractors modify early-entry sawing operations—for example, in terms of sawing depth and joint spacing for low-shrinkage concrete mix pavements.
Concrete Pavement Patching Techniques vs. Performance & Traffic Delay

NEED & OBJECTIVES
The concrete paving industry and state DOTs seek an optimal balance between construction methods, materials, and costs to minimize delay time and improve the performance of patching materials. The objective of this project was to provide an evaluation of concrete pavement patching techniques related to patch thickness, strength development, and traffic opening in order to optimize concrete pavement patching practices.

FINDINGS & CONCLUSIONS
- Increased patch depth enhances the concrete strength gain associated with the heat of hydration and maturity testing.
- Maturity testing effectively determines opening times to traffic vs. achieved flexural or compressive concrete strength.
- The Schmidt hammer can monitor strength gain over time in concrete pavement patches.
- Near-surface concrete strength development may benefit from the compression effect of early traffic loading and from cement hydration. Before concrete starts to harden, proper compression from appropriate traffic loads may facilitate concrete early strength development by improving concrete density. However, if the load is too large or applied too early, it will damage the concrete.
- An optimal time exists for pavements made with a given concrete mix to open to traffic. Rebound test results indicate that the optimal opening time is five hours after placement for the C4 mix patches and three hours for the M4 mix patches.

PRODUCTS & BENEFITS
Improvements to concrete pavement patching practices can be made based on the research results.

SPONSORS
Iowa DOT; Iowa Concrete Paving Association

RESEARCH LEAD
Jim Cable, Iowa State University

STATUS
Completed (September 2005)

Design & Construction Procedures for Concrete Overlay & Widening of Existing Pavements

NEED & OBJECTIVES
State DOTs and local agencies are faced with aging highways and a need to extend pavement life. Existing design procedures for concrete overlays primarily involve an existing asphaltic pavement with an underlying granular base or stabilized base. The objective of this project was to provide concrete overlay strategies for existing composite pavements that require another overlay due to poor performance of the existing surface.

FINDINGS & CONCLUSIONS
- Thin concrete overlays and widening units provide a viable and economical alternative for narrow highway pavements.
- Thicker whitetopping overlays were found to improve pavement performance by lowering deflections and stress maximums that were induced in the composite pavement under static loading.
- The width, rather than the depth, of the widening units has a significant effect on reducing deflection.

PRODUCTS & BENEFITS
- This work provides the engineer with a concrete overlay solution to composite pavements and conventional asphaltic concrete pavements that are in need of surface rehabilitation.
- A concrete overlay design procedure has been developed that provides for acceptable performance for traffic volumes of up to 2,000 ADT and in excess of 10 years.
- The results of this study provide the engineer with a way to use existing deflection technology coupled with materials testing and a combination of existing overlay design methods to determine the design thickness of the concrete overlay.
Unbonded Ultrathin Whitetopping of Brick Streets

NEED & OBJECTIVES
Many Iowa cities retain brick street surfaces in downtown and residential areas as the base for modern driving surfaces. However, the original brick surfaces were not built to handle current traffic loads. In recent years, these surfaces have tended to shift and become uneven, creating safety problems. Asphalt overlays have been the typical rehabilitation technique in these situations. While this technique has proven successful in some cases, in other cases the combination of the movement of the brick and the flexibility of the asphalt accentuated the original problem. The objectives of this project were to demonstrate the ability to design and place an ultrathin (approximately 3 inches) concrete overlay on an existing base of asphalt and brick and to evaluate the short- and long-term performance of the concrete overlay in comparison to the performance of an asphalt overlay of similar depth.

FINDINGS & CONCLUSIONS
• Ultrathin overlays can be successfully used as a rehabilitation technique for aging brick-surfaced streets that are experiencing increased traffic loads from serving as truck routes and reduced performance due to the failure of previous flexible overlays.
• Conventional mixes with the addition of polyfibers can be used to ensure the performance of the 3- to 4.5-inch-deep overlay sections.
• The deflection data from the falling weight deflectometer (FWD) indicate good load transfer in all test locations, slab sizes, and testing periods.

