



HIGH-SPEED NONDESTRUCTIVE TESTING AND INTELLIGENT CONSTRUCTION SYSTEMS

Implementing the CP Road Map ND Track

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Background

Over the past 20+ years, society has experienced a wide array of technological advances, from the personal computer to the cell phone. During this time, the research community has refined a number of NDT technologies. However, these tools have largely been confined to pavement management uses and have not been applied extensively to the concrete paving process.

Advances in technology could benefit both the construction and inspection teams in several key ways. DOTs have expressed interest in the benefits of ND testing. The equipment industry, however, faces both a technical challenge and an investment challenge of investing without having any certainty of a market. Establishing a working group that properly frames the issues, agrees on the technologies, and prioritizes the work efforts is critical for overcoming this investment challenge.

The CP Road Map has identified nine potentials systems that could be developed and integrated into the paving operations:

- Temperature/Moisture/Strength/Stiffness Changes and Development
- Pavement Thickness
- Dowel/Tie Bar/Reinforcement Alignment
- Curing Effectiveness
- Slab Support
- Workability
- Air Void Systems
- Mix Density and Volumetrics
- Smoothness/Texture (Skid Resistance & Splash/Spray)

With wireless and telecommunication systems, information can be shared all over the country, with specialists working to improve the operation without even being on site.

Background information on the CP Road Map and other corresponding research tracks can be downloaded from the FHWA website at: <http://www.fhwa.dot.gov/pavement/pccp/pubs/05047/>.

CP ROAD MAP
shaping the future of concrete pavement



it's your move!

Benefits of ND Testing Integrating with the Paving Operation

Both industry and government will benefit from these tools by reducing reliance on slow and sometimes poorly managed small-sample testing programs. The technologies targeted in this research track are intended to form the basis of an Intelligent Construction System (ICS) that could sense and adjust the paving process automatically while informing contractors and inspectors of changes and/or deficiencies in construction. Continuous and real-time sampling could be configured to detect changes to the approved mix design and the preprogrammed line and grade values. These technologies would also allow industry and government to use the data for long-term pavement management and evaluation. In this regard, this research track is interdependent with multiple tracks within the CP Road Map.

ND TRACK GOALS

- *To improve construction operations by providing continuous and rapid feedback to make changes on the fly.*
- *To develop NDT methods that use continuous and real-time sampling to monitor performance-related concrete mix properties and reduce the number of human inspectors.*
- *To integrate data collection with materials management and pavement management systems to solve future problems and evaluate*

and performance.

The ND Track Research Team will identify, promote, and coordinate the research and technology that is necessary to achieve this goal. It will promote collaboration among partners, and ensure that duplication is minimized.

Identifying the Gaps

In developing the CP Road Map, and with the ND Track Goal in mind, a thorough review of the state of the practice was made. During this process, gaps were identified with respect to testing methods commonly used to monitor the paving operation. These gaps have both short and long term effects on the industry. In the short term, gaps exist from the practice of manual data collection of a limited number of parameters and locations during construction. The inability to collect the correct data in the proper amounts also effectively limits our industry from fully implementing mechanistic pavement design procedures and performance based specifications.

To move forward, we must first look at the various components of the paving process and determine where technology and practice are lacking. To address the gaps in current practice, the ND Track will address field control issues and ongoing efforts with existing technologies. Another goal focuses solely on the technological gaps that must be closed to move towards a fully automated construction monitoring process. The final goal of the ND Track is to integrate field control practices with technological advances to form a fully integrated ICS.

An idealized ICS for concrete paving is shown in Figure 1. In this figure, we see a member of the construction or inspection team with access to multiple data streams tracking the paving process.

This document further describes the framework of the ND Track of the *Long-Term Plan for Concrete Pavement Research and Technology - The Concrete Pavement Road Map* published in September 2005.

Mission Statement for the ND Track

Under the ND Track, the concrete pavement industry will work together to develop an integrated set of technologies that can rapidly assess and track construction parameters related to pavement construction

These continuous streams of data will allow the paving process to be managed much more effectively and efficiently.



Figure 1. Idealized Intelligent Construction System for Concrete Paving

The ND Track: a Plan to Bring Technologies Together

A structured outline for the ND Track was presented in the original CP Road Map. The Track was divided into subtracks, and then again into tasks that describe individual “compartments” of research and technology. Collectively, the work program will meet the goal of the Track, but only if collaboration is realized. Although some related work has been ongoing since the publication of the CP Road Map in 2005, it has not been directly focused towards the goals of the ND Track. This demonstrates the need to formally manage the ND Track to realize these goals.

