news

Missouri S&T

Center for Transportation Infrastructure and Safety

Fall 2013: Vol. 8 | Issue 2

From the desk of the Director

CTIS Concrete Batching Plant

A new, state-of-the-art high sheer dual-mixer concrete batching plant is the latest addition to the research facilities available to CTIS faculty and students. The plant is currently being assembled and installed and is scheduled for completion by the end December. CTIS Director Dr. K. Khayat envisions this batching plant being permanently housed in the Butler-Carlton Hall Advanced Construction Materials Laboratory, a building expansion project that has been identified in the Civil, Architectural and Environmental Engineering Department VISION 2020 strategic plan.

CTIS is pleased to report that the second annual Transportation Infrastructure Engineering Conference, held in Jefferson City, MO at the Capitol Plaza Hotel on September 13, 2013, was another great success for the Center. The conference was chaired by CTIS Director, Dr. K. Khayat and co-chaired by Mr. William Stone, the Research Administrator of Missouri Department of Transportation. 135 people attended the event. The event will be held again the Fall of 2014 on the Missouri S&T campus.

In this issue:

FEATURED PROJECT:

Automated measurement and control of concrete properties in a ready mix truck

- Kamal H. Khayat, Professor of Civil, Architectural and Environmental Engineering, Missouri S&T
- Nicolas Ali Libre, Visiting Scholar, Center for Infrastructure Engineering Studies, Missouri S&T

Figure 1. Missouri S&T research team at Ozinga Ready-Mix Concrete in Chicago, IL

This study, initiated in July 2013, aimed at investigating the efficiency of an automated system, developed by VERIFI LLC, in managing fresh properties of concrete in the ready mix industry. VERIFI is an automated system that measures and records the properties of fresh concrete in real-time in a truck mixer. The system is also able to maintain the slump at target value by automatically adding water and/or a high range water-reducing (HRWR) admixture to maintain the targeted slump consistency of the concrete during concrete transport and delivery within the predefined allowable water-to-cementitious ratio (W/CM) limit. The project was undertaken in collaboration with Dr. Eric Kohler and Dr. Ezgi Yurdakul of the VERIFI LLC., Mr. William Stone of MoDOT, Mr. Paul Ozinga and Mr. Scott Kelly of Ozinga RMC, Inc. in Chicago.

In this research, 20 batches of concrete with six different mixture proportions were examined to evaluate the efficiency of the VERIFI system in maintaining slump consistency of concrete resulting from water addition or the incorporation of HRWR admixture. The investigated concrete mixtures are targeted for pavement, beam and column and municipal use and had slumps ranging between 2 and 10 in. and 28-day compressive strengths of 3500 to 8750 psi.

- Continued Next Page -

Automated measurement and control of concrete properties in a ready mix truck (continued)

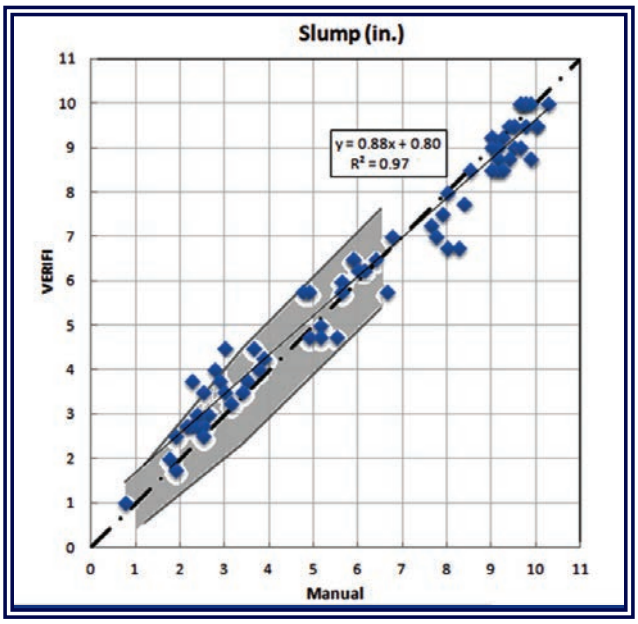

Figure 2. Manual slump measurement vs. Verifi measurement (acceptable precision in ASTM C143 are shown in gray)

For each batch, concrete was sampled at 30-minute intervals up to 90 minutes and tested for slump, temperature, air content, unit weight, water content using the microwave method, bleeding, and rheology. Cylindrical concrete specimens were cast and tested for compressive strength at 3 and 28 d (or 3 and 14 d for IDOT mixtures).

