Research on Concrete Applications for Sustainable Transportation

RE-CAST

MISSOURI S&T

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In this issue:

CONSORTIUM MEMBERS:

Missouri University of Science and Technology

University of Illinois at Urbana-Champaign

Rutgers, The State University of New Jersey

University of Miami

Southern University and A&M College

Director's Message

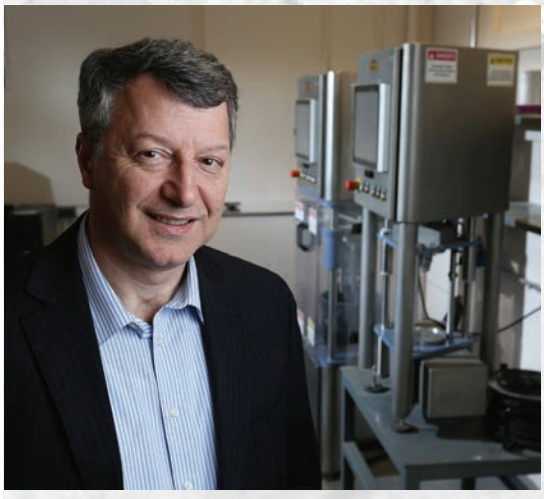
First, I would like to take a moment and wish our readers a Happy New Year! I hope that everyone has enjoyed the holidays and is re-energized for a new year full of innovation and progress.

In this issue, we provide some featured project updates, highlighting some of the recent progress our faculty and students have made.

We are happy to report that Daniel Ivan Castaneda, a Ph.D. candidate under the supervision of Dr. David Lange, RE-CAST Associate Director at UIUC, was selected as the 2015 RE-CAST Outstanding Student of the Year. More information about Daniel and his work can be found in the following pages.

On Dec. 1, the RE-CAST Center offered a webinar presented by Dr. Julie Hartell, Assistant Professor at Oklahoma State University on "*The Use of Resistivity Testing to Improve Concrete Quality.*" Please watch our website for other upcoming webinars and events.

This issue includes some activities at the University of Miami on the "*Design and Construction of Externally Bonded FRP Systems for Strengthening Existing Structures*", as well as activities at far reaching at Australia.



Best wishes for the New Year.

Kamal H. Khayat
RE-CAST Director

OUTREACH/WORKFORCE DEVELOPMENT

2015 RE-CAST Student of the Year: Daniel Castaneda

2015 RE-CAST Outstanding Student of the Year, Daniel Castaneda, pictured with USDOT Office of the Assistant Secretary, Gregory Winfree (left) and CUTC President, Mr. Joel Volinski (right)

For the past 24 years, the U.S. Department of Transportation (USDOT) has honored an outstanding Student from each University Transportation Center (UTC) at a special ceremony held during the Transportation Research Board (TRB) Annual Meeting. This year, the RE-CAST University Transportation Center selected Mr. Daniel Castaneda as its Outstanding Student of the Year. He was recognized at the 25th Annual Outstanding Student of the Year Awards ceremony that took place as part of the Council of University Transportation Centers (CUTC) annual banquet on Saturday, January 9, 2016 in Washington, D.C. Mr. Castaneda was selected for his outstanding academic performance as well as the technical merit and national importance of his research. Additional information on Mr. Castaneda's qualifications for this award are outlined on the following page.

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OUTREACH/WORKFORCE DEVELOPMENT

