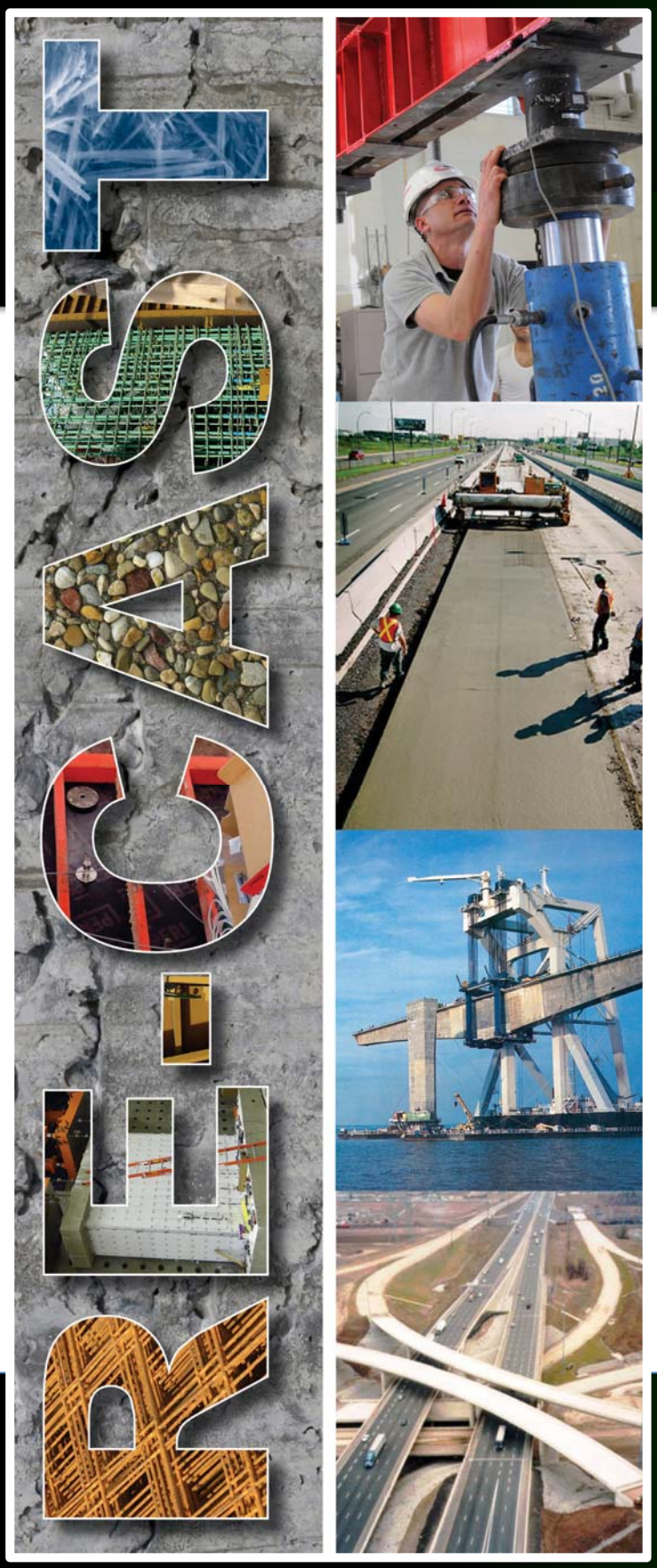

PROGRAM PROGRESS PERFORMANCE REPORT #8

GRANT: DTRT13-G-UTC45
Reporting Period: 4/1/2017 – 9/30/2017

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
- 1-C-2. Changes in Workability and Air-Void System of Concrete Due to Pumping
- 2-A. High-Volume Recycled Materials for Sustainable Pavement Construction
- 2-B-1. Rapid Pavement Rehabilitation
- 2-B-2. Rapid Pavement Construction
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- 2-C. Development of Rapid PCC Pavement Repair Materials and Construction Techniques
- 2-D. Flexural Performance of Concrete Beams Strengthened using Different Repair Techniques
- 3-A. Performance of Fiber Reinforced Self-Consolidating Concrete for Repair of Bridge Sub-Structures and fiber-reinforced Super-workable Concrete for Infrastructure Construction
- 3-B. Ultra-High Performance Fiber Reinforced Concrete for Infrastructure Rehabilitation
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- 3-C-2. FRP Reinforcement for Concrete: Performance Assessment and New Construction
- 3-C-3. Use of Internal Curing Materials to Improve Performance of Concrete Infrastructure
- 3-D. Durability of GFRP Bar Reinforcement Extracted from In-service Concrete Structures

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:

Feys, D. and A. Hernandez, "Influence of Casting Conditions on Durability and Structural Performance of HPC-AR: Optimization of Self-Consolidating Concrete to Guarantee Homogeneity during Casting of Long Structural Elements," Project 00050028, RE-CAST: Research on Concrete Applications for Sustainable Transportation, USDOT: GRANT: DTRT13-G-UTC45, Project Period: 1/1/15 – 5/15/17.