The results of this research indicate that the VERIFI system is able to accurately measure concrete slump and temperature in the truck for the wide range of concrete mixtures. The accuracy of the VERIFI system in measuring slump and temperature of concrete in a truck mixer is shown to be 0.5-in. and 1.5 °F, respectively. This is within the acceptable variation limit stated in ASTM C143 and ASTM C1064. The VERIFI system is shown to be capable of adjusting slump automatically to maintain the target slump by adding water and/or water-reducing admixture.

The mean and standard deviation of the difference between the slump of concrete at delivery time and target slump are 0.66 in. and 0.42 in., respectively. Adding water in transit instead of in one single addition at the jobsite to maintain the slump within the specified range does not negatively affect concrete performance. The compressive strength of concrete was higher when water was added gradually during the transportation vs. single addition of water at the job site.

FEATURED PROJECT:

Functionally graded biomimetic energy absorption concept development for transportation systems

- Victor Birman, Engineering Education Center in St. Louis, Professor, Dept. of Mechanical Engineering, Missouri S&T

This research project employed the concept observed in biology extrapolating it to a development of energy and shock absorbent devices in transportation systems. In previous biological research, the PI and his colleagues noted a low-stiffness "band" in the attachment between tendon and bone and hypothesized that this band serves as an energy absorbing component in the attachment. This is in line with the observation that toughness of both engineering and biological materials increases with the decrease in their stiffness (so-called "banana curve"). In shock absorbers developed for transportation systems the concept utilizing a compliant energy-absorbent material may be combined with functional grading of the material, so that a higher stiffness, higher strength section provides the necessary strength, while a lower stiffness section serves to absorb the maximum amount of energy.

The structure developed in the present study consists of a cylindrical foam shell embedded within relatively rigid layers protecting the foam from environment and accidental loads. Static or dynamic loading is applied in the axial direction (**Figure 1**). The grading in the radial direction is such that the mass density and stiffness are power functions of the radial coordinate. Such situation can be found in variable-density open-cell or closed-cell foams. It is shown that a more efficient design is achieved with a denser and stiffer material adjacent to the inner surface and a less dense, more compliant material at radial locations approaching the outer surface.

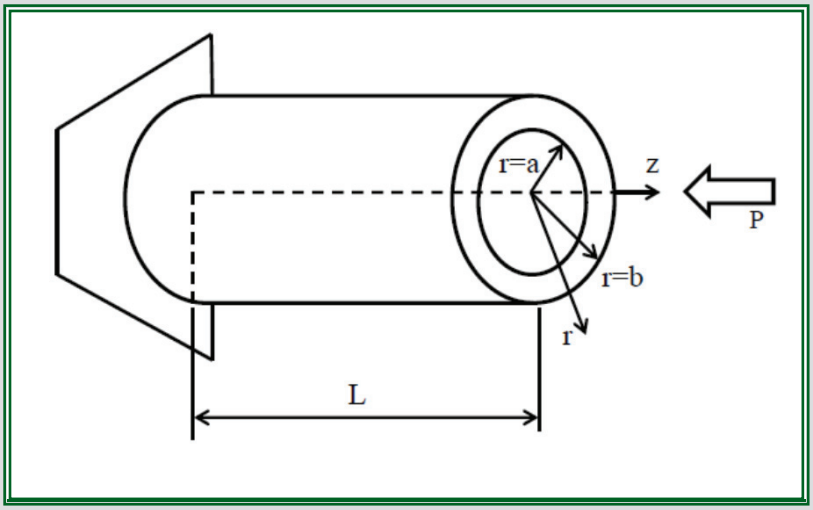

Figure 1. Foam cylinder loaded by axial force. The inner and outer boundaries are supported by stiffer layers providing environmental and accidental loading protection.

