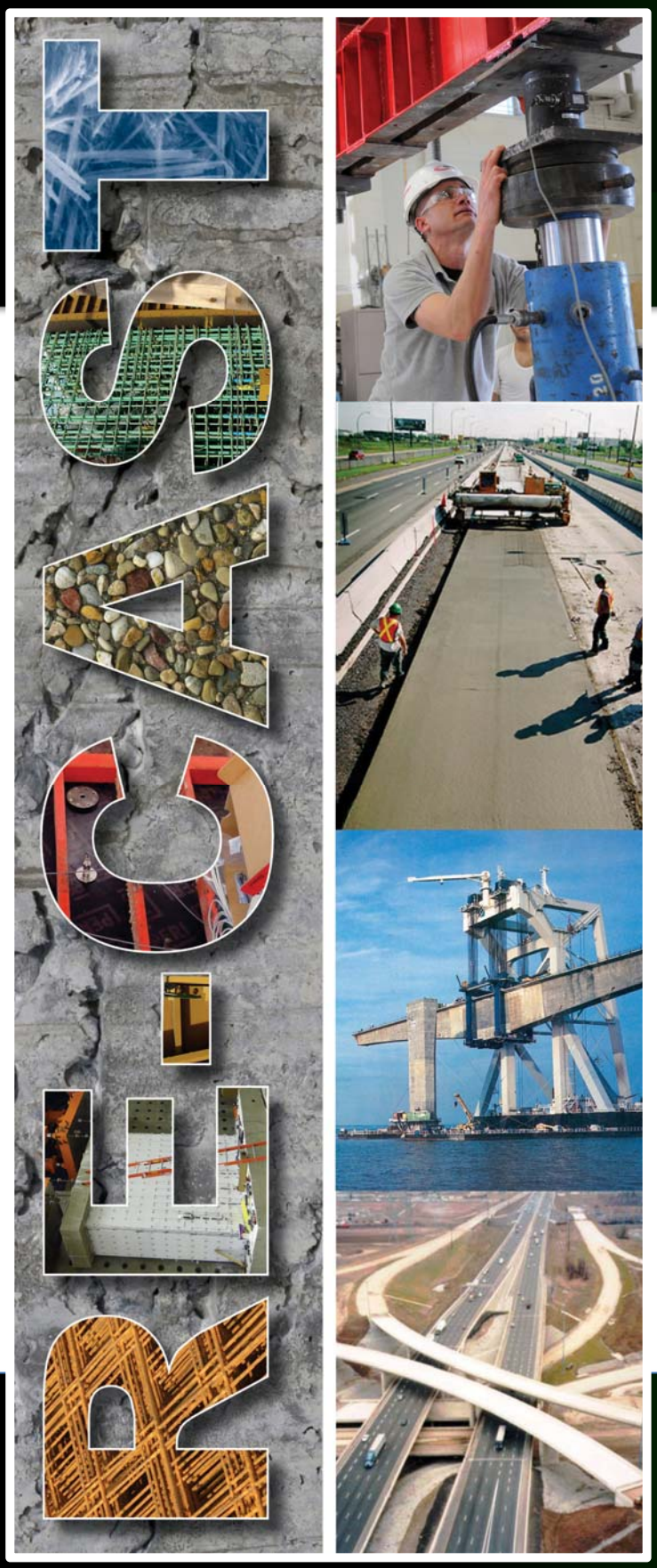

PROGRAM PROGRESS PERFORMANCE REPORT #9

GRANT: DTRT13-G-UTC45
Reporting Period: 10/1/2017 – 3/30/2018

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
- 1-C-1. Optimization of Self-Consolidating Concrete to Guarantee Homogeneity during Casting of Long Structural Elements
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- 3-D. Durability of GFRP Bar Reinforcement Extracted from In-service Concrete Structures
- 3-E. Flexural Performance of Concrete Beams Strengthened using Different Repair Techniques
- 3-F Performance-Based Specifications of Fiber-Reinforced Concrete with Adapted Rheology to Enhance Performance and Reduce Steel-Reinforcement in Structural Members

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: (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 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:

In this reporting period, the following projects were completed and final reports submitted:

Lange, D., "Formwork Pressure Measurements and Prediction of High Performance Concrete with Adapted Rheology," Project 00042134-02-2, Research on Concrete Applications for Sustainable Transportation, USDOT: GRANT: DTRT13-G-UTC45, Project Period: 6/1/2016 – 6/30/17.

Khayat, K.H., Valipour, M., "Design and Performance of Cost-Effective Ultra High Performance Concrete for Bridge Deck Overlays," MoDOT, January 2018, 121 p.

Khayat, K.H., Meng, W., Valipour, M., "Use of Lightweight Sand for Internal Curing to Improve Performance of Concrete Infrastructure," MoDOT, January 2018, 82 p.

Project Updates

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

Missouri S&T - This project seeks to develop and validate the behavior of a new class of ecological and crack-free high-performance concrete (Eco- and crack-free HPC) with the aim of reducing cement content and high resistance to shrinkage cracking designated for sustainable pavement (Eco-Pave-Crete) and transportation infrastructures (Eco-Bridge-Crete). The optimized Eco- and crack-free HPCs were used to cast some large scale slab sections and reinforced concrete beams to evaluate the shrinkage deformation and flexural performance of the optimized Eco-Pave-Crete and Eco-Bridge-Crete. Based on the laboratory investigation and full-scale structural evaluation, recommendations were established for the use of Eco- and crack-free HPC for pavement and transportation infrastructure applications. The final report was submitted to MoDOT in May 2017. The team is collaborating with MoDOT to carry out field implementation.

University of Oklahoma - In May 2017, the research team submitted the final report for their portion of research Project 1A, documenting their findings, recommendations, and guidelines.

Rutgers University - The Rutgers team continued to evaluate the shrinkage performance of FR-SCC with different types of steel and synthetic fibers in accordance with AASHTO Standards. One steel fiber (Sika product, steel hooked) and two synthetic fibers (Sika and Euclid products, macro 1.5") were used. The results show that Euclid synthetic fibers were more effective to reduce crack widths than Sika synthetic fibers when they were compared with typical HPC (23.2% for Euclid vs. 4.8% for Sika). Moreover, Sika steel fibers were slightly more effective than Euclid synthetic fiber 26.3%.

