Research on Concrete Applications for Sustainable Transportation

# RE-CAST

MISSOURI S&T

Vol. 2 :: Issue 3 :: JULY 2015

## In this issue:



**CONSORTIUM MEMBERS:**

**Missouri University of Science and Technology**

**University of Illinois at Urbana-Champaign**

**Rutgers, The State University of New Jersey**

**University of Miami**

**Southern University and A&M College**

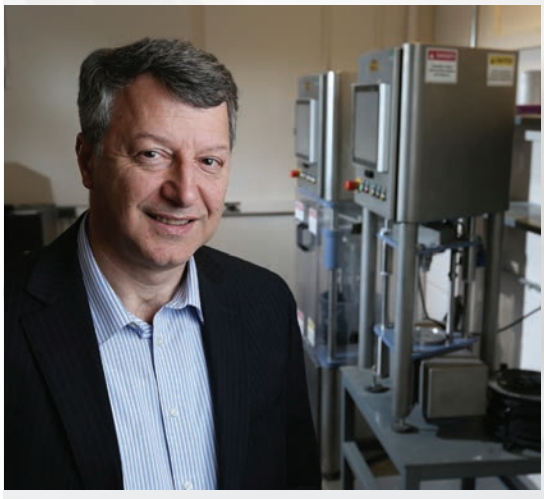
## Director's Message

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

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

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

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



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

-Kamal H. Khayat
*RE-CAST Director*

# EDUCATION/WORKFORCE DEVELOPMENT

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

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

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

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

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# EDUCATION/WORKFORCE DEVELOPMENT

## *Special Workshop (continued)*

### Instructors:

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

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

### Workshop Lecture Topics:

Topic 1- Concrete Bridges

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

Topic 2- Concrete Pavement

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

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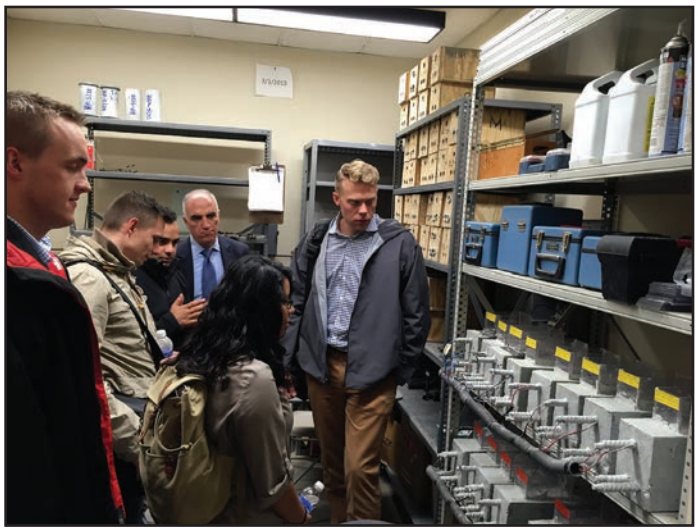
# EDUCATION/WORKFORCE DEVELOPMENT

