Research on Concrete Applications for Sustainable Transportation

RE-CAST

Missouri S&T

Vol. 4 :: Issue 2 :: SPRING 2017

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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

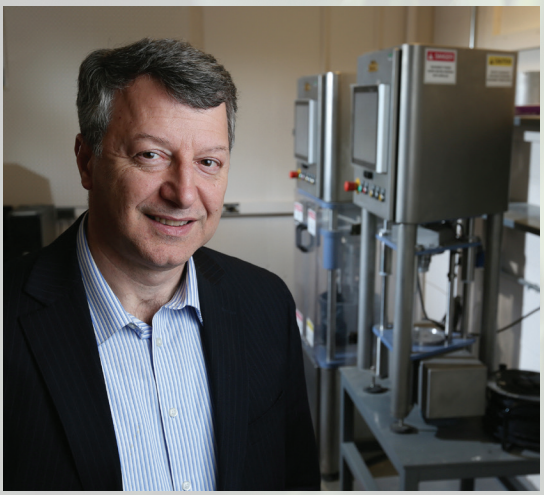
As the 2016-2017 academic year comes to a close, we would like to take a moment to share a few highlights since our last newsletter.

We have included two research project updates and invite any questions our readers may have about them. Our research team's contact information is available on our web page and we invite your feedback.

We hosted an online webinar on January 23. Dr. Jeffery Volz of RE-CAST presented "Concrete Pavement Containing High Volumes of Recycled Materials." This webinar, along of many others, are available for viewing on our website. We invite you to visit our webinar library for additional details and sign up for our upcoming webinars.

We are also happy to share with you two success stories. One features a Missouri S&T Ph.D. student who was awarded a travel grant and recognition from the American Society for Nondestructive Testing and another featuring a title that was bestowed on one of our Associate Directors, Dr. David Lange, from UIUC.

We hope that everyone enjoys the upcoming summer break and utilizes that time to catch up on your to-do list.



Kind regards,

Kamal H. Khayat
RE-CAST Director

FEATURED PROJECT

Using Artificial Intelligence to Predict Performance of Concrete Incorporating Recycled Concrete Aggregate

- Hamed Sadadi, Ph.D. candidate in civil engineering, Missouri S&T
- Kamal H. Khayat, Ph.D., Jones Professor of civil engineering, Missouri S&T

Figure 1. Availability of adhered residual mortar and contaminations in RCA piles

Introduction

Construction and demolition (C&D) waste accounts for considerable portion of solid wastes in the U.S. with estimated 535 million tons in 2014, which represents 65% increase since 2003 (EPA 2004 & 2016). Concrete products constitute more than 70% of the C&D waste in 2014. Considering the need to produce more than 2.5 billion tons of aggregate in the U.S. for the construction industry by 2020, an increase from 2 billion tons in 2004 (FHWA 2004), the incorporation of recycled concrete aggregate (RCA) to replace a part of virgin aggregate can result in substantial reduction in the use of non-renewable natural resources and concrete waste in landfills.

The heterogeneous nature of RCA stemming from the adhered residual mortar, origin of the waste concrete source, recycling process, level of chemical contamination, etc. can lead to a wide range of performance when RCA is incorporated (**Figure 1**). The degree of heterogeneity of RCA can be reflected in its key physical properties, including variability in specific gravity (2.0-2.5), water absorption (2%-8%),

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Using Artificial Intelligence *(con't)*

and Los Angeles (LA) abrasion mass loss (20%-50%). Such variability of RCA quality can decrease engineering properties, such as compressive strength, modulus of elasticity, and splitting tensile strength. of concrete by 0-40% (NCHRP 2013).

Proper strategies enabling the prediction of the performance of concrete based on the characteristics of the RCA are required to increase the market share of RCA in production of new concrete for transportation infrastructure.