The team implemented the FR-HPC mix design into a major highway bridge in New Jersey. The HPC and FR-HPC mixture were poured alternatively throughout the entire length of bridge deck (approx. 1 mile). The team completed a barrage of testing to evaluate the performance difference between FR-HPC and HPC. Then the team performed the crack mapping of the entire bridge deck (crack width and length were measured). It was found that the fibers reduced the number of crack by 20%, the width of crack by 17%, the cracking area by 33.4% and

the cracking intensity (the cracking area (square inches) divided by the total deck surface area (square foot)) by 33.4%. The team is currently planning to re-visit the bridge and perform another crack mapping and the results will be analyzed and compared.

New York University - The research team has distributed a customized survey to Missouri S&T team to collect information on Ultra-high Performance Concrete (UHPC) as a concrete overlay. Based on the information received, both deterministic and probabilistic methodology have been applied to develop hypothetical LCCA examples for a UHPC bridge deck overlay. Since UHPC as a concrete overlay is a relatively new approach, the research team has carefully investigated several projects using UHPC material in U.S. and Europe as well as the laboratory results from Missouri S&T to determine the best values to use in LCCA. UHPC benefits from three aspects were considered when compare UHPC with conventional Portland Cement Concrete and Latex-modified Concrete: 1) Longer service life, 2) volume reduction, 3) fast construction and public time-saving. A draft report on UHPC was prepared and the final report on project 1-A was reviewed and submitted.

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

This project is complete and a final report was published, as noted previously.

Project 1-C-1. Optimization of Self-Consolidating Concrete to Guarantee Homogeneity during Casting of Long Structural Elements

This project has been completed and a final report was submitted.

Project 1-C-2. Changes in Rheology and Air Void System in SCC Due To Pumping

One additional major pumping test to evaluate the change in rheology, workability, air-void system and freeze-thaw durability of self-consolidating concrete was executed in October 2017. Pumping conditions, i.e. flow rate, boom configuration, presence of a reducer were varied for four mixtures with different initial slump flow. Freeze-thaw tests currently reveal no damage. Scaling tests show damage for some of the mixtures, and is strongly influenced by pumping conditions, especially the flow rate. Scaling tests will be repeated on molded surface instead of finished surface.

Attempting to reverse-engineer the lubrication layer composition through the rheology of paste, mortar and concrete with varying maximum aggregate size has revealed a very strong dependency of the rheological properties on the applied shear rate in the paste. Premixing the cement paste and gently incorporating the aggregate seems to work. Krieger-Dougherty types of relationships are being developed for different aggregate grain size distributions to enable the reverse-engineering of the lubrication layer composition.

Measuring the rheological properties of cement pastes under pressure has revealed an immediate response of viscosity to increased pressure and a majority of the air is dissolved for pressures around 5 bar. This result will help in the analysis of the pumping tests.

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

Missouri S&T - Results obtained from laboratory investigation of various concrete mixtures were analyzed and candidate mixtures were proposed for field implementation. The research team is working along with the Missouri Department of Transportation to secure proper job sites for field implementation phase of the project.

UIUC - This study considers recycled fine materials for controlled low strength materials (CLSM) and foam cement. We are using x-ray computed tomography to capture microstructural information in 3D. We have used 3D printing technology to construct physical models of the foam system to aid interpretation.

The modeling of crushing behavior is advancing well. Yu Song is a PhD student who is using this topic for his PhD dissertation. Kate Hawkins and Karthik Pattaje are MS students involved in laboratory work related to materials incorporating recycled fines with adapted rheology for sue in additive manufacturing and 3D printing.

The work has produced models of structure and experiments on crushing behavior that is the subject of dynamic (LS-DYNA) models of crushing behavior. These models form the basis of materials design methodology.

Jamie Clark completed her MS thesis in December 2017 with thesis entitled "Characterization of the Cellular Structure of Foamed Cement using X-ray computed tomography [2017]. The thesis represents a major report of results of this project.

University of Oklahoma - The team is working with one of our industry sponsors, Dolese Bros., the research team developed large-scale concrete mixes containing 100% RCA for the coarse aggregate. Aggregate preparation included pre-wetting the RCA to reach SSD conditions. The mixes were used to construct several pavement slabs within a new parking lot for a local Norman, Oklahoma business. These mixes met all quality control measures for the project. As a result, recommendations for using high amounts of RCA in mix designs will include methods similar to using lightweight aggregate, such as pre-wetting to achieve a consistent product.

New York University - Life Cycle Cost Analysis: Refer to project update in Project 1-A.

Project 2-A-2. Passive Wireless Sensors for Monitoring Behavior of Recycled Aggregate Concrete

The UIUC team is implementing a passive RFID system with modules for RH/TEMP and STRAIN measurement. We are evaluating the performance of RFID data logger and wireless read ranges of RFID system, and study material factors that influence performance. The project includes development of methods for embedding passive RFID tags into concrete materials. This sensor system allows for fast and contact-free reading of data. These technologies contribute to health monitoring strategies and sustainable construction.

Project 2-B-1. Rapid PCC Pavement Rehabilitation

The research team continued on improving the high early strength concrete (4,000 psi in 4 hours) to be used in rapid joint rehabilitation of PCC pavement. The standard procedures to absorb water inside the aggregates before the mix for internal curing and make the aggregate in saturated surface drying (SSD) condition were achieved and useful to make consistent moisture conditions of aggregate and water content of the mixture.

In an effort to understand the effects of RCA on early age strength of concrete, recycled concrete aggregate (RCA) was replaced with virgin aggregate. The preparation of virgin aggregate was the same as the RCA, and achieved SSD condition before mixing. The field implementation is planned to observe surface cracking and any other potential problems in the mixture and joint repair project.

Project 2-B-2. Rapid Pavement Construction

Missouri S&T - Highly flowable, highly thixotropic SCC mixtures could not be developed, based on the materials investigated. As a result, the hardened properties evaluation will not be performed on this project. Instead, the research team is using the results to distinguish between structural build-up caused by flocculation or hydration and intends to deliver more extensive interpretation tools for certain rheological test methods. The final report is under production.

SUBR - A separate project was initiated to develop vibration-free concrete (VFC) mixtures in corporation with Dr. Feys in Missouri University of Science and Technology. Dr. Feys provided three VFC mixtures and the measurement of hardened concrete properties is proceeded. With selected mixtures, the bond strength test between VFC repair concrete and old concrete is planned. Dr. Shin is planning for mini-slab test in the laboratory.