- Continued Next Page -

Functionally graded biomimetic energy absorption concept development for transportation systems (continued)

The exact solution developed in the study for stresses and energy absorption is rather unique both accounting for functional grading as well as satisfying the governing equations of anisotropic elasticity without any simplifying assumptions that are often adopted in problems involving the analysis of functionally graded structures. Moreover, the micromechanical aspect of the problem is exactly satisfied, i.e. the local constitutive equations for foam reflect the actual grading in the radial direction.

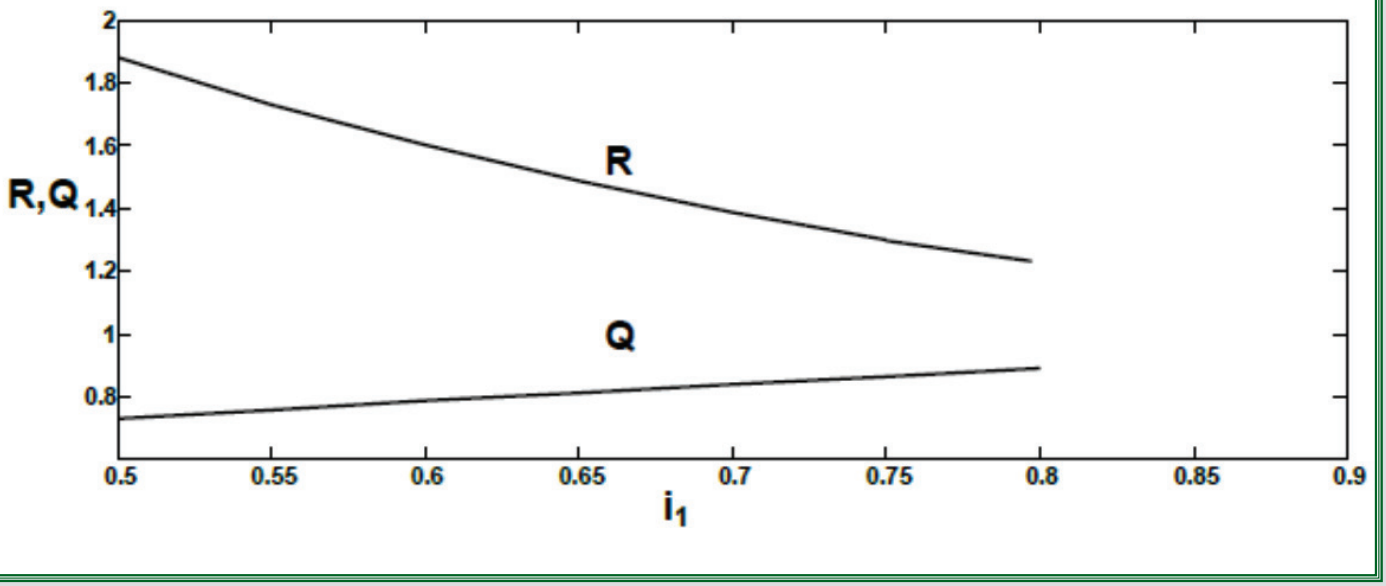

Figure 2. Example of the effect of the material density at the inner radius (nondimensional quantity along the horizontal axis) on the normalized energy absorption (Q) and normalized weight (R). A lower mass density results in higher energy absorption and lower weight of the device.

The solutions are developed for axial static loading as well as for the case where the load is a harmonic function of time. The optimization implies that the grading of foam should be such that the stresses at any location do not violate the strength requirements, while the energy absorption is maximized and the weight is minimized compared to a homogeneous cylinder with the a constant material density.

As a result of the numerical analysis it is demonstrated that a relatively higher energy absorption and weight savings over a homogeneous cylinder are achievable in a functionally graded cylinder (**Figure 2**). An overall reduction of the stiffness throughout the radial coordinate is beneficial to the energy absorption and it also result in a lighter cylinder. Parametric analysis for static and dynamic cases can be based on the explicit solution demonstrated in the study.

