PROGRAM PROGRESS PERFORMANCE REPORT #11

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Reporting Period: 10/1/2018 – 3/30/2019

REsearch on Concrete Applications 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.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
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Education and Workforce Development (EWD) Goals

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

Education Objectives:

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

Workforce Development / Outreach Objectives:

A. Outreach Activities to Attract New Entrants into the Transportation Field
   1) RE-CAST members will seek opportunities to invite junior faculty from complementary fields, such as engineering management, mechanical engineering, chemical engineering and chemistry to team up with RE-CAST faculty on various research projects.
   2) *Graduate Research Assistantship in Transportation Areas (GRATA)* - RE-CAST will provide graduate research assistantships to highly qualified Ph.D. students.
   3) *Invited Speakers and Field Trip Visits* – RE-CAST will collaborate with the CIES at S&T and student societies at the participating Universities, including ASCE and ACI to organize bi-monthly seminars featuring invited speakers from industry
   4) *ACI / Portland Cement Association (PCA) / Prestressed Concrete Institute (PCI) Co-Funded Scholarships* – RE-CAST will explore the possibility of providing matching funds to the scholarship programs that these organizations currently offer on a nation-wide basis for Fellowship students
   5) *Student Competition* – RE-CAST will work with professional student societies to organize a new competition on sustainable construction materials.
      1. Two competitions will be organized: (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:

Several final project reports are in the final review stage and will be published in May 2019.

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.

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 team prepared additional section for field implementation of Eco-Crete-Bridge or Fiber-Reinforced High-Performance Concrete (FR-HPC) in the final report. In addition, the team continue to perform the creep testing of SCC and FR-SCC with polypropylene fiber and/or steel fiber.

New York University - NYU team extended the previous literature review on network-level Life Cycle Cost Analysis (LCCA) studies and identified the goals for an ideal network-level optimization model. The team was able to integrate the developed project- and network-level LCCA models into a two-level bottom-up tool. At the project-level, the tool can identify all feasible maintenance, repair and rehabilitation strategies for multiple facility based on project-level constraints. At the network level, the tool is able to solve the multi-objective optimization problem to find the best combination of projects to meet network-level goals by choosing among project candidates found in the project-level model.

The final collective report with input from the RE-CAST consortium universities is completed and will be submitted in May 2019.

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

Substantial advances have been made in analyzing the hardened air-void samples before and after pumping. All results so far are included, and the team is working on outlier analysis and comparing the hardened air-void system to scaling and freeze-thaw test results. The results on rheology of cement pastes under pressure will enable us to determine the dissolution and reappearance characteristics of air versus time, providing the theoretical background for the effects on concrete pumping.

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 and performance-based specifications were developed for field implementation. The final collective report with input from the RE-CAST consortium universities is completed and will be submitted in May 2019.

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. 3D printing technology has been used to construct physical models of the foam system to aid interpretation.

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 OU research team continued monitoring the concrete pavements from the field implementation phase including performing falling weight deflectometer testing. The team also continued work on compiling the laboratory and field test testing results and writing the final report.

New York University - NYU team studies and identified the goals for an ideal network-level optimization model. The team was able to integrate the developed project- and network-level LCCA models into a two-level bottom-up tool. At the project-level, the tool can identify all feasible maintenance, repair and rehabilitation strategies for multiple facility based on project-level constraints. At the network level, the tool is able to solve the multi-objective optimization problem to find the best combination of projects to meet network-level goals by choosing among project candidates found in the project-level model.

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

This project was completed and the final report was published.

Project 2-B-1. Rapid PCC Pavement Rehabilitation

SUBR - 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. One effort was made to monitor temperature inside the concrete using thermos couples and DAQ. A warm electric blanket (Sunbeam Xpress Heat, 6 level hear setting)

was selected to monitor temperature of the concrete cylinder by choosing different temperature level. The study continued to determine the appropriate level of temperature to simulate 100°F inside the blanket. Among the six levels of temperature setting, Level 1 and Level 2 were selected to monitor the temperature at the surface of concrete cylinder covered by the blanket. The field implementation is planned to observe surface cracking and any other potential problems in the mixture and joint repair project. The field implementation will bring an idea to cover the repair surface with electric blanket to accelerate setting and strength gaining.

