Research on Concrete Applications for Sustainable Transportation

RE-CAST

MISSOURI S&T

Vol. 4 :: Issue 3 :: SUMMER 2017

Special issue:

Featured **Field Implementation** Projects + GRADS

CONSORTIUM MEMBERS:

Missouri University of Science and Technology

University of Illinois at Urbana-Champaign

Rutgers, The State University of New Jersey

University of Miami

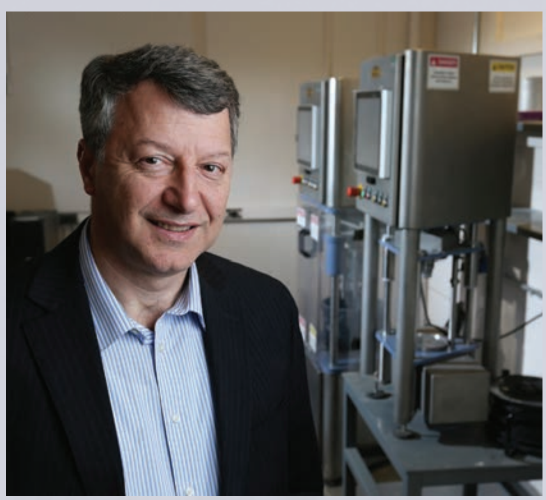
Southern University and A&M College

Director's Message

Welcome back to the 2017-2018 Academic Year! The first day of classes aligned with the solar eclipse on August 21st. At Missouri S&T, the near-total eclipse peaked at 1:15pm, when the moon obscures 99.8 percent of the sun. It was surely a sight to see.

Now that classes are back in session, and the students are filling the sidewalks of campus, we would like to share some of the activities that RE-CAST investigators have been busy with over the summer session.

In particular, this issue features several field implementation projects that have taken place recently across the country. Three projects featured in this issue took place in Missouri, Illinois and New Jersey. It is in alignment of our goal to demonstrate our new technologies into practice via field implementation and validation. These field implementation projects entail comprehensive and intensive planning with contractors, designers, materials supplies and State DOT officials. We are proud to present these success stories to you in the following pages.



We encourage your feedback about our research. Please visit our website for our researchers' contact information.

Kamal H. Khayat
RE-CAST Director

FEATURED PROJECT

Field Implementation of Fiber Reinforced High Performance Concrete: *A Case Study of Implementation of Fiber Reinforced High Performance Concrete for Bridge Redecking in New Jersey*

- Hani Nassif, PE, PhD, Professor of Civil Engineering, Rutgers University
- Chaekuk Na, PhD, Research Associate, Rutgers University
- Adi Abu-Obeidah, PhD, Research Associate, Rutgers University

(a) Casting trial slab

(b) Casting specimens

Figure 1. Demonstration slab casting and sampling

The RIME (Rutgers Infrastructure Monitoring and Evaluation) team has been collaborating with the Missouri University of Science and Technology and New York University to investigate the use of fibers in self-consolidating concrete (SCC) mixtures and its life cycle cost as part of RE-CAST Project 3A. Based on the results from this project, researchers at RIME group worked on the implementation of Fiber Reinforced High Performance concrete (FR-HPC) in bridge decks. Bridge redecking in urban areas requires the staged construction process to minimize traffic congestion that can reduce cracking potential due to heavy trucks. Heavy trucks traveling in adjacent lane to the fresh concrete pours could result in premature cracking at early age (i.e., 6-12 hours). In order to minimize such cracks, the RIME Team proposed to the New Jersey Turnpike Authority (NJTA) the addition of macro