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

The research project seeks to develop guidelines for the use of RCC for rapid construction of concrete pavement. Work progress concentrated on the optimization of aggregate combinations to achieve maximum packing density, determining proper production techniques to adjust the air-void system in RCC. The optimized concrete mixtures are found to satisfy strength requirements for pavement construction. Work is under way to prepare for field implementation in collaboration with MoDOT and the City of Mexico, MO for summer 2018.

Project 3-A. Performance of Fiber Reinforced Self-Consolidating Concrete (FR-SCC) for Repair of Bridge Sub-Structures & Fiber-Reinforced Super-workable Concrete (FR-SWC) for Infrastructure Construction

Missouri S&T - The optimized FR-SWC was used for bridge deck construction involving approx. 330 yd^3 of concrete in summer 2017. The team continues to monitor in-situ concrete strain, temperature, and relative humidity. Finite element modeling is also underway to validate the results.

University of Oklahoma - The implementation phase of this project involves repairs to the I-244 Bridge over the Arkansas River. The repairs were completed in mid-September, and the research team designated one of the repaired girders for testing. This girder was removed from the bridge and transported to the University of Oklahoma Structural Engineering Laboratory. The structural repair capacity test will involve loading two end regions of the girder to failure in separate stages. Both end regions of the 50-foot-long girder experienced significant deterioration and required repairs to the prestressing strand and mild steel in the girder and deck. Both the girder and deck were patched with the fiber-reinforced, self-consolidating concrete (FR-SCC) repair material developed in this project. The results of this load test will be used to evaluate the efficacy of the FR-SCC repair material through comparison with the results of the tests of a control girder previously removed from the bridge and designated in good condition.

Rutgers University -The team completed testing 55 of small scale and repaired beams, and developed the crack map for each individual beam. Based on the experimental results, the following conclusions were made. (1) FR-SCC and FR-Ferro repair mixes provided improved flexural capacity. (2) The fiber content plays an important role in crack initiation regardless of fiber type but does not affect the ultimate load capacity. (3) The proposed mixes could be effective and viable options to repair the damaged beam at a relatively low cost and in a short time. In addition, the team tested eight (8) of large scale and 2-span continuous prestressed T-section beams with steel tendons. The team is currently compiling and analyzing the testing results (strain, stress and deflection data) and will report the results in the next report.

New York University - Life Cycle Cost Analysis: Refer to project update in Project 1-A.

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

This project has been completed and a final report was submitted.

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

Missouri S&T - During this reporting period, the repair design process for the strengthening of a four span bridge for rehabilitation has reached the 85% stage. The bridge site was visited and thoroughly surveyed. All remedial concrete work was documented. This structure will serve as the implementation project and test bed for pre- and post-strengthening load testing. During the next reporting period the current project schedule includes finalizing the repair design using four different repair systems (one for each span). Then, during the next reporting period, strengthening and evaluation of the repair systems will initiate with coordination of technician support at Missouri S&T to assist in the implementation. This field implementation project also involves partners at the University of Miami. A no cost extension will be requested to complete all aspects of the project due to delays associated with a very harsh and extended winter conditions in Missouri.

University of Miami - The final report was completed and submitted for the University of Miami tasks.

Project 3-C-2. FRP Reinforcement for Concrete: Performance Assessment and New Construction

Volumes I and III of III of the final report was completed and submitted. Volume II is being finalized. During the reporting period, UM research efforts were devoted to continuation of work on this project. Specimens were extracted from five bridges during the previous quarter have been partially tested. Based on the outcomes of these tests, it will be possible to establish the potential aging and degradation of FRP reinforcement subject to service conditions under different environments and states of stress for various years

Project 3-C-3. Use of Internal Curing Materials to Improve Performance of Concrete Infrastructure

The effect of different curing regimens was explored to establish the beneficial effect of internal curing using lightweight sand. The project was finished during this reporting period and a final report is under preparation.

Project 3-D. Durability of GFRP Bar Reinforcement Extracted from In-service Concrete Structures

Missouri S&T - During this reporting period, a series of FRP reinforced bridges constructed 15-18 years ago were autopsied in several states to study the long-term performance of fiber reinforced polyer (FRP) bridges. Samples were received during this period at Missouri S&T and physical and microscopic evaluation of the samples was initiated. During the next reporting period evaluation of the autopsied samples will continue. The ACI Foundation, a sponsoring agency for this project, has identified three (3) additional new bridges to be added to the project list for sampling and evaluation to augment the data base of study. These additional projects will increase the size of the data base and significance of the work being undertaken. A no cost extension will be requested to allow addition study.

University of Miami - The University of Miami is providing assistance in round robin testing of samples extracted from various bridges.

Education and Workforce Development (EWD) / Outreach Objectives Accomplished

1) Invited seminar: Dimitri Feys - Rheology: The Link Between Mix Design, Placement and Performance of Concrete, Research seminar, University of Arkansas, Fayetteville, AR (February 2018)
2) Invited seminar : Dimitri Feys - Why Placement is Critical for the Long-Term Performance of (Self-Consolidating) Concrete, Research seminar in Concrete Materials area, University of Illinois at Urbana Champaign, Champaign, IL (February 2018)
3) Univ. of Jinan Plan 111, Nov. 5, 2017 – seminar by David Lange and future collaboration with faculty at Jinan over next five years. Students will be trained. Recycled concrete work from RE-CAST will be moved forward.
4) “Concrete Design Symposium 2017” October 2-3, 2017, Simpson Strong-Tie Manufacturing and Training Facility West Chicago, Illinois. Short course on FRCM presented by A. Nanni.
5) “Taller Internacional: Rehabilitación de Estructuras de albañilería con Sistemas Adheridos – Avances y experiencia internacional: Parte I y II” during “XIII Convención Internacional ACI PERU - Cusco 2017,” Centro de Convenciones Mun. De Cusco. Short course on FRCM presented by A. Nanni.
6) 2018 FDOT-FRP Industry 2nd Winter Workshop, Fri, Feb 9, 2018. Presentation by A. Nanni
7) “The Past, Present, and Future of Structural Health Monitoring (SHM) of Civil Infrastructure” on Wednesday, 12/13/2017 Webinar presented by Dr. Hani Nassif, Rutgers University.