Student of the Year Award *(continued)*

2015 Outstanding UTC Student of the Year Awardees

Daniel Ivan Castaneda is a Ph.D. Candidate in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign, one of the RE-CAST consortium partners. His research seeks to understand the consequence of design, handling, and placement of fresh materials as they relate to the long-term durability of civil infrastructure. His work includes examining the loss of air-entrainment in extensively vibrated fresh concrete with adapted rheology; investigating bond of repair materials in non-ideal placement conditions; thoughtful selection of sorptive aggregates to control diffusion processes in alternative, sustainable binder systems; development of a field-test to measure residual stresses in plain concrete pavements and structures; and instrumentation of recycled aggregate pavements. Daniel is originally from southern California and attended the University of California, Berkeley, where he completed his B.S. in 2008. Thereafter, he worked as a systems analyst in Silicon Valley where he drafted analytical solutions for the Federal Aviation Administration regarding aircraft excursions out of protected Class B airspace. Throughout Daniel's academic and professional career, he has been strongly motivated to increase the number of qualified women and underrepresented persons in STEM fields and has been involved in numerous outreach and retention efforts. He intends to continue as a researcher of civil engineering materials after he defends his dissertation in early 2016. His adviser, David A. Lange, believes that this award affirms Daniel's contributions to RE-CAST's themes on adapted rheology of high performance concrete and utilizing recycled materials in new construction; and it summarily recognizes Daniel's overall accomplishments.

FEATURED PROJECT

Flexural behavior of UHPC panels reinforced with GFRP grids

- Weina Meng, Ph.D. Candidate, Civil Engineering, Missouri S&T
- Kamal H. Khayat, Ph.D., Civil Engineering, Missouri S&T

The use of glass fiber reinforced polymer (GFRP) grids in reinforced concrete construction offers several advantages, such as high tensile strength and excellent corrosion resistance. Experimental and numerical studies to investigate flexural performance of ultra-high performance concrete (UHPC) panels reinforced with GFRP grids (GFRP-UHPC panel) were carried out. Such panels can be prefabricated and used as stay-in-place formwork for various types of structural elements, especially elements subjected to severe environmental conditions. The flexural performance of panels containing different reinforcement configurations was evaluated in three-point bending tests. A three-dimensional non-linear finite element model was established using ABAQUS, which incorporates the concrete damage plasticity (CDP) model and can be used to predict the post-fracture behavior. The numerical model was experimentally validated using the three-point bending test results. The proposed GFRP-UHPC panel system is shown to be promising for the development of lightweight, high-performance permanent formwork system. Such formwork can be used in accelerated construction of critical infrastructures to enhance the crack resistance and extend service life of the concrete structure.

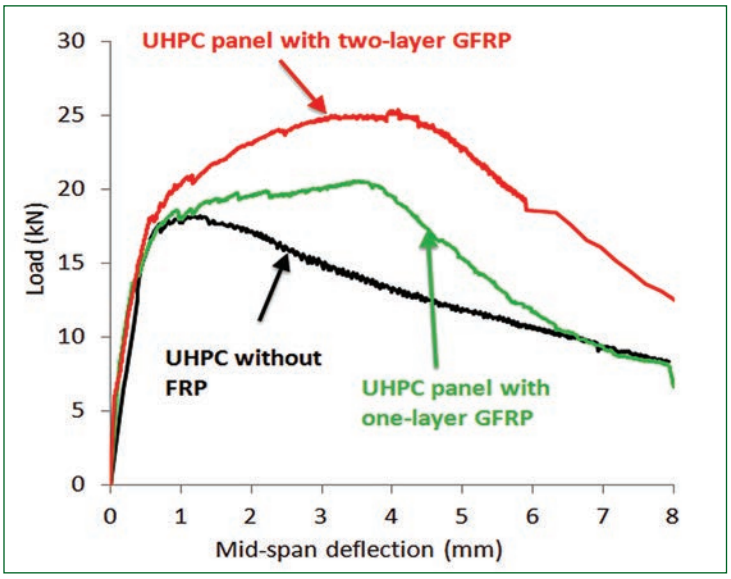

Figure 1. Load-deflection relationships

The load-deflection relationships of the tested panels are compared in **Figure 1**. The peak loads of the single-layer and the dual-layer GFRP reinforced UHPC panels were shown to increase by 20% and 23%, respectively, compared to the reference panel. The thermal toughness was increased by 12% and 59%, for the single-layer and dual-layer GFRP grids, respectively.