Hadad, H., Pino, V. and A. Nanni, "Performance of FRCM Strengthened Beams Subject to Fatigue," Project #00042134-04, RE-CAST: Research on Concrete Applications for Sustainable Transportation, USDOT: GRANT: DTRT13-G-UTC45, Project Period: 9/30/14 – 5/31/17.

Myers, J. and V.G. Venancio, "Ultra-high Performance Fiber-Reinforced Concrete (UHPFRC) for Infrastructure Rehabilitation Volume II: Behavior of Ultra-High Strength Concrete Bridge Deck Panels Compared to Conventional Stay-In-Place Deck Panels," Project #00047713, RE-CAST: Research on Concrete Applications for Sustainable Transportation, USDOT: GRANT: DTRT13-G-UTC45, Project Period: 8/1/14 – 6/30/17.

Myers, J. and V.G. Venancio, "Influence of Casting Conditions on Durability and Structural Performance of HPC-AR: Optimization of Self-Consolidating Concrete to Guarantee Homogeneity during Casting of Long Structural Elements," Project #00050028, RE-CAST: Research on Concrete Applications for Sustainable Transportation, USDOT: GRANT: DTRT13-G-UTC45, Project Period: 8/1/14 – 6/30/17.

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 NRMCA sustainable concrete carbon calculator was applied to determine the embodied total energy and CO2 emission associated with material manufacturing process, material transportation, and concrete production. The optimum concrete mixtures developed for pavement and bridge applications exhibited significantly lower embodied energy and global potential warming compared to the MoDOT reference concrete mixtures designated for pavement and bridge applications. The research team is collaborating/following up with MoDOT to finalize the transportation infrastructure element types and locations for field implementation. The details of sensors and data acquisition systems required for the project were finalized with the collaboration of MoDOT engineers. Two data acquisition systems have been prepared in order to monitor changes of deformation, temperature, and relative humidity in concrete element as a function of time.

University of Oklahoma

In May, 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 completed evaluating the restrained shrinkage performance of fiber-reinforced self-consolidating concrete (FR-SCC) with steel fiber in accordance with AASHTO as well as ASTM Standards. During this period, the AASHTO standard testing results were compiled. It was found that fibers reduce crack widths when they are utilized in the mix design. ST0.50 reduced the maximum crack width by up to 31% and ST0.65 reduced the crack width by half. The results proved that higher percentage of steel fiber resulted in less cracking area.

New York University

The research team has developed two separate frameworks for both Project-level Life Cycle Cost Optimization Model (P-LCCOM) and Network-level Life Cycle Cost Optimization Model (N-LCCOM). P-LCCOM aims to automate the process of testing different combination of planned construction and rehabilitation strategies at the project-level and finding the optimal combination while N-LCCOM aims to select the best subset of projects to meet network-level goals. Various economic and engineering models with different search algorithms (i.e. Generic Algorithm) have been tested and evaluated in the proposed optimization models to balance the trade-off between cost and effectiveness and to arrive at the optimum life cycle strategy.

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

This project aimed to understand the mechanisms responsible for the formwork pressure drop in SCC over time and to improve the methodology for the measurement and modelling of the formwork pressure. The project is complete, and the results are documented in an MS thesis by Kavya Vallurupalli.

The experiments demonstrated the sensitivity, accuracy, and applicability of formwork models for predicting the formwork pressure of a wide range of self consolidating concrete mixtures. Within the first few hours of the pressure decay, the reversible changes in concrete dominate the pressure decay and slight variation in the mix proportions, mixing procedure alter the pressure decay significantly indicating the sensitivity of SCC mixes. The formwork dimensions also affect the pressure decay indicating the importance of including the formwork dimension parameter while developing the models for prediction of formwork pressure.

Recommendations were developed for reducing variations in mixture properties. The particle to particle interaction is a key for understanding thixotropic properties, and is a primary cause of pressure decay in the initial hours after casting before the hydration process becomes dominant.

A report of this work is represented by the thesis by K. Vallurupalli entitled “Formwork Pressure and Rheology of Self Consolidating Concrete [2017]”. Ms. Vallurapalli went on to join RE-CAST at S&T for her Ph.D.