## *Special Workshop (continued)*



### Lab Topics

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

### Field Visit

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

# FEATURED PROJECT

## Economical and Crack-Free HPC with Adapted Rheology:

## *Full Scale Specimen Testing*

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

**Figure 1. Completed Reinforcing Cage**

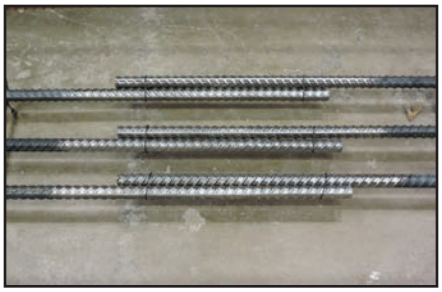


**Figure 2. Cleaned Bars**

**Figure 3. Test Fixture Fabrication**

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

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

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

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

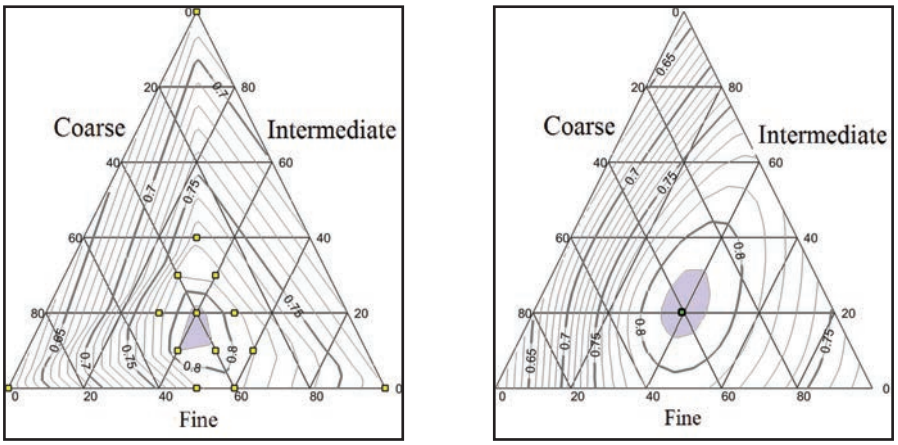
With the focus of the RE-CAST projects on improving the condition of our nation's deteriorating infrastructure, the OU research team has been able to solicit multiple large donations in support of their efforts. These donations included 50 tons of aggregate, 20 tons of cement, and 10 tons of fly ash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

# FEATURED PROJECT

## Roller Compacted Concrete (RCC) for Rapid Pavement Construction

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

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




(a) (b)

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

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

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# Roller Compacted Concrete *(continued)*

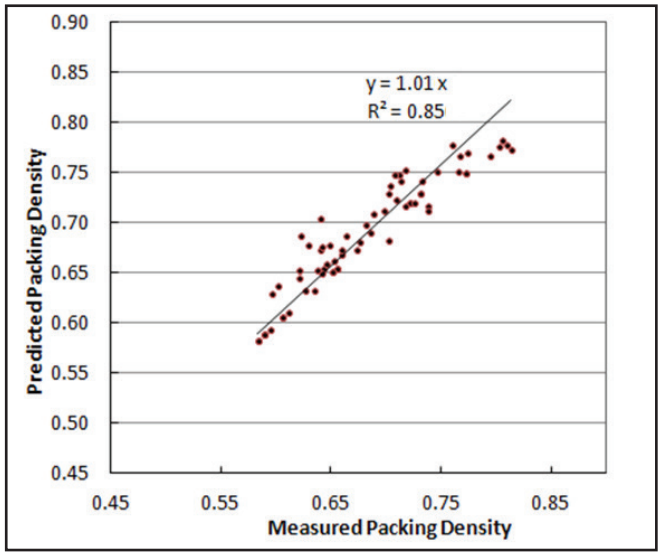


**Figure 2. Estimated packing vs. experimental packing density of various aggregate combinations**

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

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

# OUTREACH/DIVERSITY

## A Fascinating Afternoon with the Women in Concrete Alliance

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

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

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

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# OUTREACH/DIVERSITY

## Women in Concrete Alliance *(continued)*

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

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

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

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

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

# DIVERSITY/OUTREACH

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


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

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

# Student Spotlight

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

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

# FEATURED PROJECT

## Dynamic Segregation of Self-Consolidating Concrete

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

**Figure 1. Tilting Box**

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

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

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# FEATURED PROJECT

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

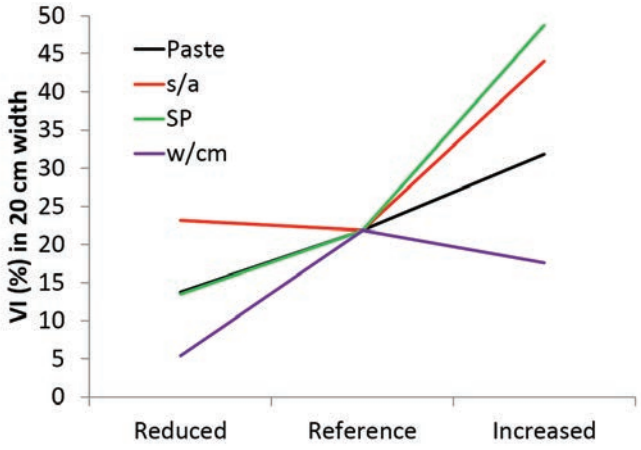


**Figure 2. Influence of mix design parameters on dynamic segregation (VI) of SCC**

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

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

# FEATURED PROJECT

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

References:

