news
MISSOURI S&T
CENTER FOR TRANSPORTATION INFRASTRUCTURE AND SAFETY
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2012: A Look Back

Snow on S&T campus Winter 2102

The year 2012 marked a year of significant change in the CTIS. Under the direction of a new center director, Dr. Kamal H. Khayat, the Center has been re-vitalized with the introduction of new polices to stream-line operations, new initiatives to bolster interdisciplinary research and education. This includes the acquisition of new equipment and update of existing facilities that bring unique research capabilities to the campus. The Center is evolving at full speed with the vision of becoming a focal point for infrastructure material research in the national arena.

Over the past year, the CIES staff has undertaken a labor-intensive effort to transform the previously under-utilized laboratory space in the basement of the Engineering Research Laboratory into a new Advanced Construction Materials Laboratory. This new laboratory will enable the development, manufacturing, and implementation of innovative and sustainable materials for civil infrastructure, with an emphasis on cement-based materials.

In May 2012, the Center began the aquisition of 35 highly specialized pieces of material testing equipment. The largest and most unique piece of equipment, which will be delivered to S&T in August 2013, is a new dual-mixer concrete batching plant consisting of two planetary motion high shear mixers with 750-L and 250-L output capacities. This custom designed system will allow for consistency and repeatability in concrete research experiments, a capability that is currently unavailable at the University of Missouri.

In this issue:

FEATURED PROJECT:

Rapid repair of severely damaged reinforced concrete columns

- Lesley Sneed, Asst. Professor, Dept. of Civil, Architectural and Environmental Engineering, Missouri S&T

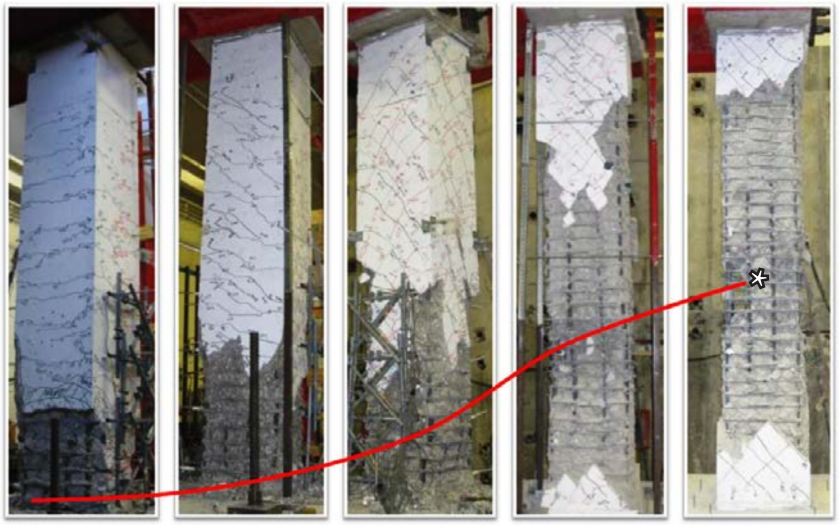

Figure 1. Damage Conditions of the Original Columns Prior to Repair

* Red line indicates plastic hinge location

Damage to bridge structures during an earthquake can have devastating social and economic consequences, especially for those bridges located along key routes that are critical for emergency response and other essential functions. Thus rapid and efficient repair techniques are needed to enable quick reopening of these bridges to mitigate the impact on the community.

The objective of this study is to develop an effective and rapid repair technique for severely damaged reinforced concrete (RC) columns under combined loading effects, including torsion, using externally bonded carbon fiber reinforced polymer (FRP) composites. The term "rapid" refers to a three-day period as defined in ATC-18 and other recent studies.

The use of externally bonded strengthening systems can significantly shorten the time required to complete a repair. FRP composites are particularly attractive for this purpose because of their high strength- and stiffness- to-weight ratios and ease of installation compared with other materials. This study will fill in critical gaps in the literature with respect to the severe damage level and the inclusion of torsion. Also, the large scale nature of the test specimens considered in this study allows for the evaluation of the constructability of the proposed repair technique in practice.

The experimental work includes testing of five large-scale, severely damaged, square RC columns with the same nominal geometry and material properties. The test specimens utilized in this project were designed, constructed, and tested to failure as part of a separate study aimed at investigating the behavior under combined loading effects, namely torsion, flexure, shear, and axial loads. **Figure 1** shows each of the

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Figure 2. Testing of Repaired Column

severely damaged columns prior to repair, in order of increasing applied torsional moment-to-flexural ratio (T/M). The differences in the damage extent and plastic hinge location are due to the different loading combinations during the previous tests.