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

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

Two major pumping tests to evaluate the change in rheology, workability, air-void system and freeze-thaw durability of self-consolidating concrete were executed in August and September. Pumping conditions, i.e. flow rate, boom configuration, presence of a reducer were varied for four mixtures with different initial slump flow. Durability tests are ongoing.

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. Modifications in mixing procedure are investigated attempting to minimize this discrepancy.

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. Different types of sensors, including the concrete strain gages, relative humidity sensors, and thermocouples were procured. Moreover, the data acquisition systems were designed and assembling of the systems is underway. The team is working on preparation of sensors, wirings, and connections for field implementation.

UIUC

This study considers recycled fine materials for controlled low strength materials (CLSM) and foam cement. The team are using x-ray computed tomography to capture microstructural information in 3D and 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 Ph.D. 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 use in additive manufacturing and 3D printing. Jamie Clark completed her MS thesis “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 research team noted unusual behavior from several mixture designs containing significant amounts of recycled concrete aggregate (RCA). An aggregate absorption rate test developed by the researchers found that RCA can take as long as 30 to 40 minutes to become fully saturated, which is much longer than the standard mixing time and was likely the cause of the anticipated behavior. Subsequent mixtures used a technique developed by the team to provide the RCA in a saturated surface dry condition. This technique involved placing the RCA in 55-gallon drums filled with water. After 24 hours of soaking, the RCA was removed from the drums and placed in a wire basket suspended from a swivel mechanism attached to an industrial drill. The basket was spun for 5 minutes to remove excess water, and the RCA was then placed into sealed 55-gallon drums to maintain the SSD state prior to mixing. Extensive testing and refinement of this technique verified the efficacy in reaching a SSD condition of the RCA. As a result, recommendations for using high amounts of RCA in mixture 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-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. To minimize drying shrinkage and cracking, internal curing was adopted with light weight concrete and recycled concrete aggregate. The early age strength was achieved to $3,500 psi with recycled concrete aggregate, which is still not satisfied the target strength with many trial mixes. It is in the stage to replace the recycled concrete aggregate with virgin limestone aggregate to further enhance the 4 hour strength to the target strength. Repeatability of the mix to produce early high strength concrete is still the

major issue, and research team is trying to make a quality control in the mixing process. 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

Over ten concrete mixtures were evaluated aiming to combine high thixotropy and green strength development with high fluidity of the mixture. Decreasing the paste volume has resulted in lower thixotropy development because of the adjustment of HRWRA to achieve the target fluidity. Keeping the HRWRA constant enhances thixotropy for low paste volumes, but fluidity decreases. HRWRA dosage appears strongly contraproductive for thixotropy development, which also explains why specific mixtures with slag, silica fume, and/or attapulgite clay perform or not. Mix designs are being finalized for the large-scale evaluation, although sufficient shape-stability of 4x8' cylinders could not be achieved.

SUBR

This project was funded in June 2016 to apply VFC mixtures in rapid pavement construction. The first stage of the project is to develop VFC mixtures in Missouri S&T by Dr. D. Feys. Research team received an interim report on the VFC mixture in July 2017, but still waiting for the VFC mixtures to be used in the measurement of hardened concrete properties. Dr. Shin is planning for pre-field and field implementation

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. Work is aiming at investigating ways to enhance frost durability of RCC. For selected mixtures, compressive strength at 7 and 28 days, surface resistivity, freeze and thaw resistance, deicing salt-scaling, and permeable voids have been measured. 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 Rolla.

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 following activities were accomplished during this period: 1) Working with the ready-mix concrete supplier to finalize mixture design. 2) Casting of a 10x10-foot mock-up slab with different rebar configurations. 3) Finalize the fabrication of six sensor stations (baskets) and installation of sensors at the Taos bridge site and connection to data acquisition system. 4) Support concrete casting operations and sampling seven concrete deliveries to evaluate key fresh and mechanical properties. 5) Monitoring of in-situ concrete strain, temperature, and relative humidity. The optimized FR-SWC was used for bridge deck construction involving approx. 330 yd^3 of concrete.

University of Oklahoma

The implementation phase of this project involves repairs to the I-244 Bridge over the Arkansas River. The research team tested a full-scale AASHTO Type II prestressed bridge girder removed from this bridge. Following a detailed survey, this girder was designated in good condition and will serve as a control girder for comparison to a severely deteriorated girder that will undergo repairs using the fiber-reinforced, self-consolidating concrete (FR-SCC) developed in this study. The research team is currently monitoring the concrete repairs being performed on site of the I-244 bridge. Once repaired, the girder will be removed, shipped to the OU structures lab, and tested in a similar manner to the control girder.