Technology Transfer Objectives Accomplished

1) The RE-CAST website contains links to listing of upcoming technology transfer events, educational seminars and workshops, presentations, and project reports.
2) The 7th annual Missouri S&T/MoDOT Transportation Infrastructure Conference took place in Rolla, MO on Friday, December 8, 2017. Keynote speakers include Dr. Amr Elnashai, Vice President/Vice Chancellor for Research and Technology Transfer at the University of Houston, Dr. David Lange, Director of the Center for Excellence for Airport Technology at University of Illinois at Urbana-Champaign and Dr. Peter Taylor, Director of the National Concrete Pavement Technology Center at Iowa State University.
3) Brown Bag Seminar at O’Hare International Airport, Kamal Khayat, Jan 17, 2018. Included discussions with Chicago Department of Aviation about demo projects in Summer 2018.
4) “The Past, Present, and Future of Structural Health Monitoring (SHM) of Civil Infrastructure” on Wednesday, 12/13/2017 Webinar presented by Dr. Hani Nassif, Rutgers University.
5) Several RE-CAST faculty presented keynote and invited presentations, as elaborated in part below.

Diversity Objectives Accomplished

1) Missouri S&T has made an effort to enhance diversity in the graduate and undergraduate team helping with the large scale pumping tests. They have recruited one female undergraduate for a 1-semester research program, have recruited a Hispanic M.Sc. student and have a paid African-American undergraduate student. A female post-doc fellow and a female PhD candidate joined Dr. Khayat's RE-CAST team in Fall 2017.
2) Rutgers University has recruited female and minority undergraduate students to help test beams.
3) NYU has a female graduate student conducting the LCCA research portions of the RE-CAST projects.
4) Southern University and A&M College hosted the **Summer Transportation and Energy Institute** (STEI) in the summer 2018. Dr. Alex Shin of RE-CAST gave a lecture on RE-CAST projects and provided financial support to buy teaching materials.
5) UIUC student Jamie Clark, an African American female student, is in Prof. D. Lange's group working with partial support from RECAST funding.
6) Three University of Oklahoma female undergraduate students completed their honors college research as part of RE-CAST Projects 2A and 3A. The students, Kayla Buster, Maranda Leggs, and Michelle Manwarren presented their research at the 2017 Oklahoma Transportation Research Day.

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

The RE-CAST has archived a library of webinars provided by the Center in the Missouri S&T Scholars Mine. The webinars are available to the public at no charge.

For the full-scale pumping tests, (senior) undergraduates and graduates are encouraged to help the research team, exposing the students to field testing of concrete, concrete mixing, transport and placement, etc. So far, 10 undergraduate and 7 graduate students have been involved in the testing.

The Rutgers team hosted an ethic courses for the local transportation agency on 3/9/2018.

1.D - How Have The Results Been Disseminated?

Prof. D.A. Lange is serving as ACI President in 2018-19 and will be reporting on RE-CAST through the year during his many presentations to ACI Chapters.

David Lange, "Novel Solutions for Recycling Concrete at Airports" Keynote lecture,CIES Symposium, Rolla, MO, December 8, 2017.

Progress in RE-CAST research has been presented at the ACI Spring Convention in Salt Lake City. Results on project 2B were presented in a session on controlling fresh SCC properties. Results from 1C-2 were discussed in a session on undergraduate research, and the project evolution was discussed during the ACI 237 (SCC) committee meeting.

The Rutgers team proposed the FR-HPC and FR-HESHPC to the local transportation agency. The FR-HPC has been implemented in one major bridge in New Jersey and the FR-HESHPC is currently being reviewed by the agency and engineers. The team is assisting the contractors and the engineers for the success of the implementation for the bridge deck.

Key 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 2018 in Las Vegas, 2018 TRB Meeting in Washington, D.C., ACI Spring 2018 Convention in Salt Lake City, UT, ACI Fall 2018 Convention in Las Vegas, NV, the annual ACERS Cements conference in State College, PA, June 2018, the 12th UTC Spotlight Conference in Washington D.C., as well as overseas, including the 10th International Conference on Cement and Concrete, ISCC2018, China.

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

- **Summer Transportation Institute at SUBR -** Southern University and A&M College will host National Summer Transportation Institute (NSTI) 2018. 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 (9th and 10th 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.

- **S&T Transportation Infrastructure Conference -** December 8, 2017.
- For project 1C-2: The project from ACI will run until Dec 2018. One more pumping test has been performed early April 2018, and three more are planned between April and June 2018. Results will be analyzed soon. Other experimental work is ongoing to further understand the behavior of air under pressure and the formation of the lubrication layer
- In the next reporting period, the Missouri S&T and University of Miami teams will continue to work on Phase II of Field Implementation Project involving field strengthening and rehabilitation.
- The Rutgers team will perform the additional crack mapping of the bridge deck with FR-HPC and HPC mix. Then the results will be compiled to quantify the effect of the FR-HPC and HPC on the concrete cracking performance. In addition, the team will work to complete the verification process of the FR-HESHPC mix.
- The Rutgers team will prepare 4 additional continuous prestressed T-section beams with steel tendons to perform a single point load testing. The team will evaluate the behavior of concrete beams prestressed with both unbonded and bonded tendons under two loading types.
- The New York University team will continue to collaborate with Rutgers team on implementing project-level and network-level LCCA for the four repair techniques proposed in Project 2-D. The team will continue to work on the implementation of Network LCCA features and incorporate it into the web-based LCCA software.
- In the next reporting period, SUBR plans to: Finalize concrete mixtures satisfied the target strength focusing on the repeatability of the mixture by controlling moisture conditions on LWA and RCA. Apply the early strength concrete to the pre-field and field implementation. Measure hardened properties of vibration free concrete (VFC) mixes provided by Missouri S&T. Fabricate bond strength specimens with the selected VFC mixes and identify the mixes that can be used in bonded concrete overlay and apply in pre-filed test. Using the measured physical properties and performance, a numerical model will be developed to predict the performance of bonded concrete overlay.

2. PRODUCTS

2.A - Publications, Conference Papers, and Presentations

1) **Journal Publications** (in part):

Megid, W.A., **Khayat, K.H.**, Evaluating Structural Buildup at Rest of SCC Using Workability Tests, ACI Materials Jr., 115(2), March 2018, pp. 257-265.

Meng, W., **Khayat, K.H.**, and Bao, Y., Flexural Behavior of Ultra-High Performance Concrete Panels Reinforced with Embedded Fiber-Reinforced Polymer Grids, Cement, Concrete and Composites, April 2018.

Bate, B., Zhu, J., Cao, J., and **Khayat, K.H.**, Determination of Mortar Setting Times Using Shear Wave Velocity Evolution Curves Measured by the Bender Element Technique, Cement and Concrete Research, 106, 2018, pp. 1-11.