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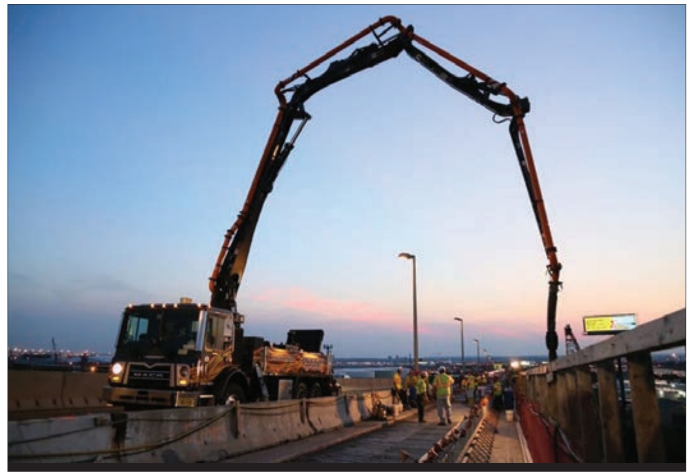
FR-HPC for Bridge Redecking *(con't)*

(a) Casting reconstructed bridge decks



(b) Pumping FR-HPC mix

Figure 2. Field Implementation

synthetic fibers to the existing HPC mix. The addition of these fibers with the appropriate dosage can improve tensile strength and reduce drying shrinkage without compromising the compressive strength, durability, and workability.

The RIME Team, in collaboration with the NJTA, developed a detailed implementation program for the FR-HPC mixture design. The most successful mixture design satisfying the fresh concrete properties, durability and strength requirements under laboratory conditions was selected for field implementation.

Prior to the implementation, a demonstration slab (9' x 20') was casted by the contractor to evaluate the workability and placeability of the FR-HPC mixture, as well as strength and durability properties. Vibrating wire strain gages (VWSGs) were also installed at several locations to monitor the shrinkage and temperature distributions.

Figure 1 shows the field activities for the demonstration slab. The demonstration slab process included casting specimens to verify the concrete strength and durability requirements, as presented in **Figure 1(b)**.

After the required criteria during the demonstration slab were met, the FR-HPC mixture was employed for the bridge redecking alongside the regular NJTA HPC mixture, as shown in **Figure 2.**

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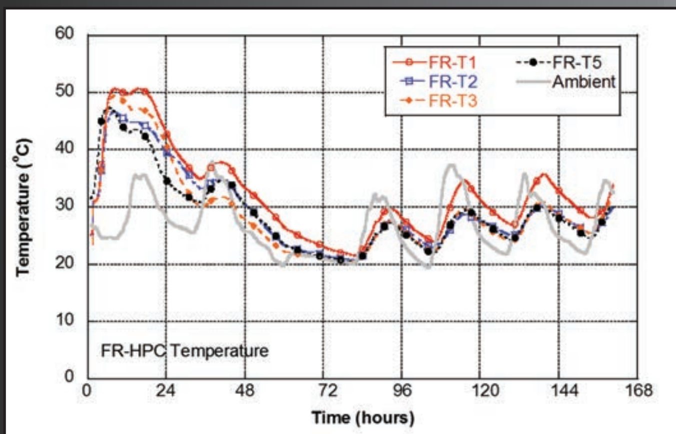
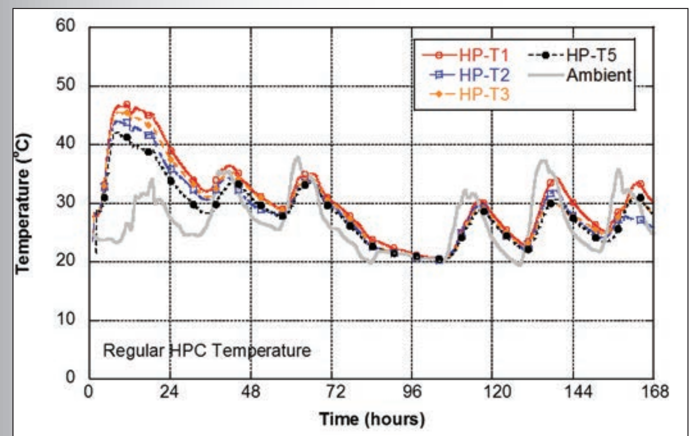
FR-HPC for Bridge Redecking *(con't)*



(a) FR-HPC



(b) HPC

Figure 3. Heat of Hydration of FR-HPC and HPC

The concrete was cast in several decks directly from the truck using a hydraulic pump. To closely monitor the concrete behavior, the Rutgers Team instrumented VWSGs in the negative and positive moment regions of the FR-HPC as well as HPC decks to monitor the heat of hydration as well as the strain induced by the concrete during and after the curing period.