Rutgers University

The team completed testing and analyzing 10 full-scale repaired beams. During this period, the team developed the crack map for each individual beam. Based on the experimental testing of full-scale beam, the following conclusions were made. (1) FR-SCC repair mixes provided improved flexural capacity to Class A control mix. (2) The fiber content regardless of fiber type plays an important role in initial cracking but does not affect the ultimate load (3) FR-SCC could be an effective and viable option to repair the damaged beam at a relatively low cost in a short period of time.

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 project Co-PI has initiated the design process for the strengthening of a MoDOT four span candidate bridge for rehabilitation to serve as the implementation test bed. During the next reporting period the current project schedule will be to complete the preliminary repair design using four different repair systems (one for each span). Then, during the Spring 2018 timeframe, 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 will also involve partners at the University of Miami.

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.

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

Mixing for both experimental blocks one and two has been completed, and all the test specimens have been fabricated. The effect of different curing regimens was explored to establish the beneficial effect of internal curing using lightweight sand. Four curing regimens were explored. For this block the compression testing has been completed and the drying shrinkage measurements are ongoing. The results indicate that internal curing benefits the development of compressive strength. The use of internal curing can potentially decrease the required curing time. As for drying shrinkage, the benefits are less clear. For Types 2 and 3a there is potentially a slight benefit, but for Type 2 there was an apparent increase in drying shrinkage. It is not immediately evident if curing regimen plays a role in this. However, it is clear that the longer curing certainly decreases the drying shrinkage. The test matrix of the second block was finalized and conducted. All of the specimens have been fabricated, and the tests are currently being conducted. Compressive strength testing up to 28 days has been completed, and drying and autogenous shrinkage measurements are ongoing. The data for these tests is currently begin analyzed. The 56 day tests will begin next week and will be completed with the last sorptivity measurements made on near the end of November. The 91 day tests will begin in early November and be completed by the first week of December.

Education and Workforce Development (EWD) / Outreach Objectives Accomplished

1) Dr. A. Nanni of University of Miami gave a keynote presentation at MURICO5, “Trends and standards development for composites in structural strengthening and new construction in the US” Mechanics of Masonry Structures Strengthened With Composite Materials, Bologna, June 28- 30, 2017.

2) Dr. A. Nanni of University of Miami gave an ACI Webinar, "Design and Construction with Fiber-Reinforced Polymer (FRP) Bar, Part 1," August 22, 2017
3) D.A. Lange served as judge of the National Aeronautics and Space Administration's (NASA) 3-D Printed Habitat Challenge, Peoria, IL, August 17-19, 2017.
4) D.A. Lange and K. Riding conducted collaborative testing and training of personnel at the Nortrak precast concrete manufacturing plant in Cheyenne, WY on June 5-9, 2017.
5) In this reporting period, Education objectives were advanced by talks/posters given at the American Ceramic Society Cements Division meeting in Atlanta, GA, June 26-28, 2017.

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 13th quarterly **newslette**r was published in May 2017 – see Attachment A.

3) The 14th quarterly **newslette**r was published in September 2017 – see Attachment B.

4) The 6th annual Missouri S&T/MoDOT Transportation Infrastructure Conference is scheduled to take 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.

5) D. Lange invited lecture at International Conference on Advances in Sustainable Construction Materials & Civil Engineering Systems (ASCMCES-17), Sharjah, UAE, April 18-20, 2017.

6) D. Lange invited lecture on "Crushing Behavior of Foam Concrete" at 9th International Symposium on Cement & Concrete (ISCC2017) in Wuhan, China on Oct 31-Nov 2, 2017.

7) D. Lange invited lecture on "Gradients and Driving Forces of Early Age Volume Change" at 2nd Int'l Conference on Early Age Cracking and Serviceability in Cement Based Materials and Structures (EAC-2), Brussels, Belgium, September 12-14, 2017.

8) D. Lange invited lecture on "Characterization of the Crushing Behavior of Foam Concrete" at Brunel University, London, UK on September 16, 2017.

9) 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) Southern University and A&M College hosted the **Summer Transportation and Energy Institute** (STEI) in the summer 2017. Dr. Alex Shin of RE-CAST gave a lecture on RE-CAST projects and provided financial support to buy teaching materials.
3) UIUC student Jamie Clark, an African American female student, is in Prof. D. Lange's group working with partial support from RECAST funding.

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 at Missouri S&T, 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, 9 undergraduate and 7 graduate students have been involved in the testing.