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

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

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

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

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

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

# FEATURED PROJECT

## Evaluation of UHPC Joints in Bridge Girders

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

- Saipavan Rallabhandi, Graduate Student, Missouri S&T

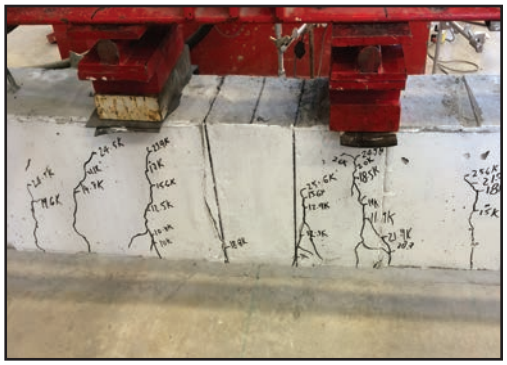

**Figure 1. UHPC Joint**

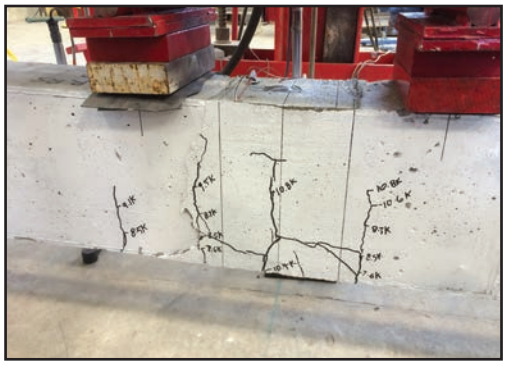

**Figure 2. HS-SCC Joint**

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

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

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

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# FEATURED PROJECT

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

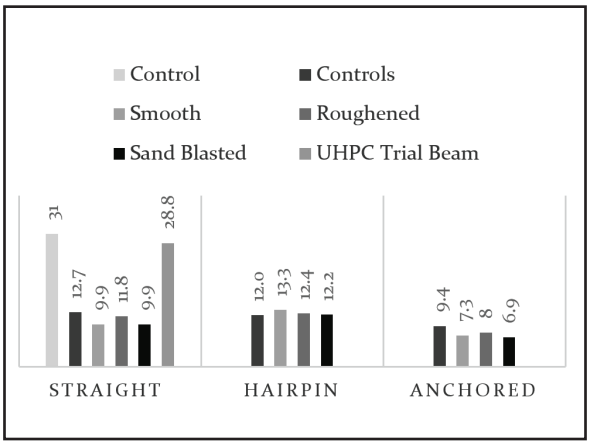


**Figure 3. Peak Load**

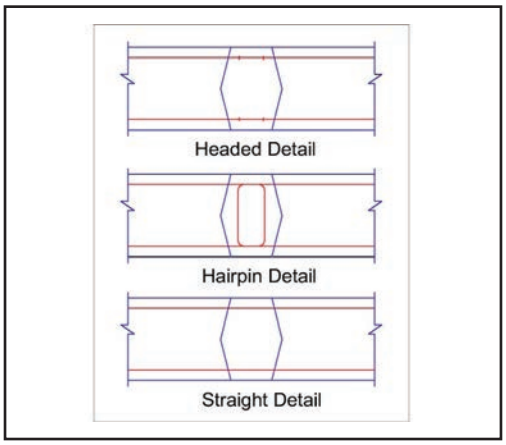


**Figure 4. Joint Detail**

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

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

# WEBINAR SERIES

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

**May 5, 2015 at 2pm ET**

Presenter: Elizabeth Birriel, Florida DOT

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

Presented in Spanish with English Closed-Captioning

# UPCOMING TECHNOLOGY TRANSFER EVENTS

*Save the Dates:*

## SCC2016 - "Flowing Towards Sustainability"

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

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

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

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## Contact Information:

Website:
http://recast.mst.edu

Email:
re-cast@mst.edu

Director:
Kamal H. Khayat - khayatk@mst.edu

Coordinator/Newsletter Editor:
Abigayle Sherman - abigayle@mst.edu

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