The FR-HPC mixture had a similar workability as a regular NJTA HPC mixture and achieved the strength and durability requirement as per the Technical Specifications.

Figure 3 shows the heat of hydration of FR-HPC and regular HPC during the wet-curing period for the first 7 days (168 hours). The team will continue monitoring the field performance of FR-HPC bridge deck compared to HPC deck.

Final results will be documented in a special report describing this implementation project and will be posted on the RE-CAST website after its completion.

FEATURED PROJECT

Slab Displacements at O'Hare International Airport

- David Lange, Ph.D., Professor of Civil Engineering, UIUC
- Jeffrey Roesler, Ph.D., Professor of Civil Engineering, UIUC

Figure 1. Students installing sensors in pavement at O'Hare International Airport

University of Illinois researchers are studying thermal displacement of concrete slabs at O'Hare International Airport in Chicago. Cyclic temperature swings cause the slabs to expand and displace during hot periods, and allow incompressible materials to enter open joints during cold periods (**Figure 1**).

The extreme behavior squeezes joint material out during hot weather and opens joints during cold weather (**Figure 2**).

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Slab Displacements at O’Hare International Airport *(con’t)*

Figure 2. In cold weather, joints open to allow intrusion of incompressible materials

Figure 3. String-pot sensor has integrated data-logger to monitor long-term displacements

Self-contained displacement sensors were installed in cored holes that span adjacent slabs, so the joint displacements can be monitored with time (**Figure 3**). In addition, over 100 manual points are being monitored periodically on the apron between Concourse B and Concourse C where United Airlines operates most of its more than 1000 daily arrival and departures. The manual measurements are conducted in a manner similar to Whitmore gages (**Figure 4**).

Figure 4. Students manually record displacements across joints

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Slab displacements at O'Hare International Airport *(con't)*