In view of the short time frame for the rapid repair, the repair materials used in this study were selected for ease of installation, compatibility with the other materials, and capabilty of achieving their required strengths within the short timeframe. LA40 repair mortar, a one-component shrinkage-compensated micro concrete provided by BASF® Company, was used to replace the removed damaged concrete. Unidirectional high strength carbon fiber fabric, MBrace® CF 130, was used as the external reinforcement to compensate for the loss in strength due to material degradation. Over a three-day period, each of the columns was repaired in the High Bay Structural Engineering Research Laboratory at Missouri S&T using the developed repair technique. Then the repaired column was tested to failure under the same loading combination as the previous test (see **Figure 2**). The performance of the repair method was evaluated by comparing the response of the repaired columns with the corresponding original columns.

Preliminary findings indicate that the developed repair procedure can be practical and achievable as an emergency repair. Additionally, this repair method can be effective in restoring the bending and/or torsional strength of severely damaged columns without fractured reinforcing bars. Results also suggest that the repair method can restore the stiffness and ductility capacity of the columns to levels that can meet the needs of a temporary repair and allow emergency use after an earthquake.

The original column specimens were part of project NEESR-SG: Seismic Simulation and Design of Bridge Columns under Combined Actions, and Implications on System Response led by Dr. David Sanders (PI at Univ. of Nevada, Reno) with Dr. Abdeldjelil Belarbi (CoPI at Missouri S&T). Funding for the repair project was sponsored by the University of Missouri Research Board and the National University Transportation Center at Missouri S&T.

FEATURED PROJECT:

Diagnostic sensor network for structure health monitoring

- Maggie Cheng, Associate Professor, Department of Computer Science, Missouri S&T
- Genda Chen, Professor, Dept. of Civil, Architectural and Environmental Engineering, Missouri S&T

Figure 1. Wireless sensor networks placed on bridge structures

Wireless sensor networks can be placed inside of or on the surface of a structure to monitor the health state of the structure and to detect changes in the structure. For this purpose, the sampled data must be reliable and represent the true state of the structure.

However, in reality, the measured data often come with uncertainty, and thus cannot always be interpreted with a theoretical model. When disagreement occurs, the measured data may or may not represent an anomalous state of the structure. Anomaly in data could originate from the source of a structure due to unknown loads and material properties, errors introduced during measurement, and signal contamination in the process of data communication. One must distinguish the structure anomaly from the sensor network anomaly. To this end, the spatial and temporal correlation of the data collected at different sampling points of the structure, as well as the network behavior that could introduce anomaly in the data must be fully understood.

This project represents a new research direction in the diagnosis of coupled cyber-physical systems. Two Ph.D. students, Yi Bao (Civil) and Quanmin Ye (Computer Science), are working on the project. The team is generating preliminary results on the asymptotic distribution of test statistics, developing effective means for estimator design and data gathering. The ultimate goal is to reconstruct the contour map of some critical parameters of the structure, and to be able to monitor and assess the structural condition of bridges in real-time.

Outreach Activities

Fall ¡Sí Se Puede!

November 9-12, 2012

Minority Student Partipants at Fall ¡Sí Se Puede!

The Society of Professional Hispanic Professionals annually coordinates ¡Sí Se Puede! This helps students to explore the career options Missouri S&T has to offer and gives them an inside look at real college life. It is an on-campus visit program for Hispanic and Latino students to explore a future career in math and science. During their time at Missouri S&T the students meet faculty and staff that volunteer their time to teach students about degree programs, career options, co-ops and internships.

Upcoming Events

Pre-College Initative	February 15-18th, 2013
Society of Hispanic Professional Engineers Regional Conference	Late March, early April, 2013
Hit the Ground Running (HGR) Summer Enrichment Program	July 7-26th, 2013

2012: Past Events

Minority Intro to Technology & Engineering (MITE)	June 5-10, 2012, June 19-24, 2012
Hit the Ground Running Summer Enrichment Program	July 8th-27th 2012
Fall Si Se Puede	November 9-12, 2012
Society of Hispanic Professional Engineers National Conference	November 14-18th, 2012, Fort Worth, TX
National Society of Black Engineers Fall Regional Conference	November 9-11, 2012 Austin, TX

For more information about any of our upcoming Outreach Events, please contact our Student Diversity, Outreach and Women's Programs Office at 573-341-4212; sdowp@mst.edu.