Project 2-B-2. Rapid Pavement Construction

SUBR - With the measured properties of the vibration free concrete (VFC) mixtures provided by Dr. Feys at Missouri S&T, the AC mixtures were chosen to further modify the mixtures to develop high early strength. In the previous report (July to September 2018), the AC mixture was modified by increasing dosage of the set accelerator. In this report period, the accelerator was further added up to 40 oz while keeping other mixture proportions. With the same trend, the strength gain at early age was increased with increasing dosage of accelerator. With the AC mixtures containing 36 and 40 oz. of set accelerator, other key material properties, such as drying shrinkage and splitting tensile strength will be measured. Bond strength test between VFC repair concrete and old concrete are underway, including testing of in-siyu properties ina lab-scale slab.

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

The main objective of this research was to develop high-performance Roller Compacted Concrete (RCC) with enhanced solid skeleton to secure greater workability, mechanical properties, and frost durability. The study involved the development of a mixture design methodology to select aggregate proportioning and particle-size distribution of combined aggregates that can secure high packing density and lead to enhanced performance. RCC mixtures with high packing density of aggregate combination and suitable fresh and hardened properties were used to introduce air-entraining agent (AEA) at different dosages. The effect of binder content, AEA dosage, workability level, adjusted by varying the water-to-solid ratio, mixer type, and compaction energy on RCC performance was evaluated. Test results indicate that the performance of RCC can be improved with the increase in packing density of aggregate skeleton. Higher packing density can enable the reduction of cement content through improved compacted structure of the solid particles. RCC mixtures made with 40% sand, 20% intermediate aggregate, and 40% coarse aggregate lad to the highest packing density and best workability and mechanical properties. A final report is under review and will be published in May 2019.

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 – In summer 2017, the RE-CAST team at Missouri S&T cast FR-SWC to replace a bridge deck in MO. After data were collected up to 260 days, and a 3D finite element model (FEM) was developed to predict the structural strain values in the concrete deck developed due to the weight of the bridge. A typical 12-in. (305 mm) mesh element was used for the FEM of the bridge deck, girders, and diaphragm. The applied loads were limited to the self-weight of the bridge. Modeling was conducted for the bridge deck at three different ages of 3, 56, and 260 days with the corresponding material properties that varied with time. The estimated strain values were compared to those recorded by the in-situ sensors in the longitudinal and transverse directions.

University of Oklahoma - The OU research continued observing repairs to the I-244 Bridge over the Arkansas River and has begun writing the final report.

Rutgers University - The team completed testing of small scale and large scale specimens to evaluate various strengthening and repairing techniques of the beams including the fiber-reinforced self-consolidating concrete (FR-SCC) and fiber-reinforced ferro cement (FR-FC). The team started drafting the final report for this project.

New York University - The NYU team has developed and enhanced the proposed integrated LCCA-based approach for finding feasible maintenance, rehabilitation and replacement strategies at the project level and optimizing best project selection for transportation infrastructure network. A probabilistic multi-objective framework was developed for conventional and innovative construction material and technologies. The hypothetical improvement rate method introduced in project 1A and 3A is applied to provide a reasonable estimate of the performance for the new construction material and technology.

A comprehensive final report of the work carried out by the RE-0CAST consortium Universities will be submitted in Spring 2019.

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 - Implementation of the new technology validated during the laboratory studies, the project Co-PI has successfully worked with the Missouri Department of Transportation to identify a four span candidate bridge for rehabilitation, Missouri Bridge P0058, to serve as the implementation test bed. Prior to strengthening, the bridge has been load tested to provide a baseline on serviceability and behavior. During the reporting period materials have been received and were prepped for field installation. During the next reporting period, the research team plans to install the materials on Bridge P0058 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 was finalized and published.

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. Different lightweight sands coupled with external water curing regimes were investigated. The project was finished during this reporting period and a final report has been submitted.

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

Missouri S&T - This study is evaluating the durability of fiber reinforced polymer (FRP) reinforcing bars as internal reinforcement of existing concrete bridge extracted from FRP RC Bridges after 10 or more years of service. The state of Missouri has had a number of FRP projects that FRP reinforcing bars serve as internal reinforcement. During this past reporting period the S&T team has been evaluating GFRP bars extracted from field projects. In total 11 bridges have been sampled in collaboration with efforts through ACI SDC, the University of Miami, Penn State University and Owens Corning. Evaluation of the samples will be on going during the next reporting period with a Final Report expected upon completion in 2019.

University of Miami - During the reporting period, the final report was completed and submitted for the University of Miami tasks.