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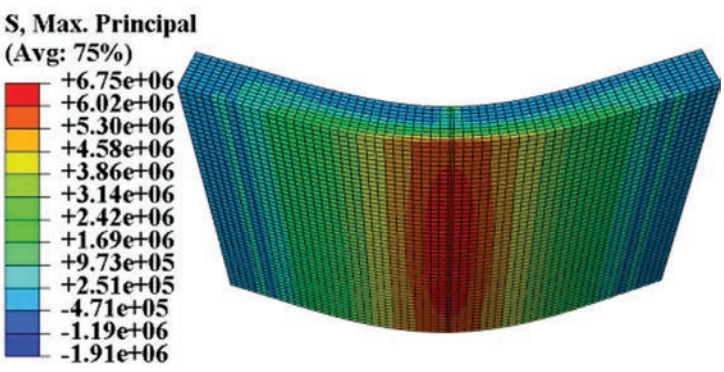
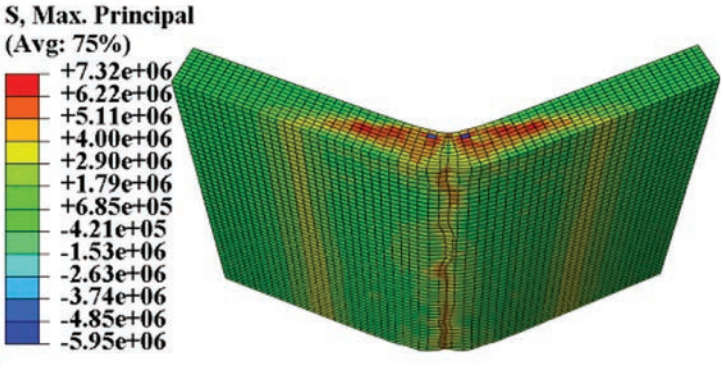
FEATURED PROJECT

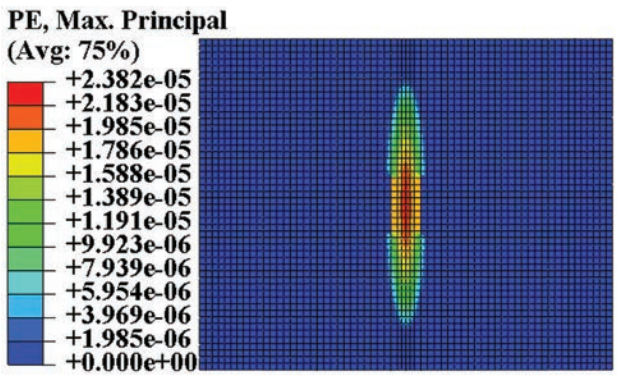
Flexural behavior of UHPC panels reinforced with GFRP grids *(continued)*



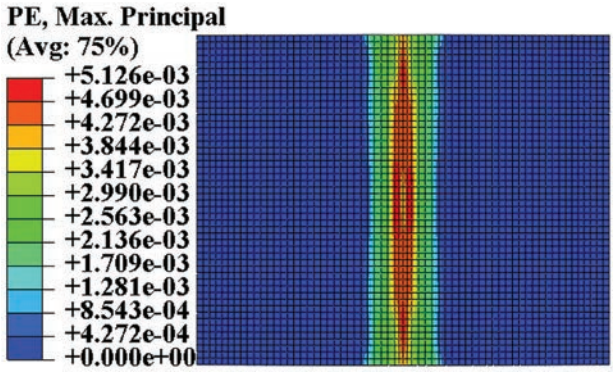
2(a) Unit: Pa



2(b) Unit: Pa



2(c) Unit: m/m



2(d) Unit: m/m

Figure 2. Simulation results of stress: (a) distribution of MPS before cracking (scale factor: 500), (b) distribution of MPS after cracking (scale factor: 10), (c) distribution of PS at 0.1-mm mid-span deflection, and (d) distribution of PS at at 0.5-mm mid-span deflection

Figures 2(a) and (b) show the distribution of maximum principle stress in the panel. Before the occurance of cracking, the maximum principal stress (MPS) was located at the bottom of the panel at mid-span. The deflection curve was in a parabolic shape. However, after cracking that occurs at mid-span, the MPS can relocate to the region near the top. **Figures 2(c) and (d)** show the development of plastic strain (PS, strain larger than the elastic strain limit) with the increase of the mid-span deflection. The PS first appeared at the center of the panel, and then propagated along the mid-span.