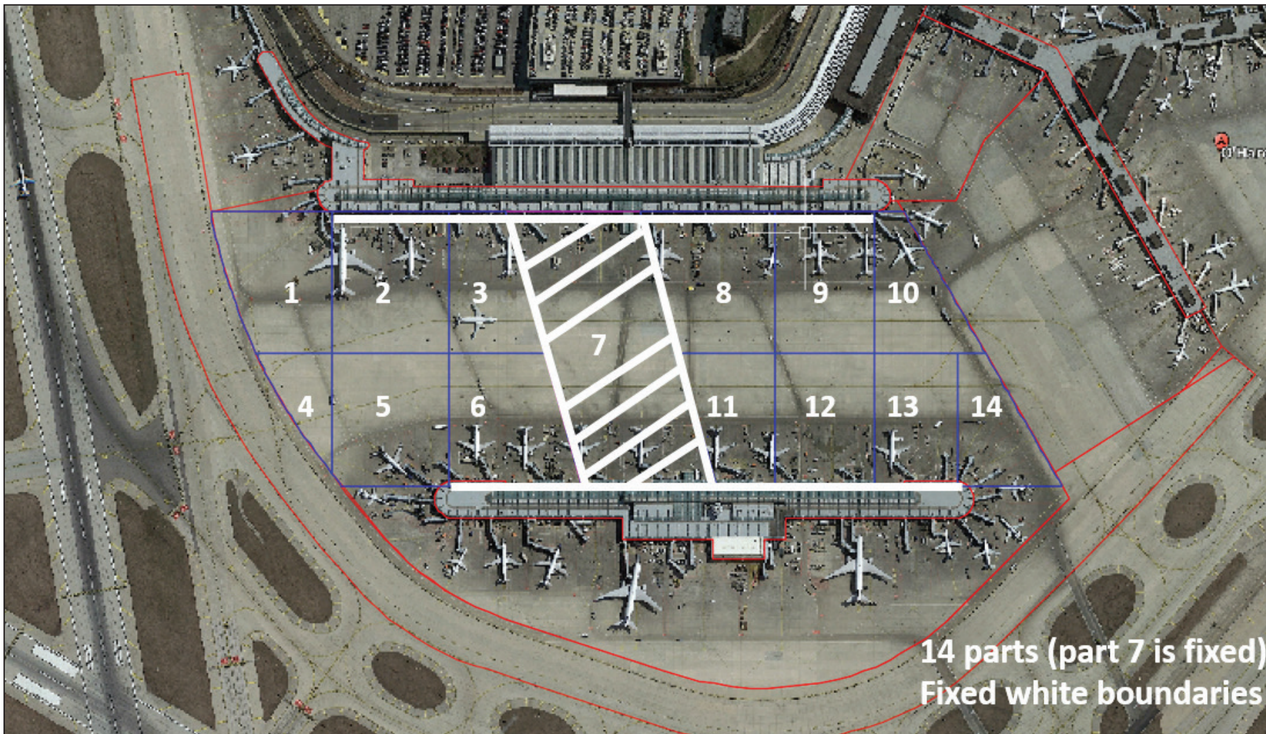

Figure 5. An FEM model will capture the effects of rigid structures and boundaries on pavement stress distribution

A finite element model is being developed to describe stress distribution under various temperature scenarios, and capture the effect of rigid structures such as foundations and utility vaults (**Figure 5**).

All of the work by UIUC is performed at night between 11pm and 4am. The airport activity slows down at night, but O'Hare is one of the busiest airports in the world, and it never really sleeps. The team includes Profs. David Lange and Jeffrey Roesler, students Omar Jadallah, Yu Song, Ruofei Zou, Juan Fernandez, Prakhar Gupta.

Zak Bergman and Ross Anderson are the primary engineering contacts representing O'Hare and the Chicago Department of Aviation. UIUC has been working with O'Hare for more than 10 years, and Re-CAST has facilitated several research projects at O'Hare. This study began in Spring 2017 and will continue through the 2017-18 winter season. The findings will be used by an outside engineering firm to formulate a solution.

FEATURED PROJECT

Field Implementation of Steel Fiber Concrete for Construction of a Bridge Deck at Taos, Missouri

- Kamal H. Khayat, P.Eng., Ph.D., Professor of Civil Engineering, Missouri S&T
- Ahmed Abdelrazik, Ph.D. candidate in Civil Engineering, Missouri S&T
- William Stone, P.E., MoDOT
- Anousone Arounpradith, P.E., MoDOT

In collaboration with the Missouri Department of Transportation (MoDOT) led by Mr. William Stone, PE, and Mr. Anousone Arounpradith, PE, the RE-CAST team at Missouri S&T undertook an implementation project to put into practice research findings for the use of fiber-reinforced concrete with adapted rheology (FRC-AR) for a bridge replacement at Route M/J over Route 50 near Taos, Missouri. The two-span concrete NU-girder bridge measures approximately 245 ft in length. This implementation project included the validation of key properties of the cast-in-place concrete and the instrumentation of 8.5 in. thick bridge deck to monitor temperature and strain variations during and after construction.

