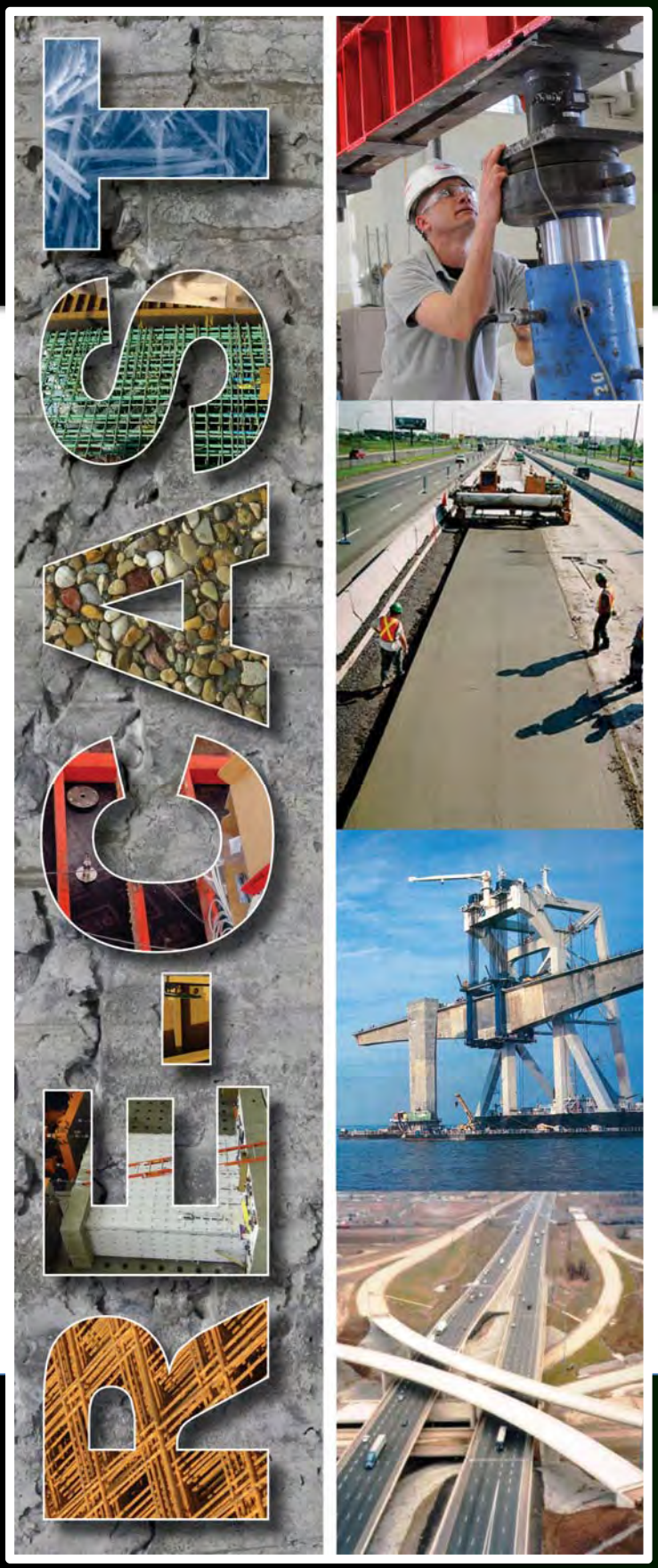

PROGRAM PROGRESS PERFORMANCE REPORT #4

GRANT: DTRT13-G-UTC45
Reporting Period: 4/01/2015 – 09/30/2015

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

Consortium Members:

Missouri University of Science and Technology
Rolla, MO

University of Illinois at Urbana-Champaign
Urbana, IL

Rutgers, The State University of New Jersey
Piscataway, NJ

University of Miami
Coral Gables, FL

Southern University and A&M College
Baton Rouge, LA

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1. ACCOMPLISHMENTS

1.A - What Are The Major Goals And Objectives Of The Program?

The overall goal of this grant is to develop the next generation of cement-based construction materials that are essential to address the growing technical and environmental requirements of the transportation infrastructure. The research program aims to fast-track the acceptance of these technologies and develop national standards and guidelines for their use in the reconstruction of the nation's infrastructure for the 21st Century.

Research Goals

The RE-CAST program goal stated above will be accomplished by performing the following research projects:

- 1-A. Ecological and Crack-Free High-Performance Concrete with Adapted Rheology
- 1-B. Formwork Pressure Measurements and Prediction of High-Performance Concrete with Adapted Rheology
- 1-C. Influence of Casting Conditions on Durability and Structural Performance of High-Performance Concrete with Adapted Rheology
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Education and Workforce Development (EWD) Goals

The main goal of RE-CAST's Education and Workforce Development program is to develop a workforce trained in the interdisciplinary scholarship needed to understand and address the complex issues facing the implementation of a durable, reliable, and sustainable infrastructure. This is to be achieved by creating multidisciplinary educational opportunities for undergraduate and graduate students in the theme areas of the Center, as well as outreach activities for practitioners.

Education Objectives:

1) RE-CAST faculty members will collaborate to create the following courses related to the major thrust areas of the Center:
   - Fundamentals of Rheology and Self-Consolidating Concrete (S&T and UIUC)
   - Structural Health Monitoring Applied to Transportation (Rutgers University and SUBR)
   - Repair Materials and Strategies for Civil Infrastructure (Multiple Universities)
2) RE-CAST is to collaborate with national laboratories and DOT research entities, such as NIST and MoDOT-R&D, to host students on scholarly efforts.
3) The Center will actively contribute to annual conferences in the transportation field organized by the consortium Universities, including the Transportation and Highway Engineering Conference and the Structural Engineering Conference at UIUC as well as the Transportation Infrastructure Conference at S&T.

Workforce Development / Outreach Objectives:

A. Outreach Activities to Attract New Entrants into the Transportation Field
   1) RE-CAST members will seek opportunities to invite junior faculty from complementary fields, such as engineering management, mechanical engineering, chemical engineering and chemistry to team up with RE-CAST faculty on various research projects.
   2) *Graduate Research Assistantship in Transportation Areas (GRATA)* - RE-CAST will provide graduate research assistantships to highly qualified Ph.D. students.
   3) *Invited Speakers and Field Trip Visits* – RE-CAST will collaborate with the CIES at S&T and student societies at the participating Universities, including ASCE and ACI to organize bi-monthly seminars featuring invited speakers from industry
   4) *ACI / Portland Cement Association (PCA) / Prestressed Concrete Institute (PCI) Co-Funded Scholarships* – RE-CAST will explore the possibility of providing matching funds to the scholarship programs that these organizations currently offer on a nation-wide basis for Fellowship students
   5) *Student Competition* – RE-CAST will work with professional student societies to organize a new competition on sustainable construction materials.
      1. Two competitions will be organized at different locations: (a) design of concrete with a minimum of 50% of recycled materials with the highest strength at Rutgers University/SUBR; and (b) development of fiber-reinforced thin elements with minimum fiber content and maximum ductility at UM/S&T.
   6) *UTC Student of the Year* – Each year, RE-CAST will select a Student of the Year based on scholarly merit and academic achievement.

B. Primary and Secondary School Transportation Workforce Outreach
   1) RE-CAST will support the *Minority Introduction to Technology and Engineering* MITE summer program.
   2) *Proposed Activities with Career Technical Education System* – RE-CAST will reach out to local technical trade schools to offer short courses for students in construction-related degree programs to showcase recent developments within their trade.

Technology Transfer Goals

The main goal of RE-CAST related to technology transfer is to work towards advancing transportation proficiency through technology transfer and educational opportunities and to make research results available to potential users in a form that can be implemented.

Technology Transfer Objectives:

A. Partnerships Across Sectors to Move Research into Practice
   1) RE-CAST will collaborate with MO-LTAP and LA-LTAP to introduce and deliver new materials related to RE-CAST research themes that can be incorporated into workshops and technology transfer activities to service providers and professionals from the transportation industry.
   2) RE-CAST will work with the Louisiana Transportation Research Center (LTRC) on technology transfer.

B. Technical Assistance to Others in Applying Research Results
   1) The Center's website will publish detailed documentation of special construction procedures through videos and photos and will also provide data from the research investigations.
   2) Faculty from RE-CAST as well as technical staff will be available to provide technical assistance to practicing engineers and state and local agencies in the design and construction of the various materials developed by the RE-CAST program.

3) RE-CAST faculty will actively disseminate knowledge and develop guidelines and standards through numerous technical committees (TRB, ACI, ASCE, PCI, ACerS, RILEM, and CSA).
4) RE-CAST faculty members will also organize sessions at the technical conventions (e.g., TRB, ACI, ASTM, and ASCE) to disseminate the latest findings in the theme areas of sustainable construction materials, NDE and monitoring of infrastructure, service life prediction, and LCCA of transportation infrastructure.
5) RE-CAST will also collaborate with various technical committees (e.g., ACI) to develop certification programs on special test methods dealing with the characterization of the materials developed in the research program, including rheological properties, dynamic segregation, and pumpability of HPC-AR.
6) RE-CAST will also collaborate with other UTCs working in the State of Good Repair focus area as well as other national/regional centers, including the NSF Industry/University Coop. Research Center for the Integration of Composites into Infrastructure (CICI) at UM and the Infrastructure Monitoring and Evaluation (RIME) Group at Rutgers University.

C. Technology Transfer Mechanisms/Creation of New Business Entities
1) The RE-CAST research team will work with the Technology Transfer and Economic Development Center (TTED) at S&T to develop marketing plans and subsequent commercialization of any product(s) and deliverables that can stem from the research program.

D. Information Exchanges
1) The team will publish the findings of the proposed research in joint publications involving the different faculty and their students from the partnering consortium members.
2) Social media (Facebook and LinkedIn) will be utilized to publicize on-going research, training, and technology transfer events, including field demonstrations, webinars, and educational videos stemming from research activities.
3) Research outcomes of the RE-CAST program will be uploaded into the U.S. DOT Research Hub in a timely manner.
4) A website with links to a listing of upcoming technology transfer events, educational seminars and workshops, presentations, and project reports.
5) Quarterly newsletters highlighting project updates, featured faculty and students, and field implementations of research projects.

Diversity Goals

The main goal of RE-CAST with regard to Diversity is to broaden participation and enhance diversity of the students, researchers, and practitioners involved in transportation-related activities and careers. In the consortium Universities, many initiatives have been created to ensure an inclusive environment related to race, ethnicity, gender, gender identity, sexuality, disability, economic class, religion, and country of origin.

Diversity Objectives:

1) Summer Internship for Underrepresented Students - SUBR and Rutgers University, through collaborative projects among faculty members of the Center, will offer summer internship programs to undergraduate students to undertake internship programs at partner institutions.
2) RE-CAST will provide support in educational and outreach activities and financial aid in the form of scholarships to bring underrepresented students into transportation engineering-learning opportunities through the following programs:
    - The *Women's Leadership Program* at S&T
    - The *Summer Transportation Institute* at SUBR

- *The Gates Millennium Scholars Program* at UM
- The *Hammond Scholars Program* at UM

1.B - What Was Accomplished Under These Goals?

Research Objectives Accomplished:

Completed Project

University of Miami successfully completed the first year project and published the following report:

Pino, V. and A. Nanni, "FRCM and FRP Composites for the Repair of Damaged PC Girders," Project #00042134-04, RE-CAST: Research on Concrete Applications for Sustainable Transportation, USDOT: DTRT13-G-UTC45, GRANT: DTRT13-G-UTC45, Project Period: 1/1/2014 – 12/31/16

Project Updates

1-A. Ecological and Crack-Free High-Performance Concrete with Adapted Rheology

Missouri S&T

The aim of this project is to develop a new generation of environmentally friendly and crack-free high-performance concrete (HPC) designated for pavement (Eco-Pave-Crete) and bridge desk constructions (Eco-Bridge-Crete). The third phase of laboratory testing carried out to evaluate the effect of different shrinkage reducing/compensating materials on autogenous and drying shrinkage and mechanical properties of concrete equivalent mortars proportioned with optimized binder compositions. The investigated materials included expansive agents (CaO-based EX and MgO-based EX), crack reducing admixture, and lightweight sand. The fourth phase of laboratory testing was carried out to optimize Eco and crack-free HPC. Based on the obtained results from phases 1, 2, and 3, the effect of different binder compositions, aggregate characteristics, and shrinkage mitigating methods were considered to design Eco and crack-free HPC designated for different applications (Eco-Pave-Crete and Eco-Bridge-Crete). The research program will proceed to examine further key engineering properties and durability of the optimized mixtures selected in the phase 4. Furthermore, full-scale specimens, including slab and beam members will be constructed to evaluate shrinkage deformation, cracking resistance, and structural performance of the optimized Eco-Pave-Crete and Eco-Bridge-Crete mixtures.

University of Oklahoma

The University of Oklahoma research team also developed and optimized the mix designs for two types of economical and crack-free high performance concretes, Eco-Pave-Crete for paving applications and Eco-Bridge-Crete for bridge applications. The research team established the conventional concrete control mixtures based on an Oklahoma Department of Transportation (ODOT) Class A mixture for pavement applications and a Class AA mixture for bridge applications. The OU research team has also focused on bond and shear behavior in full-scale reinforced concrete beams constructed with selected Eco-Bridge-Crete mixtures. The results of these tests will be used to evaluate the performance of the Eco-Bridge-Crete mix designs, which are currently under development. The research team has continued to refine the Eco-Bridge-Crete optimized mix, with plans to construct and test full-scale beam specimens during the forthcoming quarter. The research program will be continued on moving the technology from the laboratory to the field to evaluate the performance of selected mix designs of the Eco-HPCs. Working with ODOT, Garver Engineering, and the City of Norman, the research team has identified the implementation project for Oklahoma, which will involve new concrete pavement for Decatur Avenue located in Norman, Oklahoma.

Rutgers University

The Rutgers Team has evaluated the use of fiber-reinforced self-consolidating concrete (FR-SCC) as an economical and crack-free high performance concrete. The restrained shrinkage of such concrete was evaluated using the shrinkage ring test. Two kinds of strain gauges were used for the restrained shrinkage test: one is a foil

strain gauge (FSG) and the other is a vibrating wire strain gauge (VWSG). The research team has contacted two local transportation agencies: the New Jersey Turnpike Authority (NJTA) and the Port Authority New York and New Jersey (PANYNJ). The engineers of the agencies were interested in using the new material (economical and crack free high performance concrete) and its application. The team and the agencies will discuss to select an appropriate field project for the implementation. The research will involve the long-term creep testing of the FR-SCC.