ACerS Cements Division Symposium on June 26-28, 2017 at Georgia Tech in Atlanta, GA featured several grad student presentations on RECAST research.

1.D - How Have The Results Been Disseminated?

Recordings of 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 electronically to approx. 1200 recipients.

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 2017 in Las Vegas, 2017 TRB Meeting in Washington, D.C., ACI Spring 2017 Convention in Milwaukee, WI, ACI Fall 2017 Convention in Anaheim, CA, the annual ACERS Cements conference in Atlanta, GA, June 2017, the 11th UTC Spotlight Conference in Washington D.C., as well as overseas, including the 9th International Conference on Cement and Concrete, ISCC2017, Wuhan, China.

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

- Publish 15th and 16th newsletters
- **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 -** Planned for December 8, 2017.
- For project 2B, the results will be analyzed, summarized and reported. For project 1C-2, one full-scale pumping tests is planned for October, and two in February and March. The research on this project is ongoing.
- 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 University team will follow up the monitoring of the performance of FR-HPC mix design compared to the HPC mix design. The team will perform the crack mapping of the bridges and collect all available data, such as concrete testing results, concrete pouring reports, environmental condition, etc. The team will compile all data to evaluate the effectiveness of the FR-HPC and report the results in the progress reports in the following periods.
- The New York University team will continue to collaborate with Missouri S&T team on implementing deterministic and probabilistic LCCA for ultra-high performance concrete (UHPC) materials. The team will closely work with other RE-CAST team members to evaluate current LCCA and P-LCCOM/N-LCCOM methodologies and incorporate them into the web-based LCCA software.

2. PRODUCTS

2.A - Publications, Conference Papers, and Presentations

1) **13th quarterly newslette**r published in May 2017 – see Attachment A.
2) **14th quarterly newslette**r published in September 2017 – see Attachment B.
3) **Journal Publications** (in part):

Meng, W., **Khayat, K.H.**, Effect of Hybrid Fibers and Fiber Contents on the Fresh, Mechanical Properties and Autogenous Shrinkage of UHPC, Journal of Materials in Civil Engineering, Jan. 2018, DOI: 10.1061/(ASCE)MT.1943-5533.0002212.

Meng, W., Samaranayake, V.A., and **Khayat, K.**, Factorial Design and Optimization of UHPC with Lightweight Sand, ACI Materials Jr., Jan.-Feb. 2018, 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, Journal of Materials in Civil Engineering, Jan. 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.

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.

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

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, Aug. 2017, pp. 54-66.

Sadati, S., Arezoumandi, M., **Khayat, K.H.**, and **Volz, J.S.**, Bond Performance of Sustainable Reinforced Concrete Beams, ACI Materials Jr., 114 (4), July-Aug. 2017, pp. 537-547.

Mehdipour, I., Horst, M., Zoughi, R., and **Khayat, K.H.**, Use of Near-Field Microwave Reflectometry to Evaluate Steel Fiber Distribution in Cement-Based Mortars, Journal of Materials in Civil Engineering, 29, Issue 7, July 2017, pp. 1-12, DOI 04017029.

Yuan, Q., Zhou, D., **Khayat, K.H.**, and **Feys, D.**, On the Measurement of Evolution of Structural Build-up of Cement Paste with Time by Static Yield Stress Test vs. Small Amplitude Oscillatory Shear Test, Cement and Concrete Research, 99, 2017, pp. 183-189.

Bao, Y., Valipour, M., Meng, W., Chen, G., and **Khayat, K.H.**, Distributed Fiber Optic Sensor-Enhanced Detection and Prediction of Shrinkage-Induced Delamination of Ultra-High-Performance Concrete Overlay, Smart Materials and Structures, 26, 2017, 085009 (12 p.).

Omran, A.F., **Khayat, K.H.**, Effect of Formwork Characteristics on SCC Lateral Pressure, Journal of Materials in Civil Engineering, 9 (5), 2017, 04016293 (10 pp).

Omran, A.F., **Khayat, K.H.**, Progress to Understand Influence of Reinforcement Density on SCC Lateral Pressure, Materials and Structures, 50 (2), 2017, 152.

Wu, Z., Shi, C., and **Khayat, K.H.**, Effect of Nano-SiO2 Particles and Curing Time on Development of Fiber-Matrix Bond Properties and Microstructural of Ultra-High Strength Concrete with Nano-SiO2 Particles, Cement and Concrete Research, May 2017, 95: 247-256.

Meng, W., **Khayat, K.H.**, Improving Flexural Performance of Ultra-High-Performance Concrete by Rheology Control of Suspending Mortar, Composites Part B: Engineering, 117, May 2017, pp. 26-34.