Meng, W., **Khayat, K.H.**, Effect of Graphite Nanoplatelets and Carbon Nanofibers on Rheology, Hydration, Shrinkage, Mechanical Properties, & Microstructure of UHPC, Cement & Concrete Research, 2018, pp. 64-71,

Mehdipour, I., **Khayat, K.H.**, Enhancing the Performance of Calcium Sulfoaluminate Blended Cements with Shrinkage Reducing Admixture or Lightweight Sand, Cement and Concrete Composites, 87, 2018, pp. 29-43.

Mehdipour, I., **Khayat, K.H.**, Understanding the Role of Particle Packing Characteristics in Rheo-Physical Properties of Cementitious Suspensions: A Literature Review, Construction and Building Materials, 161, Feb. 2018, pp. 340-353.

Mehdipour, I., Zoughi, R., **Khayat, K.H.**, Feasibility of using Near-Field Microwave Reflectometry for Monitoring Autogenous Crack Healing in Cementitious Materials, Cement and Concrete Composites, 85, 2018, pp. 161-173. doi.org/10.1016/j.cemconcomp.2017.10.014.

Hwang, S.D., Lepesqueux, E., and **Khayat, K.H.**, Effect of Lightweight Aggregate on Key Properties of SCC Designated for Repair Applications, Jr. of Sustainable Cement-Based Materials, 7 (2), 2018, pp. 79-98.

Wu, Z., Shi, C., **Khayat, K.H.**, Multi-Scale Investigation of Microstructure, Fiber Pullout Behavior, and Mechanical Properties of Ultra-High Performance Concrete with Nano-CaCO3 Particles, Cement and Concrete Composites, 2018, 86, Feb., pp. 255-265.

Meng, W., **Khayat, K.H.**, Effect of Hybrid Fibers on Fresh Properties, Mechanical Properties and Autogenous Shrinkage of Cost-Effective UHPC, Journal of Materials in Civil Engineering, 30 (4), 2018, 04018030,

Meng, W., Samaranayake, V.A., and **Khayat, K.**, Factorial Design and Optimization of UHPC with Lightweight Sand, ACI Materials Jr., Jan.-Feb. 2018, pp. 129-138, DOI: 10.14359/51700995.

Mehdipour, I., **Khayat, K.H.**, Elucidating the Role of Supplementary Cementitious Materials on Shrinkage and Restrained Shrinkage Cracking of Flowable Eco-Concrete, Jrnl. of Materials in Civil Engineering, 30(3), 2018.

Sadati, S., **Khayat, K.H.**, Rheological and Hardened Properties of Mortar Incorporating High-Volume Ground Glass Fiber, Construction and Building Materials, 5 (152), 2017, pp. 978-89.

Hosseinpoor, M., **Khayat, K.H.**, and Yahia, A., Numerical Simulation of Dynamic Segregation of Self-Consolidating Concrete (SCC) in T-Box Set-up, Computers and Concrete, 20 (3), 2017, pp. 297-310.

Meng, W., **Khayat, K.H.**, Effects of Saturated Lightweight Sand Content on Key Characteristics of Ultra-High-Performance Concrete, Cement and Concrete Research, 101, 2017, pp. 46-54.

Meng, W., Yao, Y., Mobasher, B., and **Khayat, K.H.**, Effects of Loading Rate and Notch-to-Depth Ratio of Notched Beams on Flexural Performance of Ultra-High-Performance Concrete, Cement and Concrete Composites, 83, 2017, pp. 349-59.

Hosseinpoor, M., **Khayat, K.H.**, and Yahia, A., Numerical Simulation of Self-Consolidating Concrete Flow as a Heterogeneous Material in L-Box Set-up: Effect of Rheological Parameters on Flow Performance, Cement and Concrete Composites, 1 (83), 2017, pp. 290-307.

Sadati, H., **Khayat, K.H.**, Restrained Shrinkage Cracking of Recycled Aggregate Concrete, Materials and Structures, 50 (4), 2017, p. 206.

Long, W., **Khayat, K.H**., Yahia, A., Hwang. S.-D., and Xing, F., Rheological Approach in Proportioning and Evaluating Prestressed Self-Consolidating Concrete, Cement and Concrete Composites, 82, 2017, pp. 105-116.

Liu, J., Shi, C., Ma, X., Khayat, K.H., Zhang, J., and Wang, D., An Overview on the Effect of Internal Curing on Shrinkage of High Performance Cement-Based Materials, Construction & Building Materials, 15 (146), 2017, pp. 702-712.

Sadati, H., **Khayat, K.H**., Rheological and Hardened Properties of Mortar Incorporating High-Volume Ground Glass Fiber, Construction & Building Materials, 152, 2017, pp. 978-989.

Mehdipour, I., Kumar, A., and **Khayat, K.H**., Rheology, Hydration, and Strength Evolution of Interground Limestone Cement Containing PCE Dispersant and High Volume Supplementary Cementitious Materials, Materials and Design, 127, 2017, pp. 54-66.

Aljaberi, Z.K., **Myers, J.J.**, ElGawady, M.A., "Pseudo-Static Cyclic Loading Comparison of Reinforced Masonry Walls Strengthened with FRCM or NSM FRP," Elsevier's Construction and Building Materials, Amsterdam, Netherlands, April 2018, Vol. 167, Pages 482-495, doi.org/10.1016/j.conbuildmat.2018.02.043.

Aljazaeri, Z.R., **Myers, J.J.**, "Erratum for Strengthening of Reinforced Concrete Beams in Shear with a Fabric-Reinforced Cementitious Matrix," American Society of Civil Engineering – Journal of Composites for Construction, doi: 10.1061/(ASCE)CC.1943-5614.0000726, December 2017, Vol. 21, No. 6, 21(6)08217001-1.

Alghazali, H.H., **Myers, J.J.**, "Shear Behavior of Full-Scale High Volume Fly Ash-Self Consolidating Concrete (HVFA-SCC) Beams," Elsevier's Construction and Building Materials Journal, Amsterdam, Netherlands, Vol. 157, December 2017, pp. 161-171, doi: https://doi.org/10.1016/j.conbuildmat.2017.09.061.

Alghazali, H.H., **Myers, J.J.**, "Optimization Performance of High Volume Fly Ash Self-Consolidating Mixtures with Hydrated Lime (Mortar Component)," ACI Special Publication, MI, SP-320-46, August 2017.