PRODUCTS & BENEFITS
• Ultrathin concrete overlays can be placed quickly with minimal closure and traffic delay.
• In areas where asphalt overlays have failed in the past due to the overlay material’s flexibility, ultrathin concrete overlays are a better alternative.

Long-Life Concrete Pavements

Improving the Foundation Layers for Concrete Pavements Track

NEED & OBJECTIVES
The objective of this research is to improve the construction methods, economic analysis and selection of materials, in situ testing and evaluation, and development of performance-related specifications for pavement foundation layers. All aspects of foundation layers will be investigated, including thickness, material properties, permeability, modulus/stiffness, strength, volumetric stability, and durability. Field investigations will be conducted at various sites in multiple states. Evaluating pavement foundation design input parameters at each site will provide a link between what is actually constructed and what is assumed during design.

ANTICIPATED BENEFITS
This study will result in conclusive findings that make pavement foundations more durable, uniform, constructible, and economical. The final report will be a compilation of what we currently know and all the new knowledge gained during the course of this study. It will include best construction practices to provide stable and uniform pavement foundations, outline QC/QA testing recommendations, provide design aids, and suggest improvements specifications. The results of this study will be included in the pooled fund study’s Manual of Professional Practice for Design, Construction, Testing and Evaluation of Concrete Pavement Foundations.
**Scan Team Implementation Plan (STIP) for Long-Life Concrete Pavements**

**NEED & OBJECTIVES**
In May 2006, a team of 13 concrete pavement and materials specialists from the United States visited Canada and five countries in Europe to identify the design philosophies, materials requirements, construction practices, and maintenance strategies they use to construct and manage portland cement concrete pavements with long life expectancies. The objective of this project is for the CP Tech Center to provide implementation support to FHWA on the Scan Team Implementation Plan (STIP) recommendations. The task order currently underway is for technical and implementation support of two-lift paving technology.

**FINDINGS TO DATE**
- A demonstration project and open house on two-lift concrete paving were held in Saline County, Kansas, in the fall of 2008. The objective of the project was to verify that two-lift paving can be constructed economically using traditional equipment and paving methods and to evaluate several surface texturing methods for optimizing surface characteristics.
- Research is underway to monitor the performance of the various test sections in Kansas.

**ANTICIPATED BENEFITS**
- As quality aggregate becomes scarce in some regions, two-lift paving will become a more viable economic option. Two-lift construction can accommodate the use of different qualities of aggregates to improve the economy of the mix.
- Two-lift paving will help some agencies around the country consume growing recycled asphalt stockpiles, which could reduce overall costs while benefiting the environment.
- Two-lift paving has the potential to meet emerging surface characteristics needs by providing a high-quality and durable surface.

**Development of a Device for Analysis of Portland Cement Concrete and Composite Pavements, Phase I Feasibility Study**

**NEED & OBJECTIVES**
Detecting portland cement concrete (PCC) and composite pavement distress is a difficult and cumbersome task with commercially available equipment. Using currently available technologies to obtain the needed measurements over a large network of highways is costly, slow, and creates hazardous conditions for both the traveling public and test technicians. The long-term goal of this effort is to develop a device that will detect and measure pavement distresses impacting the performance of PCC and composite pavements while traveling at highway speeds. Phase I assessed the feasibility of developing such a device and establish the market need.

**FINDINGS & CONCLUSIONS**
- It appears that it is theoretically possible to make the measurements needed to manage a system-wide rigid pavement inventory. It should, however, be pointed out that the identified technologies would appear to be required to operate at the limits of their accuracy and precision. With the rapid advance of technological capabilities, this may optimistically become a non-issue.
- The market needs study indicates that there is interest in the use of a system for making system-wide PCC pavement measurements. The costs users might be willing to pay for such measurements appear to be in line with other similar types of measurements and what might be possible with such a device.