FEATURED PROJECT

Flexural behavior of UHPC panels reinforced with GFRP grids *(continued)*

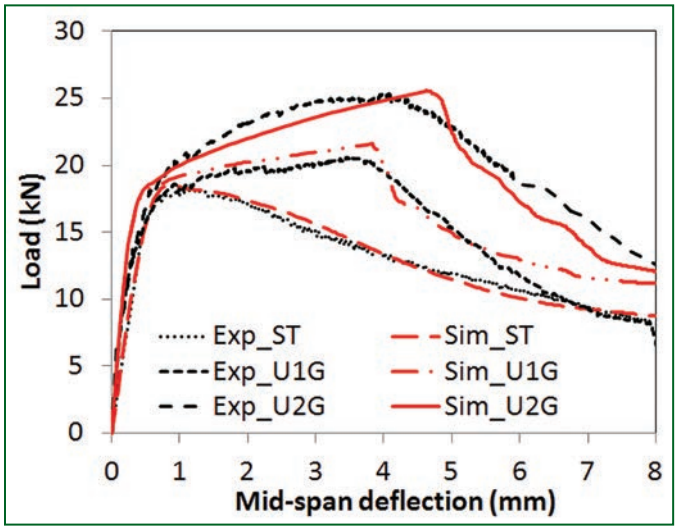


Figure 3. Load-deflection relationships of the panels with 40-mm thickness

Figure 3 compares the experimental (Exp_ST, U1G, and U2G) and numerical (Sim_ST, U1G, and U2G) results. Both results are in good agreement, thus validating the validity of the numerical model. For the elastic stage before cracking occurs, the experimental and numerical results were in excellent agreement (up to 1% error).

Based on the results obtained to date, the use of the GFRP grids can significantly enhance the peak load and energy dissipation, and therefore, the panel's load carrying capacity can be enhanced.

OUTREACH/TECHNOLOGY TRANSFER

Workshop to connect with the Latin American FRP repair market

A one-day workshop on **"Design and Construction of Externally Bonded FRP Systems for Strengthening Existing Structures"** in Spanish Language was held on Saturday, November 14, 2015 at the University of Miami with over 100 registered participants representing 15 countries.

The main objective of this workshop was to present to the Spanish-speaking technical communities of Latin American countries and South Florida the Spanish version of CNR-DT 200 R1/2013, the guide for design and construction of externally bonded FRP systems to existing structures that that has been recognized as one of the most advanced and technically-sound documents on the subject in the world. A guideline, by its nature, is not a binding regulation, but represents an aid for practitioners. The availability of this guide is intended to complement existing regulations where they exist or be the basis for design/construction where they lack.

The second objective was to learn from experts in the Americas about the most compelling challenges to the maintenance and repair of the built stock including case histories and experiences in relevant projects. The workshop concluded with a visit to lab facilities and exhibits from FRP suppliers, contactors, and designers.