New York University

The New York University research team continued to work on the development of the probabilistic life cycle cost analysis (LCCA) methodology. Basic LCCA concepts, such as economic indicators, discount rate, uncertainties and reliability, time factors, and LCCA cost components were carefully described using specific and easy to understand examples. A web-based software tool that can access state-wide infrastructure data is being developed. This tool is able to automatically extract road and traffic data for each link. This data is needed to calculate LCCA of each individual links using the proposed LCCA methodology for different scenarios. The team will incorporate a flexible interface to define performance functions specific to the construction materials and technologies used. The web-based tool for performing LCCA will be developed continuously and be tested using New Jersey specific network data.

Project 1-B. Formwork Pressure Measurements and Prediction of High-Performance Concrete with Adapted Rheology

At UIUC, a laboratory study of rheological properties that control formwork pressure is underway. The project aims improving measurement methods of formwork pressure using a static column. The research team is also analyzing results from the Toronto “SCC Live” study conducted in August 2014 in collaboration with S&T. There remains much to learn about those tests, and we continue to apply modeling concepts to that data along with past data. We have used “adapted rheology” concepts to develop a high flow grout for repair of runway light cans at O’Hare International Airport using a novel pre-placed aggregate technique, and this new method was the subject of an on-site field demo in Oct 2015.

Project 1-C. Influence of Casting Conditions on Durability and Structural Performance of High-Performance Concrete with Adapted Rheology

Project 1-C-1. Dynamic Segregation

Experimental work has been performed in the laboratory to identify critical parameters of self-consolidating concrete (SCC) which influence dynamic segregation. Findings indicate the necessity to control rheology of the concrete (avoid low yield stress and low plastic viscosity). Furthermore, the paste volume and sand-to-total aggregate ratio appear to have a major effect

Eight full-scale prestressed beams were produced at Coreslab Structures in Missouri: three rectangular 30-ft long beams, two rectangular 60-ft long beams and three 30-ft I-beams. The beams were cast with varying SCC compositions and properties. The casting point was held at one end, and the SCC was allowed to flow freely along the beam. Workability, rheology and segregation resistance were monitored on site. After casting, non-destructive evaluation using ultrasonic pulse velocity, in collaboration with Dr. Julie-Ann Hartell from Oklahoma State University, was applied to investigate the stiffness of select beams which indicated the presence of some significant non-homogeneity. Pull-out tests of pre-stressed strands were performed, but the results are still under investigation.

Project 1-C-2. Changes in Rheology and Air-Void System in SCC due to Pumping

A full-scale test series has been performed in collaboration with EllisDon and CBM-St-Marys at Toronto, in which three different SCC mixtures were pumped. Workability, rheology and the hardened air-void system were analyzed before and after pumping, indicating potentially a major influence of the pipe configuration and

flow rate on these properties. The results under analysis may well lead to proposing changes to guidelines to minimize the loss of the air-void system due to pumping.

Project 2-A. High-Volume Recycled Materials for Sustainable Pavement Construction

Missouri S&T

Work is currently underway on concrete optimization, development of eco-friendly concrete for single layer pavement, and development of eco-friendly concrete for double layered pavement construction. Several concrete mixtures made with various replacement ratios of coarse and fine recycled concrete aggregate (RCA) are produced. Mixtures were proportioned with water-to-cementitious materials ratio (w/cm) of 0.40, and with 323 kg/m^3 of a ternary binder (with 50% Portland cement, 15% Class C fly ash, and 35% slag. Key mechanical properties, electrical resistivity, and shrinkage characteristics of the specimens are investigated. Analysis of the obtained data enables the research team to select concrete mixtures with highest possible RCA replacement levels that meet the desired criteria for further investigations in terms of durability and structural performance. Concrete mixtures proportioned with lower cementitious materials content, additional binder types, and various w/cm will be investigated.

University of Oklahoma

The University of Oklahoma research team has investigated potential implementation phases of the project findings to date with the Oklahoma Department of Transportation; Oklahoma City, Norman, and Tulsa, Oklahoma, City Planning Departments; Grand River Dam Authority; and the Oklahoma Turnpike Authority. Work is underway for investigating the properties of various concrete mixtures proportioned with virgin and recycled aggregates available at the state of Oklahoma.

New York University

Work is going on, aiming at development of the probabilistic LCCA methodology. Basic LCCA concepts such as economic indicators, discount rate, uncertainties and reliability, time factors, and LCCA cost components were carefully described using specific and easy to understand examples. In order to reflect the advantages and challenges presented by the introduction of the new construction technologies / materials, two approaches to link laboratory performances of new materials / technologies onto future field performance predictions are proposed:

1) To apply an assumed (hypothesized) improvement rate (e.g. from the deterioration functions of the infrastructure) when comparing new technology / material with the conventional material.

2) To utilize the empirical correlation between a given material's laboratory performance and its limited field performance as an indication of its life time performance.

Examples for the proposed methodologies were presented for both deterministic and probabilistic approaches. Stochastic treatments that will allow representation of the high degree of uncertainty when evaluating a new material were also proposed. As more information becomes available, the proposed technique will be continually re-evaluated and enhanced.

University of Illinois at Urbana-Champaign

The main emphasis of the team at UIUC is in the use of recycled fine materials for controlled low strength materials (CLSM). The very fine material is particularly challenging because these particles are difficult to characterize. Therefore, the team is developing a new method for measuring moisture content of very small particle systems for which standard methods of obtaining "saturated surface dry" specimens are unsatisfactory. The new methods use electrical properties to assess moisture content. The team is also advancing experimental studies of Engineered Material Arresting Systems (EMAS) which are used at the end of runways at airports. It is believed that CLSM concepts can be used for EMAS applications, providing airports with sustainable and locally constructed options which have potential for cost savings.

Project 2-B-1. Rapid PCC Pavement Rehabilitation

The Southern University at Baton Rouge research team worked on developing high early strength concrete to be used in rapid joint rehabilitation of PCC pavement. The target strength of the high early strength concrete is 4,000 psi in 4 hours. To minimize drying shrinkage and cracking, internal curing was adopted with lightweight concrete and recycled concrete aggregate. The early age strength is approaching to the target strength by optimizing moisture and admixtures of the designed mixture. The shrinkage and thermal properties of the mixtures were also measured. The scope of the project was expanded to the application of early strength concrete and SCC in partial depth repair with additional funding. The substrate concrete of the cylindrical bond strength tests are fabricated and cured.

Project 2-B-2. Rapid Pavement Construction

2-B-2-1. Research on Thixotropy and Workability Loss of Vibration-free Concrete in View Accelerating Pavement Construction by Slipforming

Tests on different cement-pastes have been performed to investigate structural build-up, structural breakdown and workability loss, as a function of cement paste composition and temperature. Significant advances have been made on how structural breakdown influences the rheological properties of cement pastes. Findings indicate that cement paste becomes more fluid when higher shear rates are applied prior to rheological testing. The research team is currently analyzing the results with models from the literature.

2-B-2-2. Roller Compacted Concrete for Rapid Pavement Construction

Optimum selection of the several coarse aggregate in the state of Missouri has been carried out to investigate their suitability for roller compacted concrete (RCC). In addition to numerical analysis, aggregate types and combinations were optimized through experimental packing measurements using the ICT compaction method. 17 different aggregate combinations were then used to prepare RCC mixtures that were then tested for compressive strength, Vebe time, segregation index and electrical resistivity. The maximum packing density of the aggregate was found to correlate well with enhanced RCC performance.

The project is currently focusing on producing adequate air-void system in RCC. The goal of this task is to develop production techniques to adjust the amount of entrained air in RCC. The compaction and uniformity of the air-void system will also be investigated according to ASTM C 457 – *Microscopic Determination of Air-Void Content and Parameters of the Air-Void System in Hardened Concrete*. The air-entraining admixtures, use of non-traditional dosage, air-entraining agents, workability level, mixer type, compaction technique and binder volume are adjusted. Samples taken from each mixture will be tested for compressive strength, air-void system, permeable void ratio, electrical resistivity, freeze thaw resistance, and deicing salt-scaling resistance.

Project 3-A. Performance of Fiber Reinforced Self-Consolidating Concrete for Repair of Bridge Sub-Structures and fiber-reinforced Super-workable Concrete for Infrastructure Construction

Missouri S&T

The RE-CAST 3A project undertaken at Missouri S&T consists of three Tasks: *Task 1*- literature review, *Task* 2- mixture optimization, with three Subtasks (*2A, 2B, and 2C*), and *Task 3*- structural performance of monolithic and repaired beams in flexure. *Tasks 1, 2A*, and *2B* are completed, *Task 2C* is 90% completed, and 25% of Task 3 is completed. *Task 2A* involved the testing of 24 concrete mixtures to optimize fly ash and expansive agent contents that can be used in SCC. The concrete was tested for key fresh properties, compressive and splitting tensile strengths, and electrical resistivity. Mixtures with Class C 30% fly ash replacement and either 4% Conex or 8% K-comp expansive agent showed good performance.

Task 2B involved the testing of eight SCC and eight superworkable concrete (SWC) mixtures to selected efficient fiber types. Six fiber types were investigated with SCC mixtures, including propylene synthetic fiber (PLP), carbon fiber (CA), two different types of hooked steel fibers (ST1 & 3D), a hybrid of crimpled Steel

fiber and polypropylene multifilament fiber (STPL), as well as a combination of micro and macro steel fibers (STST). Extensive workability evaluation and testing of mechanical properties has been undertaken, including the testing of flexural toughness and flexural crack resistance. The SWC mixtures included one plain SWC and seven FR-SWC mixtures made with propylene synthetic fiber (PLP), four types of hooked steel fibers (ST1, 3D, 4D, and 5D), a hybrid of crimpled steel fiber, a polypropylene multifilament fiber (STPL), as well as a combination of micro and macro steel fibers (STST). All of the optimized SCC, FR-SCC, SWC, and FR-SWC mixtures achieved the targeted passing ability criteria, modified J-Ring flow diameter greater than 24 in. (600 mm), and surface settlement less than 0.5%. Properties investigated included compressive strength, splitting tensile strength, modulus of elasticity, flexural strength, flexural toughness (ASTM C1609), fracture energy (RILEM TC-162), as well as surface electrical resistivity. In *Task 2C* four fiber types were selected for further evaluation of FR-SWC: ST1, 5D, STST, and STPL. The fibers were incorporated at 0.75%. The STPL fiber was eliminated. The remaining mixtures with steel fibers ST1, 5D, and STST achieved the targeted fresh and mechanical properties. Four mixtures out of 12 mixtures were evaluated in *Task-2C* for drying shrinkage, restrained shrinkage, as well as freeze/thaw durability. In total, 36 beam reinforcing cages were completed in Task-3. Testing of some of the mixtures in Task-2C evaluated drying shrinkage, restrained shrinkage, freeze/thaw durability and creep is underway.

Rutgers University

The research team has established the full-scale beam testing program of the repaired beams with FR-SCC to evaluate the flexural performance under two-point loading. The team cast nine (9) beams and each beam has two layers of concrete; typical class A was used for existing concrete layer, and the FR-SCC was used as the repair material for the bottom layer. A dynamic data acquisition system with various sensor technologies such as foil strain gauges, load cells, linear variable differential transformers (LVDTs), and vibrating wire strain gauges was used to monitor the flexural behavior of the FR-SCC repaired beams. Currently, the research team is conducting the full-scale beam testing and the results can be presented in the next report.

The team has designed the testing program to perform the creep testing of the FR-SCC. A static data acquisition system with nine (9) VWSGs was used to monitor the creep and shrinkage strain. The team has started loading the creep rig at the age of 28 days.

As part of this project, a web-based software tool that can access state-wide infrastructure data is being developed. This tool is able to automatically extract road and traffic data for each link. This data is needed to calculate LCC of each individual links using the proposed LCCA methodology for different scenarios.

Project 3-B. Ultra-High Performance Fiber Reinforced Concrete for Infrastructure Rehabilitation

Ultra-high performance Concrete (UHPC) is characterized by high compressive and tensile strengths. Compared to other High strength concretes (HSC's), UHPC can help reduce the joint transfer stresses. The main objective of this research was to evaluate the use of UHPC in bridge girder connections, study the effect of different joint details and effect of surface preparation of end of the girder. The test matrix consists of 22 beams, 8-in. by 12-in. by 84-in. which includes a 6-in. connection filled with UHPC, high-strength Self-consolidating concrete (HS-SCC) and conventional concrete as the monolithically cast control specimens. Three types of surface preparations used were investigated, including smooth, roughened and sandblasted. The different joint details included hairpin, straight-lap, headed rebar configurations (each with different lap lengths). A four-point loading was applied near the joint, and a load rate of 0.02 in./min was used. The results indicated that UHPC (peak load 28 Kips) as a joint material performs significantly better than a HS-SCC (peak load 12 kips) joint as compared to the conventional concrete monolithically cast control specimen (peak load 31 kips). From the three different configurations, straight lap (26-28 kips) performed the best. There was no significant effect of surface preparation; however, there was very small increase in capacity for girders whose ends were roughened.

Another objective of this research was to evaluate the use of UHPC in a non-prestressed MoDoT end connection configuration using UHPC with a cast-in-place (CIP) Deck. This work is on-going. The test matrix consists of 5 specimens 8-in. by 12-in. by 84-in., which includes a 6-in. connection filled with UHPC, MoDoT B mix and 4-in. by 20-in. by 84-in. deck cast with MoDoT B mix, UHPC and conventional concrete as well monolithically cast control specimens. This research is currently in the casting phase. The specimens will be tested using a four-point loading using a load rate of 0.05 in./min. The effect of UHPC in connections will be evaluated.

In parallel to this work is the study of UHPC stay-in-place (SIP) bridge deck panels. These panels are thinner and lighter than traditional SIP bridge deck forms. They will be evaluated in flexure and shear performance. The test matrix consists in 16 half scale panels of 4 foot long and 2 feet wide. The variable parameters are going to be the thickness (i.e., 2-in. and 3-in.) and reinforcement type (i.e., conventional rebars, welded wire fabric, prestressed and without reinforcement). UHPC panels will be cast without shrinkage reinforcement as the fibers alone are expected to bridge the cracks from it. Control deck panels with conventional concrete panels are going to be tested to serve as a baseline.