2E. Compacted Concrete Pavement Evaluation

Missouri S&T - The study aims at determining the performance of compacted concrete pavement (CCP) mixtures for pavement construction. The CCP is comprised of similar proportions as that of RCC; however, it utilizes an admixture that enables better finishing and durable surface texture. The major difference in construction is that CCP has a longer “fresh” or “green” period and requires little or no rolling that makes the riding surface more

uniform and consistent. The use of CCP technology is supposed to secure smooth texture during paving. A field implementation was carried out in fall 2018 in collaboration with MoDOT, MnDOT, and the NRRA for use of concrete compacted pavement (CCP) using concretes with and without synthetic fibers as part of a larger project that constructed in Scott County, Missouri. The project was undertaken to assess construction issues and characterize the long-term performance of the proposed CCP. The optimized concrete mixtures are found to satisfy strength requirements for pavement construction. The work in progress during this reporting period and includes conducting laboratory tests on saw-cut and cored samples. Tests include compressive and flexural strength tests carried out at 120 and 180 days, freeze-thaw durability, de-icing salt scaling resistance, and drying shrinkage. The results of this research project aim to add value to the current state of practice related to the use of CCP, synthesize current technical knowledge, study the potential problems associated with using CCP in pavement construction in Missouri, and propose guidelines on how to avoid critical construction issues and poor quality issues. The study deals with practices recognized by MoDOT and MnDOT. The outcomes of the research will provide guidelines for the selection of proper ingredients, mixture optimization methodology, as well as suitable design features to ensure cost-effective and durable CCP.

3-F. Performance-Based Specifications of Fiber-Reinforced Concrete with Adapted Rheology to Enhance Performance and Reduce Steel-Reinforcement in Structural Members

Missouri S&T - The proposed project seeks to optimize the characteristics of concrete made with expansive agents (EA) and lightweight sand (LWS) to enhance mechanical properties, restrained shrinkage cracking, and transport properties of mixtures developed in projects 1-A and 3-A. The system of EA-fiber characteristics-moist curing is systematically optimized to enhance shrinkage cracking resistance, improve mechanical properties (due to the chemically-pre-stressing condition) and transport properties (due to lower crack potential and crack width). In the second phase, steel reinforcement in structural members is partially replaced by means of steel fibers. A careful design of rheological properties of the fluid fibrous mixture is conducted to achieve efficient alignment of the fibers along the casting-flow direction. This can make the best use of fibers in the structural elements.

3G. Performance of Synthetic Fiber-Reinforced Concrete with Adapted Rheology

Missouri S&T - The project seeks to reduce the cracking potential of concrete using EA, shrinkage reducing admixtures (SRAs), fibers, proper curing, including internal curing, and their combinations. Proper curing is provided through mixture design, use of lightweight sand, and/or external source (i.e., moist curing). In the first phase of this study, SRA-fiber system of self-consolidating concrete (SCC) and super workable concrete (SWC) mixtures from previous projects is optimized to achieve superior performance including autogenous shrinkage, restrained shrinkage, mechanical properties (tensile and compressive strength), frost durability, and transport properties. The investigation includes the SRA and two types of synthetic fibers from GCP applied technologies. Furthermore, the effect of rheological properties of fiber alignment along the casting-flow direction of structural elements is evaluated. Viscosity modifying agents and superplasticizers are used to improve the stability of the concrete mixture and distribution of the fibers. The project investigates the corrosion resistance of reinforcing bars in pre-cracked FR-SCC and FR-SWC mixtures. The cracking is controlled to achieve different widths for mixtures with different fibers. The transport properties of the concrete matrix is investigated. The enhancement in tensile/flexural toughness and shrinkage/crack resistance of FRC made with partially replacement of the steel reinforcement in flexural members with the optimized mixtures is also evaluated.

3H. Enhanced Performance of Fiber-Reinforced Concrete for Construction and Repair

Missouri S&T - The purpose of this research is development a novel technique to enhance properties of Eco-Bridge-Crete, FR-SCC and FR-SWC for higher crack resistance and improved flexural properties in construction and repair by taking advantage of hybrid fibers, chemical admixtures (shrinkage reducing agents and expansive agents) and lightweight sand. A binary or ternary system of EA, SRA and LWS with selected fibers will be

optimized to enhance shrinkage cracking resistance, mechanical properties and durability of the targeted mixtures. The incorporation of fibers with EA, SRA and LWS can increase the flexural properties and help to replace a portion of steel reinforcement bars in flexural members or reduce thickness of repair overlays without compromising flexural strength/toughness and crack resistance. The selected mixtures will be used in large-scale members to assess their structural performance in construction and repair.

