Center Supports Innovative Research

Enhancement of Bridge Decks Through the Use of Ultra High Performance Concrete Overlays

Reinforced concrete decks serve as the workhorse on most bridges, supporting traffic and distributing loads down to the primary load bearing members. However, bridge decks of this type are susceptible to damage through a variety of mechanisms such as freeze-thaw cycling, chemical attack from surface treatments, and mechanical stresses induced from dynamic vehicle loads. This damage is often exacerbated in “Salt States” where deicing chemicals are frequently used during the winter months, contributing to premature deterioration of the bridge deck. This damage often manifests as degradation of the deck system in the form of reinforcing steel corrosion, subsurface delaminations, and eventually surface spalling, all requiring repair and rehabilitation.

To address these challenges, there is a need for developing solutions to extend the service life of existing bridge decks, and expand the service life window of new bridge decks. Often, from an existing inventory perspective, this is accomplished in the form of an overlay that functions to provide an additional structural layer for protection of the superstructure from contaminant penetration as well as providing a durable wearing surface for traffic. A similar approach is feasible for new bridge deck systems where a durable overlay can be applied as a protective topping on a traditional bridge deck. In both applications an overlay needs to be extremely durable and provide sufficient bearing capacity for the expected loads, all while remaining compatible with the existing bridge deck or substrate. Ultra-high performance concrete (UHPC), which is a relatively new breed of concrete, has the potential to satisfy these requirements.

As part of an ongoing research study, supported by the University Transportation Center for Materials in Sustainable Transportation Infrastructure (MiSTI) at Michigan Tech and Lafarge North America, a project team is investigating the use of UHPC in a thin-bonded overlay system for bridge deck applications. The ongoing study is exploring aspects related to the design and implementation of UHPC from both rehabilitation and new construction perspectives.

Building on a Summer Scholars project, supported by UTC-MiSTI on characterization of the interfacial bond between UHPC and conventional concrete, the focus of these research activities center on challenges of implementation of UHPC as an overlay in both the rehabilitation of existing bridge decks and as a thin topping for precast deck panels. Ongoing investigations include further evaluation of the bond with consideration of surface preparation, stress-states, and long-term resistance to freeze-thaw cycling. In addition, emphasis is being placed on refining a UHPC formulation with optimal casting characteristics, minimizing the thickness of the overlay while maintaining sufficient durability characteristics and aspects of constructability including cross-slope and riding surface preparation. The potential benefit of this type of solution is a more sustainable solution for both repairs and new construction without significant deviation from current established practices.
Director’s Corner

In this issue of the UTC-MiSTI Transportation News, we focus on the products of the Center’s research activities. Through externally sponsored research contracts with the Michigan Department of Transportation, Center researchers have developed a tool to assess the carbon footprint of highway construction, evaluated testing methods to measure mixture properties important to pavements freeze-thaw durability, and produced a manual of practice for using recycled concrete in Michigan road contraction. Internal research investigations sponsored by the Center further the understanding of materials and their role in the sustainability of our nation’s transportation infrastructure. This knowledge is being transferred to the transportation community through publications and presentations discussing the use of recycled asphalt pavement and ultra-high performance concrete to enhance bridge deck performance. Center staff are also conducting research pertaining to the use of supplementary cementitious materials to mitigate alkali silica reactivity (ASR) distress, and developing improvements to the AASHTO T318 test for determining the water content of fresh concrete. More information on all of these studies can be found at the references websites listed throughout this newsletter and on the Center’s website at [www.misti.mtu.edu](http://www.misti.mtu.edu).

Research Supports Solutions to Reduce Carbon Footprint

Project Develops Tool to Assess Carbon Footprint of Highway Construction

Motivated by the need to address the challenges of global climate change, recent MiSTI research has developed and implemented a project-based life cycle framework that can be used to estimate the carbon footprint for typical highway construction work items found in reconstruction, rehabilitation and Capital Preventive Maintenance (CPM) projects. The framework builds on existing life cycle assessment methods and develops project inventories for new construction using data collected from 14 highway construction, rehabilitation, and maintenance projects in the State of Michigan. The carbon footprint for each of the projects was calculated in terms of CO₂ equivalents of greenhouse gas (GHG) emissions. The primary life cycle emissions include products and processes involved in the raw material acquisition and manufacturing phase, and the pavement construction phase. The secondary emissions include vehicular use and maintenance operations during the service life of the pavements.

The framework also implements a method to calculate project level construction emission data. By using a project-based framework, the research helps resolve problems in defining system boundaries and functional units for pavement life cycle assessment methods. In addition, based on the emissions calculated from observed projects, the research also developed a web based tool, the Project Emission Estimator (PE-2). This can be used to benchmark GHG life cycle emissions for highway reconstruction, rehabilitation, and preventive maintenance projects. The research suggests ways of implementing the proposed framework within MDOT to help reduce the CO₂ footprint of highway construction projects.
Steel Fiber Addition to Ultra-High Performance Concrete (UHPC) Mix.