The UHPC deck panels are expected to have similar resistance that conventional concrete panels have with reduced thickness at a lower reinforcement ratio. This results in lighter structures and panels easier to transport and place. Also, as previous researches shows, UHPC structures are more durable and have lower permeability because it develops less cracks compared to conventional concrete.

The test setup will simulate a half-scale truck tire due to the reduced scale size of the test specimens. This work is on-going with separate tests to achieve flexure failure and shear dominate failure. Strain gauges will monitor the strain in the rebars, while LVDT's and inclinometers will monitor deflection and rotation of the panels. Also, crack development will be monitored. After the testing is done, results from UHPC and control panels will be compared. A study of load/cost ratio will also be developed.

Project 3-C. Performance of Reinforced Concrete Decks Strengthened with Fabric-Reinforced-Cementitious-Matrix Composites

The fiber reinforced cementious matrix (FRCM) is a new composite system that is under investigation for implementation into the infrastructure renewal market. It is therefore crucial to investigate its performance fully before use in a specific structural field application or implementation project. As this system addresses some concerns with more traditional FRP composite strengthening systems that use a polymer-based resin system, structural engineers need to fully understand its structural performance in a variety of conditions for strengthening of reinforced concrete (RC) elements. One of the most important aspects for a structural element in bridge applications is its ability to resist the oscillatory loads through its entire life. For that, the fatigue and flexure performance of the RC beams strengthened with FRCM composite were investigated. The parameters included within this study included the FRCM's reinforcement ratio, the environmental exposure, and the fatigue frequency. The experimental work included testing of 12 RC beams. Two beams served as control beams. Five beams strengthened with one ply of the FRCM composite and the other five beams strengthened with four plies of the FRCM composite. The test matrix were divided into three groups based on the exposure conditions. Group 1, beams were tested under laboratory conditions. Group 2, beams were subjected to severe environmental conditions such as freezing and thawing cycles, high temperature and humidity cycles. Within the environmental chamber cycling regime, some beams were under their self-weight and the others were subjected to sustained loads (i.e. continuous stress). Group 3, beams were seated for exposure to natural environmental conditions up to 1.5 year. Beam fatigue testing was accomplished under a loading rate ranging from 35% to 65% of the beams' expected ultimate capacities at 5Hz frequency. The fatigue performance of the strengthened RC beams were evaluated based on their stiffness measurements at the mid-span, where a maximum displacement occurred. Then the stiffness degradation with the increasing of the fatigue cycles were

determined. The beams that were unexposed to the environmental conditions (control beams and strengthened beams) observed approximately 12% degradation in the beams' stiffness. The exposed beams under no loading observed approximately 10% degradation in the beams' stiffness out of the unexposed beams. The exposed beams under loading observed approximately 20% degradation in the beams' stiffness out of the unexposed beams. All the beams were tested up to failure after 2 million fatigue cycles. Some of the conclusions can be drawn:

1. The RC beams' fatigue performance improved when an FRCM strengthening system was used.
2. All of the FRCM strengthened beams survived for 2 million fatigue cycles.
3. The higher percentage of the stiffness's degradation in all beam specimens were observed at the first 250,000 cycles.
4. The unexposed beam specimens had a lower stiffness's degradation than that observed in the exposed beam specimens.
5. The sustained loads reduced significantly the beam specimens' stiffness.
6. The exposure of the beam specimens to high temperature and humidity inside the environmental chamber concluded their higher ultimate load capacity.
7. Using four plies of the FRCM systems had a great influence on both fatigue performance and flexure performance (ultimate load and displacement ductility). It was found that the strengthened beam specimens with four plies observed mostly the same percentage of stiffness degradation in the beam specimens strengthened with one ply even though those beam specimens were under high loading rate.
8. The environmental exposure does not affect the beam specimens' failure mode. The slippage mode was observed for all strengthened beam specimens with one ply and the debonding mode was observed for all strengthened beam specimens with four plies.
9. The flexure capacity of the beam specimens was not affected by the long term fatigue cyclic loading.

The next phase of study presently under investigation includes the shear evaluation of strengthened RC members using a non-continuous u-wrap. An update on this work will be provided in the next reporting update.

Education and Workforce Development (EWD) Objectives Accomplished

1) RE-CAST hosted its **8th research seminar** on May 5 – see Appendix A.
2) RE-CAST hosted its **9th research seminar** on May 13 – see Appendix B.
3) RE-CAST has planned its **10th research seminar** on October 22 – see Appendix C.
4) Graduate Student Workshop on **Structural Health Monitoring of Transportation Infrastructure Facilities**
    - During the first week of June, a group of 21 students gathered for an accelerated course on the SHM of transportation infrastructure facilities. The workshop offered participants 2 days of classroom lectures and a half-day for field visits. Participants learned the fundamentals of SHM for concrete bridge and pavement, and were able to understand the role of SHM and deployment and data analysis of various sensor technologies.
5) Brown Bag Seminar on Rehabilitation of Taxiways A&B at O'Hare Int'l Airport
    - September 4, 2015, presentations from three faculty members
    - Included info from UTC project on CLSM and grouts with recycled materials
    - 25 participants from Chicago Department of Aviation
    - Three graduate students from UIUC participated
6) Training session for Repair of Runway Lights at O'Hare International Airport
    - October 2, 2015, led by UIUC
    - Related to UTC project on CLSM and high flow grouts with recycled materials

- Presented procedures for repair / Executed demonstration project
- 10 participants from Chicago Department of Aviation
- Three graduate students from UIUC participated

Technology Transfer Objectives Accomplished

1) Social media (**Facebook and LinkedIn**) pages have been utilized to publicize on-going research, training, and technology transfer events.
2) The RE-CAST **website has been updated** to contain links to listing of upcoming technology transfer events, educational seminars and workshops, presentations, and project reports.
3) The 5th quarterly **newslette**r was published in April 2015 – see Appendix D.
4) The 6th quarterly **newslette**r was published in July 2015 – see Appendix E.
5) The seventh quarterly **newsletter** will be published in October 2015
6) Developed repair methods and transferred these methods to Chicago Department of Aviation personnel.
7) See Section 2. PRODUCTS for further publications, conference papers and presentations

Diversity Objectives Accomplished

1) **Summer internship program**
   - The University of Oklahoma (OU) sponsored a summer internship for an undergraduate student from Nepal, Nischal Pradhan. Nischal, a native of Kathmandu, Nepal, is an undergraduate student studying civil engineering at the National Institute of Technology, Warangal, India. During his internship, Nischal was involved in the design and testing of concrete mixtures for RE-CAST projects 1A, 2A, and 3A. OU also sponsored a summer internship for Alixandra Bradford, a female undergraduate civil engineering student at OU. Alix was also involved in the design and testing of concrete mixtures for RE-CAST projects 1A, 2A, and 3A.
   - Three University of Miami undergraduate students were supported during the summer of 2015 to work on RE-CAST research. Each received an 8-week scholarship to perform research under the supervision of faculty and graduate students. The three selected students were Matthew Kesler, Catherine Wells and Kyrah Williams. Of the three, two were minority and female students. One of them was selected in conjunction with the Gates Millennium Scholars/Hammond Scholars Programs.
   - UIUC student Nanaissa Maiga, a black female student with French citizenship, participated as undergraduate researcher in D. Lange's group in Summer and Fall 2015. She worked on concrete materials testing under the supervision of graduate students sponsored by the UTC funding.
   - Sarah Vanhooser, Senior Civil Engineering undergraduate student was involved with project 1C-1 on Dynamic Segregation during the CE 4900 Research course she took with D. Feys in the 2015 Summer Semester. Sarah was involved in the experimental work in the laboratory and during the field work at Coreslab Structures. She also attended the 6th Advances in Cement-based Materials Conference during which Margarita Ley (M.Sc. student working with Sarah) presented the results.
2) Southern University and A&M College hosted **National Summer Transportation Institute (NSTI)** during June 1 - 26, 2015. The College of Engineering served as the housing facility for the institute's classroom based activities and construction projects. This year, twenty four high school students (9^{th} and 10^{th} grade) were selected to participate from several parishes in Louisiana. Dr. Shin participated in the NSTI as the speaker on June 4, 2015. He presented his on-going research on the rapid pavement repair sponsored by RE-CAST and related subjects. RE-CAST financially supported to purchase laboratory experiment set-up and supplies for the NSTI activities.

1.C - What Opportunities For Training And Professional Development Has The Program Provided?

The RE-CAST has provided and planned **three well attended research seminars** as professional development opportunities. The topics/dates of those seminars are:

1. Date: Tuesday, May 5, 2015
   - Presenter: Elizabeth Birriel, P.E. Deputy State Traffic Operations Engineer, ITS Program Manager, Florida Department of Transportation
   - Topic: *Connected Vehicle Technology: Current Efforts, Demonstration and Future Plans of FLDOT*
   - Recording posted on RE-CAST website
2. Date: Wednesday, May 13, 2015
   - Presenter: W. Micah Hale, Professor of Civil Engineering, The University of Arkansas
   - Topic: *Alkali-Silica Reaction (ASR) and ASR Mitigation*
   - Offered jointly with the Southern Plans Transportation Center (SPTC)
3. Date: Thursday, October 22, 2015
   - Presenter: Charles Hanskat, Executive Director, American Shotcrete Association
   - Topic: *Shotcrete for Repair and Rehabilitation of Highway Facilities*
   - Will be recorded and posted on RE-CAST website

Summer Internship Program – see previous section for detail.

1.D - How Have The Results Been Disseminated?

The recordings of the previous seminars are available on the RE-CAST website. A summary of all RE-CAST activities are outlined in the Center's quarterly newsletter, which is distributed to a listserv of approximately 1200 recipients.

Findings of various research projects are being compiled to prepare scientific papers and technical presentations at various conventions. Some these findings have already been disseminated at the World of Concrete 2015 in Las Vegas, 2015 TRB Meeting in Washington, D.C., and ACI Spring 2015 Convention in Kansas City, as well as overseas, including the ACI Columbia Chapter/Columbian Association of Seismic Engineering seminar held July 23 in Bogota, Colubmia and the Congress of Pathology and Concrete Technology, Porto Alegre, Brazil in June of, 2015.

1. E - What Do You Plan To Do During The Next Reporting Period To Accomplish The Goals And Objectives?

1) First annual student competition
   - This activity is under discussion amongst the RE-CAST team.
2) Publish 7th and 8th newsletters
3) Schedule 11th, 12th and 13th bi-monthly research seminars
   - The following webinars are scheduled:
     - Date: Thursday, October 22, 2015
       - Presenter: Charles Hanskat, Executive Director, American Shotcrete Association
       - Topic: *Shotcrete for Repair and Rehabilitation of Highway Facilities*
       - Will be recorded and posted on RE-CAST website
   - Date: Dec. 1, 2015
     - Presenter: Prof. Julie Hartell, Oklahoma State University
     - Topic: TBD

- *Webinar is being co-sponsored with the Southern Plain Transportation Center (SPTC) at the University of Oklahoma in an effort to collaborate with other UTC Centers that are working on similar Strategic Goals of the U.S.DOT.*

- Date: February 2015
  - Presenter: Prof. Maria Juenger, The University of Texas at Austin
  - Topic: TBD

4) **Summer Transportation Institute at SUBR** - Southern University and A&M College will host National Summer Transportation Institute (NSTI) in 2016. The College of Engineering will serve as the housing facility for the institute's classroom based activities and construction projects. Up to 20 high school participants (9^{th} and 10^{th} grades) will be selected from parishes in Louisiana. Dr. H. Shin from RE-CAST will participate in the NSTI as the speaker. He will present the Center's on-going research on rapid pavement repair and related subjects.
5) **S&T Transportation Infrastructure Conference**
   - December 4, 2015 at St. Louis University, in collaboration with MoDOT and RE-CAST, where some of the faculty members will give invited lectures from RE-CAST sponsored projects.
6) Budgeted funds will be used to provide support in the form of **scholarships to bring underrepresented students into transportation engineering-learning opportunities** in collaboration with the Hammond Scholars Program at UM, established to honor the legacy of UM's first director of minority affairs.
7) A **one-day** workshop in Spanish will be offered at UM on November 14, 2015 with the following title: "Diseño y Construcción de Sistemas FRP para el Reforzamiento de Estructuras Existentes." ("Design and Construction of FRP Systems for Strengthening Existing Structures.")
8) **UIUC student Nanaissa Maiga, a black female student with French citizenship,** will continue as undergraduate researcher, thus advancing diversity goals through the UTC program.
9) Sponsor a high student at Missouri S&T for the Fall 2015 and Spring 2016 as part of the RE-CAST outreach mission.

2. PRODUCTS

2.A - Publications, Conference Papers, and Presentations

1) 8th research seminar on May 5 – see Appendix A.
2) 9th research seminar on May 13 – see Appendix B.
3) 10th research seminar on October 22 – see Appendix C.
4) April 2015 Newsletter: see Appendix D.
5) July 2015 Newsletter: see Appendix E.
6) Journal Publications:

Zhang, K., Z. Fang, **A. Nanni**, J. Hu, and G. Chen, "Experimental Study of a Large-Scale Ground Anchor System with FRP Tendon and RPC Grout Medium," *ASCE J. Compos. Constr.,* Vol. 19, No. 4, July-Aug. 2015, pp. 04014073-1 to 11.

Arezoumandi, M., Drury, J.T., **Volz, J.S.**, and **Khayat, K.H.** (2015) "Effect of Recycled Concrete Aggregate Replacement Level on Shear Strength of Reinforced Concrete Beams," *ACI Materials Journal*, 112(4):559-568.

Arezoumandi, M., Smith, A., **Volz, J.S.**, and **Khayat, K.H.** (2015) "An Experimental Study on Flexural Strength of Reinforced Concrete Beams with 100% Recycled Concrete Aggregate," *Engineering Structures*, 88:154-162.

Wallevik, O.H., **Feys, D**., Wallevik, J.E., and **Khayat, K.H.**, Avoiding Inaccurate Interpretations of Rheological Measurements for Cement-Based Materials, CCR, 2015, http://www.sciencedirect.com/science/article/pii/S000888461500126X.

Feys, D., Khayat, K.H., Recent Developments in Evaluating Pumping Behaviour of Flowable and Self-Consolidating Concrete, *Journal of Sustainable Cement-Based Materials*, 2015, http://dx.doi.org/10.1080/21650373.2014.997321.