The **main objectives of the research** that is being planned as part of the work of RE-CAST are:

1. Development of a smart system using artificial intelligence techniques (e.g. artificial neural networks) to predict the performance of concrete incorporating RCA
2. Validation of the developed system using additional datasets obtained from laboratory investigation
3. Development of guidelines to optimize the use of RCA in concrete production for transportation infrastructure

The project will develop guidelines to predict concrete performance based on RCA characteristics. The research program mainly targets concrete used in structural and pavement applications that is of great interest to owner agencies and engineers considering the design and use of sustainable concrete for structural applications. Enabling greater use of RCA in such applications can have considerable benefit from the volume of concrete waste products that can be recycled in concrete construction, as well as the potential savings and reduced emissions associated with decreased hauling distances in light of on-site recycling.

Research Methodology

Four main phases are considered for this research, including the development of a comprehensive database of properties of concrete made with RCA ,expert model development, laboratory investigation, and development of guidelines. A summary of the research methodology is provided below.

Phase I: Development of comprehensive database of properties of concrete incorporating fine and coarse RCA. Of main interest are: (1) key engineering properties of RCA, including water absorption, specific gravity, deleterious materials content, LA abrasion resistance, and water soluble sulfate and chloride contents; (2) raw materials and mix design of concrete where RCA is employed (binder type and content, w/cm, RCA replacement level, properties of virgin aggregate); (3) concrete properties, including mechanical properties and durability.

Phase II: The database will be analyzed using artificial neural networks and statistical data analysis to develop models to predict compressive, splitting tensile, and flexural strengths, and modulus of elasticity of concrete made with RCA.

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Using Artificial Intelligence *(con't)*

Phase III: Data obtained by testing concrete with different RCA materials used at replacement levels of 0, 25%, and 50% of coarse and fine RCA will be employed to verify the accuracy of the models. The RCA will be procured from various recycling centers in the state of Missouri representing wide range of properties (e.g. LA abrasion of 25%-50% and water absorption of 3%-8%). Of special interest is to quantify the effect of RCA properties on compressive, splitting tensile, and flexural strengths, modulus of elasticity, shrinkage, water absorption, frost durability, and electrical resistivity.

Phase IV: Guidelines will be developed for the selection of RCA to ensure proper mechanical properties and durability of different concrete classes targeted in this research. This work will be based on the results derived from Phases I to III.

References

NCHRP synthesis 435, (2013), Recycled materials and by-products in highway applications, volume 6, reclaimed asphalt pavement, recycled concrete aggregate, and construction demolition waste, Transportation Research Board.

Gonzalez, G. P., & Moo-Young, H. K. (2004). Transportation applications of recycled concrete aggregate. FHWA state of the Practice National Review.

United States Environmental Protection Agency (2004), RCRA in focus: construction, demolition, and renovation, https://www.epa.gov/hwgenerators/resource-conservation-and-recovery-act-rcra-focus-hazardous-waste-generator-guidance

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STUDENT SPOTLIGHT

RE-CAST student receives conference grant/recognition

Iman Mehdipour: Travel Grant and Session Chair recognition at ASNT Conference

Mr. Iman Mehdipour, RE-CAST Ph.D. student at Missouri S&T, received a student travel grant, as well as recognition for being a Session Chair, at the American Society for Nondestructive Testing (ASNT) 26th Research Symposium held in Jacksonville, FL on March 13-16, 2017.

Congratulations to Iman for this recognition of his leadership, service, and interdisciplinary research. Iman presented results of work dealing with the use of microwave NDT technique to monitor autogenous cracking healing of cementitious materials, work performed in collaboration with Prof. K. Khayat (Civil Engr.) and Prof. R. Zoughi (Electrical Engr.) of Missouri S&T.

FEATURED PROJECT

Restrained Shrinkage Behavior of SCC with Steel Fibers

- Hani Nassif, Ph.D., Professor of Civil Engineering, Rutgers University
- Giuseppe Liberti, M.S. student, Rutgers University

Figure 1. PSI crimped steel fibers

The Rutgers team has evaluated the restrained shrinkage performance of self-consolidating concrete (SCC) with steel fiber. The use of SCC is becoming more popular because it eliminates the need for external consolidation while securing the strength and other key properties of high performance concrete (HPC). Since SCC typically contains a higher amount of cementitious materials than conventional concrete, the SCC is prone to greater levels of shrinkage that can result in cracking under restrained conditions.