Education and Workforce Development (EWD) / Outreach Objectives Accomplished

1) At UIUC, Ph.D. student Ruofei Zou has progressed satisfactorily, completing his Ph.D. coursework with strong grades and passed his Preliminary Exam on Jan 12, 2018. He anticipates completion of his Ph.D. dissertation in Dec 2019.
2) Invited presentation: K. Khayat, "Effect of Fiber Characteristics on Fresh and Hardened Properties of Fiber-Reinforced Concrete," ACI Spring Convention, March 25, 2019, Quebec City, Qc, Canada.
3) Invited presentation: K. Khayat, "Design and Performance of Self-Consolidating Concrete for Repair of Concrete Infrastructure," ACI Spring Convention, March 25, 2019, Quebec City, Qc, Canada.
4) Invited presentation: K. Khayat, "Concrete Pavement Incorporating Recycled Concrete Aggregate: The RE-CAST Experience," ACI Quebec and Eastern Ontario Chapter Annual Meeting, Dec. 5-6, 2018, Sherbrooke, Qc, Canada.
5) Keynote presentation: K. Khayat, "Recent Advances in the Design of Cost-Effective UHPC with Adapted Rheology," Keynote speaker, 14th International Conference on Recent Advances in Concrete Technology and Sustainability Issues, Beijing, China, October - November 2018.
6) Invited Speaker: K. Khayat, "Effect of Rheological Properties on Quality of Formed Surfaces Cast with SCC and Superworkable Concrete," Nov., 2018, CBMA, Beijing, China.
7) Keynote presentation: K. Khayat, "Improving Flexural Performance of Ultra-High Performance Concrete by Rheology Control of Suspending Mortar," 2nd International Symposium on Ultra High-Performance Concrete, Fuzhou, China, November 2018.

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) A UIUC, Ruofei Zou will participate at the American Ceramic Society Cements Division Meeting on June 16-18, 2019 at UIUC, and is scheduled to give a poster presentation.
3) Several RE-CAST faculty presented keynote and invited presentations, as elaborated in part below.
4) S&T Transportation Infrastructure Conference – April 22, 2019.

Diversity Objectives Accomplished

1) Missouri S&T has made progress 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 2018.
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) This project supports the Lange Research Group which has 10 students with diverse background, including underrepresented groups. In the group of 10 students, there are four women. UIUC students Nanaissa Maiga (MS) and Jamie Clark (PhD) are black female engineering students pursuing advanced degrees in Prof. Lange's research group, thus advancing diversity goals through the UTC program.
5) OU sponsored an undergraduate research internship for Kevin Lepissier, an International minority student, to work on the RE-CAST projects. Based on this work, Kevin has decided to pursue a Master of Science degree at OU.

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.

The RE-CAST funding provides partial support for many conferences and symposia including the following:

- Five students from the Lange research attended the 2018 Fall Convention of the American Concrete Institute in Las Vegas, NV. The students participate in ACI committee work.
- 7 students from the Lange research group will attend the American Ceramic Society Cements Division Meeting on June 16-18, 2019 at UIUC.
- Several post-docs and students attended the Spring ACI convention from the Missouri S&T RE-CAST team.
- Special Session on GFRP Durability led by Dr. John Myers at the ACI Committee 440L meeting during the ACI 2019 Spring Conference on March 24, 2019 in Quebec City, Quebec, Canada.

The RE-CAST program supports students who are active in the ACI Student Chapter. A RE-CAST student currently serves as President.

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.

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 in the U.S. and elsewhere.

The Rutgers team provided two technical specifications to a local transportation agency (New Jersey Turnpike Authority). The specifications are the fiber-reinforced high-performance concrete (FR-HPC) and high-early strength HPC (HES-HPC), and both mixes and specifications were implemented on the major highway bridges.

The NYU team has developed informative video demo about the web-based LCCA tool and will disseminate this information to our partner, other colleagues, and on research exhibitions.