Bao, Y., Meng, W., Chen, Y., Chen, G, and **Khayat, K.H.**, "Measuring Mortar Shrinkage and Cracking by Pulse Pre-Pump Brillouin Optical Time Domain Analysis with a Single Optical Fiber," *Materials Letters*, Vol. 145, pp. 344-346, April 2015.

R. Serpell, J. Henschen, J. Roesler, **D.A. Lange**, "Relative Proportioning Method for Controlled Low-Strength Material," ACI Materials Journal, Vol. 112, No. 2, pp 179-188, 2015

7) Conference Papers:

A.M. Ley Hernandez, S. Vanhooser, **D. Feys**, "Influence of Mix Design parameters on dynamic segregation of self-consolidating concrete," Presented at the 6th Advances in Cement-based Materials Conference, ACERS, July 20-22, 2015.

Selicato, F., M. Moro, L. Bertolini and **A. Nanni**, "Sustainable Concrete Without Chloride Limits," 2015 International Concrete Sustainability Conference, May 11-13, Miami, FL.

Nassif, H. et al., "Fatigue Assessment of Centenarian Railway Bridges with Structural Health Monitoring Data," ISHMII7, July 1-3, 2015, Turin, Italy

Nassif, H.,"Structural Health Monitoring (SHM) for Evaluation and Quality Control of Concrete Structures," 2nd JCI/ACI Joint Seminar, Jul. 13, 2015, Tokyo, Japan

8) Keynote/Invited Presentations:

Kamal H. Khayat

"Mix Design and Materials Aspects Affecting Form Pressure Exerted by SCC," *ACI Spring 2015 Convention*, Kansas City, April, 2015 (invited).

"Performance of SCC Made with Ternary Cements," *ACI Spring 2015 Convention*, Kansas City, April, 2015 (invited).

"Automated Measurement and Control of Concrete Properties in a Ready Mix Truck," *ACI Spring 2015 Convention*, Kansas City, April, 2015 (invited).

"Performance of Fiber-Reinforced SCC in Concrete Infrastructure Rehabilitation," keynote speaker, XI Cinpar 2015, Congress of Pathology and Concrete Technology, Porto Alegre, Brazil, June, 2015 (keynote).

David Lange

"Models and Mechanisms for Evaluating Form Pressure of SCC," ACI Spring Convention, April 12, 2015. (recording available ACI website)

Hani Nassif

"Structural Health Monitoring (SHM) for Evaluation and Quality Control of Concrete Structures," 2nd JCI/ACI Joint Seminar, Jul. 13, 2015, Tokyo, Japan (invited)

Antonio Nanni

"Case Studies on Strengthening of Concrete and Masonry Structures," Colombian Association of Engineers & ACI Colombian Chapter, Bogota, Colombia – July 23, 2015 (invited)

"Extending the life of concrete structures: FRCM technology" ICRI Southeast Florida Chapter Meeting – September 17, 2015 (invited)

2.B - Website(s) or Other Internet Site(s)

Website: http://recast.mst.edu

Facebook: https://www.facebook.com/RECASTCenter

LinkedIn: https://www.linkedin.com/groups/RECAST-University-Transportation-Center-6626216?trk=anet_ug_hm&gid=6626216&home=

2.C - Technologies or Techniques

Nothing to Report.

2.D - Inventions, Patent Applications, and/or Licenses

Nothing to Report.

2.E - Other Products, Such As Data Or Databases, Physical Collections, Audio Or Video Products, Software Or Netware, Models, Educational Aids Or Curricula, Instruments, Or Equipment.

Nothing to Report.

3. PARTICIPANTS & COLLABORATING ORGANIZATIONS

3.A - What Organizations Have Been Involved As Partners?

The main consortium members of this University Transportation Center remain the same as the proposal:

- Missouri University of Science and Technology, Rolla, MO - LEAD
- University of Illinois at Urbana-Champaign, Urbana, IL
- Rutgers, The State University of New Jersey, Piscataway, NJ
- University of Miami, Coral Gables, FL
- Southern University and A&M College, Baton Rouge, LA

As stated in the proposal, the RE-CAST team is also partnered with Dr. H. Celik Ozyildirim, as a consultant, from the Virginia Center for Transportation Innovation and Research, Charlottesville, VA. Dr. Ozyildirim's main implication is to provide input for field implementation and development of specifications and standards.

In addition to the main consortium members, two additional universities are collaborating with with RE-CAST, due to faculty moving to those universities after the proposal was submitted. Those new partners are:

- The University of Oklahoma, Norman, OK (Dr. Jeffrey Volz)
- New York University Polytechnic School of Engineering, Brooklyn, NY (Dr. Kaan Ozbay)

Several state governments and industrial partners are involved in various on-going RE-CAST projects and are providing financial and in-kind support to the research program. Those agencies are listed on the next page. The highlighted agencies are new in this reporting period.

- **AIG**
- Bowman, Barrett and Associates, Chicago, IL, financial support
- **CBM/St. Mary's, Canada**
- **Chicago Department of Aviation**
- **City University of New York**
- Coreslab Structures Inc., Marshall, MO
- Dolese Bros. Co., Oklahoma City, OK financial support
- **EllisDon Construction, Canada**
- **Garver Engineering, Norman, OK**
- Grand River Dam Authority, Vinita, OK
- **Hanyang University (Korea)**
- **K-FIVE Construction Corp., Lemont, IL**
- **Kansas State University**
- **Kyunghee Univ. (Korea)**
- Louisiana Transportation Research Center (LTRC), Baton Rouge, LA, financial support
- Missouri Department of Transportation, Jefferson City, MO, financial support
- Missouri University of Science and Technology, Rolla, MO, in-kind support
- New Jersey Department of Transportation Research Division, West Trenton, NJ, financial support
- **New Jersey Turnpike Authority**
- **New York City Department of Transportation**
- **New York State Department of Transportation**
- New York University Polytechnic School of Engineering, Brooklyn, NY, financial support
- **Noblis**
- O'Hare Modernization Program, Chicago, IL, financial support
- Oklahoma Department of Transportation, Oklahoma City, OK
- Oklahoma City, Norman, and Tulsa, OK, City Planning Departments
- **Oklahoma State University**
- Oklahoma Turnpike Authority, Oklahoma City, OK
- **Sensocrete, Canada**
- Small Modular Reactor Research and Education Consortium, financial support
- **State University of New York Maritime College**
- **State University of New York at Stony Brook**
- Structural Technologies, Hanover, MD, financial support
- University of Illinois, Urbana-Champagne, Champaign, IL, in-kind support
- University of Miami, Coral Gables, FL, financial support
- **University of Nevada, Las Vegas**
- University of Oklahoma, in-kind support
- **University of Ottawa, Canada**
- **University of Sao Paulo (Brazil)**
- **University of Sherbrooke, Canada**
- Virginia Center for Transportation Innovation and Research (via VirginiaTech) Charlottesville, VA, financial support
- **Qatar Foundation**

3.B - Have Other Collaborators Or Contacts Been Involved?

The Research Advisory Committee (RAC) is composed of the following individuals:

William Stone, Research Administrator, P.E. (RAC President)
*Missouri Department of Transportation, Jefferson City, **MO***

Ross Anderson, Senior Vice President
*Bowman Barrett & Associates, Chicago, **IL***

Casimir Bognacki, Chief of Materials Engineering
*Port Authority of New York and New Jersey, New York, **NY***

Harvey DeFord, Ph.D., Structural Materials Research Specialist
*Florida Department of Transportation State Materials Office, Gainesville, **FL***

Chiara "Clarissa" Ferraris, Ph.D., Physicist
*National Institute of Standards and Technology, Gaithersburg, **MD***

Jim Myers, P.E., Senior Staff Engineer
*Coreslab Structures, Inc., Marshall, **MO***

Karthik Obla, Ph.D. P.E., Vice President, Technical Services
*National Ready Mix Concrete Association, Silver Spring, **MD***

Zhongjie "Doc" Zhang, Ph.D., Pavement Geotechnical Research Administrator
*Louisiana Transportation Research Center, Baton Rouge, **LA***

The objectives of the RAC to advise the Center's Director and Associate Directors on management and activities of the Center and to contribute to the Center core mission. The Center will interact with state DOTs, public agencies, and three primary industry components through the RAC.

The group will meet again to discuss this report at the TRB meeting in 2016.

4. IMPACT

4.A - What Is The Impact On The Development Of The Principal Discipline(s) Of The Program?

RE-CAST researchers are providing new construction and repair materials that can be implemented to enhance sustainability and service life of transportation infrastructure. For example, RE-CAST researchers are developing new repair methods that offer improved cost-efficiency and rapid installation to the O'Hare Airport.

They are also delivering strategies for new materials that utilize recycled fine material , recycled coarse aggregate, use of industrial by-products, including fly ash, glass and recycled tires for use in concrete that would otherwise be landfilled.

4.B - What Is The Impact On Other Disciplines?

Some of our work involves laboratory studies of flow and rheology of cement based systems, and the work involves fluid mechanics models of suspensions where properties are related to particle size and shape. This general knowledge applies to other disciplines such as Materials Science as it relates to generic suspensions.

4.C - What Is The Impact On The Development Of Transportation Workforce Development?

Several graduate and undergraduate students have been recruited to staff the RE-CAST projects for FY2015 and FY2016. For the undergraduate students, working with graduate students and world-renown faculty helps them with experiential learning activities and raise their interest in the transportation field.

We have been involved in training activities related to new construction materials and repair methods, including activities at the Chicago O'Hare Airport.

4.E - What Is The Impact On Physical, Institutional, And Information Resources at the University or Other Partner Institutions?

Nothing to report at this time.

4.F - What Is The Impact On Technology Transfer?

Several invited speakers/keynote speaker lectures are scheduled for the Spring of 2016, many of which will report on some of the research findings of RE-CAST projects, including the 4th Annual Transportation Infrastructure Conference in St. Louis in Dec. 2015.

SCC2016, an international conference focusing on the Design and Use of Self-Consolidating Concrete, is being sponsored by RE-CAST. This event will attract engineers, architects, government officials, researchers, academics, students, contractors, and industry professionals from around the world.

4.G - What Is The Impact On Society Beyond Science And Technology?

The RE-CAST projects are developing the next generation of cement-based construction materials to address the growing technical and environmental requirements of the nation's transportation infrastructure. The ultimate goal of the RE-CAST program is to fast-track the acceptance of these technologies and develop national standards and guidelines for their use in the reconstruction of the nation's infrastructure for the 21st Century, which will have a lasting impact on our nation's society. This research theme addresses a Grand Challenge for our society and has been recognized recently at Missouri S&T as one of four strategic areas for future growth in education and research on campus.

5. CHANGES/PROBLEMS

5.A - Changes In Approach And Reasons For Change

Nothing to report at this time.

5.B - Actual Or Anticipated Problems Or Delays And Actions Or Plans To Resolve Them

Nothing to report at this time.

5.C - Changes That Have A Significant Impact On Expenditures

Nothing to report at this time.

5.D - Significant Changes In Use Or Care Of Animals, Human Subjects, And/or Biohazards

Not Applicable.

5.E - Change Of Primary Performance Site Location From That Originally Proposed

No Change to Report.

6. SPECIAL REPORTING REQUIREMENTS

Nothing to Report.

APPENDIX A

RE-CAST May 5 Webinar:
Connected Vehicle Technology: Current Efforts, Demonstration and Future Plans of FLDOT

WEBINAR

Connected Vehicle Technology: Current Efforts, Demonstration and Future Plans of FLDOT

Presented in Spanish with English Closed-Captioning

Elizabeth Birriel, P.E.

Deputy State Traffic Operations Engineer

ITS Program Manager

Florida Department of Transportation

PRESENTER BIO

Elizabeth works for the Florida Department of Transportation (FLDOT) as the Deputy State Traffic Operations Engineer. She is also the Statewide ITS Program Manager. With over 21 years of experience in the transportation industry and with FDOT, program areas under her responsibility include deployment of 511 Advanced Traveler Information System in the state of Florida, creation of the SunGuide® software to be used in all 12 FDOT transportation management centers in Florida, development and reporting of ITS Performance Measures and Connected Vehicle efforts in Florida. Under her leadership, FLDOT deployed a Connected Vehicle Test Bed in Orlando Florida in 2011, one of only a few in the nation.

Elizabeth is involved in several national level efforts such as AASHTO's Connected Vehicle Working Group and the Connected Vehicle Pooled Fund Study Group. She is an active member of ITS America and ITS Florida. Elizabeth received her B.S. degree in electrical engineering and a Master's degree in transportation engineering. She is also a graduate of the Certified Public Manager (CPM) program and is a registered Professional Engineer in the state of Florida.

ABSTRACT

This presentation will focus on Connected Vehicle efforts in Florida and a Connected Vehicle Technology Demonstration held in Florida in August 2014. The presentation will also discuss future Connected Vehicle efforts being considered by the Florida Department of Transportation.

Tuesday, May 5

Time:
2 pm - 3 pm ET

RE-CAST

FDOT

APPENDIX B

RE-CAST May 13 Webinar:
Alkali-Silica Reaction (ASR) and ASR Mitigation

WEBINAR

Alkali-Silica Reaction (ASR) and ASR Mitigation

ABSTRACT

In 2012 it was discovered that roughly 4 miles of an interstate median barrier along Interstate 49 in Northwest Arkansas had rapidly deteriorated. After the initial inspection, a sample was submitted for analysis, and found to contain evidence of alkali-silica reaction (ASR). A research program was implemented with the goal of determining the cause of ASR and developing a program for mitigating the ongoing deterioration. The median barrier had not deteriorated equally throughout the 4 miles, and the level of damage varied considerably throughout the length. A research program was implemented to evaluate several treatment methods, with the goal of slowing or arresting the deterioration within the median barrier. Several sections of the median barrier were instrumented to measure expansion and internal relative humidity. The barrier wall has been monitored for approximately two years. The aggregates used in the median barrier construction were also evaluated in laboratory testing, which included the AMBT and CPT. The laboratory results were compared to the findings from the petrographic analysis. The results of the laboratory testing were used to develop recommendations on the prevention of ASR in concrete which contains the same aggregates.