OUTREACH/TECHNOLOGY TRANSFER

RE-CAST work makes its way down under

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

Dr. Myers presenting at the PLSE 2015 Conference in December 2015

This past December and November, RECAST Investigator, Dr. John J. Myers, gave a series of five technical presentations at the **Second International Conference on Performance-based and Life-cycle Structural Engineering (PLSE 2015)** in Brisbane, Queensland, Australia and the E**ighth International Structural Engineering and Construction Conference (ISEC-8)** in Sydney, New South Wales, Australia. His technical presentations extended RE-CAST work to a broad new audience and included presentations on Strengthening of Reinforced Concrete Beams in Shear with Fiber Reinforced Cementitious Matrix, the Creep and Shrinkage of Ecological Self-Consolidating Concrete, the Effect of Accelerated Curing on Abrasion Resistance of HVSCM-SC, the Influence of Near-Surface mounted (NSM) FRP with Cementitious Material on the Out-of-Plane Behavior of Reinforced Masonry Walls, and the Live-Load Distribution Factors and Service Response of Missouri Bridge A7957. These presentations and technical papers included Missouri S&T Ph.D. student co-authors Zena Aljazaeri, Hayder Alghazali, Zuhair Al Jaberi and Eli Hernandez.

FEATURED PROJECT

Fatigue performance of reinforced concrete beams strengthened with fabric reinforced cementitious materials

- John J. Myers, Ph.D., P.E., Professor of Civil and Architectural Engineering, Missouri S&T
- Zena R. Aljazaeri, Ph.D. student, Missouri S&T

One of the most important aspects for a structural element in bridge applications is its ability to resist the oscillatory loads through its entire life. For that, Dr. John Myers and his graduate student, Zena Aljazaeri, have been studying the fatigue performance of FRCM composite in strengthening RC beams as part of RE-CAST program Project 3C. The study parameters were the FRCM's reinforcement ratio, the environmental exposure, and the fatigue frequency. The experimental work included testing of 12 RC beams. Two beams served as control beams. Five beams strengthened with one ply of the FRCM composite and the other five beams strengthened with four plies of the FRCM composite. The test matrix was divided into three groups based on the exposure conditions. Group 1, beams were tested under laboratory conditions. Group 2, beams were subjected to severe environmental conditions such as freezing and thawing cycles, high temperature and humidity cycles. Within the environmental chamber cycling regime, some beams were under their self-weight and the others were subjected to sustained stress.

Figure 1. Beams inside Environmental Chamber

STUDENT SPOTLIGHT

RE-CAST student wins second place at 4th annual Missouri S&T/MoDOT Transportation Infrastructure Conference poster competition

RE-CAST Ph.D. student, Zena R. Aljazaeri with RE-CAST Director and Conference Chairman Dr. Kamal H. Khayat

Zena Aljazaeri with MoDOT Research Administrator and Conference Co-Chairman Mr. William Stone

RE-CAST Ph.D. student, Zena R. Aljazaeri won second place at the 4th Annual Missouri S&T / MoDOT Transportation Infrastructure Conference poster competition. Her poster presented the work she has preformed under the RE-CAST project entitled "**Fatigue and Flexural Behavior of Reinforced Concrete Beams Stregnthened with Fiber Reinforced Cementitous Matrix.**"

The conference was held on December 4, 2015 at the St. Louis University Campus in collaboration with MoDOT. Nearly 100 participants attended the event which featured presentations of cutting edge research and field implementation projects in transportation infrastructure engineering.

This year's conference showcased recent findings in the areas of advanced construction materials, non-destructive testing and structural health monitoring of transportation infrastructure.

This was the first year that a student poster competition was held, which attracts 15 students from three area universities to compete. Three judges from the Missouri Department of Transportation met with each student to discuss thier poster and chose three winners. RE-CAST is proud of the recognition that Zena recieved at this event.

FEATURED PROJECT

Fatigue behavior of FRCM strengthened RC Beams

- Vanessa Pino, Ph.D. candidate, Department of Civil Engineering, University of Miami
- Houman A. Hadad, Ph.D. candidate, Department of Civil Engineering, University of Miami
- Antonio Nanni, Ph.D., Department of Civil Engineering, University of Miami