**PRODUCTS & BENEFITS**
- State departments of transportation across the country would benefit from the development of this device.
Attributes of Good In-Service Pavements

NEED & OBJECTIVES
The objective of this research was to provide an initial evaluation of key factors contributing to concrete pavement deterioration and the typical attributes of good in-service pavements.

FINDINGS & CONCLUSIONS
• Deterioration of concrete pavement is a continuous process that may start with one specific type of distress and continue with the combination of additional distress types. Distress processes mutually promote each other.
• In pavement degradation, water plays an important role. Poor drainage conditions are generally associated with poor performance of pavement sections. A subbase with good drainability is necessary for adequate performance.
• A major factor on most concrete pavement distress types is the traffic loading condition of the pavement.
• One of the most commonly observed pavement distresses in low- to mid-volume county roads is longitudinal cracking. This type of failure can result from concrete materials, mix design, and construction-related practices as well as from heavy agricultural loading and subgrade failure.
• A well-compacted, engineered subgrade designed to meet the traffic loads in varying environmental conditions is crucial for long-lasting performance.

PRODUCTS & BENEFITS
This research provides a better understanding of how pavement design, materials and mix design, construction, and traffic loading contribute to concrete pavement deterioration. This knowledge can be used to provide longer lasting concrete pavements.

Soil Stabilization of Non-Uniform Subgrade Soils

NEED & OBJECTIVES
Soil treated with self-cementing fly ash is often used to stabilize fine-grained subgrades but without a complete understanding of the short- and long-term behavior. The objectives of this project were to understand the influence of non-uniform subgrade support on pavement performance and develop guidelines for using self-cementing fly ashes to stabilize soils.

FINDINGS & CONCLUSIONS
• Non-uniform foundations reduce pavement performance; uniform subgrade reduces critical pavement responses, such as deflections, and leads to improved pavement life.
• Fly ash increases compacted dry density and reduces optimum moisture content. Soil stabilized with fly ash exhibits increased freeze-thaw durability.
• Unsoaked soil-fly ash mixtures exhibit higher strengths for higher compaction energies at low moisture contents. Increasing compaction effort at high moisture contents shows little benefit for increasing compressive strength. In most instances, compaction delay has a negative influence on strength gain of soil-fly ash mixtures.

PRODUCTS & BENEFITS
• Pavement life can be increased and pavement performance improved by using more uniform subgrade/subbase support.
• The benefits of using self-cementing fly ash for soil stabilization include environmental incentives, because material used does not have to be wasted; cost savings, because fly ash is typically cheaper than cement and lime; and availability, because fly ash sources are distributed geographically across the state.
• This project resulted in construction guidelines and specification recommendations for using self-cementing fly ashes to stabilize soils.
Concrete Preservation and Rehabilitation Workshop

**NEED & OBJECTIVES**
The need for engineered preservation and rehabilitation strategies for maintaining the nation's highway pavements has never been greater. In the face of shrinking budgets and increasing traffic levels, highway agencies are continually being asked to "do more with less" in the management of their pavement network. For portland cement concrete (PCC) pavements, there are a variety of preservation and rehabilitation strategies that are available to meet the demands of highway agencies. However, selecting the most cost-effective strategy continues to be a significant challenge to the transportation professional. The objective of this project is to develop a 1½-day workshop on PCC pavement preservation and rehabilitation with complementing reference documents, instructional materials, and handouts.