Presented by:

Prof. W. Micah Hale

Professor of Civil Engineering

The University of Arkansas

Wednesday, May 13

Time:
11 am - 12 pm CDT

SOUTHERN PLAINS TRANSPORTATION CENTER

SPONSORS:

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RE-CAST

APPENDIX C

RE-CAST October Webinar:
Shotcrete for Repair and Rehabilitation of Highway Facilities

WEBINAR

Shotcrete for Repair and Rehabilitation of Highway Facilities

ABSTRACT

This seminar presented by the **American Shotcrete Association** (ASA) will give the owner, design engineer, project specifier, field inspector, and general contractors an overview on how shotcrete can be efficiently, and cost effectively used for structural repair and rehabilitation of concrete bridges and associated structures. We will provide a basic overview of the shotcrete process, cover the design, specifying and detailing considerations for shotcrete repairs.
Next, we will use specific project case studies from a variety of projects across the USA to illustrate field considerations and the sustainability benefits gained when using shotcrete for repair including reduced formwork needs and scheduling advantages. We will also discuss achieving quality of shotcrete addressing field inspection, specific placement techniques, nozzleman certifications, and contractor qualifications. We will wrap up with a discussion of new ASA programs for shotcrete inspector training, and contractor qualification as well as providing a listing of appropriate references and resources on use of shotcrete for structural concrete repair.

Presented by:

Charles Hanskat, P.E.

Executive Director

American Shotcrete Association

Thursday
October 22

Time:
11 am - 12 pm CDT

RE-CAST

APPENDIX D

RE-CAST April 2015 Newsletter

Research on Concrete Applications for Sustainable Transportation

RE-CAST

MISSOURI S&T

Vol. 2 :: Issue 2 :: APRIL 2015

In this issue:

CONSORTIUM MEMBERS:

Missouri University of Science and Technology

University of Illinois at Urbana-Champaign

Rutgers, The State University of New Jersey

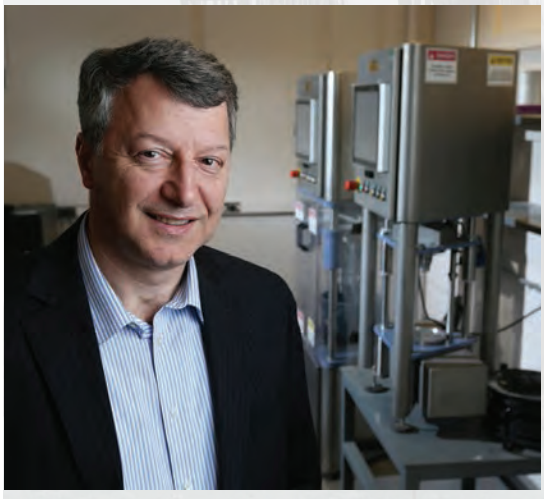
University of Miami

Southern University and A&M College

Director's Message

As the summer approaches, RE-CAST has many exciting plans in place to engage several different audiences in our research and outreach activities.

We are proud to report an outreach activity sponsored by Dr. Antonio Nanni, Associate RE-CAST Director at University of Miami, that engaged young children in the exciting science of making concrete. Children from United Way Center for Excellence Demonstration School visited the lab facilities at UM and learned how to make their very own mix design. These types of activities will help engage the next generation of transportation professionals, from a very early age.



On March 30, the RE-CAST Center offered a webinar jointly presented by Dr. David Lange, Associate RE-CAST Director at University of Illinois at Urbana-Champaign, and his student Dr. Tyler Oesch from U.S. Army Engineer Research and Development Center at Vicksburg, MS. The recorded webinar is available for viewing on our website.

We also have two webinar scheduled in May that will be announced on our website.

This summer, RE-CAST is offering a summer internship experience for undergraduate students to participate in RE-CAST project.

This issue of our newsletter provides many more updates on the exciting activities happening at RE-CAST.

-Kamal H. Khayat
RE-CAST Director

OUTREACH/WORKFORCE DEVELOPMENT

"Start Early, Repeat Often" – the next STEM generation

Children from the United Way Center for Excellence Demonstration School learn to make concrete with students from the University of Maimi

For children from the United Way Center for Excellence Demonstration School, a laboratory experiment that might intimidate most young adults starting college, is instead a fascinating wonderland waiting to be explored and re-invented. This group of very young students aged three to five came to visit the University of Miami's College of Engineering Structures and Materials laboratory to learn about concrete and construction materials.

After a brief lab tour showing the large test frames required for structural testing and a discussion of what they knew about concrete, the young students were set up in groups to make their very own concrete mix designs. They used different kinds of gravel and sand, which they were eager to feel with their own hands and even put some in their pockets. Because actual cement would be harmful to their skin, they were given cooking flour instead, then some concrete coloring to create their own custom concrete mixtures. The last ingredient was the water as they worked diligently to mix, explore, and play with their creation. Once completed, the mixtures was placed in a standard 4 inch. diameter concrete cylinder as would be done in the field for strength testing. Finally, an actual concrete cylinder was tested, and they were able to see first the strength of concrete and what a concrete failure looks like.

- Continued Next Page -

OUTREACH/WORKFORCE DEVELOPMENT

"Start Early, Repeat Often" *(continued)*

Remy Gordon, the children's teacher, and several parents were in attendance as Drs. Francisco De Caso and Diana Arboleda, and graduate students Vanessa Pino and Zahra Karim lead the young kids in the experiment, hosted by Dr. Antonio Nanni, Chair of the Civil, Architectural, and Environmental Engineering Department and Associate Director of the RE-CAST University Transportation Center (UTC).

UM is a partner in the RE-CAST UTC, which sponsored the event.

The United Way Center for Excellence in Early Education is an innovative learning, teaching, and training initiative dedicated to elevating the quality of early care and education in Miami-Dade County and beyond.

FEATURED PROJECT

Recycled Fines for Controlled Low Strength Materials

- David Lange, Ph.D., Prof. of Civil Engineering, University of Illinois at Urbana-Champaign
- Yu Song, M.S. student, University of Illinois at Urbana-Champaign
- Jihwan Kim, Ph.D., Visting Scholar, University of Illinois at Urbana-Champaign

The University of Illinois is developing new sustainable materials for infrastructure applications in partnership with the O'Hare International Airport. The study focuses on use of recycled materials, particularly the fine particles that are generated by concrete crushers. While recycled coarse aggregates are readily reused for pavement substructure or for new concrete, the fine particles are generally disposed in landfills. Fine particles are challenging because their high water absorptivity and high fineness pose severe problems for normal concrete mixtures. In contrast, the research is developing mix design strategies for controlled low strength materials (CLSM) that are useful for backfill, such as used for trenching operations for underground utility lines at airports. Another niche application at airports is the use of CLSM materials as a cast-in-place alternative for Engineered Material Arresting Systems (EMAS) that are constructed at the end of runways for the purpose of arresting airplanes that overrun the end of the runways. Arresting systems are one viable option to create safe conditions when land is restricted at the end of runways. When the aircraft overruns the end of the runway, the aircraft landing gear penetrates the EMAS, and drag forces bring the aircraft to a safe halt. The properties of the EMAS need to be tuned so that emergency vehicles can drive on top of the EMAS while the aircraft gear loads are sufficient to punch through the surface. The EMAS strength, fracture energy, and durability need to be considered in the material design. The research is exploring strategies that use fine recycled particles so that the EMAS can be locally produced while advancing sustainability objectives. One novel material design strategy under consideration uses superabsorbent polymer inclusions and foaming strategies to reduce density and strength to more consistently achieves target strengths that may as low as 30-50 psi compressive strength range. **Figure 1** shows how super absorbent polymer beads create opportunity for large voids that reduce density and strength.

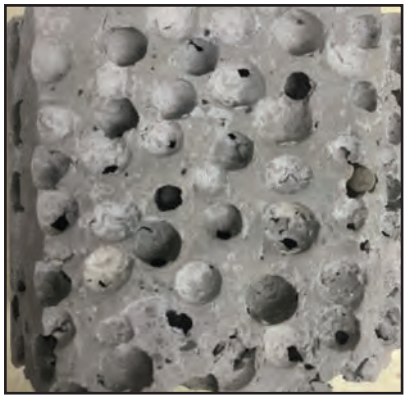


Figure 1. CLSM with large voids created by superabsorbent polymer inclusions

The research is also exploring new ways to characterize moisture in very fine particle systems. Particles that pass the 200 sieve are like dust, and the conventional methods for measuring sand moisture condition do not work because it is very hard to define saturated surface dry conditions.

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Recycled Fines for Controlled Low Strength Materials *(con't)*

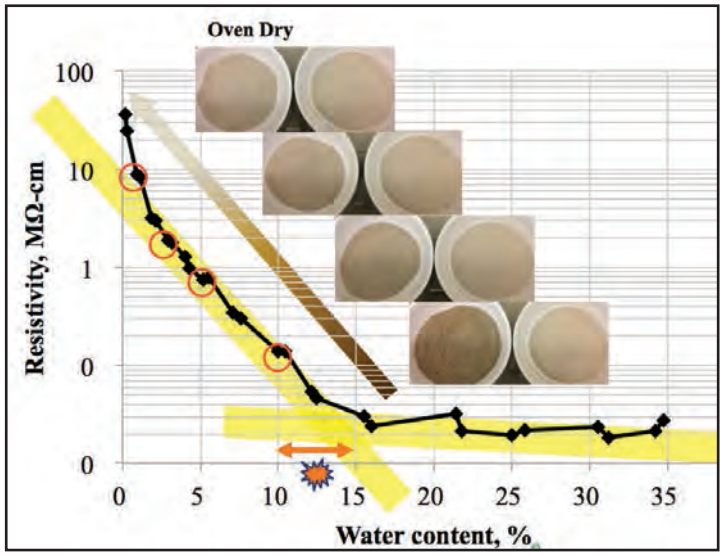
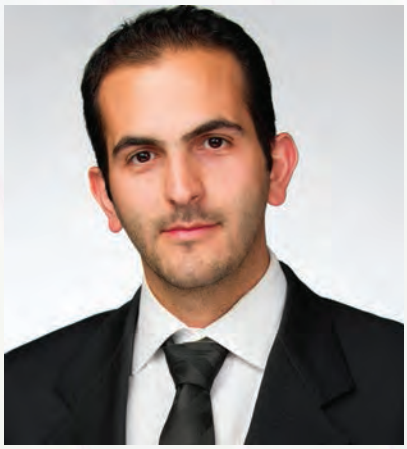


Figure 2. Effect of water content on resistance value of recycled fines

An alternative method being considered defines saturated surface dry condition as a function of electrical resistance across a sample of packed particles. **Figure 2** shows how electrical resistance drops as moisture increases, and a plateau is observed when the particles are saturated. Easy and practical test methods for characterizing fine particles will help establish reliable mixture design methodology for fine recycled materials.

Student Spotlight

RE-CAST Student Awarded ACI Missouri Chapter Honorary Abdeldjelil "DJ" Belarbi Scholarship : *Iman Mehdipour*



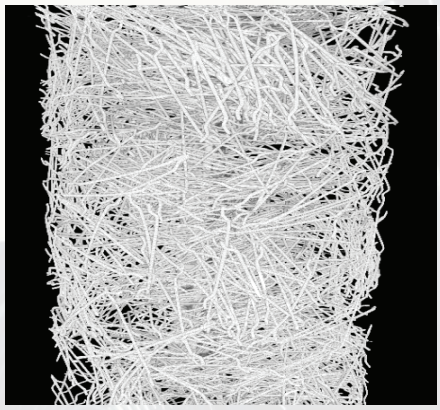
Mr. Iman Mehdipour, Ph.D. candidate at Missouri S&T, was awarded the ACI Missouri Chapter Honorary Abdeldjelil "DJ" Belarbi Scholarship for 2015-2016. The competition was very tough this year, and the RE-CAST Center is proud of this student's achievement.

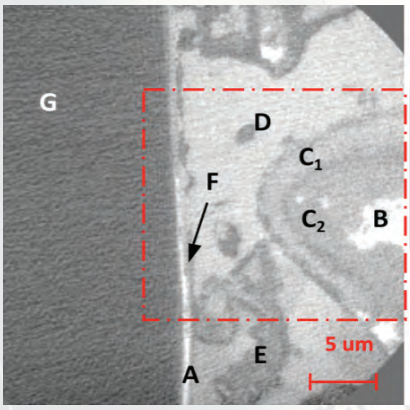
Mr. Mehdipour started his Ph.D. studies under direction of Prof. Kamal H. Khayat in the field of "Ecological and Crack-Free High Performance Concrete" in 2013. His academic achievement, community services experience, and six years of experience working as an engineer made him a good candidate for this scholarship award.

TECHNOLOGY TRANSFER

Drs. David Lange and Tyler Oesch give RE-CAST Webinar:

Three-Dimensional Study of Concrete Microstructure using X-ray Computed Tomography





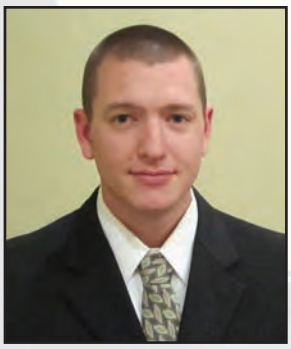
Webinar Abstract:

New technology has made it possible to create three-dimensional images of microstructure to better understand the performance of concrete. X-ray computed tomography (XCT) has been used to study phases — aggregate, paste, air bubbles, porosity and fibers — and discern crack propagation of samples under load. This webinar features recent research that explores how XCT can be applied to concrete materials over a range of scale that encompasses small cement grains on the low end to steel fibers and aggregate on the high end. XCT provides unprecedented opportunities: This advanced technique enables the interrogation of wet samples over time to observe hydration; study distribution of entrained air bubbles; evaluate samples under various levels of loading to study crack propagation and contrast HPC and OPC; and investigate fiber reinforced materials to appreciate how fibers influence fracture. The research community is only beginning to appreciate how these powerful new techniques would lead to profound new knowledge about complex concrete materials.

Prof. David Lange

RE-CAST Assoc. Director

University of Illinois, Urbana, IL



Dr. Tyler Oesch

U.S. Army Engineer Research and Development Center at Vicksburg, MS

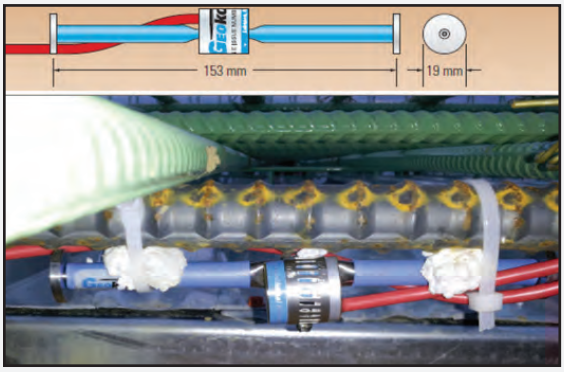
View the Webinar at: recast.mst.edu/webinars

EDUCATION

RE-CAST Graduate Student Summer Workshop:

Structural Health Monitoring of Transportation Infrastructure Facilities

June 1-3, 2015 at Rutgers, The State University of New Jersey



The short course will introduce graduate engineering students and practicitions to the field of structural health monitoring in transportation infrastructures through two-day lectures and half-day field trip to instrumental test beds in New Jersey.