The OU research team presented the results of Project 3A to the Bridge Division of the Oklahoma Department of Transportation (ODOT). Based on field implementation project, ODOT is incorporating the FR-SCC repair material specifications into their specifications. There are plans for additional implementation of this concept to repair continuity joints and beam end regions on several prestressed concrete bridges in Oklahoma. Similar achievements have been achieved in Missouri where the team of Dr. Khayat has developed the first specification for FR-SWC for bridge deck replacement and carried out field implementation projects.

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, Gordon Research Conference on Advanced Materials for Sustainable Infrastructure Development in Hong Kong (Khayat – Vice Chair of Conference), ACI Fall 2018 Convention in Las Vegas, NV, the annual ACERS Cements conference in State College, PA, the 12th UTC Spotlight Conference in Washington D.C., as well as overseas, including the 10th International Conference on Cement and Concrete in China.

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

- Missouri S&T continued working on the design/construction of the **Advanced Materials and Construction Lab (ACML)**, which broke ground on October 12, 2018. Construction of a new $6.5 million lab that is expected to strengthen Missouri S&T's position as a national leader in addressing the challenges of aging public infrastructure. Phase I of this project was funded by UTC Grant DTRT06-G-0014, which funded the $2.25M of specialized research equipment that will be housed in this new lab.
- The RE-CAST Center will continue to support of students involved in RE-CAST research, encourage professional development via conferences and workshops, and reward students through financial support and travel support for their professional service activities. Our next months will focus on closure of the project and remaining technical objectives.
- The New York University team will continue to collaborate with Rutgers team on applying network-level LCCA for bridge beams with different repair techniques proposed in Project 2-D. The team will continue to enhance the functionalities in the web-based LCCA software.
- In the next reporting period, the S&T team has the last pumping test planned for April, looking at SCC mixtures with a PNS plasticizer. Freeze-thaw and scaling tests are ongoing. Available durability results will be cross-linked with other parameters, such as the hardened air-void system.

2. PRODUCTS

2.A - Publications, Conference Papers, and Presentations

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

Feys, D. and Asghari, A., "Influence of Maximum Applied Shear Rate on the Measured Rheological Properties of Flowable Cement Pastes," Cement and Concrete Research, 117, pp.69-81, 2019.

Ley-Hernandez, A.M., **Feys, D**. and Hartell, J.A., "Effect of Dynamic Segregation of Self-Consolidating Concrete on Homogeneity of Long Pre-Cast Beams," Materials and Structures, 52(1), p.4, 2019.

Sadati, S., da Silva, L.E.B., Wunsch, D., and **Khayat, K.H.**, "Artificial Intelligence to Investigate the Modulus of Elasticity of Recycled Concrete Aggregate," ACI Materials Jr., 116 (1), pp. 51-62 Jan.-Feb. 2019.

Bate, B., **Khayat, K.H.**, Zhang, S., Chen, P., Reply to "A discussion on the paper "Determination of Mortar Setting Times using Shear Wave Velocity Evolution Curves Measured by the Bender Element Technique" by J. Carette and S. Staquet, Cement and Concrete Research, 115, pp. 203-206, January 2019, on-line Nov. 2018.

Megid, W.A., **Khayat, K.H.**," Effect of Structural Buildup at Rest of SCC on Mechanical and Transport Properties of Multilayer Casting," Construction and Building Materials, 196, pp. 626-636, January 2019.

Naji, S., **Khayat, K.H.**, and Karray, M., "Effect of Piezoelectric Ring Sensor Size on Early-Age Property Monitoring of Self-Consolidating Concrete," ACI Materials Jr., 115 (6), pp. 813-824, 2018.

Casteneda, D. Riding, K. **Lange**, **D.A.** "Prediction of Freezing Temperature inside Concrete Crossties at the Rail Seat," J. Mat. Civil Eng. (ASCE), Vol. 31, No. 1, 2019.

Koch, J., Castaneda, D., Ewoldt, R.H., and **Lange, D.A.** "Vibration of fresh concrete understood through the paradigm of granular physics" Cement and Concrete Research, Volume 115, pp 31-42, 2019.

Y.F. Silva, **D.A. Lange**, S. Delvasto, "Effect of incorporation of masonry residue on the properties of self-compacting concretes," Construction and Building Materials, Vol. 196, pp 277-283, 2019.

Abeol Seoud, M.A., **Myers, J.J.**, "Flexural Behavior of Hybrid Composite Beam (HCB) Bridges," Advances in Materials Science and Engineering, Hindawi Publishers, Vol. 2019, pp 1-9, March 2019.