The ND Track currently identifies 22 problem statements. The proposed research is organized into three subtracks and presented in a recommended sequence:

- ✓ Subtrack ND.1: Field Control
- ✓ Subtrack ND.2: Nondestructive Testing Methods
- ✓ Subtrack ND.3: Nondestructive Testing and Intelligent Construction Systems Evaluation and Implementation

Problem statements contained in the plan may correspond to one or more individual projects. Over the course of the ND Track, each problem statement will be developed into research project statements that will contain detailed descriptions of the research to be accomplished, specific budgets, and definite timelines. Detailed problem statements for the ND Track are not included here for brevity, but can be found in the National CP Tech Center Publication, *Long-Term Plan for Concrete Pavement Research and Technology – The Concrete Pavement Road Map: Volume II, Tracks*, published September 2005.

Foundational, Recent, and Ongoing Work

The following is a summary of some of the more relevant work that is foundational in nature, recently completed, and/or ongoing. While categorized under the Subtrack headings, no attempt is made here to prioritize their relevance. Collaboration with the sponsors and researchers of these projects will be important to the success of the ND Track.

Subtrack ND.1: Field Control

- ✓ Stringless Paving – Multiple Equipment Manufacturers
- ✓ Advanced Quality Systems – FHWA/ARA/Fugro/Transtec
- ✓ Reflective Ultrasonic Technique for Early Age Strength Determination – Northwestern University
- ✓ Maturity Testing for Highway and Airfield Concrete – IPRF/ Multiple State DOTs/Vendors
- ✓ Nondestructive Evaluation of Iowa Pavements: Phase I – Iowa DOT/Iowa State
- ✓ Implementation of TEMP System – FHWA CPTP Task 7 – Transtec
- ✓ Performance Specifications for Rapid Highway Renewal – SHRP II R-07 – Trauner

Subtrack ND.2: Nondestructive Testing Methods

- ✓ Nondestructive Testing for Design Evaluation and Construction Inspection – SHRP II R-06 – Texas A&M
- ✓ Thermochron and Hygro Button Innovation – Texas DOT/Univ. of Texas
- ✓ Scanning Lasers for Real-Time Pavement Thickness Measurement – Iowa DOT/Iowa State
- ✓ Integrating Deflection and Ground Penetrating Radar – Texas DOT/Texas A&M
- ✓ Accuracy of Ground Penetrating Radar for Pavement Layer Thickness – Univ. of Kentucky
- ✓ Demonstration of Seismic and Maturity Testing Technologies – Univ. of Texas-El Paso/AP Tech
- ✓ Magnetic Tomography for Dowel Bar Location – FHWA CPTP Task 7 – ARA
- ✓ Demonstration of SmartCure to Monitor Curing Operations – FHWA/Transtec
- ✓ Accelerated Implementation of Intelligent Compaction – FHWA/Pooled Fund/Transtec
- ✓ Examining the Benefits and Adoptability of Intelligent Soil Compaction – NCHRP 21-09
- ✓ Measuring Pavement Profile at the Slip-Form Paver – Ames Engineering/GOMACO
- ✓ Concrete Pavement Surface Characteristics Program – FHWA/Iowa State

Subtrack ND.3: Nondestructive Testing and Intelligent Construction Systems Evaluation and Implementation

- ✓ Nondestructive and Innovative Testing Workshop – FHWA CPTP Task 59 - Transtec
- ✓ Leveraging Technology to Improve Construction Productivity – FIATECH

Stakeholders and Partners

Successful collaboration under the ND Track will require participation from a number of diverse groups, many of which are listed below.

- ✓ Active Stakeholders and Partners
 - ◆ AASHTO
 - ◆ ACPA Chapters
 - ◆ ACPA National
 - ◆ FIATECH
 - ◆ FHWA
 - ◆ NRMCA
 - ◆ PCC Paving Equipment Manufacturers
 - ◆ PCC Paving Contractors
 - ◆ Sensor and Nondestructive Testing Vendors
 - ◆ State DOTs
 - ◆ TRB Committee AFH50

Inaugural ND Track Forum

An ND Track Forum was held in Austin, Texas in June 2008 to address the issues raised in this paper. As with the Mix Track and Surface Characteristics Track, the strategic forums proved very beneficial to organize and kick off work under this track.