- Lectures: Monday, June 1, 2015 - Tuesday, June 2, 2015
- Field Trip: Wednesday, June 3, 2015

Learning Objectives: by the end of the course, graduate students will be able to:

- Define various aspects of structural health monitoring (SHM) used in transportation infrastructure
- Describe the role and needs of SHM
- Understand sensor technologies and data processing for SHM
- Investigate the difficulties and pitfalls of SHM
- Discuss various SHM case studies
- Application of SHM in concrete bridges, pavement, design, and rehabilitation

This course will be jointly presented by **Dr. Hani Nassif**, RE-CAST Assoc. Director, Professor of Civil Engineering at Rutgers University and **Dr. Alex Hak-Chul Shin**, RE-CAST Researcher, Associate Professor at Southern University. Watch for registration at http://www.recast.mst.edu.

FEATURED PROJECT

Economical and Crack-Free HPC with Adapted Rheology: *Packing Density Approach to Select Aggregates*

- Kamal H. Khayat, Ph.D., Professor of Civil Engineering, Missouri S&T
- Iman Mehdipour, Ph.D. Candidate, Missouri S&T

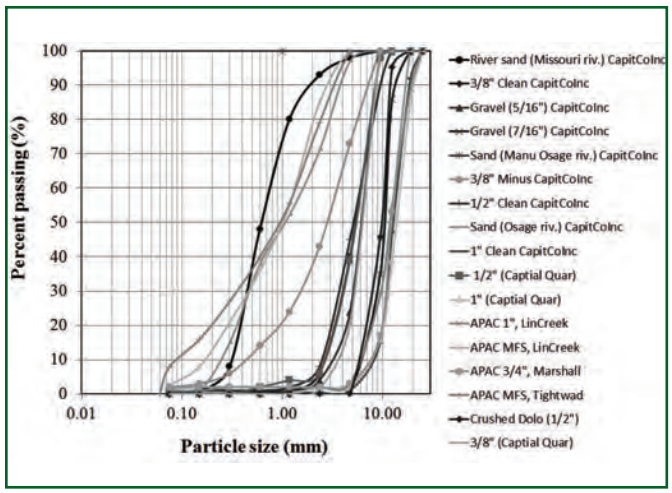


Figure 1. PSD of investigated aggregates

An essential step of producing ecological and environmentally friendly concrete (Eco-Crete) is to enhance the packing density of the aggregate skeleton. For a given workability, an increase in packing density can reduce paste volume, hence leading to greater resistance to cracking and reducing cost and emissions.

As part of RE-CAST project 1A, an experimental program was undertaken to evaluate the influence of physical characteristics of fine and coarse aggreagates including shape, texture, and particle-size distribution (PSD), on packing density. In total, 17 aggregate samples from different aggregate quarries in Missouri were sampled. The PSD of investigated aggregates (fine, intermediate, and coarse aggregates) is shown in **Figure 1**. The packing density of aggregate blends was determined using the loose packing approach (ASTM C29), dense packing approach using rodding (ASTM C29), and dense packing approach with an intensive compaction tester (ICT), as shown in **Figure 2**.

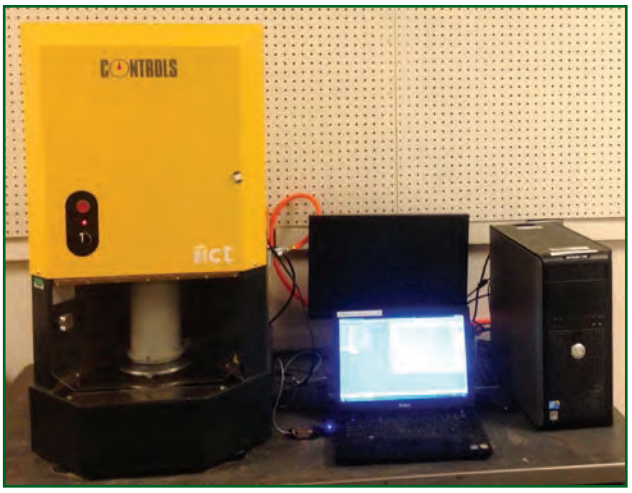


Figure 2. Packing density measurement using ICT

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Economical and Crack-Free HPC with Adapted Rheology:
Packing Density Approach to Select Aggregates (con't)

The packing density of the tested aggregates determined using the ICT is plotted in **Figure 3**. Depending on the shape, texture, and PSD of aggregate, the packing density of mono-sized aggregates varied from 0.59 to 0.73. Typical results for ternary aggregates combination shown in **Figure 4**. Given different types and replacement rates of aggregate, the packing density of ternary systems varied from 0.70 to 0.82. The spread between the minimum and maximum packing densities of 0.12, corresponds to void volume that should be filled with cement paste.

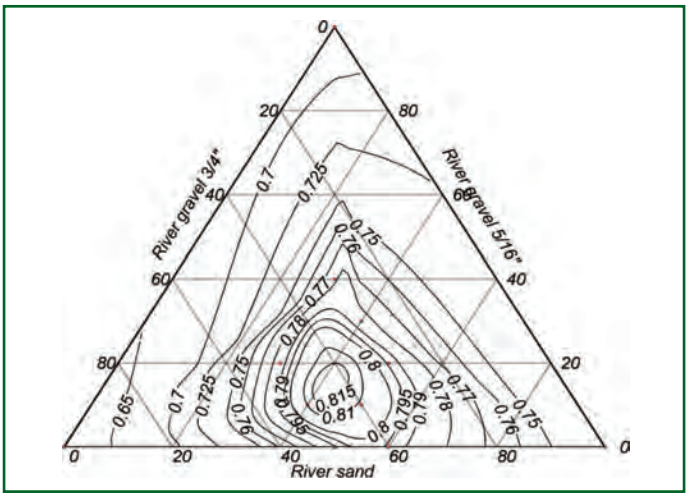

Figure 4. Ternary packing diagram for investigated aggregates

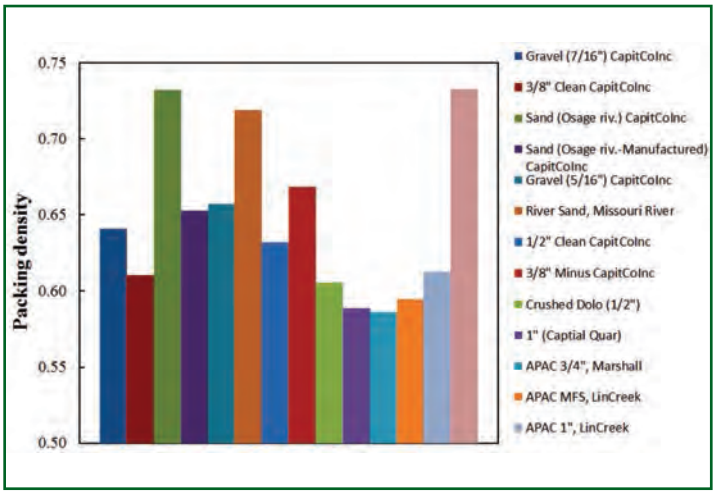

Figure 3. Packing density of investigated aggregates using ICT

Research is underway to optimize binder and aggregate combinations and to incorporate fibers and expansive admixtures/shrinkage reducing admixtures to develop a new generation of environmentally friendly and crack-free high-performance concrete (Eco and crack-free HPC) designated for pavement (Eco-Pave-Crete) and bridge desk constructions (Eco-Bridge-Crete).

DIVERSITY AND OUTREACH

RE-CAST Offers Undergraduate Summer Research Internships

RE-CAST is excited to be offering an Undergraduate Summer Research Internship program at Missouri University of Science and Technology and the University of Miami. Undergraduate civil engineering students from the consortium institution are eligible to apply for an 8-week internship to work on RE-CAST research projects. This program will offer excellent education, training, and research opportunities for students at the undergraduate level. Preference will be given to populations that have been historically underrepresented in engineering. The students will have two options to choose from, as elaborated below.

OPTION A: UNIVERSITY OF MIAMI	
Project Title	Use of Composites in Repair of Transportation Infrastructure
Research Advisor	Dr. Antonio Nanni, RE-CAST Associate Director
Brief Description of Project	Student/s will be engaged with experimental characterization and certification of innovative construction composites. All aspects of research will be covered, including experiment and specimen development, testing, data collection and analysis, and reporting. The student/s will be in a laboratory environment and will learn how to use different advanced test equipment.

OPTION B: MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY	
Project Title	Project A: Strengthening and Repair of Structural Concrete with a Fabric-reinforced-cementitious-matrix Project B: Ultra-high Performance Fiber-Reinforced Concrete for Infrastructure Rehabilitation
Research Advisor	Dr. John Myers, RE-CAST Focus Area Leader
Brief Description of Project	Project A: The overall objective of this project is to evaluate existing methods of repair of bridge girders, subjecting a new FRCM system to environmental studies, and a practical field strengthening implementation project. Project B: This study aims at developing sustainable concrete materials for infrastructure applications. The main idea is to develop a cost effective and sustainable ultra-high performance fiber-reinforced concrete (UHPC) to be used in concrete infrastructure applications where enhanced durability and extended service life are key. This study examines UHPC performance in varied bridge joint details and panels.

FEATURED PROJECT

Rapid Pavement Repair

- Alex Hak-Chul Shin, Ph.D., P.E. Associate Professor, Southern University and A&M College
- Denita Walker, Graduate Student, Southern University and A&M College

Cracking in Full-Depth Repair

Instruments to Measure Thermal Properties of Concrete

Portland cement concrete (PCC) pavements have been used with great success in many locations across the U.S. and the world. The main detriment to PCC pavement is rapid repair using hydraulic cement based material: the pavement can develop strength quickly, but in doing so, it generally shrinks and can lead to shrinkage cracking.

The main objective of the research is to determine the feasibility of producing cost effective materials for rapid pavement repair. The study will evaluate mixture optimization as well as fresh and hardened properties and durability aspects of such novel materials through laboratory tests. Two types of pavement technologies will be applied in this project:
1) crack-free early strength concrete, and
2) self-consolidating concrete mixture for repair.

Several methods are being considered to minimize stresses caused by shrinkage and temperature changes. Internal curing using the lightweight aggregate (LWA), recycled concrete aggregate (RCA), expanded slate (shale), and superabsorbent polymer are being investigated. Internal curing can reduce substantial autogenous shrinkage at early age and increase long term strength in high-performance blended cement mortars. The effects of absorption and deception capacity of the aggregate with the size of materials are being investigated. Following these studies, use of synthetic fiber and shrinkage-reducing admixtures (SRA) of repair concrete will be considered.

Field implementation will also be carried out to investigate in-situ performance of the proposed concrete in different geographic locations in the U.S. (e.g., Louisiana and Missouri). The project will also evaluate life cycle cost analysis (LCCA) to determine the economic impact of using such novel material in infrastructure applications.

This project is sponsored by the Louisiana Transportation Research Center (LTRC) and Southern University in partnership with RE-CAST.

UPCOMING WEBINARS

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

May 5, 2015 at 2pm ET

Presenter: Elizabeth Birriel, Florida DOT

"*Connected Vehicle Technology: Current Efforts, Demonstration and Future Plans of FLDOT*"

Will be presented in Spanish with English Closed-Captioning

May 13, 2015 at 11am CDT

Presenter: W. Micah Hale, Professor of Civil Engineering
The University of Arkansas

"*Alkali–Silica Reaction (ASR) and ASR Mitigation*"

Being presented in conjunction with the
Southern Plains Transportation Center at University of Oklahoma

UPCOMING TECHNOLOGY TRANSFER EVENTS

Save the Dates:

SCC2016 - "Flowing Towards Sustainability"

Dates: May 15-18, 2016 **Location: Washington, DC**

Overview: The conference combines the RILEM Symposium on SCC and the North American Conference on the Design and Use of SCC and will be held jointly with the National Ready Mix Concrete Association (NRMCA) International Concrete Sustainability Conference The conference is supported by Missouri S&T, the RECAST Center, NRMCA, the Center for Advanced Cement-Based Materials (ACBM), as well as RILEM and ACI. For more information, visit: www.scc2016.com.

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'RE-CAST University Transportation Center' listed under Groups

APPENDIX E

RE-CAST July 2015 Newsletter

Research on Concrete Applications for Sustainable Transportation

RE-CAST

MISSOURI S&T

Vol. 2 :: Issue 3 :: JULY 2015

In this issue:

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

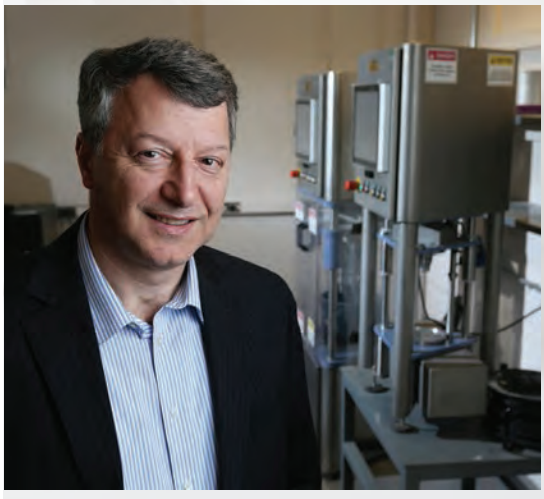
Director's Message

As the summer winds down, RE-CAST has many exciting updates to report.

The RE-CAST partners at Rutgers University and Southern University at Baton Rouge joined forces to offer a special workshop on Structural Health Monitoring from June 1-3 at the Rutgers campus. Over 20 students attended the workshop, which included lectures, laboratory demonstrations and field visits.

RE-CAST has been involved in a number of activities sponsored by Dr. Antonio Nanni, Associate RE-CAST Director at University of Miami, and Chair of the Department of Civil, Architectural and Environmental Engineering, which involved a luncheon in which female students exchanged one on one conversation with distinguished guests and 12 women concrete industry professionals.