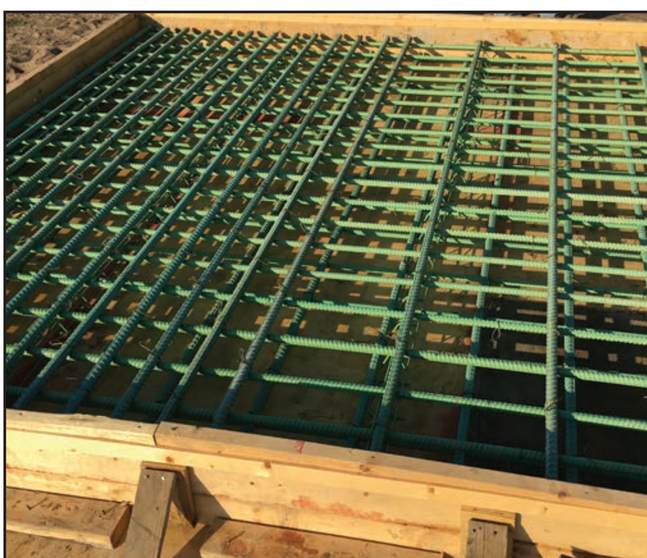

Figure 1. Mock-up slab placement with different top rebar spacing of 5x6 in. and 15x6 in. that correspond to different longitudinal rebar spacing locations along the bridge deck

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Steel Fiber Concrete for Construction of a Bridge Deck at Taos, Missouri *(con't)*

The optimized FRC-AR incorporated 0.5%, by volume, of micro-macro steel fibers and 5% CaO-based expansive agent (G-Type), by mass of binder, to mitigate the risk of cracking and extend the service life of the bridge. The air-entrained concrete incorporated a polycarboxylate-based high-range water-reducing admixture (HRWRA) and a polysaccharide-based viscosity-modifying admixture (VMA) to ensure high workability and adequate stability of the fresh mixture.

The Missouri S&T Team, in collaboration with the concrete supplier, conducted various trial batches to reproduce laboratory findings. The most successful mixture satisfying the fresh concrete properties and strength requirements under laboratory conditions (Phase I of this collaborative RE-CAST project) was selected for field implementation.

A mock-up slab measuring 10 ft x 10 ft x 8.5 in. with rebar spacing representing different areas of the bridge deck was cast by the contractor to evaluate the workability and finishability of the mixture. The mock-up slab enabled the extraction of core samples to assess fiber distribution and compare in-situ properties to those of cast samples. The mock-up slab included a 2% cross-slope to simulate the inclination at the crown of the bridge that has to be taken into consideration in finalizing the required workability of the FRC-AR. **Figure 1** shows the mock-up slab. Findings from the mock-up pour were incorporated for the production, placement, and finishing of the new bridge deck.

Prior to a concrete slab casting, the RE-CAST team installed six sensor towers (**Figure 2** - next page) at various locations of the bridge to monitor temperature, humidity, and concrete strain at six locations of the bridge. Each tower had three humidity sensors, three thermocouples, and 12 concrete strain gages. Nearly 110 wires were connected to a data acquisition system that was installed at the bridge site.

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Bridge Deck at Taos, Missouri *(con't)*

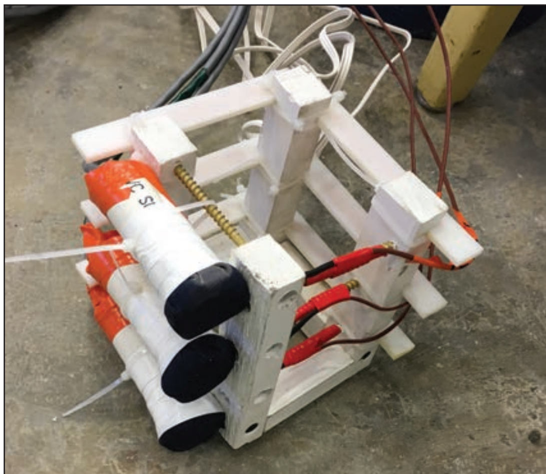

Figure 2. Sensor tower contains three humidity sensors, three thermocouples, and twelve concrete strain gages (six on tower and six adjacent to the steel rebars)

Concrete placement was carried out between approximately midnight and 7 am on July 26, 2017 and necessitated the casting of 330 yd^3 of FRC-AR. The FRC-AR was successfully placed using two pumps. In total, 40 concrete trucks were used for the mixing and delivery of the concrete. Given the high ambient temperature, ice was used as partial replacement of mixing water. The RE-CAST team sampled seven trucks to evaluate the workability, mechanical properties, and drying shrinkage of the FRC-AR. As shown in **Figure 3a**, all concrete was sampled at the end of the pumpline. **Figure 3b** shows the Missouri S&T research team at the construction site.