Objectives

- ✓ To achieve consensus on the ultimate objectives of the ND Track.
- ✓ To validate what knowledge gaps exist today.
- ✓ To identify how we as an industry can work to fill these gaps.
- ✓ To identify early projects and their funding mechanisms.
- ✓ To help advance the CP Road Map ND Track to a dynamically managed program.

Agenda

- ✓ Introduction to CP Road Map
 - ◆ Brief History of Program
 - ◆ Current CP Tech Center Role in Implementation and Administrative Support
 - ◆ The Definition and Importance of Collaboration.
- ✓ Presentation of Draft ND Track Framework
- ✓ Summary of ND Work
 - ◆ Foundational
 - ◆ Recently Completed
 - ◆ Ongoing
- ✓ Discussion with goal of Consensus
 - ◆ Overall Objective
 - ◆ Gaps
 - ◆ Short-Term Projects and Products
 - ◆ Long-term Project and Products
- ✓ Identification of Funding Partners for Short-Term Projects
- ✓ ND Track Communications, Coordination, and Collaboration Plan
- ✓ What Happens Next?

Participant List

- ✓ FHWA/USDOT
 - ◆ Gary Crawford, Office of Pavement Technology
- ✓ State DOT
 - ◆ Shannon Swietzer, North Carolina Turnpike Authority (AFH50)
 - ◆ Hua Chen, Texas DOT
 - ◆ Bryce Simons, New Mexico DOT
 - ◆ Doug Schwartz, Minnesota DOT
- ✓ Pavement Industry
 - ◆ Kevin Klein, GOMACO
 - ◆ John Eisenhour, Terex Roadbuilding
 - ◆ John Maurer, Ames Engineering
 - ◆ Dennis Warren, Texas Concrete Paving Association
- ✓ Academia and Other Industry
 - ◆ John Daniewicz, Rhino Analytics
 - ◆ Randall Jean, Baylor University

- ✓ National CP Tech Center
 - ◆ Paul Wiegand, National CP Tech Center
 - ◆ Ted Ferragut, TDC Partners, Ltd.
 - ◆ Dennis Turner, The Transtec Group, Inc.
 - ◆ Rob Rasmussen, The Transtec Group, Inc.
 - ◆ David Merritt, The Transtec Group, Inc.

Ranking Parameters

A brainstorming exercise at the forum was conducted to rank measurement parameters according to importance and ease of implementation in a real-time monitoring system. The results are summarized below:

Importance (highest to lowest)	Ease of Implementation (easiest to most difficult)
✓ Fresh Mix Properties/Variations	✓ Curing
✓ Curing	✓ Surface Characteristics
✓ Surface Characteristics (smoothness/texture)	✓ Fresh Mix Properties/Variations

Action Plan

In order to effectively build off of the work to date, a number of early products are recommended under the ND Track. These early products should include:

1. Identify most critical parameters to monitor during construction:
 - a. Fresh mix properties/variability
 - b. Curing operations
 - c. Smoothness/texture
2. Identify corresponding technologies to assess most critical parameters to monitor during construction.
 - a. Framework study that shows system integration of all potential devices, their location, their interrelationship, the wireless communication system, and the availability of information at various locations on the paving train, plant, or test laboratory.
 - b. Complete and detailed study of sensor technologies
 - c. Detailed study of types and protocols for wireless network tools to transmit and record sensor readings in an integrated communication system. This would include considerations to develop robust equipment and sensors needed to withstand equipment vibrations, weather, and other potential problems from the construction environment
3. Identify long-term research needs:
 - a. Assess real-time measurement needs and techniques for concrete mix properties and variability
 - i. Systems approach that would link data from plant, transport vehicles, and paving equipment.
 - b. Develop causality links between paving operations and mix properties/variations on changes to pavement smoothness and texture.

- c. Identify techniques and technologies to properly measure air void system in the appropriate location on the paving operation.
4. Identify short-term implementation needs:
 - a. Develop equipment performance specifications for curing monitoring system similar to SmartCure
 - i. Provide model specification to National Concrete Consortium.
 - b. Search for funding mechanisms or incentives to further implement available real-time smoothness and/or texture monitoring systems.
5. Organize symposium of 40-50 attendees from concrete paving and sensing industries to discuss technologies to address identified measurement needs.
 - a. Present engineering parameters of concrete paving that would benefit from new and improved sensing technologies.
 - b. Present sensing technologies that directly address identified needs for concrete paving.
6. Further study of stringless paving operations, including superelevated, horizontal, and vertical curves.

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