On May 5, the RE-CAST Center offered a webinar jointly presented by Elizabeth Birriel, Florida DOT, on "*Connected Vehicle Technology: Current Efforts, Demonstration and Future Plans of FLDOT*" The webinar was presented in Spanish with English Closed-Captioning. The recorded webinar is available for viewing on our website. Please watch our website for upcoming webinars.



This issue of our newsletter provides many more updates on the exciting activities happening at RE-CAST.

-Kamal H. Khayat
RE-CAST Director

EDUCATION/WORKFORCE DEVELOPMENT

Special Workshop: Structural Health Monitoring (SHM) Course of Transportation Infrastructure Facilities -June 1-3, 2015

Partcipants and Instructors for RE-CAST SHM Special Workshop at Rugters University

During the first week of June, a group of 21 students gathered for an accelerated course on the SHM of transportation infrastructure facilities. The workshop was held at the Rutgers Infrastructure Monitoring and Evaluation (RIME) Laboratory and offered participants 2-days of classroom lectures and a half-day for field visits. The classroom lectures covered various SHM topics of concrete bridges as well as pavement and state-of-the-art sensor technologies. The class lectures were also augmented by laboratory hands-on experiences of various SHM sensors, such as weigh-in-motion system and piezoelectric sensors, strain transducers, accelerometers, vibrating wire type sensors, corrosion sensors, creep rig testing set-up, maturity meters, etc. The course was concluded by a visit to two bridges to learn more about field deployment of SHM systems on active projects.

The workshop was led by two faculty members from the RE-CAST Team as shown below. Students from the RE-CAST consortium universities as well as non-consortium universities attended the workshop. This enabled participants from various academic institutions to network with each other and discuss current research topics as well as future research challenges. Students learned the fundamentals of SHM for concrete bridge and pavement, and were able to understand the role of SHM and deployment and data analysis of various sensor technologies.

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EDUCATION/WORKFORCE DEVELOPMENT

Special Workshop (continued)

Instructors:

Dr. Hani Nassif, P.E., Ph.D., FACI, Professor of Civil and Environmental Engineering
Rutgers University and Associate Director of RECAST

Dr. Alex Hak-Chul Shin, P.E., Ph.D., Associate Professor of Civil and Environmental Engineering
Southern University and A&M College

Workshop Lecture Topics:

Topic 1- Concrete Bridges

- 1-1 Fundamentals of SHM for Infrastructure Facilities
- 1-2 Weigh-in-Motion System and Live Load Model Development for Bridges
- 1-3 SHM for the Measurement of Vibration and Strain of Concrete Bridges
- 1-4 SHM for the Evaluation of Railroad Bridges
- 1-5 Corrosion Monitoring of Concrete Bridge Deck
- 1-6 Application of Maturity Method to Assess the Compressive Strength of Cast-In-Place Concrete at Early Ages
- 1-7 SHM for the Development of a Reliability-Based Deflection Limit State for Girder Bridges
- 1-8 SHM of Bridge Approach Concrete Slabs

Topic 2- Concrete Pavement

- 2-1 Overview for Concrete Pavement
- 2-2 Modeling and Analysis of Pavement
- 2-3 Senor Technology and Instrumentation
- 2-4 Field Implementation
- 2-5 Data collection and processing, Examples, and Discussions

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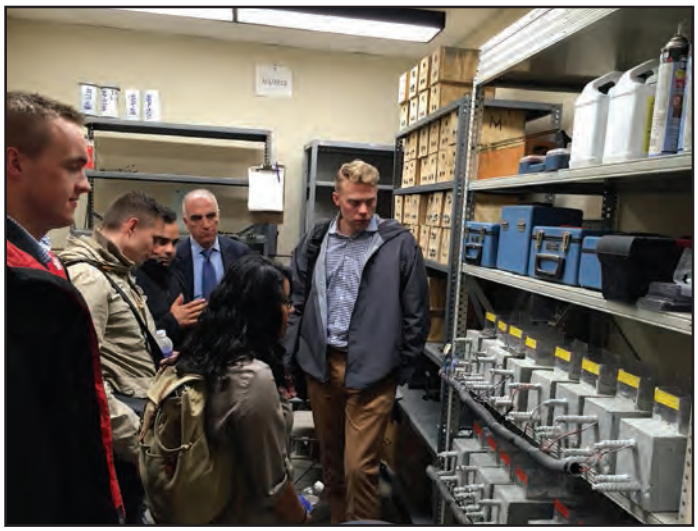
EDUCATION/WORKFORCE DEVELOPMENT

Special Workshop (continued)



Lab Topics

The laboratory portion of the 3-day course provided hands-on experience of the various SHM sensor technologies. Students were able to learn how the sensors are working, how the sensors are instrumented and how to collect and process data. The sensors and systems introduced during laboratory class are (1) weight-in-motion sensor and system, (2) strain transducer and accelerometer with the structural testing system, (3) vibrating-wire type sensors with data logger, (4) creep rig system, (5) multi-probe corrosion sensors, and (6) maturity probe and meter.

Field Visit

The students visited two bridges: the Doremus Avenue Bridge located in Newark Port Area, which is the main truck route for the port area in New Jersey and the New Jersey Turnpike Authority Newark Bay-Hudson County Extension highway near toll plaza 14C on the east extension of the New Jersey Turnpike (I-95). These bridges are one of the most crowded bridges in the New York area. The students were able to learn the actual field SHM implementation data and processing, as well as some of the difficulties associated with sensor instrumentation.

FEATURED PROJECT

Economical and Crack-Free HPC with Adapted Rheology:

Full Scale Specimen Testing

- Jeffery S. Volz, Ph.D., Assoc. Prof. of Civil Engineering, University of Oklahoma
- Jonathan Drury, Ph.D. Candidate, University of Oklahoma
- Derek Garcia, M.S. Student, University of Oklahoma
- Kodi Wallace, M.S. Student, University of Oklahoma

Figure 1. Completed Reinforcing Cage

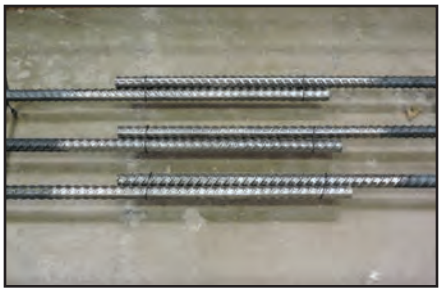


Figure 2. Cleaned Bars

Figure 3. Test Fixture Fabrication

The focus of the University of Oklahoma (OU) research effort for RE-CAST Project 1A involves full-scale specimen design, construction, and testing as well as field implementation of the developed technology. To accomplish these tasks, the OU team has worked in parallel with the Missouri S&T research efforts in developing mix designs based on materials indigenous to the State of Oklahoma. This work has also been conducted in close cooperation with the Oklahoma Department of Transportation (ODOT).

The conventional concrete control mixture for the project is based on an ODOT Class AA mixture, which has the following requirements:

- Minimum Cement Content: 564 lb/yd^3 (335 kg/m^3)
- Air Content: 6.5±1.5%
- Slump: Maximum of 9±1 in. (230±25 mm) after addition of water reducer
- Minimum 28-day compressive strength: 4,000 psi (27.6 MPa)

Based on this mix design, the research team is currently constructing control specimens for bond splice strength and shear strength evaluation. **Figure 1** is a photograph of a completed reinforcing cage for a bond splice test specimen, and **Figure 2** shows a close-up view of the cleaned bars within the midspan splice region of the test specimen. The team is currently installing strain gages at the end of each spliced bar to measure strain during testing. **Figure 3** is a photograph of the test fixture currently under fabrication within the Donald G. Fears Structural Engineering Lab at OU.

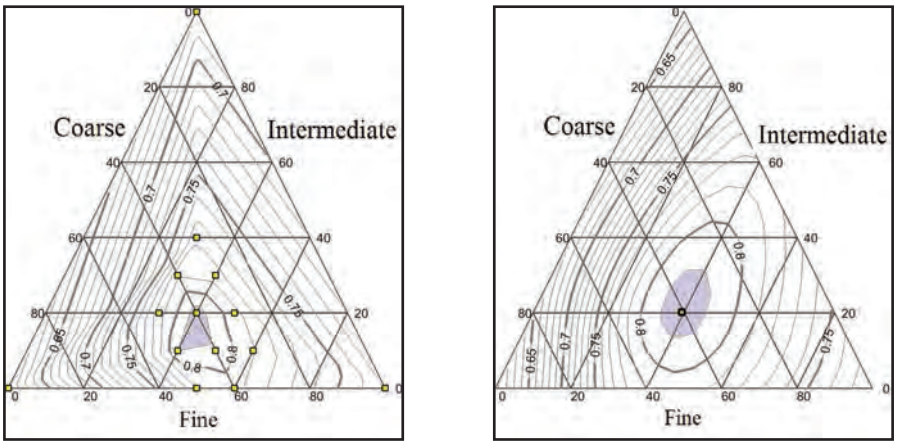
With the focus of the RE-CAST projects on improving the condition of our nation's deteriorating infrastructure, the OU research team has been able to solicit multiple large donations in support of their efforts. These donations included 50 tons of aggregate, 20 tons of cement, and 10 tons of fly ash from the Dolese Bros. Company, Oklahoma City, OK; 30 tons of recycled concrete aggregate and 20 tons of river gravel from Metro Materials, Norman, OK; and a $100,000 equipment grant from the OU Foundation.

FEATURED PROJECT

Roller Compacted Concrete (RCC) for Rapid Pavement Construction

- Kamal H. Khayat, Ph.D., Prof. of Civil Engineering, Missouri S&T
- Nicolas Libre, Ph.D., Asst. Professor (NTT) of Civil Engineering, Missouri S&T

Missouri S&T team in collaboration with Missouri Department of Transportation (MoDOT) has been evaluating the characteristics of Roller Compacted Concrete (RCC) for pavement applications as part of RE-CAST Project 2B. This study aims at developing cost-effective RCC mixtures through optimized particle size distribution to be used in accelerated pavement construction. The first stage of the experimental program was aimed at developing a protocol to assist with selecting aggregate combinations in mixture proportions and to develop a decision support tool and proposed specifications for ternary mixtures. In total, 17 different aggregate types that have been collected from various quarries, and 150 mixtures have been tested for packing density. Numerical techniques were developed to model the packing density of aggregate combinations. A typical comparison of measured packing density with theoretical models in ternary mixture is shown in **Figure 1.** The results of numerical modeling and experimental measurements show that it is possible to estimate the packing density and optimal gradation of certain combination of aggregates given some input parameters identified by the research program, as demonstrated in **Figure 2**.



(a) (b)

Figure 1. Ternary packing diagram of measured packing density (a) and predicted values by model (b) (region with highest packing density are shown in blue)

RCC mixtures with various aggregate blends were also studied. It was found that RCC proportioned with a higher sand-to-coarse aggregate ratio than that indicated for maximum packing were found to exhibit lower workability and compressive strength. Concrete mixtures with very high coarse-to-sand aggregate ratio generally exhibited excessive segregation and higher porosity.

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Roller Compacted Concrete *(continued)*

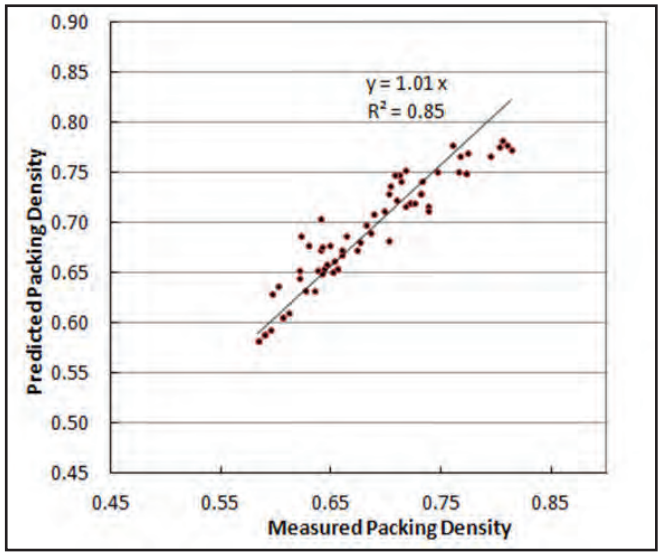

Figure 2. Estimated packing vs. experimental packing density of various aggregate combinations

The research team is also RCC mixture with proper air-void system. As a part of this effort, parameters affecting the stability and microstructure of air-void system will be considered. These parameters include admixture dosage, workability level, mixer type and compaction techniques. Field implementation will also be carried out to investigate in-situ performance of the RCC at different locations in the U.S. Field instrumentation similar to that used in NUTC-MoDOT project carried out in Doniphan, MO in 2013 to monitor the performance of RCC pavement will be employed (**Figure 3**). The research project will also evaluate life cycle cost analysis to determine the economic impact of using such novel material in infrastructure applications.

Figure 3. Sensors and DAQ system powered by solar panel for monitoring performance of RCC pavement performance

OUTREACH/DIVERSITY

A Fascinating Afternoon with the Women in Concrete Alliance

- Diana Arboleda, Ph.D., Lecturer, University of Miami

Women may be a minority in any College of Engineering, but get them to band together towards a goal, and the results are impressive. Recently, a group of graduate and undergraduate women in the Civil Architectural and Environmental Engineering Department (CAE) at the University of Miami wrote to their President, Donna Shalala, asking for her help in getting a number of prominent women in the concrete industry, in town for a conference, to have lunch with them under the sponsorship of RE-CAST. President Shalala was delighted to do so and on the first day of the conference, the UM CAE women students hosted a lunch in which they exchanged one on one conversation with their distinguished guests, 12 women concrete industry professionals.

Among the guests were: ***Anne Ellis***, P.E., former President of the American Concrete Institute and Vice President, Global Initiatives, AECOM, a global provider of architecture, design, engineering, and construction services; ***Julie Garbini***, Executive Director of the Ready Mix Concrete Research & Education Foundation; ***Kimberly Kayler***, Co-founder of the Women in Concrete Alliance (WICA); ***Teresa Cendrowska***, Vice President, Global Cooperation at American Society for Testing and Materials; and, ***Monica Manolas***, Vice President of Human Resources, Cemex, USA. These ladies were speakers at the International Concrete Sustainability Conference and panelists at a forum presented by the Women in Concrete Alliance, an organization whose objective is "to supply information, opportunities, and mentoring to women working in the concrete construction industry."