Research Team:
Dr. Devin Harris, Assistant Professor, Michigan Technological University, Principle Investigator
Sarah Shann, M.S., student
Miguel Angel Carbonell Munoz, M.S., student
David Froster, B.S., student
Jayeeta Sarkar, M.S., (graduated May 2010)

Project Sponsors:
Michigan Technological University
UTC-MiSTI

Publications:
1. Transportation Research Board (presented as a poster)

2. Transportation Research Record (accepted for publication)

Abstracts Accepted:


Abstracts Submitted:
1. ACI Research In Progress: “Performance of Ultra-High Performance Concrete for Application as a Thin-Bonded Bridge Deck Overlay.”

2. Bond in Concrete 2012: “Bond Strength of Ultra-High Performance with Normal Strength Concrete: Estimation of Failure Envelope.”
Freeze-Thaw Durability of Concrete Pavement
Research Evaluates Changes Impacting Concrete Pavements for Cold Climates

Freeze-thaw cycling can negatively impact the durability of a concrete pavement. State highway agencies are challenged with designing pavements to withstand the cyclic freezing and thawing common in northern states. One critical characteristic of mixture design, and the focus of this study, is the entrained air-void system. Entrained air provides areas, or voids, to allow water to freeze without damaging the concrete. Current standards for concrete air-void systems were established in the mid 1900’s and over the years a number of changes have occurred that impact the hydrated cement paste and therefore the required air-void system. These include the introduction and adoption of synthetic air entraining admixtures (AEA), adoption of lower water-to-cement ratios, and an increase in the use of supplementary cementitious materials (SCM). Entrained air is a vital component of hardened concrete and methods of ensuring a uniform distribution of air bubbles rely on AEAs. Concerns over global warming and the necessity to reduce the carbon footprint of concrete pavements have in part lead to an increased use of SCMs. Common SCMs include fly ash and ground blast furnace slag. The use of SCMs provides a beneficial reuse of materials that might otherwise be land filled causing additional environmental burden.

As part of this study, researchers also evaluated new methods for characterizing concrete mixtures. Emerging testing methods used to measure mixture properties, and evaluated in this study, include the Air Void Analyzer (AVA) and the Cementometer™. Additionally, AASHTO T318 Standard Method of Test for Water Content of Freshly Mixed Concrete Using Microwave Oven Drying, and petrographic-based analysis were evaluated.

Results:
A total of 148 concrete mixtures were produced and analyzed using 16 tests to characterize and assess the performance of each mixture. The results indicated that current specifications for air content offer conservative estimates of performance and the use of SCMs does not require deviation from traditional air-void thresholds. Mixtures using reduced amounts of cementitious material, relative to standard mixtures, can result in more durable concrete.

The technology testing phase of this study showed the AVA did not produce accurate results for measuring the air content of a concrete mixture and the Cementometer™ used in testing the water to cement ratio, also did not yield testing resiliency. Attention to calibration is critical if the Cementometer™ method is adopted. The research affirmed the classic limitation of an air-void system spacing factor equal or less than 0.2 mm is sound. However, the study also produced evidence that some mixtures with a spacing factor greater than 0.2 mm can provide acceptable freeze-thaw durability.

Report: http://michigan.gov/mdot/0,4616,7-151-9622_11045_24249-262753--,00.html

Research Sponsor:
Michigan Department of Transportation

Research Team:
Dr. Karl Peterson, Research Assistant Professor, Michigan Technological University, Principle Investigator
Dr. Lawrence Sutter, Professor, Michigan Technological University, Co-principle Investigator
Michael Yokie, Research Associate, Michigan Technological University
Jacob Vermillion, M.S., (graduated May 2010)
The January 2012 issue of the journal Construction and Building Materials features two articles representing research on Reclaimed Asphalt Pavement (RAP). This research project was sponsored by USDOT through Michigan Technological University Materials in Sustainable Transportation Infrastructure (MiSTI) – University Transportation Center.

Authors:
Baron Colbert, Ph.D., student
Dr. Zhanping You, Associate Professor, Michigan Technological University

“The Determination of Mechanical Performance of Laboratory Produced Hot Mix Asphalt Mixtures using Controlled RAP and Virgin Aggregate Size Fractions”
Transportation officials face pressures to repair and rebuild roads in a cost effective manner. RAP is considered to be a solution to keeping construction costs lower and is being used pavement more frequently. This study investigates HMA performance with varying degrees of RAP in order to determine the influence of fractioned RAP materials on asphalt mixture performance.


“The Properties of Asphalt Binder Blended with Variable Quantities of Recycled Asphalt using Short Term and Long Term Aging Simulations”
One possible solution for the transportation industry to build economical and sustainable roadways is increasing the use of recycled asphalt pavements (RAP). This paper investigates the performance of recycled asphalt that has been blended with an asphalt binder. The research characterizes and evaluates three asphalt binder aging states.