Mehdipour, I., **Khayat, K.H.**, Effect of Particle-Size Distribution and Specific Surface Area of Different Binder Systems on Packing Density and Flow Characteristics of Cement Paste, Cement, Concrete and Composites, 78, 2017, pp. 120-131.

Y. Song, R. Zou, D. Castaneda, K.A. Riding, and **D.A. Lange**, "Advances in Measuring Air-Void Parameters in Hardened Concrete Using a Flatbed Scanner," ASTM J. Testing and Evaluation, 45(5), 2017.

J. Kim, G. Zi, D.A. **Lange**, "Measurement of Water Absorption of Very Fine Particles using Electrical Resistivity," ACI Mat. J., accepted, 2017.

A. Shurpali, J.R. Edwards, R. Kernes, **D.A. Lange**, C. Barkan, "Improving the Abrasion Resistance of Concrete to Mitigate Concrete Crosstie Rail Seat Deterioration (RSD)," J. Materials Performance and Characterization (ASTM), accepted 2017.

C. Sun, **D.A. Lange**, J. Xiao, and T. Ding, "Contact behavior between cracked surfaces of recycled aggregate concrete," J. Construction and Building Materials, accepted 2017. (CONBUILDMAT-D-17-01764R1).

D. Casteneda, K. Riding, **D.A. Lange**, "Measurement and Validation of Freezing Internal Temperature of Concrete Crossties at the Rail Seat," J. Mat. Civil Eng. (ASCE), accepted 2017.

J. Koch, D. Castaneda, R.H. Ewoldt, and **D.A. Lange**, "Vibration of fresh concrete understood through the paradigm of granular physics" submitted to Cement and Concrete Research, 2017.

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, doi: http://dx.doi.org/10.1520/STP160120160119.

Aljazaeri, Z.R., **Myers, J.J.**, "Strengthening of Reinforced Concrete Beams in Shear with a Fabric-Reinforced Cementitious Matrix," American Society of Civil Engineering – Journal of Composites for Construction, October 2017, Vol. 21, No. 5, 21(5)04017041, pp. 1-11, doi: https://doi.org/10.1061/(ASCE)CC.1943-5614.0000822.

Gooranorimi, O., and **A. Nanni**, "GFRP Reinforcement in Concrete after 15 Years of Service," ASCE JCC, Vol. 21, No. 5, Sept.-Oct. 2017,DOI: 10.1061/(ASCE)CC.1943-5614.0000806, 04017024-1 to 9.

Pino, V., H. Hadad, F. De Caso, **A. Nanni**, U. Ebead, and A. El Refai, "Performance of FRCM Strengthened RC Beams Subject to Fatigue," ASCE JBE, Vol. 22, No. 10, Aug. 2017, DOI: 10.1061/(ASCE)BE.1943-5592.0001107, 04017079-1 to 11

Gooranorimi, O., W. Suaris and **A. Nanni**, "A Model for the Bond of a GFRP Bar in Concrete," Engineering Structures, 146 (2017) 34–42, June 2017.

Conference Papers (in part):

Aljazaeri, Z.R., **Myers, J.J.**, "Environmental Effects on the Durability Performance of FRCM Composite Bonded to Concrete," 5th International Conference on Durability of Fibre Reinforced Polymer (FRP)

Composites for Construction & Rehabilitation of Structures (CDCC 2017), Sherbrooke, Quebec, Canada, July 19-21, 2017, Paper Submitted, 9 pages.

Wang, W., **Myers, J.J.**, "Bond Performance of SRP-to-Concrete Subjected to Environmental Cycling and Sustained Loading," 5th International Conference on Durability of Fibre Reinforced Polymer (FRP) Composites for Construction & Rehabilitation of Structures (CDCC 2017), Sherbrooke, Quebec, Canada, July 19-21, 2017, Paper Submitted, 8 pages.

Gheni, A.A., ElGawady, M.E., **Myers, J.J.**, "Thermal Characterization of Concrete Masonry Units Manufactured Using Recycled Tires as an Aggregate," 13th Canadian Masonry Symposium (13 CMS), Halifax, Nova Scotia, Canada, June 4-7, 2017, Paper Submitted, 11 pages.

Gheni, A.A., ElGawady, M.E., **Myers, J.J.**, "Cyclic Behavior of Concrete Masonry Units Manufactured with Recycled Tires as an Aggregate," 13th Canadian Masonry Symposium (13 CMS), Halifax, Nova Scotia, Canada, June 4-7, 2017, Paper Submitted, 11 pages.