Alghazali, H.H., **Myers, J.J.**, "Performance Study of Ecological Self-Consolidating Cement Mixtures (ECO-SCCM)," American Society of Civil Engineering – Journal of Materials in Civil Engineering, Vol. 29, Issue 12, December 2017, pp. 1-11, doi: https://doi.org/10.1061/(ASCE)MT.1943-5533.0002102.

Gooranorimi, O., **Myers, J.**, and **Nanni, A.**, "GFRP Reinforcements in Box Culvert Bridge: A Case Study After Two Decades of Service," Concrete Pipe and Box Culverts, ASTM STP1601, J. Meyer and J. Beakley, Eds., ASTM International, West Conshohocken, PA, October/November 2017, pp. 75–88,

Aljazaeri, Z.R., **Myers, J.J.**, "Strengthening of Reinforced Concrete Beams in Shear with a Fabric-Reinforced Cementitious Matrix," ASCE Journal of Composites for Construction, October 2017, Vol. 21, No. 5, pp. 1-11.

Conference Papers (in part):

Alghazali, H.H., **Myers, J.J.**, "Evaluation of Prestress Losses for Bridge A7957 Constructed with High Strength Concrete (Field Study)," 2017 PCI Convention and National Bridge Conference, Denver, Colorado, Feb. 20-24, 2018, 14 pages.

Al-Jaberi, Z., **Myers, J.J.**, ElGawady, M.A. "Environmental Effect on Reinforced Masonry Walls Strengthened with NSM and Cementitious Adhesive," Proceedings for the 10th Australasian Masonry Conference, Sydney, Australia, February 11-14, 2018. Paper Submitted, 12 pages.

Gheni, A.A., ElGawady, M.A., **Myers, J.J.**, "New Eco-friendly Masonry Units for Better Thermal and Acoustic Insulation," Proceedings for the 10th Australasian Masonry Conference, Sydney, Australia, February 11-14, 2018. Paper Submitted, 12 pages.

Rallabhandhi, S., **Myers, J.J.**, "Non-Prestressed Bridge deck-girder composite with End-Girder Continuity Detail using Ultra High Performance Concrete (UHPC) within the End Connection," 3rd International Symposium on Ultra-High Performance Fibre-Reinforced Concrete (UHPFRC 2017), Montpellier, France, October 2-4, 2017, Paper Submitted, 8 pages.

Alghazali, H.H., **Myers, J.J.**, "Evaluation of Strains and Stresses of Prestressed Girders for Bridge A7957, MO, USA (Field Study)," 4th International Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures (SMAR 2017), Zurich, Switzerland, September 13-15, 2017, Paper Submitted, 8 pages.

Hernandez, E., **Myers, J.J.**, Chen, G., "Dynamic Load Allowance of a Prestressed Concrete Bridge through Field Load Tests," 4th International Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures (SMAR 2017), Zurich, Switzerland, September 13-15, 2017, Paper Submitted, 8 pages.

Aljaberi, Z., **Myers, J.J.**, ElGawady, M.E., "Effectiveness of FRCM System in Strengthening Reinforced Masonry Walls Subjected to Cyclic Loading," 39th International Association for Bridge & Structural Engineering (IABSE 2017), Vancouver, BC, Canada, Sept. 19-23, 2017, Paper Submitted, 9 pages.

Aljazaeri, Z.R., Alghazali, H.H., **Myers, J.J.**, "Flexure Performance of Two-Way Concrete Slabs Reinforced with Carbon Fiber Grid," 39th International Association for Bridge & Structural Engineering (IABSE 2017), Vancouver, British Columbia, Canada, September 19-23, 2017, Paper Submitted, 10 pages.

Aljazaeri, Z.R., Janke, M., **Myers, J.J.**, "Experimental Investigation on Anchorage Systems for Enhancing the Mechanical Performance of FRCM Composites in Retrofitting RC Structural Beams," 8th International Conference on Advanced Composites in Construction (ACIC 2017), University of Sheffield, Sheffield, England, UK, September 5-7, 2017, Paper Submitted, 6 pages.

Wang, W., **Myers, J.J.**, "Flexural Behavior of GFRP Reinforced Panels with Varying Reinforcement Ratios after Long-term Filed Exposure," 8th International Conference on Advanced Composites in Construction (ACIC 2017), University of Sheffield, Sheffield, England, UK, September 5-7, 2017, Paper Submitted, 6 pages.

Gooranorimi, O., G. Claure, W. Suaris and **A. Nanni**, "Bond-Slip Effect in Flexural Behavior of GFRP RC Slabs," Composites Structures, https://doi.org/10.1016/j.compstruct.2018.03.027

Spadea, S., M. Rossini and **A. Nanni**, "Design Analysis and Experimental Behavior of Precast Double-Tee Girders Pre-Stressed with CFRP Strands," PCI Journal, Vol. 63, No. 1, Jan.-Feb. 2018, Pp.72-83.

Gooranorimi, O., G. Claure, F. De Caso and **A. Nanni**, "Post-Fire Behavior of GFRP Bars and GFRP-RC Slabs," ASCE JMCE, Vol. 30, No. 3, March 2018, 040117296-1 to 8.

Presentations (in part):

Dimitri Feys

Dimitri Feys, Controlling Fresh Properties of SCC: Why Mixing Energy and Placement Matter, Presented during the ACI Spring Convention, Salt Lake City, UT, March 2018

Alexandra Wehar, Dimitri Feys, Kyle Riding, Influence of Pumping Parameters on the Freeze-Thaw and Scaling Resistance of Highly Workable Concrete, ACI Spring Convention, Salt Lake City, UT, March 2018

Invited seminar: Dimitri Feys - Rheology: The Link Between Mix Design, Placement and Performance of Concrete, Research seminar, University of Arkansas, Fayetteville, AR (February 2018)

Invited seminar : Dimitri Feys - Why Placement is Critical for the Long-Term Performance of (Self-Consolidating) Concrete, Research seminar in Concrete Materials area, University of Illinois at Urbana Champaign, Champaign, IL (February 2018)

Kamal H. Khayat

2018 American Concrete Institute **(ACI) Wason Medal for the Most Meritorious** paper published by the institute in 2016. Nov. 2017; presented March 2018. Paper: Gardner, Keller, **Khayat, Lange**, and Omran, "Field Measurements of SCC Lateral Pressure - Toronto 2014 Experimental Program SCC under Pressure, Concrete International, March 2016.