(a)

(b)

Figure 3. (a) Sampling of the FRC-AR during the casting of the bridge deck and (b) S&T research team

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Bridge Deck at Taos, Missouri *(con't)*

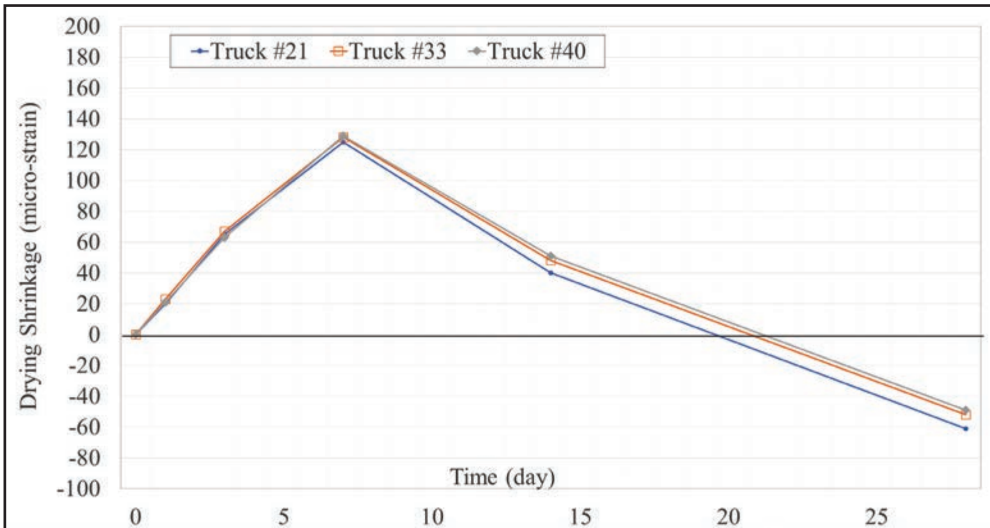

Figure 4. Shrinkage results of samples taken from different trucks during 28 days, including 7 days of moist curing

Figure 4 shows typical drying shrinkage results of samples taken from three different trucks. **Figure 5** summarizes temperature variations at sensors located at various depths of the concrete deck (1, 2, and 3, respectively) at a given location. Observations after one month of construction indicate excellent performance of the FRC-AR. The deck will undergo long-term monitoring and inspection. Finite element modeling is under progress to better understand the contribution of shrinkage or expansion strain in the bridge deck on overall performance. The project will involve data collection to conduct detailed life cycle cost analysis and the development of guidelines for bridge deck construction using FRC-AR.

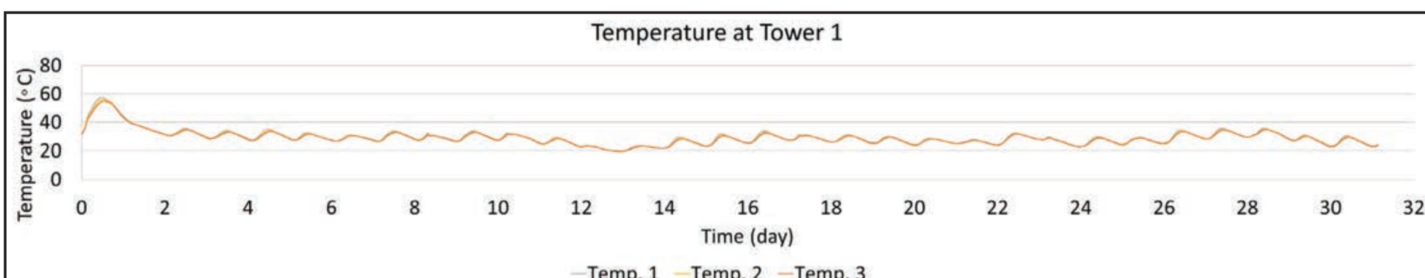

Figure 5. Temperature variations at upper, middle, and lower depths of concrete deck (1, 2, and 3, respectively) for Tower 1