**ANTICIPATED BENEFITS**
The material developed will be in modular form to allow future workshop facilitators to include modular sections if desired. Some sections of the workshop materials will be included as part of every workshop, such as the Introduction and Pavement Preservation Concepts. The overall learning objectives of the workshop are to provide participants with information on how to do the following:
1. Evaluate the condition of existing concrete pavements
2. Select the appropriate category (preservation or rehabilitation) based on the evaluation
3. Select cost-effective and timely techniques within that category
4. Determine the materials and construction procedures of each technique that will provide the optimal combination of extended pavement service life and cost

Effective Training Program for the Hispanic Construction Workforce

**NEED & OBJECTIVES**
Hispanic workers comprise nearly 20% of the U.S. construction industry's workforce nationwide. The Bureau of Labor Statistics reports that while overall construction fatalities have been dropping, the number of fatalities among Hispanics at construction sites is increasing. The objective of the project was to develop useful training courses and tools to address the safety and productivity issues associated with the increasing numbers of Hispanics in the construction workforce.

**FINDINGS & CONCLUSIONS**
- More effective language and cultural training for Hispanic and American construction workers can help facilitate communication on the jobsite and reduce the high fatality rate among Hispanic workers.
- For training to be effective, the focus should be integration instruction (cultural awareness, safety standards, improved relationships, and language instruction) rather than simply language training.

**PRODUCTS & BENEFITS**
- Effective training can help facilitate communication on the jobsite and reduce the high fatality rate among Hispanic workers.
- The integration training approach allows crews to "break the ice," which is necessary in crews where two or more cultures are represented. Integration between these groups helps minimize hazards and miscommunication and increase harmony and productivity on the jobsite.
- The courses are designed to minimize interference with daily construction operations by exploring innovative ways of delivering the developed course materials.
Deicer Scaling Resistance of Concrete Pavements & Bridge Decks Containing Slag Cement

NEED & OBJECTIVES
Ground granulated blast-furnace slag improves many properties of both plastic and hardened concrete. Concrete containing slag generally exhibits excellent long-term strength and durability. However, some concerns exist about the scaling resistance of concrete containing slag. The objective of this project is to investigate the variables that impact the scaling resistance of concrete containing slag cement. Researchers will determine from the field study and construction/design records which mixtures and construction parameters produce scale-resistant concrete containing slag. The lab study will investigate how specific variables influence the deicer scaling resistance of concrete mixtures. The effectiveness of ASTM C672 in predicting the deicer scaling behavior of field concrete will be evaluated.

FINDINGS TO DATE
• Phase 1 of this research project indicated that scaling was occasionally observed on field concrete pavements and bridge decks that contain slag cement.
• Phase II will consist of a laboratory evaluation of binary and ternary mixtures with different cementitious materials contents and slag replacement percentages.

ANTICIPATED BENEFITS
• This project will result in a better understanding of how specific variables influence the deicer scaling resistance of concrete containing slag cement.
• Alternative procedures will be recommended to improve the correlation between lab and field performance of concrete containing slag cement.

SPONSORS
FHWA;
Pooled fund (TPF-5[100]);
Connecticut, Iowa, Kansas, New York, and Ohio;
Slag Cement Association

RESEARCH LEADS
Scott Schlorholtz, Iowa State University;
Doug Hooton, University of Toronto

FUNDING
$450,000

STATUS
Phase I completed
Phase II in development

Improved Pavement Curing Materials & Techniques

NEED & OBJECTIVES
Curing of concrete is important for concrete pavement durability. The objectives of this research were to evaluate the effect of different curing materials and techniques on concrete pavement properties and to better understand the relationships between various concrete test measurements and concrete properties affected by curing.

FINDINGS & CONCLUSIONS
• Concrete property values vary considerably with depth, regardless of curing method.
• The sorptivity test is effective for evaluating the subtle changes in near-surface layer concrete properties related to microstructure development as these properties are impacted by different curing methods.

PRODUCTS & BENEFITS
Adequate curing can help ensure the uniformity of the concrete layers, control moisture and temperature conditions, and prevent or minimize random cracking in concrete pavements during the first few days after construction.