Khayat, K.H., Wu, Z. Mehdipour, I., The Role of Particle Characteristics in the Design and Performance of Eco-Crete, Proceedings 9th International Conference on Cement and Concrete, Editor Yao Y., ISCC2017, Wuhan, China, November 1-3, 2017. Keynote presentation.

Khayat, K.H., Influencing Factors and Models to Predict Form Pressure Exerted by SCC, ACI Spring Convention, Salt Lake City, Utah, March 24-28, 2018. Invited presentation.

Meng, W., Khayat, K.H., Feasibility of Using GFRP Reinforced UHPC Elements for Stay-In-Place Formwork, ACI Spring Convention, Salt Lake City, Utah, March 24-28, 2018. Invited presentation.

Khayat, K.H., Robustness of SCC Incorporating Different Viscosity-Enhancing Admixtures, ACI Spring Convention, Salt Lake City, Utah, March 24-28, 2018. Invited presentation.

Khayat, K.H., Surface Settlement of SCC – How Critical is it on Concrete Performance? ACI Spring Convention, Salt Lake City, Utah, March 24-28, 2018. Invited presentation.

Abdulhameed, H., Nassif, H., and Khayat, K.H., Use of Fiber-Reinforced Self-Consolidating Concrete to Enhance Serviceability Performance of Damaged Beams, TRB 2018, Jan. 2018.

David Lange

D.A. Lange, "Characterization of the Crushing Behavior of Foam Concrete", invited lecture at Brunel University, London, Sep 16, 2017.

Koch, Jeremy A.; Castaneda, Daniel I.; Lange, David A.; Ewoldt, Randy H., "Granular physics in yield-stress fluids: Carbopol suspensions versus wet concrete," Society of Rheology Annual Meeting, Tampa, FL, February 12-16, 2017.

Y. Song and D.A. Lange, "Crushing Behavior of Foam Concrete," in Proc. of the 9th Int'l Symposium on Cement and Concrete (ISCC2017), Wuhan, China, October 31 - November 3, 2017

David Lange, "Novel Solutions for Recycling Concrete at Airports" keynote lecture at CIES Symposium, Rolla, MO December 8, 2017.

John J. Myers

"Diagnostic Test for Load Rating of a Prestressed SCC Bridge," ACI 2017 Fall Conference, Anaheim, California, October 16, 2017 (co-presenter, ACI Committee 239 as Special Invited Presentation).

"Diagnostic Test for Load Rating of a Prestressed SCC Bridge," American Concrete Institute (ACI) 2017 Fall Conference, Anaheim, California, October 18, 2017 (co-presenter).

"Bond Performance of Eco-Friendly Self-Consolidating Concrete (Concrete with 70% Cement Replacement)," ACI 2017 Fall Conference, Anaheim, California, October 17, 2017 (co-presenter).

"Evaluation of FRP and FRCM Composites for the Strengthening of Reinforced Masonry Walls," American Concrete Institute (ACI) 2017 Fall Conference, Anaheim, California, October 15, 2017 (co-presenter).

"Non-prestressed Composite Bridge Deck-Girder with End-Girder Continuity Detail using UHPC within the End Connection," 3rd International Symposium on Ultra-High Performance Fibre-Reinforced Concrete (UHPFRC) Montpellier, France, October 4, 2017.

"Optimization Performance of High Volume Fly Ash Self-Consolidating Mixtures with Hydrated Lime (Mortar Component)," 10th ACI/RILEM International Conference on Cementitious Materials and Alternative Binders for Sustainable Concrete (ICCMC 2017) Montreal, Quebec, Canada, October 3, 2017.

Antonio Nanni

Presentations at: FRPRCS-13; The 13th International Symposium on Fiber-Reinforced Polymer Reinforcement for Concrete Structures' Anaheim, CA USA, 14-15 Oct 2017

- Case-Specific Parametric Analysis as Research-Directing Tool for Analysis and Design of GFRPRC Structures by Marco Rossini, Eleonora Bruschi, Antonio Nanni, and Fabio Matta
- Durability of GFRP Reinforcement in Seawater Concrete by Morteza Khatibmasjedi, and Antonio Nanni
- Implementation of Closed GFRP Stirrups in FRP-RC Design of Traffic Barriers by Paolo Rocchetti, Guillermo Claure, Francisco de Caso y Basalo and Antonio Nanni

Hani Nassif

H. Abdulhameed, H. Nassif and K. Khayat, "Use of Fiber-Reinforced Self-Consolidating Concrete to Enhance Serviceability Performance of Damaged Beams", Transportation Research Board's 97th Annual Meeting, Washington D.C., 2018

H. Nassif, "Comparison of Model Predictions for SCC with and Without Fibers", ACI Spring Convention 2018, Salt Lake City, UT.

Kaan Ozbay

"J. Gao, K. Ozbay, F. Zuo, and A. Kurkcu, "A Life Cycle Cost Analysis Approach for Emerging Intelligent Transportation Systems with Connected and Autonomous Vehicles", Transportation Research Board's 97th Annual Meeting, Washington DC, USA, 2018"

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

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 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 RE-CAST projects and are providing financial and in-kind support to the research program. The highlighted agencies are new in this reporting period:

- AIG
- American Concrete Pavement Association, Oklahoma and Arkansas Chapter
- Bekaert Corp. - Arkansas
- BASF - Joseph Dazcko and Tim Filer
- Bowman, Barrett & Associates, Chicago, IL
- **Capital Holdings - MO**
- CBM-St-Mary's Toronto
- Chicago Department of Aviation
- City University of New York
- Clayton Concrete Materials and Ready Mix, Edison, NJ
- Chicago Bridge & Iron Co., Trenton, NJ
- Cole County Industries – MO
- Coreslab Structures Inc., Marshall, MO
- Dewberry, Bloomfield, NJ
- Dolese Bros. Co., Oklahoma City, OK