Transportation Infrastructure Conference 2017

cies.mst.edu/conference

Friday, Dec. 8

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Rolla, MO

Save the Date

Submit an abstract

Missouri S&T

MoDOT

EDUCATION/WORKFORCE DEVELOPMENT

RE-CAST GRADUATES

Adi Abu-Obeidah, **Ph.D.**, Rutgers University

Thesis Title: *Flexural Behavior of Concrete Beams Prestressed With Bonded and Unbonded Tendons*

Graduation: May 2017

Advisor: Dr. Hani H. Nassif

Zena R. Al-Jazaeri, **Ph.D.**, Missouri S&T

Thesis Title: *Rehabilitation and Strengthening of Reinforced Concrete Members Using A Fiber Reinforced Cementitious Matrix Composite*

Graduation: December 2016

Advisor: Dr. John J. Myers

Jamie V. Clark, **M.S.**, Univ. of IL at Urbana-Champaign

Thesis Title: *Characterization Of the Cellular Structure of Foamed Cement*

Graduation: August 2017

Advisor: Dr. David A. Lange

Zeeshan Ghanchi, **M.S.**, Rutgers University

Thesis Title: *Restrained Shrinkage Behavior of Polypropylene Fiber Reinforced Self-Consolidating Concrete*

Graduation: May 2017

Advisor: Dr. Hani H. Nassif

EDUCATION/WORKFORCE DEVELOPMENT

RE-CAST GRADUATES (con't)

Omid Gooranorimi, Ph.D., University of Miami

Thesis Title: *Investigation of Bond, Microstructure and Post-fire Behavior of GFRP Reinforcement for Concrete*

Graduation: August 2016

Advisor: Dr. Antonio Nanni

Aida Margarita Ley Hernandez, M.S., Missouri S&T

Thesis Title: *Influence of Mix Design Parameters on Dynamic Segregation of Self-Consolidating Concrete and Consequences on Performance of Precast Beams*

Graduation: July 2016

Advisor: Dr. Dimitri Feys

Giuseppe Liberti, M.S., Rutgers University

Thesis Title: *Restrained Shrinkage Behavior of Crimped Steel Fiber Reinforced Self-Consolidating Concrete*

Graduation: May 2017

Advisor: Dr. Hani H. Nassif

Iman Mehdipour Ph.D., Missouri S&T

Thesis Title: *Characterization And Performance of Eco and Crack-Free High-Performance Concrete for Sustainable Infrastructure*

Graduation: June 2017

Advisor: Dr. Kamal H. Khayat

EDUCATION/WORKFORCE DEVELOPMENT

RE-CAST GRADUATES (con't)

Weina Meng, **Ph.D.**, Missouri S&T

Thesis Title: *Design And Performance of Cost-Effective Ultra-High Performance Concrete for Prefabricated Elements*

Graduation: June 2017

Advisor: Dr. Kamal H. Khayat

Austin Messerli , **M.S.**, The University of Oklahoma

Thesis Title: *The Performance of Cement-Limiting and High-Volume Recycled Material Mix Designs for Use in Concrete Pavements through Laboratory and Field Implementation*

Graduation: May 2017

Advisor: Dr. Jeffery S. Volz

Radhakrishnan Moni, **M.S.**, New York University

Mr. Moni worked on the development of the web-based Life Cycle Cost Assessment (LCCA) software tool and established a flexible interface that can access state-wide infrastructure data. His main effort was to combine the proposed LCCA methodology with a unified database, online map service, interactive charts & summary reports.