Aljaberi, Z., **Myers, J.J.**, ElGawady, M.E., "Performance of Reinforced Masonry Walls Strengthened with FRP Composite Exposed to Harsh Environmental Conditions," 13th Canadian Masonry Symposium (13 CMS), Halifax, Nova Scotia, Canada, June 4-7, 2017, Paper Submitted, 7 pages.

Aljaberi, Z., **Myers, J.J.**, ElGawady, M.E., "Seismic Performance of Reinforced Masonry Walls Strengthened with FRMC Subjected to Cyclic Loading," 13th Canadian Masonry Symposium (13 CMS), Halifax, Nova Scotia, Canada, June 4-7, 2017, Paper Submitted, 12 pages.

Hernandez, E., **Myers, J.J.**, "Initial Response of a Prestressed Self-Consolidating Concrete (SCC) Bridge Using Diagnostic Load Tests," 5th International Symposium on Life-Cycle Civil Engineering (IALCCE 2016), Delft, The Netherlands, 2017, pp 1072-1079.

Gooranorimi, O., T. Bradberry, and **A. Nanni**, "Durability of GFRP Reinforcement in Built Structures: A 15-Year Old Concrete Bridge Deck," Fifth International Conference on Durability of Fiber Reinforced Polymer (FRP) Composites for Construction and Rehabilitation of Structures, July 19-21, 2017, Sherbrooke, Quebec, Canada, pp. 87-94.

Drury, J.T., Looney, T.J., Arezoumandi, M., and **Volz, J.S.**, "An Experimental Study on Bond Strength of Reinforcing Steel in High-Volume Fly-Ash Concrete," Proceedings of the 2017 World of Coal Ash (2017 WOCA), Lexington, KY, May 2017, Paper No. 150, 14 pp.

Drury, J.T., Messerli, A.J., Allen, L.D., and **Volz, J.S.**, "An Investigative Study on the Feasibility and Performance of High-Volume Recycled Content Concrete Pavement," Proceedings of the 2017 World of Coal Ash (2017 WOCA), Lexington, KY, May 2017, Paper No. 151, 19 pp.

Presentations (in part):

Dimitri Feys

Lunkad, P., Feys, D., "Study of the thixotropic behavior of fresh cement paste modified with micro- and nano-sized materials/particles," 8th Advances in Cement-based materials (Cements 2017) – ACERS, Atlanta, June 2017.

Asghari, A.A., Feys, D., "Sensitivity of Workability Loss of Flowable Cement Paste to Small Changes in Constituent Elements and Mixing Procedure," 8th Advances in Cement-based materials (Cements 2017) – ACERS, Atlanta, June 2017.

Galvez Moreno, D., Feys, D., "Particle Size Distribution of the Lubrication Layer of Highly Workable Concrete, 8th Advances in Cement-based materials (Cements 2017)," 8th Advances in Cement-based materials (Cements 2017) – ACERS, Atlanta, June 2017.

Kamal H. Khayat

Khayat, K.H., Hosseinpour, M., and Yahia, A., Numerical Simulation of Dynamic Segregation of SCC under Restricted & Non-Restricted Flow Conditions, Invited presentation, ACI Spring Convention, Detroit, March 26-30, 2017.

Valipour, M., Meng, W., and Khayat, K.H., Performance of Ultra-high Performance Concrete as Cast-in-Place Thin-Bonded Concrete Overlay, Missouri University of Science and Technology, 11th University Transportation Centers Spotlight Conference Rebuilding and Retrofitting the Transportation Infrastructure September 26-27, 2017 Washington, DC.

Abdelrazik, A., Kamal Khayat, K.H., Performance of Fiber-Reinforced Self-Consolidating Concrete for Repair of Flexural Structural Elements, 11th University Transportation Centers Spotlight Conference Rebuilding and Retrofitting the Transportation Infrastructure September 26-27, 2017 Washington, DC.

David Lange

R. Zou, "Passive wireless sensors for monitoring behavior of recycled aggregate concrete," poster at the American Ceramic Society Cements Division Symposium, Atlanta, GA, June 26-28, 2017.

Y. Song and D.A. Lange, "Characterizing the foam concrete crushing behavior and material failure process under penetration," presented at the American Ceramic Society Cements Division Symposium, Atlanta, GA, June 26-28, 2017

John J. Myers

"Impact Factor of a Prestressed SCC Bridge through Dynamic Load Tests," Prestressed-Precast Concrete Institute (PCI) 2017 Convention and National Bridge Conference, Cleveland, Ohio, March 4, 2017 (co-presenter, selected by Education Committee as Invited Presentation).