- Eastern Concrete Materials and Ready Mix, Bogota, NJ
- EllisDon, Toronto
- Euclid Chemicals, East Brunswick, NJ
- **Florida Department of Transportation**
- Garver Engineering, Norman, OK
- **Grace Construction Products, MA**
- Grand River Dam Authority, Vinita, OK
- Greenman Pedersen, Inc., Lebanon, NJ,
- Hanyang University (Korea)
- K-FIVE Construction Corp., Lemont, IL
- Kansas State University
- Kyunghee Univ. (Korea)
- LaFarge North America, Whitehall, PA
- Louisiana Transportation Research Center
- Missouri DOT
- Missouri S&T
- New Jersey DOT Research Division, West Trenton, NJ
- New Jersey Turnpike Authority, NJ
- New York City DOT
- New York State DOT
- New York University Polytechnic School of Engineering, Brooklyn, NY
- Noblis
- O'Hare Modernization Program, IL
- Oklahoma DOT, Oklahoma City, OK
- Oklahoma City, Norman, and Tulsa, OK, City Planning Departments
- Oklahoma State University
- Oklahoma Turnpike Authority, OK
- Philips Hardy Inc., MO
- **Port Authority of New York and New Jersey (PANYNJ)**
- Small Modular Reactor Research and Education Consortium
- Southeast University, Nanjing, China
- State University of NY Maritime College
- State University of NY at Stony Brook
- University of Miami, Coral Gables, FL
- Structural Technologies, Hanover, MD
- University of Florida, Kyle Riding
- UIUC
- **University of Jinan (China)**
- University of Nevada, Las Vegas
- University of Oklahoma
- University of Sao Paulo (Brazil)
- University of Sherbrooke (Canada)
- VirginiaTech, Charlottesville, VA
- Wallace Engineering, Tulsa, OK
- Webcor Corp. - CA
- 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 DOT, 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, **NY***
Harvey DeFord, Ph.D., Structural Materials Research Specialist – *FLDOT State Materials Office, **FL***
Chiara "Clarissa" Ferraris, Ph.D., Physicist - *NIST, Gaithersburg, **MD***
Jim Myers, P.E., Senior Staff Engineer - *Coreslab Structures, Inc., Marshall, **MO***
Karthik Obla, Ph.D. P.E., Vice President, Technical Services - *NRMCA, Silver Spring, **MD***
Zhongjie "Doc" Zhang, Ph.D., Pavement Geotechnical Research Administrator -*LTRC, Baton Rouge, **LA***

4. IMPACT

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

The field demonstration project can be used as a case study that shows the applicability of new mix design developed by RE-CAST member for concrete bridge decks or other application.

We are delivering strategies for new materials with self-consolidating characteristics, and materials with recycled fine material from concrete crushing operations that would otherwise be landfilled. The new materials are Foam Cement and Controlled Low Strength Materials that are suitable for backfill for construction projects.

The FR-HPC mix designs that were developed by the RECAST consortium members can be widely used for the bridge deck projects. This mix design will minimize the cracking and therefore prolong the service life of the deck. This improvement will have a major impact on the development of the principal disciplines of the program by reducing the maintenance fee and schedule.

The developed LCCA methodology built by the NYU team at both project- and network-level will provide new insights into the economic evaluation process for new construction materials and technologies. In addition, the customized LCCA software can be used as an interactive web tool that allows a wide range of users to apply LCCA, to optimize maintenance, repair and rehabilitation strategies at the project level or best utilize agency budget and resources at the network level. We are also testing our proposed LCCA methodology using real-data from various projects conducted by our RE-CAST partners. This is an important improvement over previous effort where testing and validation with various data from different projects were limited.

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

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.

The NYU team is applying the probabilistic LCCA methods developed for novel infrastructure materials in this project to Connected and Autonomous Vehicle deployment analysis. There are many similarities between LCCA of novel materials and advance and new Intelligent Transportation System (ITS) technologies. They are both new and lack field data. Thus, our probabilistic LCCA methods can be applied to ITS projects too.

The field demonstration and SHM of FR-SCC deck will help the transportation agencies understand the benefits of FR-SCC applications and adopt such materials in future designs or repair and maintenance projects. Both demonstration projects can be used as case studies that show the applicability and encourages implementation of FR-SCC for concrete bridge decks.

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 FY2014, FY2015, FY2016, FY2017 and FY2018. For the undergraduate students, working with graduate students and world-renown faculty helps them with experiential learning activities and raise their interest in transportation.

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

The customized LCCA methodology and web-based tool created by the NYU team is expected to be easier to use and thus more people will be able to use it. The NYU team is planning to have the web-based LCCA tool developed in this project as a showcase as well as a teaching tool in graduate courses that will have an impact on the transportation workforce development.

The technical specifications for use of FR-SCC will help transportation agencies understand the feasibility and adoption of FR-SCC in various infrastructure applications.

The field implementation of FR-HPC mix can be used as a case study for the lessons learned for future similar projects. Then the case studies can be compiled to used as a presentation for workshop or class that will have an impact on the transportation workforce development.

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

The Rutgers team has been closely working with NYU as well as HNTB Corp. in the context of a new major initiative in New Jersey entitled, NJDOT Bridge Resource Program (BRP) for the state transportation agency. The team plans to implement the new technologies of RECAST projects to various subtasks of BRP project.

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

The FR-SCC Technical Specification will be developed and shared between the transportation agencies and the consortium universities as a case study of field implementation. As soon as the field implementation is planned, the team will share the field experience of FR-SCC.

The Rutgers team is currently developing a technical specification for FR-HPC and FR-HESHPC. The Technical Specifications will be used by the transportation agencies, and the document will help the agency use for multiple projects. The document will be also shared with the consortium universities as a case study.

The NYU team is planning to prepare a video that will describe the new LCCA software tool.

Technical Specification of new materials will be developed and the field implementation results will be shared between the transportation agencies as well as the consortium universities as a case study of RE-CAST project. Such information will help other transportation agencies learn the new mix designs and encourage to use them for the field implementation.

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 at Missouri S&T as one of four strategic areas for future growth in education and research.

The developed on-line LCCA tool will be used by a larger group of engineers and students when it is ready for open access. The fact that we are incorporating new methodologies for LCCA estimation in the case of new materials and technologies, this tool might have greater societal impacts beyond this project. By introducing the developed on-line LCCA tool to a larger group of engineers and students in the near future might lead to greater societal impacts beyond this project since the tool is capable of LCCA estimation in the case of new materials and technologies. We will be able to facilitate the adoption of new technologies by providing agencies with important LCCA information for more informed decision making.

It is proved that the use of fiber reduces the crack severity and therefore extends the service life. Such improvement will reduce the maintenance schedule and save a vast of fund to repair the infrastructure.

The consortium continues to engage K-12 students and provides them hands on activities.

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.

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 N/A

5.E - Change Of Primary Performance Site Location From That Originally Proposed - No Change to Report.

5. SPECIAL REPORTING REQUIREMENTS - Nothing to Report.