The main objective of this study is to develop the fiber-reinforced SCC (FR-SCC) mixture designs with low shrinkage and to analyze the restrained shrinkage properties of such FR-SCC mixtures. In order to control cracking and improve cracking resistance, 1.5 in. long PSI crimped steel fibers were introduced in the mixtures, as shown in **Figure 1.** Four (4) different steel fiber volume contents of 0.35%, 0.50%, 0.65% and 0.80% were used for FR-SCC mixtures and compared with the control SCC mixtures made without fiber.

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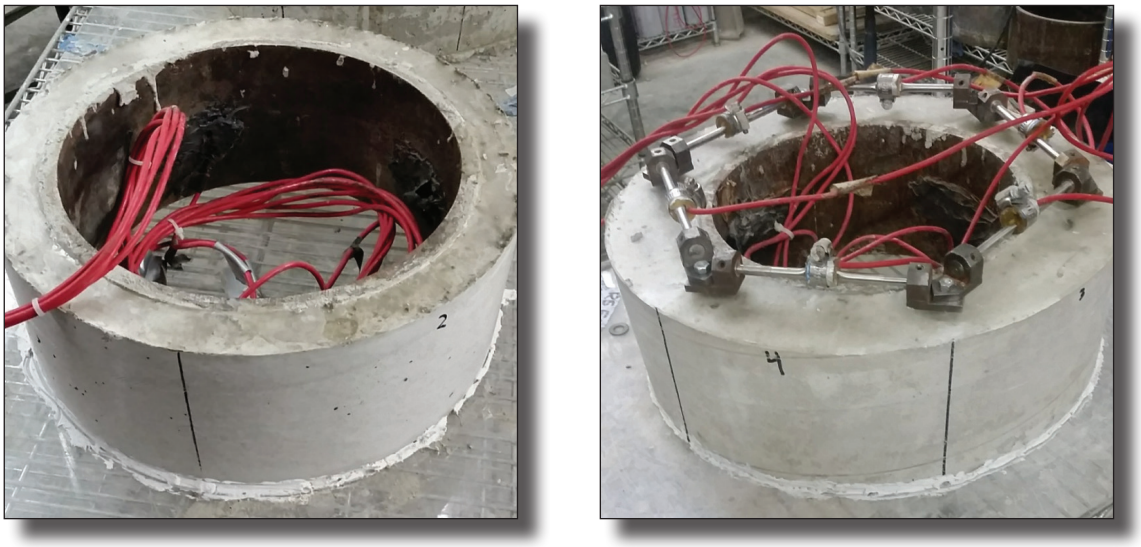
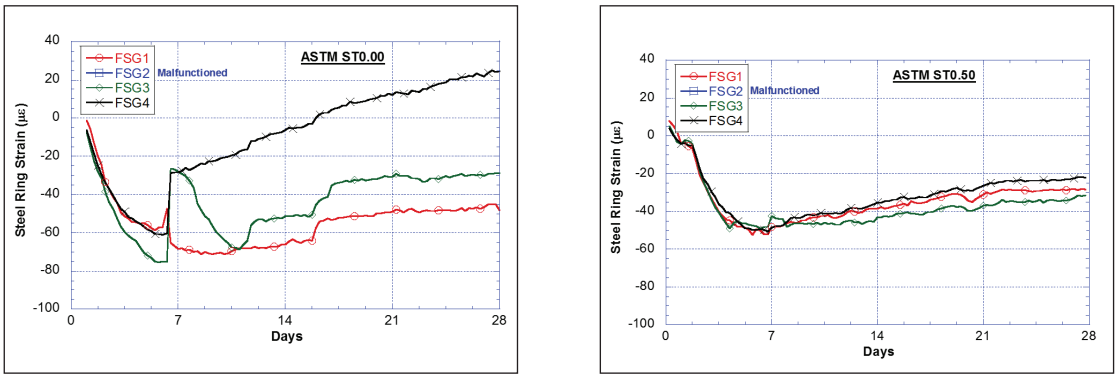
Restrained Shrinkage Behavior of SCC with Steel Fibers *(con't)*



(a) (b)

Figure 2. Restrained shrinkage ring; (a) ASTM C 1581 and (b) AASHTO T 334

In order to evaluate the shrinkage performance under restrained conditions, two restrained shrinkage rings per mixture were prepared, as shown in **Figure 2**; one ring was prepared according to ASTM C 1581 with foil strain gauges (FSGs) on the inner surface of steel ring, and the other ring was prepared in accordance with AASHTO T 334 with FSGs and vibrating wire strain gauges (VWSGs) on top of the concrete ring. **Figure 3** depicts the steel ring strain measured by FSGs for the control SCC and FR-SCC with 0.50% steel fibers.