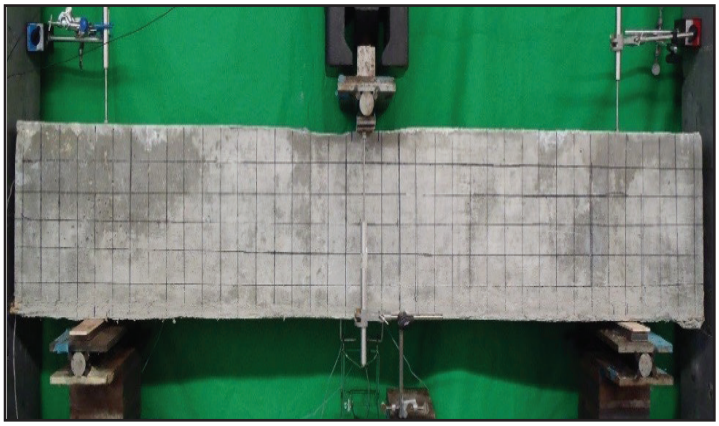


Figure 1. Test Set-up and Instrumentation

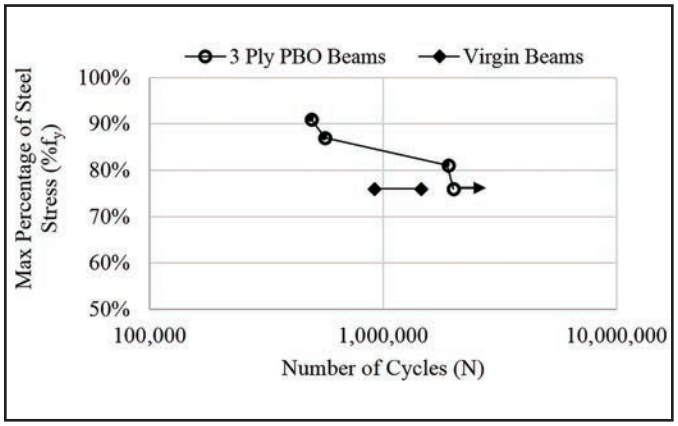


Figure 2. Load-deflection curves for control and PBO-FRCM 3 ply

Fabric reinforced cementitious matrix (FRCM) is a comparably novel composite strengthening system for existing reinforced concrete (RC) and masonry structures. Existing externally bonded strengthening technologies based on organic matrices referred to as Fiber reinforced polymers (FRP), and more novel solutions based on inorganic matrices known as FRCM systems have proven to successfully increase and restore strength in RC structures. FRCMs are deemed suitable for the repair of RC and masonry because of the excellent compatibility between the cementitious matrix and substrate.

Some concrete structures, such as bridges, experience high traffic volumes and varying vehicle axle weights causing repeated cyclic loading throughout their lifetime. Cyclic loading may cause damage to the structure, a phenomenon known as fatigue. Due to the novelty of FRCM technology, there is a lack of research regarding the long-term performance of FRCM systems when used to strengthen members subject to cyclic loads.

This study investigates experimentally some of the parameters that affect the fatigue behavior of FRCM strengthened RC beams subject to cyclic loading (**Figure 1**). The stress ration vs. number of cycles (S-N) curve depicted in **Figure 2** is obtained herein as it is typically used in fatigue-related studies to reflects the longevity limit of the member under fatigue. Failure mode, fatigue life, and the serviceability behavior of beams during cyclic loading are investigated, and preliminary results seem to show that FRCM provides an increase in strength, yield point and stiffness for a RC beam and can potentially increase its fatigue life. In addition, it was observed that the level of minimum and maximum stresses in reinforcing steel are of great importance among the other parameters in the fatigue life of RC beams strengthened with FRCM.

WEBINAR SERIES

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

October 22, 2015 at 11am CDT

Presenter: Charles Hanskat, P.E.

Executive Director, American Shotcrete Association

"Shotcrete for Repair and Rehabilitation of Highway Facilities"

December 1, 2015 at 11am CDT

Presenter: Julie Hartell, Assistant Professor

Civil and Environmental Engineering

Oklahoma State University

"The Use of Resistivity Testing to Improve Concrete Quality"

Presented in partnership with Southern Plains Transportation Center (SPTC) at University of Oklahoma

SCC2016 - "Flowing Towards Sustainability"

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

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

Register today at: **www.scc2016.com**

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