- Continued Next Page -

OUTREACH/DIVERSITY

Women in Concrete Alliance *(continued)*

Left to right: Vanessa Pino, Diana Arboleda, Zahra Karim, Anne Ellis, Kimberly Kayler, Mahsa Kamali, Jessica Flores, Kristina Carlson

The conversations sparked great interest on both parts for continued interaction through mentoring, networking, a student chapter, and a forum during Engineers' Week in Spring 2015 possibly co-sponsored by RE-CAST.

With a significant representation of women involved in concrete research on their University of Miami campus, including Ph.D. candidates, master students, undergraduate students and an adjunct professor, the UM women in concrete are enthusiastically reaching out to the communities at large to bridge the gap between academic and industry collaborations as well as inspiring the next generation of concrete professionals. They have organized outreach programs to high school students who develop enough interest to volunteer in their laboratories, and have hosted children as young as three years through special activities with hands on learning about concrete.

"As women in concrete and in engineering, they are still a minority, and feel it is important to reach out to other women who are already at high levels in the industry. These are women leaders who are making a difference in construction technology and sustainability, and can be mentors to them. Women can bring a different perspective to the issue of sustainability in construction and social responsibility. Concrete technology is part of the STEM field. Next to water, concrete is the material most used in the world and it is responsible for the development of society through infrastructure."

- Diana Arboleda, Ph.D., Lecturer, University of Miami

DIVERSITY/OUTREACH

Southern University and A&M College hosts *National Summer Transportation Institute*

RE-CAST Researcher Dr. Alex Shin (front, left) participates in SUBR National Summer Transportation Institute

Southern University and A&M College hosted National Summer Transportation Institute (NSTI) during June 1 - 26, 2015. The College of Engineering served as the housing facility for the institute's classroom based activities and construction projects. This year, 24 high school students (9th and 10th grades) were selected to participate from several parishes in Louisiana. **Dr. Alex Shin of RE-CAST** participated in the NSTI as the speaker on June 4, 2015. He presented on-going research on the rapid pavement repair sponsored by RE-CAST and related subjects. RE-CAST supported the purchase of laboratory experiment set-up and supplies for the NSTI activities.

Student Spotlight

RE-CAST Hosts Intern from Nepal : *Nischal P. N. Pradhan*

Nischal P. N. Pradhan, a native of Kathmandu, Nepal, is an undergraduate student studying Civil Engineering at National Institute of Technology Warangal, India. Expressing a deep interest in Concrete Technology, he came to the University of Oklahoma to work with the RE-CAST team as a research intern. There as an intern, he is chiefly involved in the design of concrete mixes in the Fears Laboratory, where he assists other researchers on numerous tasks. He is set to graduate in the summer of 2016.

FEATURED PROJECT

Dynamic Segregation of Self-Consolidating Concrete

- Dimitri Fey, Ph.D., Asst. Professor of Civil Engineering, Missouri S&T
- Aida Margarita Ley Hernandez, M.S. Student, Missouri S&T
- Sarah Vanhooser, Undergraduate Student, Missouri S&T

Figure 1. Tilting Box

Self-Consolidating Concrete (SCC) is an advanced concrete type which does not require external consolidation energy [1]. This is achieved by balancing the requirements for fluidity and passing ability on the one hand, and stability of the fresh concrete on the other hand. Stability is usually assessed by means of the column segregation test (North-America) [2], the sieve stability test (Europe) [3] or the visual stability index, VSI [4], although other tests are also being developed and used in practice. However, the aforementioned tests only determine the stability of SCC at rest. SCC can also segregate during flow, which is referred to as dynamic segregation.

The tilting box test (T-box) is a recently developed assessment method for dynamic segregation (**Figure 1**), allowing cyclic flow of concrete from a horizontal position to an inclined position and back to horizontal [5]. The number of cycles and the cycle time can be adjusted to simulate the flow of concrete inside a formwork. Segregation can be expressed as the volumetric index (VI), which is the difference in the volume of aggregate from the "tilt-down" section relative to the "tilt-up"-section, divided by the average aggregate volume in both sections. The larger VI, the more segregation is observed [5].

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FEATURED PROJECT

Dynamic Segregation of Self-Consolidating Concrete *(con't)*

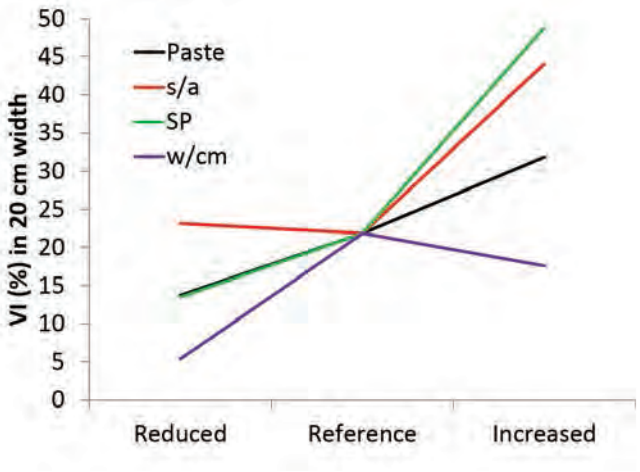

Figure 2. Influence of mix design parameters on dynamic segregation (VI) of SCC

In collaboration with Coreslab Structures, the research team at Missouri S&T has investigated the influence of mix design parameters, such as: slump flow (± 50 mm), w/cm (± 0.05), paste volume (± 25 l/m^3) and sand-to-total-aggregate ratio (s/a, ± 0.05) on dynamic segregation of a typical VMA-type SCC mix design. For all mixtures, the amount of superplasticizer (SP) was adjusted to keep the slump flow constant at 700 ± 20 mm, except for the mixtures where the amount of SP was varied to study the influence of the slump flow. The results show that increasing the paste volume, and increasing s/a beyond a critical value can increase significantly dynamic segregation (**Figure 2**). This observation can be attributed to the lower amount of coarse aggregate and the larger spacing between them, allowing more segregation. Increasing the SP content reduces stability (**Figure 2**), since the reduction in yield stress can contribute to dynamic stability, especially for mixtures with relatively low viscosity [6]. Increasing viscosity by reducing the w/cm decreased VI, but the increase in w/cm did not result in more dynamic segregation (**Figure 2**). Despite the lower viscosity, this effect can be explained by the decrease in SP content which resulted in a higher yield stress, stabilizing the high w/cm SCC mixture. Furthermore, a reduction in formwork width from 20 to 10 cm significantly reduced dynamic segregation for all concrete mixtures tested.

In the next stage of the project, the research team will cast 10 and 20 m long rectangular and I-shaped prestressed SCC beams at Coreslab Structures to determine the influence of the different mix design parameters on dynamic segregation. The segregation results will be linked to the performance of concrete cores, in terms of compressive strength and durability, taken at the top and bottom of the beams, at different distances from the casting point. Bond strength with rebars connected to the top and bottom part of the beam will also be evaluated as a function of the distance from the casting point. These results will lead to recommendations for the maximum VI as a function of flow distance and casting conditions.

FEATURED PROJECT

Dynamic Segregation of Self-Consolidating Concrete *(con't)*

References:

[1] De Schutter G., Bartos P., Domone P., Gibbs J., Self-Compacting Concrete, Whittles Publishing, Caithness (2008), 296pp.

[2] ASTM C1610/C1610M, Standard Test Method for Static Segregation of Self-Consolidating Concrete Using Column Technique (2014), 4pp.

[3] EFNARC, The European Guidelines for Self-Compacting Concrete: Specification, Production and Use (2005), 68 pp.

[4] ASTM C1611/C1611M, Standard Test Method for Slump Flow of Self-Consolidating Concrete, Appendix (2014), 6pp.

[5] Esmaeilkhanian B., Feys D., Khayat K.H., Yahia A., New test method to evaluate dynamic stability of self-consolidating concrete, ACI Materials Journal 111 (3), (2014), pp. 299-307.

[6] Esmaeilkhanian B., Khayat K.H., Yahia A., Feys D., Effects of mix design parameters and rheological properties on dynamic stability of self-consolidating concrete, Cement and Concrete Composites 54 (2014), pp. 21-28.

FEATURED PROJECT

Evaluation of UHPC Joints in Bridge Girders

- John J. Myers, Ph.D., P.E., Professor of Civil Engineering, Missouri S&T

- Saipavan Rallabhandi, Graduate Student, Missouri S&T

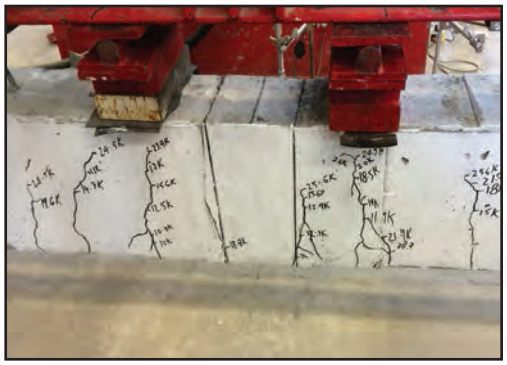

Figure 1. UHPC Joint

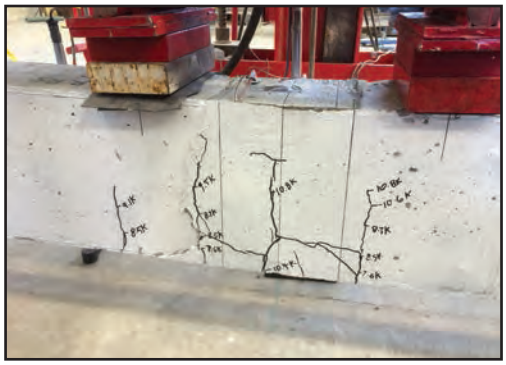

Figure 2. HS-SCC Joint

Dr. John J. Myers and Graduate Student, Mr. Saipavan Rallabhandhi, at Missouri S&T have been studying the applications of Ultra High Performance Concrete (UHPC) in bridge girders as part of RE-CAST program Project 3B. The main objectives of this research sub-task is to evaluate the use of UHPC in joints compared to alternative concretes, such as High-strength SCC (HS-SCC) for bridge girders. The study is also evaluating different joint details and the effectiveness of varied surface preparation.

The test matrix for this phase of work consists of four Control beams, nine HS-SCC beams, nine UHPC beams which have different joint detailing (Straight, Hairpin and Anchored rebar) and three different surface preparations (Smooth, Rough and Sandblasted). Two phases of testing (control and HS-SCC specimens) have been completed to date.

The Control specimen without a joint detail (continuous reinforcement in a monolithically poured element) was designed as tension-controlled

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FEATURED PROJECT

Evaluation of UHPC Joints in Bridge Girders *(continued)*

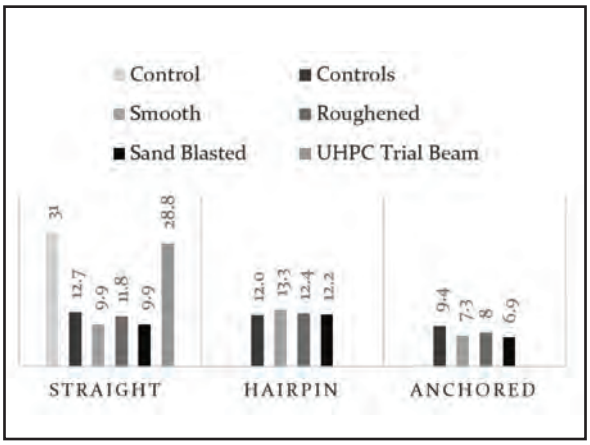

Figure 3. Peak Load

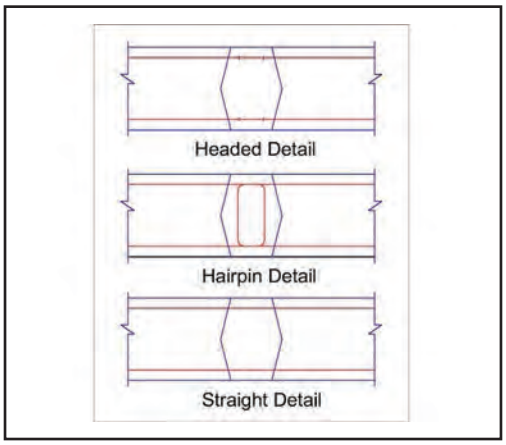

Figure 4. Joint Detail

member and failed at a peak load of 31 kips. The remaining control specimens were cast as single monolithic beams, but with different joint details. They failed in range of 9-13 kip. However, the results from HS-SCC joints with HS-SCC of 9,600 psi compressive strength concrete and different surface preparations were comparable to their respective controls with a similar joint detail. The effect of surface preparation seems to be insignificant in this particular joint detail with a shear key. However, the detail better performing was the hairpin detail because of the improved embedded length within the joint region. Failure was generally due to slippage of rebars in the joint as can be seen from the horizontal crack shown in **Figure 2**. The conventional concrete was not engaged in most cases as the slip occurred at very low loads of 8 to 11 kips in most cases. The deflection was very low corresponding to low failure load of beams. The main reasons for this failure are the concrete in the joint though high strength was not bonded enough, de-bonding at the beam-joint surface.

The first UHPC beam was fabricated as a test trial to date whose joint was filled with UHPC with SCC like properties of flow-ability, durability, high tensile and compressive strengths. It was able to perform similar to a beam without a joint. The peak load was 28 kips and deflection of 0.9-in. The failure mode can be seen in **Figure 1**. The beam was engaged while loading, though the failure started with de-bonding at beam-joint surface, the steel fibers in UHPC played an important role in increasing the capacity. It can be predicted that the UHPC joint will behave if not better, but similar with different joint detailing and surface preparation better than a 4,000 psi beam without a joint.

WEBINAR SERIES

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

May 5, 2015 at 2pm ET

Presenter: Elizabeth Birriel, Florida DOT

"Connected Vehicle Technology: Current Efforts, Demonstration and Future Plans of FLDOT"

Presented in Spanish with English Closed-Captioning

UPCOMING TECHNOLOGY TRANSFER EVENTS

Save the Dates:

SCC2016 - "Flowing Towards Sustainability"

Dates: May 15-18, 2016 **Location: Washington, DC**

Overview: The conference combines the 8th RILEM Symposium on SCC and the 6th North American Conference on the Design and Use of SCC and will be held jointly with the National Ready Mix Concrete Association (NRMCA) International Concrete Sustainability Conference The conference is supported by Missouri S&T, the RECAST Center, NRMCA, the Center for Advanced Cement-Based Materials (ACBM), as well as RILEM and ACI.

For more information, visit: **www.scc2016.com**

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