(a) (b)

Figure 3. Restrained shrinkage test results; (a) control SCC and (b) FR-SCC with 0.50% steel fibers

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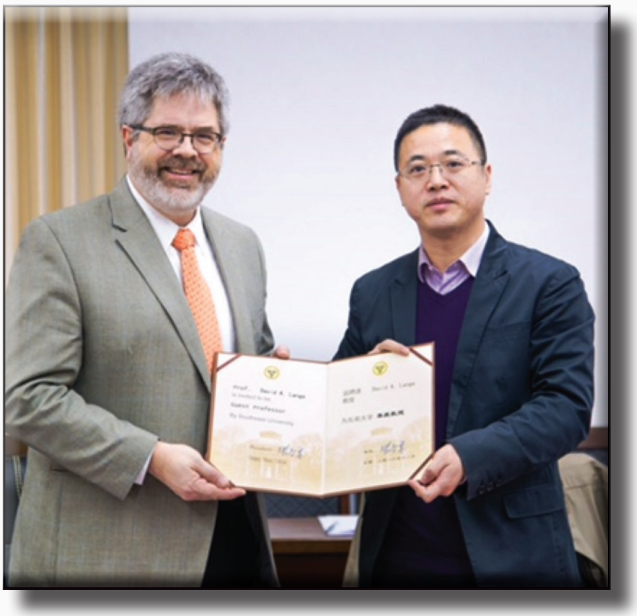
Restrained Shrinkage Behavior of SCC with Steel Fiber *(con't)*

The onset of cracking was delayed from 6.8 days to 8.1 days between two mixtures, indicating that the fibers were not very effective to delay the initial cracking. However, despite the lower strength, the FR-SCC mixtures prevented larger cracks from forming and propagating, resulting in reduced crack widths up to 73% and reduced total cracking area by up to 73% compared to the control mixture. The detailed results will be presented in the final report of RE-CAST 1A project.

LEADERSHIP SPOTLIGHT

RE-CAST Assoc. Director named Guest Professor in China



Prof. David Lange, RE-CAST Associate Director, delivered a week-long short course on "The Role of Water in Hardened Concrete" at Southeast University in Nanjing, China on February 20-25, 2017.

The lecture material included basic driving forces, autogenous shrinkage, concrete under restraint, sensors for measuring moisture, modeling gradients and stress, field testing and new ideas about freeze-thaw performance.

The short course included a laboratory activity which challenged students to make foam cement and then use a flatbed scanner to capture images of microstructure which could be used to measure air void parameters.

Southeast University recognized Prof. Lange's contributions in a ceremony by naming him a Guest Professor of the University. Prof. Yamei Zhang was Prof. Lange's host at Southeast University, and they established the basis of future collaboration.

TECHNOLOGY TRANSFER

RE-CAST Final Report Published

Check out the final report at:

https://recast.mst.edu/projects/long-termperformanceoffrcmstrengthenedbeams/

WEBINAR SERIES

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

February 23, 2017

RE-CAST Presenter: Dr. Jeffery Volz, Associate Professor

University of Oklahoma

"Concrete Pavement Containing High Volumes of Recycled Materials"

November 17, 2016

Presenter: Dr. Raissa Ferron, Assistant Professor

University of Austin at Texas

"Engineering smart, stimuli-responsive cementitious composites"

November 9, 2016

RE-CAST Presenter: Antonio Nanni

Professor of Civil Engineering, Univ. of Miami

CESTiCC, RE-CAST and the Alaska Chapter of ACI present:

"The Role of Cementitious Materials in the Next Decade"

- Joint webinar offered with CESTiCC and Alaska Chapter of ACI

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STAY CONNECTED

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