Gheni, A.A., Alghazali, H.H., ElGawady, M.A. and **Myers, J.J., Feys, D.** "Durability Properties of Cleaner Cement Mortar with by-products of Tire Recycling" Elsevier's Journal of Cleaner Production, Vol. 213, pp. 1135-1146, March 2019.

Aljaberi, Z.K., **Myers, J.J.**, Chandrashekhara, K., "Effect of Direct Service Temperature Exposure on the Bond Behavior between Advanced Composites and CMU Using NSM and EB Techniques," Elsevier's Composite Structures Journal, Vol. 211, pp 63-75, March 2019.

Gooranorimi, O., Gremel, D., **Myers, J.J., Nanni, A.** "Long-term Durability of GFRP Internal Reinforcement in Concrete Structures," American Concrete Institute (ACI) Special Publication 331, Symposium Volume-Durability of Concrete Structures Incorporating Conventional and Advanced Materials, Farmington Hills, MI, SP-331-5, pp. 69-79, March 2019.

Alghazali, H.H., Aljaberi, Z.K., Aljazaeri, Z.R., **Myers, J.J.** "Behavior of Full-Scale Damaged Beams Repaired using a Steel Reinforced Polymer (SRP) Technique," American Concrete Institute (ACI) Special Publication 331, Symposium Volume-Durability of Concrete Structures Incorporating Conventional and Advanced Materials, Farmington Hills, MI, SP-331-8, pp. 122-135, March 2019.

Aljazaeri, Z.R., Janke, M.A., **Myers, J.J.**, "A Novel and Effective Anchorage System for Enhancing the Flexural Capacity of RC Beams Strengthened with FRCM Composites," Elsevier's Composite Structures Journal, Vol. 210, pp. 20-28, February 15, 2019.

Alghazali, H.H., **Myers, J.J.**, "Bond Performance of High Volume Fly Ash Self-consolidating Concrete in Full-scale Beams," American Concrete Institute – Structural Journal, Vol. 116, No. 1, pp 161-170, January 2019.

Aljaberi, Z.K., **Myers, J.J.**, Chandrashekhara, K., "Behavior of EB FRP Masonry Bond Under Service Temperature," Advanced Materials Letters, Linkoping, Sweden, Manuscript ID AML1402152, Vol. 9, No. 11, , pp. 753-759, November 2018.

Alghazali, H.H., Aljaberi, Z.K., Aljazaeri, Z.R., **Myers, J.J.**, "Structural Performance of Severely Damaged Reinforced Concrete Beams After SRP Repair," Advanced Materials Letters, Linkoping, Sweden, Vol. 9, No. 11, pp. 789-795, November 2018.

Aljaberi, Z.K., **Myers, J.J.**, ElGawady, M.A., "Evaluation of FRP and FRCM Composites for the Strengthening of Reinforced Masonry Walls," American Concrete Institute (ACI) Special Publication, Special Publication 327 for the FRPRCS-17 Conference, SP-327, pp 32.1-32.16, November 2018.

Jingqin Gao, **Kaan Ozbay**, **Hani Nassif,** Onur Kalan, "Stochastic Multi-Objective Optimization-Based Life Cycle Cost Analysis for New Construction Materials and Technologies," Journal of the TRB.

Adi Abu-Obeidah, Gregory Brewer, **Hani Nassif**, Chaekuk Na, Frank Corso, "Utilization of Fiber Reinforced High Performance Concrete (FR-HPC) in Reconstructed Bridge Decks," TRB 2019, January 2019.

Presentations (in part):

Dimitri Feys

Galvez Moreno, D., Riding, K., and **Feys, D.**, 2019. "Rheology as a Tool to Characterize Dissolution and Reappearance of Air under Pressure in Cement Pastes," 28th Conference on Rheology of Building Materials, Regensburg, Germany.

Galvez Moreno, D., **Feys, D.**, Riding, K., 2019. "The Effect of Shear Rate on Air Dissolution in Cement Paste under Pressure," ACI Spring Convention, Quebec City.

Salinas, A., Galvez Moreno, D., **Feys, D.**, Riding, K., 2019. "Changes in Fresh Properties of Flowable Concrete Induced by Pumping," ACI Spring Convention, Quebec City.

Wehar, A., Galvez Moreno, D., Riding, K., **Feys, D**., 2019. "Influence of Pumping Parameters on The Freeze/Thaw And Scaling Resistance Of Highly Workable Concrete," ACI Spring Convention, Quebec City.