SPONSOR
Iowa Highway Research Board (TR-451, TR-479)

RESEARCH LEADS
Jim Cable, Iowa State University;
Kejin Wang, Iowa State University

FUNDING
$167,000

STATUS
Completed (March 2003)
Properties of Blended Cements for Concrete Pavements

NEED & OBJECTIVES
Adding supplementary cementitious materials (SCMs), such as fly ash and other industrial byproducts, to cements can improve concrete workability, durability, and long-term strength; however, a gap in knowledge about the variation in performance of concrete containing SCMs has limited its use. This research addressed the knowledge gap by evaluating the behavior of concrete made with SCMs under a variety of conditions.

FINDINGS & CONCLUSIONS
• Fly ash can function as a water-reducing agent in cement mixtures. As a result, ternary cement concrete can achieve the same flowability as ordinary portland cement (OPC) concrete.
• As SCM content increases, longer curing times or higher curing temperatures may be needed. Covering slabs to trap heat, extending curing times, and/or using accelerators is recommended for SCM concrete paving in cold weather conditions.
• SCM concrete can perform as well as or better than OPC concrete in hot weather. SCM concrete generally has a lower risk of thermal cracking because the maximum heat of hydration in binary/ternary concrete decreases with the amount of SCM replacements.
• The required time-temperature factor (TTF) value to open pavement to traffic should be based on the strength-TTF correlation of the concrete materials and mix proportions under the field curing conditions.

PRODUCTS & BENEFITS
A more informed use of SCMs in concrete can lead to improved concrete workability, lower risk of thermal cracking, improved concrete durability and long-term strength, and reduced overall concrete cost.

Two-Lift Concrete Pavements to Meet Public Needs

NEED & OBJECTIVES
Two-lift paving is being reconsidered as a construction technique for concrete pavements due to changes in the availability of aggregates, advances in materials knowledge and construction equipment, and the increasing demands for pavement surfaces that meet specific noise, durability, and safety objectives. Cost, mix design, and construction concerns are inhibiting the use of two-lift paving. The objective of this research was to review the two-lift paving experience and assess the challenges that restrain the use of this technique.

FINDINGS & CONCLUSIONS
• The construction costs for two-lift pavements are about double those of concrete pavements constructed using a standard one-lift technique.
• If a contractor can use less expensive aggregate in the thick lower lift, the savings might be enough to offset part or all of the additional costs of two-lift paving.
• Some of the additional costs may also be reduced with advances in two-lift paving equipment and techniques.

PRODUCTS & BENEFITS
• As quality aggregate becomes scarce in some regions, two-lift paving will likely become a more viable economic option. Two-lift paving will help some agencies around the country consume growing recycled asphalt stockpiles, which could reduce overall costs while benefiting the environment.
• Two-lift paving has the potential to meet emerging surface characteristics needs by providing a high-quality and durable surface. Wear resistance can be improved by using higher quality aggregate in the upper lift.
Pervious Concrete Mix Design for Wearing Course Applications, Phase 1

NEED & OBJECTIVES
Portland cement pervious concrete has great potential to reduce roadway noise, improve splash and spray, and improve friction as a surface wearing course. To date, two key issues that have impeded the use of pervious concrete in the U.S. are that strengths of pervious concrete have been lower than necessary for required applications and that freeze-thaw durability of pervious concrete has been suspect. The objective of this research is to conduct a comprehensive study focused on developing pervious concrete mix designs that have adequate strength and durability for wearing course pavements and have surface characteristics that reduce noise and enhance skid resistance, while providing adequate removal of water from the pavement surface and structure.

ANTICIPATED BENEFITS
This project will provide missing information about suitability and long-term behavior of pervious concrete mixes for highway applications. This information will provide the first data of its kind in the United States—data that is essential to understand the potential use of pervious concrete in pavements for noise reduction, skid resistance, splash control, and environmental benefits. The research may result in a reduction in noise in concrete pavements, increased safety due to increased skid resistance and reduced spray, as well as environmental benefits.
The mission of the National CP Tech Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.