Article: http://www.sciencedirect.com/science/article/pii/S0950061811003205

Manual of Practice Available On-Line
Using Recycled Concrete in MDOT’s Transportation Infrastructure

A study on the uses of recycled concrete in transportation infrastructure, funded by the Michigan Department of Transportation, was recently completed by researchers at Michigan Tech. This research produced a Manual of Practice - Using Recycled Concrete in MDOT’s Transportation Infrastructure which is now available on-line.

Cold climate regions present special circumstances for the construction of railroads in areas of deep seasonal frost and permafrost. The objective of this study was to advance the understanding of requirements for the design, construction, maintenance and operations of rail infrastructure in these arctic environments. The research project included an extensive literature review focusing on related rail transportation research addressing existing and planned railways located in cold-climate areas. Scan tours to visit industry experts and researchers around the world, as well as an investigation of current design practices in the performance of concrete ties in arctic conditions were conducted.

The first MS graduate of the Rail Transportation Program at Michigan Tech, Shane Ferrell, performed research gathering and analyzing data related to geotechnical challenges and applicable engineered solutions for embankment stabilization on deep seasonal frost and permafrost. This research culminated in a paper presented at the 9th International Heavy Haul Conference in Shanghai, China, followed by two other papers presented to the American Railway Engineering and Maintenance of Way Association (AREMA) and at the International Heavy Haul Association (IHHAA) conference in Calgary, Canada. Following his graduation from MTU, Shane relocated to Alaska where he has been working on the Northern Rail Extension and the Port Mackenzie Extension.

Russell Lutch, also a Rail Transportation Program graduate student, collaborated with CXT to investigate railroad track structure for his graduate work focusing on prestressed concrete railroad ties. His thesis was titled “Ultimate Capacity Optimization of Prestressed Concrete Railroad Ties” and his contributions resulted in papers presented at the AREMA Annual Conference and Exposition, as well as the Conference on Cold Regions Engineering. The research also resulted in a peer-reviewed publication in the ASCE Journal of Transportation Engineering.

In addition to the project support, Russell Lutch was sponsored by UTC-MiSTI and was selected as the UTC-MiSTI Student of the Year in 2009.

Research Team:
Dr. Pasi Lautala, Research Assistant Professor, Michigan Technological University, Principle Investigator
Dr. Dr. Devin Harris, Assistant Professor, Michigan Technological University, Principle Investigator
Shane M. Ferrell, M.S., 2009
Russell H. Lutch, M.S. 2009
Lars Leemkuil, B.S., 2011
Christopher Brokaw, B.S., 2010, Current Masters Student
Steven Chartier, B.S., Spring 2012

See Permafrost on pg. 7
Publications:


About University Transportation Centers

The University Transportation Centers (UTC) program, initiated in 1987 under the Surface Transportation and Uniform Relocation Assistance Act, authorized the establishment and operation of transportation centers in each of the 10 standard federal regions. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) reauthorized the UTCs for an additional six years and added four national centers and six University Research institutes (URI). The mission of the 14 UTCs was to advance U.S. expertise and technology transfer. The six URIs each had a specific transportation research and development mandate.

In 1998 the Transportation Equity Act for the 21st Century (TEA-21) reauthorized the UTC Program for an additional six years and increased the total number of Centers to 33. In addition to the ten regional Centers, which were to be selected competitively, TEA-21 created 23 other Centers at institutions named in the Act. TEA-21 established education as one of the primary objectives of a University Transportation Center and institutionalized the use of strategic planning in university grant management.

The Safe, Accountable, Flexible, Efficient Transportation Equity Act, enacted on August 10, 2005, authorized up to $76.7 million per year from Federal FY2005-2009 funds for grants to establish and operate up to 60 University Transportation Centers throughout the United States. Twenty of these centers were competitively selected during 2006, and forty centers are located at institutions named in the legislation. The UTC program is managed by the Research and Innovative Technology Administration, U.S. Department of Transportation.

About Michigan Technological University

Michigan Technological University is a leading public research university, conducting research, developing new technologies, and preparing students to create the future for a prosperous and sustainable world. Michigan Tech offers more than 120 undergraduate and graduate degree programs in engineering, forestry and environmental sciences, computer sciences, technology, business and economics, natural and physical sciences, arts, humanities and social sciences.

About the University Transportation Center for Materials in Sustainable Transportation Infrastructure

The University Transportation Center for Materials in Sustainable Transportation Infrastructure (UTC-MiSTI) at Michigan Technological University is a Tier II UTC. The Center conducts research, educational activities, technology transfer and workforce development in the areas of sustainability and infrastructure materials that address state and national transportation needs. Faculty, staff, students and industry work collaboratively to identify creative solutions to construct repair and maintain highway and airport pavements, bridges and rail systems.

Areas of material specialization include bituminous materials and asphalt binders; portland cement and ultra-high performance concretes; material characterization through petrographic analysis; aggregates, soils and geotechnical applications; and the use of recovered industrial materials including fly ash, slag, and cement kiln dust, and recycled asphalt and concrete materials. For more information on the activities of the UTC-MiSTI, visit the Center’s Website: www.misti.mtu.edu