Graduation: May 2017

Advisor: Dr. Kaan Ozbay

Samer Rabie, **M.S.**, Rutgers University

Thesis Title: *Effect Of Curing Conditions on Surface Resistivity in High Performance Concrete*

Graduation: May 2015

Advisor: Dr. Hani H. Nassif

EDUCATION/WORKFORCE DEVELOPMENT

RE-CAST GRADUATES (con't)

Saipavan Rallabhandhi, **M.S.**, Missouri S&T

Thesis Title: *Evaluation of Ultra-High Performance Concrete (UHPC) in Bridge Girders*

Graduation: May 2016

Advisor: Dr. John J. Myers

Seyedhamed Sadati, **Ph.D.**, Missouri S&T

Thesis Title: *High-Volume Recycled Materials for Sustainable Transportation Infrastructure*

Graduation: June 2017

Advisor: Dr. Kamal H. Khayat

Mahdi Valipour Ph.D., Missouri S&T

Thesis Title: *Design and Performance of Cost-Effective Ultra High Performance Concrete for Bridge Deck Overlays*

Graduation: August 2017

Advisor: Dr. Kamal H. Khayat

Kavya Vallurpalli, **M.S.**, Univ. of IL at Urbana-Champaign

Thesis Title: *Formwork Pressure and Rheology of Self-Consolidating Concrete*

Graduation: May 2017

Advisor: Dr. David A. Lange

EDUCATION/WORKFORCE DEVELOPMENT

RE-CAST GRADUATES (con't)

Valter Gora Venancio, **M.S.**, Missouri S&T

Thesis Title: *Behavior of Ultra-high Performance Concrete Bridge Deck Panels Compared to Conventional Stay-In-Place Deck Panels*

Graduation: May 2016

Advisor: Dr. John J. Myers

Kodi Wallace, **M.S.**, The University of Oklahoma

Thesis Title: *Performance of Fiber-Reinforced Eco-Friendly Concrete for Bridge Structures*

Graduation: August 2017

Advisor: Dr. Jeffery S. Volz

Wei Wang, **Ph.D.**, Missouri S&T

Thesis Title: *Durability Behavior of Steel Reinforced Polymer and Fiber Reinforced Polymer for Infrastructure*

Graduation: August 2017

Advisor: Dr. John J. Myers

Corey Wirkman, **M.S.**, The University of Oklahoma

Thesis Title: *Performance of Fiber-Reinforced Self-Consolidating Concrete for Repair of Bridge Sub-Structures*

Graduation: May 2017

Advisor: Dr. Jeffery S. Volz

TECHNOLOGY TRANSFER

Example of Recently Published RE-CAST Final Report

FINAL PROJECT REPORT #00047713

GRANT: DTRT13-G-UTC45
Project Period: 8/1/2014 – 6/30/17

Ultra-high Performance Fiber-Reinforced Concrete (UHPFRC) for Infrastructure Rehabilitation

Volume II:

Behavior of Ultra-High Strength Concrete Bridge Deck Panels Compared to Conventional Stay-In-Place Deck Panels

Participating Consortium Member:
Missouri S&T

Authors:
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Dept. of Civil, Arch. & Environ. Engineering
Missouri S&T

RE-CAST:
REsearch on Concrete Applications for Sustainable Transportation
Tier 1 University Transportation Center

Missouri S&T
Miami
Rutgers

Read final report at:

https://recast.mst.edu/media/research/recast/documents/finalreports/RE-CAST_3B-Vol2.pdf

WEBINAR SERIES

Visit our Webinar Library at: recast.mst.edu/webinars

Examples Include:

February 23, 2017

RE-CAST Presenter: Dr. Jeffery Volz, Associate Professor

University of Oklahoma

"Concrete Pavement Containing High Volumes of Recycled Materials"

November 17, 2016

Presenter: Dr. Raissa Ferron, Assistant Professor

University of Austin at Texas

"Engineering smart, stimuli-responsive cementitious composites"

November 9, 2016

RE-CAST Presenter: Antonio Nanni

Professor of Civil Engineering, Univ. of Miami

CESTiCC, RE-CAST and the Alaska Chapter of ACI present:

"The Role of Cementitious Materials in the Next Decade"

- Joint webinar offered with CESTiCC and Alaska Chapter of ACI

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'RE-CAST University Transportation Center' listed under Groups