Kamal H. Khayat

"Effect of Fiber Characteristics on Fresh and Hardened Properties of Fiber-Reinforced Concrete," ACI Spring Convention, March 25, 2019, Quebec City, Qc, Canada. Invited presentation.

"Design and Performance of Self-Consolidating Concrete for Repair of Concrete Infrastructure," ACI Spring Convention, March 25, 2019, Quebec City, Qc, Canada. Invited presentation.

"Concrete Pavement Incorporating Recycled Concrete Aggregate: The RE-CAST Experience," ACI Quebec and Eastern Ontario Chapter Annual Meeting, Dec. 5-6, 2018, Sherbrooke, Qc, Canada. Invited presentation.

"Recent Advances in the Design of Cost-Effective UHPC with Adapted Rheology," Keynote speaker, 14th International Conference on Recent Advances in Concrete Technology and Sustainability Issues, Beijing, China, October - November 2018. Keynote presentation.

"Effect of Rheological Properties on Quality of Formed Surfaces Cast with SCC and Superworkable Concrete," Nov., 2018, CBMA, Beijing, China. Invited Speaker.

"Improving Flexural Performance of Ultra-High Performance Concrete by Rheology Control of Suspending Mortar," 2nd International Symposium on Ultra High-Performance Concrete, Fuzhou, China, November 2018. Keynote presentation.

John J. Myers

"Durability of GFRP Rebars Extracted from Bridges with 15 to 20 Years in Service: Historic Overview," American Concrete Institute (ACI) 2019 Spring Conference, Quebec City, Quebec, Canada, March 24, 2018. Invited presentation.

"Durability of GFRP Rebars Extracted from Bridges with 15 to 20 Years in Service: Testing Series and Results," American Concrete Institute (ACI) 2019 Spring Conference, Quebec City, Quebec, Canada, March 24, 2018. Invited presentation.

"Recent Advances in Bridge Engineering in the State of Missouri and the United States of America," Special Presentation at Shibaura Institute of Technology, Tokyo, Japan, November 6, 2018. Invited presentation.

"Microstructure and Mechanical Property Behavior of In-situ FRP Reinforcement Autopsied from In-Service Bridge Structures," American Concrete Institute (ACI) 2018 Fall Conference, Las Vegas, Nevada, October 15, 2018. Invited presentation.

"Condition Assessment of Bridges in the United States," American Concrete Institute (ACI) 2019 Spring Conference, Quebec City, Quebec, Canada, March 24, 2018.

Hani Nassif

Dan Su and **Hani Nassif**, "Calibration of Service I Limit State for Reinforced Concrete Bridge Deck Designed Using Empirical Method," ACI Fall 2018, LV, October 2018.

Nakin Suksawang and **Hani Nassif**, "Structural Health Monitoring of Latex-Modified Concrete (LMC) Overlays on Bridge Decks," ACI Fall 2018, LV, October 2018.

Jingqin Gao, **Kaan Ozbay**, **Hani Nassif**, Onur Kalan, "Stochastic Multi-Objective Optimization-Based Life Cycle Cost Analysis for New Construction Materials and Technologies," TRB 2019, January 2019.

Adi Abu-Obeidah, Gregory Brewer, **Hani Nassif**, Chaekuk Na, Frank Corso, "Utilization of Fiber Reinforced High Performance Concrete (FR-HPC) in Reconstructed Bridge Decks," TRB 2019, January 2019.

Graziano Fiorillo, **Hani Nassif**, "The Application of Machine Learning Techniques for the analysis of NBI and Bridge Element Data," TRB 2019, January 2019.

Peng Lou, Thanachai Srithaninrat, **Hani Nassif**, Dongjian Gao, "Reliability-Based Assessment of Load And Resistance Factored Rating under Permit Loads for Steel Bridges," TRB 2019, January 2019.

Peng Lou, Dongjian Gao, **Hani Nassif**, Mula Reddy, "Reliability Assessment of Steel Bridges for Specialized Hauling Vehicles," TRB 2019, January 2019.

Hani Nassif, Peng Lou and He Zhang, "Structural Health Monitoring for Evaluation and Load Rating of Prestressed Concrete Bridges," ACI 2019 Spring Convention.

Peng Lou, **Hani Nassif** and Dongjian Gao, "Live Load Effects on Concrete Bridges due to Special Hauling Vehicles (SHV)", ACI 2019 Spring Convention, March 2019.