FEATURED PROJECT:

Polyurethane foam infill for fiber-reinforced polymer bridge deck panels

- Jeffery Volz, Asst. Professor, Dept. of Civil, Architectural and Environmental Engineering, Missouri S&T
- K. Chandrashekhara , Curators Professor, Dept. of Mechanical and Aerospace Engineering, Missouri S&T
- Victor Birman, Professor, Dept. of Mechanical and Aerospace Engineering, Missouri S&T

Figure 1. Testing of Mid-Scale Prototypes

Figure 2. Constructing Full-Scale Specimens for Testing

The majority of the nation's 600,000 bridges were built nearly 50 years ago using traditional materials, like steel, concrete, and steel reinforcement. The structural integrity of these bridges, nearing the end of their lifespan, has been greatly reduced due to weathering, combined with wear from vehicle traffic and de-icing chemicals and reduced maintenance. Over the last 15 years, newer designs have called for replacing the concrete and rebar with fiber reinforced polymers (FRP). Built with intricate honeycomb structures, glass or carbon fiber bridge decks are strong, lightweight and corrosion resistant. Despite offering a longer life and lower maintenance costs, fiber reinforced bridges come with a higher price tag up front — nearly twice the cost of traditional structures — because the honeycomb structure is extremely expensive to construct.

That is where researchers at Missouri S&T see an opportunity. Using a grant from the Missouri Department of Transportation matched with a grant from the CTIS, S&T researchers are exploring how high-density polyurethane foam that could eliminate the need for the honeycomb structures. Sandwiched between FRP facings, polyurethane foam is often used in cars, planes and prefabricated buildings. The research team is using a formulation of polyurethane foam that can withstand compression beneath a truck wheel. By adding glass fibers to the polyurethane foam, the new material can withstand up to 1,000 psi of compression, far greater than that which can occur beneath the tire of a fully loaded semi-truck. Built together in a factory, the sandwich deck panels could be shipped to site on trailers and are light enough that two workers could carry each panel.

The research team has completed testing of mid-scale prototypes, as shown in Figure 1, and is currently constructing full-scale specimens for testing, as shown in Figure 2. The full-scale specimens will undergo static and fatigue testing, as well as a durability evaluation, in order to evaluate the final system that will be used to construct a prototype bridge in Missouri.

Local Transportation News:

Fall Advisory Committee Meeting

The Missouri Local Technical Assistance Program (LTAP) is located at Missouri S&T and operates on funding provided by the Missouri Department of Transportation (MoDOT) and the Federal Highway Administration (FHWA). Missouri S&T's National University Transportation Center also supports the efforts of Missouri LTAP by providing 1:1 matching funds to aid in MO-LTAP's technology transfer services and deliverables.

The Missouri LTAP team met with its Advisory Committee for the second time in 2012 on November 30 at Missouri S&T Havener Center for its Fall meeting. The committee is made up of selected county commissioners, MoDOT and FHWA representatives, and individuals from various public agencies throughout the state. Eleven committee members attended along with the LTAP staff. Those members included Larry Benz, Phil Broyles, Jeff Cremer, Larry Frevert, Bob Holthaus, Bonnie McCord, Sean McGonigle, Bonnie Prigge, Greg Sager, Bill Stone, and Marc Thornsberry. MO-LTAP was represented by Heath Pickerill, Director, Kristi Barr, Program Specialist, Doreen Harkins, Administrative Assistant, Nicole Annis, Graduate Assistant and Suharsh Raj, Graduate Assistant.

The Advisory Committee provides input and feedback on strategic planning and program goals throughout the year. The intent of the committee is to assure that all four focus areas of the Work Plan are discussed and evaluated in response to client needs. The focus areas include safety, workforce development, infrastructure management and organizational excellence. The committee also discusses potential areas for program growth and how to improve the overall cost-benefit of the program while offering input on strategic planning.
Heath Pickerill, LTAP Director, opened the meeting by welcoming Sean McGonigle to the committee who will be replacing Bob Holthaus as a representative for the Missouri Association of Counties. Holthaus will be retiring at the end of the year. Pickerill thanked him for his many years of service on the committee. Pickerill then gave a summary of 2012 center activities. A total of 134 classes were offered, which was an increase from 111 classes in 2011. A total of 6,785 people attended training throughout the year. In addition, the topics covered were increased beyond what were offered in recent years. Some of the new classes included Chain Saw Safety, Chip Seal Best Practices,

Fall LTAP Advisory Committee Meeting

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Local Transportation News:

Fall Advisory Committee Meeting (con't)

Retroreflectivity Guidelines Training & Inspection Workshop, Traffic Practices Manual Training, and Work Zone Safety for Traffic Responders. A reformatted website was also launched during the summer. It is more user-friendly and offers more tools and resources such as a more user friendly training calendar, online registration, and access to the new e-Newsletter. A demonstration of the new website was provided.