"GFRP Reinforcements in Box Culvert Bridge: A Case Study after Two Decades of Service," Transportation Research Board (TRB) 2017 Annual Meeting, Committee AAF80, Washington, DC, January 9, 2017.

"Innovative Infrastructure Developments and Long-term Performance Assessment," Rolla Lion's Club Featured Dinner Speaker, Rolla, Missouri, January 5, 2017.

"Environmental Effects on the Durability Performance of FRCM Composite Bonded to Concrete," 5th International Conference on Durability of Fibre Reinforced Polymer (FRP) Composites for Construction & Rehabilitation of Structures (CDCC 2017), Sherbrooke, Quebec, Canada, July 19, 2017.

"Bond Performance of SRP-to-Concrete Subjected to Environmental Cycling and Sustained Loading," 5th International Conference on Durability of Fibre Reinforced Polymer (FRP) Composites for Construction & Rehabilitation of Structures (CDCC 2017), Sherbrooke, Quebec, Canada, July 20, 2017.

"Thermal Characterization of Concrete Masonry Units Manufactured Using Recycled Tires as an Aggregate," 13th Canadian Masonry Symposium (13 CMS), Halifax, Nova Scotia, Canada, June 5, 2017.

"Cyclic Behavior of Concrete Masonry Units Manufactured with Recycled Tires as an Aggregate," 13th Canadian Masonry Symposium (13 CMS), Halifax, Nova Scotia, Canada, June 5, 2017.

"Performance of Reinforced Masonry Walls Strengthened with FRP Composite Exposed to Harsh Environmental Conditions," 13th Canadian Masonry Symposium (13 CMS), Halifax, Nova Scotia, Canada, June 4, 2017.

"Seismic Performance of Reinforced Masonry Walls Strengthened with FRMC Subjected to Cyclic Loading," 13th Canadian Masonry Symposium (13 CMS), Halifax, Nova Scotia, Canada, June 4, 2017.

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 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 and Associates, Chicago, IL, financial support
- CBM-St-Mary's Toronto
- Chicago Department of Aviation
- City University of New York
- Clayton Concrete Materials and Ready Mix, Edison, NJ
- Chicago Bridge and Iron Company (CB&I), Trenton, NJ
- **Cole County Industries – MO**
- Coreslab Structures Inc., Marshall, MO
- Dewberry, Bloomfield, NJ, financial support
- Dolese Bros. Co., Oklahoma City, OK financial support
- Eastern Concrete Materials and Ready Mix, Bogota, NJ
- EllisDon, Toronto

- Euclid Chemicals, East Brunswick, NJ
- Garver Engineering, Norman, OK
- Grand River Dam Authority, Vinita, OK
- Greenman Pedersen, Inc. (GPI), Lebanon, NJ, financial support
- Hanyang University (Korea)
- K-FIVE Construction Corp., Lemont, IL
- Kansas State University
- Kyunghee Univ. (Korea)
- LaFarge North America (Cement Plant), Whitehall, PA
- 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, Woodbridge, NJ, financial support
- 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
- **Philips Hardy Inc. – MO**
- Small Modular Reactor Research and Education Consortium, financial support
- Southeast University, Nanjing, China
- 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 Florida, Kyle Riding**
- University of Miami, Coral Gables, FL, financial support
- University of Nevada, Las Vegas
- University of Oklahoma, financial and in-kind support
- University of Sao Paulo (Brazil)
- University of Sherbrooke (Canada)
- Virginia Center for Transportation Innovation and Research (via 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 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***

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 RECAST 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 customized LCCA software created by the NYU team serves as an all-in-one interactive tool that allows users to apply LCCA, to optimize maintenance, repair and rehabilitation strategies on the project level, and to find the best combination of the projects on the network level that best utilize agency budget and resources.

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 customized LCCA tool created by the NYU team is capable to perform probabilistic cost-effectiveness analysis that evaluates cost effect on material's energy consumption and global warming potentials. This function applies to other disciplines such as Environmental Engineering.

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 and FY2017. 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 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 technical specifications for use of FR-SCC will help transportation agencies understand the feasibility and adoption of FR-SCC in various infrastructure applications.

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

Two universities are closely collaborating in the context of a new major initiative in New Jersey titled, NJDOT Bridge Resource Program (BRP) for the state transportation agency. We are planning to use some of the new methodologies developed in this project in the new aforementioned BRP initiative.

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

Several invited speakers/keynote speaker lectures are scheduled for the Winter/Spring of 2017/2018, many of which will report on some of the research findings of RE-CAST projects.

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.

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

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.

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.