Dan Su and **Hani Nassif**, "Evaluation of WIM-Based Live Load Models for Concrete Bridges," ACI 2019 Spring Convention, March 2019.

Kaan Ozbay

"Bridge Management Decision-Making" (AHD35 Standing Committee on Bridge Management) at the 98th Transportation Research Board Annual Meeting, Washington D.C., January 2019.

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
- American Concrete Institute
- American Society of Civil Engineering
- **APTIM**
- 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
- **Euclid Chemical, Ohio**
- Florida Department of Transportation
- Garver Engineering, Norman, OK
- **GPI**
- 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
- **MnDOT**
- **MnRoad**
- 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
- **Penn State University**
- Philips Hardy Inc., MO
- Port Authority of New York and New Jersey (PANYNJ)
- Prestressed Concrete Institute
- Small Modular Reactor Research and Education Consortium
- Southeast University, Nanjing, China
- State University of NY Maritime College
- State University of NY at Stony Brook
- The Masonry Society
- Transportation Research Board
- 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 in NJ, IL, MO, OK and FL can be used as case studies that shows the applicability of advanced materials and technologies developed by RE-CAST members for the construction of durable and sustainable concrete bridge decks and pavements using HPC and FRP.

We are delivering new, embedded sensor systems that support Structural Health Monitoring of transportation infrastructure that can allow better prediction of service life and enable better management of the infrastructure.

The FR-HPC mix designs that were developed by the RECAST consortium members can be widely used for the bridge deck construction and rehabilitation. 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 comprehensive bottom-up methodology based on LCCA is able to integrate project- and network-level analysis that can fast-track the acceptance of new materials or technologies. Hypothesized improvement rates are applied to the deterioration functions of existing materials to represent the expected improved performance of a new material compared with a conventional material with relatively similar characteristics. This

new approach with stochastic treatment can be used to probabilistically evaluate new materials with limited data for their future performance. This two-level probabilistic LCCA framework provides an effective solution to many issues that have not been completely addressed in the past, including the trade-off between multiple objectives, effect of time, uncertainty and outcome interpretation. The customized interactive web-based LCCA software can be widely used 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 with real-world infrastructure data.

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 knowledge applies to other disciplines such as Materials Science as it relates to generic suspensions. Experimental work is being integrated in Artificial Intelligence and machine learning to predict material performance in other applications.

The NYU team is currently developing a technical memorandum for the web-based LCCA software. The development of the software also involves database management, cloud storage, and cyber security enhancement. The technical memorandum will help the users for future development of such web-based tools. The document will be also shared with the consortium universities of RECAST project. The general knowledge applies to other disciplines such as Materials Science as it relates to generic applications where field testing is conducted and portable equipment and embedded sensors are valued.

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, FY2018 and FY2019. 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 web-based LCCA tool has been presented as C2SMART Showcases Research at ITS-NY.

Technical specifications for use of FR-SCC, RCA, RCC, SCC and UHPC will help transportation agencies understand the feasibility and adoption of FR-SCC in various infrastructure applications. The use of new mixture designs helps the transportation agencies offer more durable bridges with less cost to the tax payers.

The field implementation of FR-HPC mixture can be used as a case study for the lessons learned for future similar projects. Case studies can be compiled to be used as a presentation for workshop or class that will have an impact on the transportation workforce development. Major findings of research are also used in preparing webinars.

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

The Rutgers team has been supporting the local transportation agency (NJDOT) under a new major initiative entitled Bridge Resource Program (BRP). The team has shared new methodologies and techniques developed in this project as innovative materials to find future collaboration and implementation under BRP project.

The web-based LCCA tool has been presented as a showcase in 2018 NYU's Annual Research EXPO.

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

The technical specifications of two mixtures (FR-HPC and HES-HPC) have been providing the understanding of new technologies to the contractors as advanced materials.

The NYU team has prepared a video that describes the new LCCA software tool.

Technical Specification of new materials have been developed, and field implementation results are being 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.

By introducing the developed web-based LCCA software to a larger group of engineers and students in the near future might lead to greater societal impacts beyond this project as it provides an easy-to-access way for the engineers or students to perform LCCA estimation. It also provides the feasibility of tool customization depends on user's specific needs.

The developed mixture designs will offer more reliable and safety bridge decks by reducing the crack severity and extending the service life. Such improvement will reduce the maintenance schedule and therefore 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.