A few of the discussion highlights from the meeting included proposed changes to the Missouri "Show-Me" Road Scholar Program, a slight adjustment in the training fees, and the training plans for 2013, which include some new classes. Some of these include Advanced Communication Skills, Construction Documents 101 - Reading Drawings & Deciphering Specifications, Introduction to Materials: Concrete, Asphalt & General Materials, and Advanced Worker Safety – Special Topics: Confined Spaces, Trenching & Shoring, and Fall Protection & Personal Protective Equipment, and Advanced Equipment Safety – Special Topics: Boom Truck & Forklift Safety. The Road Scholar Program will now have three levels. Level I will remain focused on maintenance topics. Level II will now be focused on advanced maintenance topics and intended to keep Level I graduates engaged in training.

Advisory Committee Meeting

The new Level III will consist of many of the existing supervisory skills classes that were formerly a part of Level II. Participants will still be required to complete Level I before receiving recognition in Level II; however, Level III will now be a stand-alone tract focusing on supervisory skills and can be completed without completing the first two levels. Training will be offered to local government agencies at a cost of $35/person for Level I classes, $50/person (includes lunch) for Level II classes and $75/person (includes lunch) for Level III (Supervisory Skills) classes. Level I classes will still be held from 8:00 AM – 12:00 PM; however, Level II and Level III classes will be held from 10:00 AM – 3:00 PM. Non-government entities, such as consultants / contractors, are welcome to attend training at a slightly higher fee.

The meeting concluded with closing comments from each committee member. Several members commented on the growth of the MO-LTAP program and the initiative for future growth. A few ideas that were mentioned for future training included developing a utility traffic control and work zone safety class, training on GPS and newer technologies as well as on sustainability technologies, ideas and practices. The next meeting will be held in spring 2013. If anyone has an interest in serving on the Advisory Committee, please contact Heath Pickerill at pickerillh@mst.edu or call 573-341-7637.

FEATURED PROJECT:

Cyclic performance of self-consolidating concrete

- Mohamed ElGawady, Assoc. Professor, Dept. of Civil, Architectural and Environmental Engr., Missouri S&T
- K. Khayat, Jones Endowed Professor, Dept. of Civil, Architectural and Environmental Engr., Missouri S&T

(Figure 1.a)

(Figure 1.b)

Figure 1. Fresh Properties of Mixture 1 (a) Slump Flow and (b) L-box

ACI 237 Committee defines self-consolidating concrete (SCC) as a concrete that without the influence of additional consolidation energy, flows and completely fills the spaces between the reinforcement and the formwork only under the influence of its own mass. This research investigates the behavior of SCC under cyclic axial loading. Three different mixtures were developed having target compressive strengths of 6 and 10 ksi, as shown in Table 1. Table 2 presents the fresh and hardened properties of the investigated mixtures. Figure 1 shows the results of the slump-flow and the L-box. Currently, the effect of the confinement using fiber reinforced polymers (FRP) on SCC under cyclic loading is being investigated.

Table 1: Different concrete mixtures used during this research

Mixture No.	w/cm	Cement (kg/m^3)	Fly Ash (kg/m^3)	Water (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	HRWRA (kg/m^3)	VEA (kg/m^3)	Target compressive strength (ksi)
1	0.32	350	175	168	850	850	3.68	0.42	10
2	0.38	350	175	200	837	837	1.73	-	6
3	0.42	350	175	220	827	827	1.87	1.05	6

Table 2: Fresh and hardening concrete properties of the different mixtures

Mixture No.	Slump flow (in.)	J-ring* (in.)	L- box ratio (h2/h1)	Static segregation index (%)	Compressive strength (psi)			Splitting Tensile (psi) at 28 days
					7 days	28 days	56 days	
1	26.5	0.5	1.0	14.9	5800	7300	9600	460
2	26	0.1	1.0	24.6	4500	5500	7200	240
3	26	0.1	1.0	-	4300	5200	6500	220

* Spread in height of concrete at inside and outside edges of J-ring