OUTREACH ACTIVITIES

"Hit the Ground Running" Summer Enrichment Program

July 7–26, 2013

This program is for all Student Diversity Program (SDP) scholarship recipients. For three weeks, the SDP scholars take classes in mathematics, english and chemistry. The benefits are tremendous; not only do the students have an academic head start when the fall semester begins, but they also become a team. Rigorous study prepares them for a demanding engineering curriculum, and they experience life in a dorm away from friends and family. Along with academics, scholars learn about career opportunities that await them once they earn their degree. Special seminars are hosted by industry representatives and engineering department chairs that focus on career and educational opportunities for minority students. The proven track record of this program on the Missouri S&T campus has sparked a similar program for minority freshman engineering students. Students are surveyed at the end of the program with regards to how their degree could contribute to transportation sustainability and future developments.

2013 CTIS Student of the Year

Mahdi Arezoumandi

For the past 22 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 Center for Transportation Infrastructure and Safety has selected Mr. Mahdi Arezoumandi as its Outstanding Student of the Year. He will be recognized at the TRB Conference in January along with the other UTC Outstanding Students of the Year. The award ceremony will take place on Saturday, January 11, 2014 in Washington, D.C.

Mahdi Arezoumandi
2013 CTIS Student of the Year

Student Bio: Mahdi Arezoumandi is a PhD candidate and graduate research assistant in the Department Of Civil, Environmental And Architectural Engineering at Missouri University of Science and Technology, Rolla, MO. The topic area of his graduate research is Shear and Fracture Behavior of High Performance Concretes. During his graduate scholarly activities, Mahdi was advised by Dr. Jeffery Volz. He received his B.S. and M.S. from Amirkabir University, Tehran, Iran.

Mr. Arezoumandi is a friend of TRB AFF30 committee (Concrete Bridges), TRB AFN10 committee (Basic Research and Emerging Technologies Related to Concrete), and TRB AFN20 committee (Properties of Concrete). He is also a member of ACI committee 408 (Development and Splicing of Deformed Bars) and ACI committees 445 (Shear and Torsion). His research interests include structural behavior of high performance concrete. Mr. Arezoumandi received the Nevada medal for distinguished graduate student paper in bridge engineering (2013) in addition to post tensioning institute scholarship (20l3) and Chi Epsilon scholarship (20l2).

Selection Criteria: Mr. Arezoumandi was selected as the Outstanding Missouri S&T UTC Student of the Year for his outstanding academic performance, as well as the technical merit and national importance of his research.

FEATURED PROJECT:

Highway rock fall measurements using LIDAR

- Norber Maerz, Associate Professor, Department of Geological Science and Engineering, Missouri S&T

Figure 1. Drilling and installing monitoring wells on the south site.

Rock falls on highways, while dangerous, are unpredictable. Most rock falls are of the raveling type and not conducive to stability calculations, and even the failure mechanisms are not well understood. LIDAR (LIght Detection And Ranging) has been shown to be able to measure the volumes of raveled rock as small as 1cm when repeatedly scanned over a period of time. Rock fall volumes can be correlated to external stimuli such as rainfall, seismic activity, and freeze thaw cycles to determine trigger for failure. Previous research has established a tentative relationship between rock fall and both rainfall and number of freeze/thaw cycles. The relationship is complex and implies that rainfall is most potent in the winter months. The main focus of the current research is to measure the groundwater pressure near the rock face. This is because failures are triggered not directly by rainfall, but when the groundwater pressures build up behind the rock face as a result of the infiltration of rainfall, and most likely the groundwater is retained by ice dams that restrict the drainage of groundwater. To that end two sites have been selected along highway 63 north, a north and a south sites. Both sites show indications of raveling failures, and evidence of groundwater release along the rock face. At each site multiple monitoring wells were installed (**Figure 1**). Pressure transducers will be installed in these wells. LIDAR measurements (**Figure 2**) will be used to quantify the rock fall while water pressure, rainfall, freeze-thaw cycling, and blasting records from the nearby quarry will be used to correlate to the rock fall quantities/episodes.

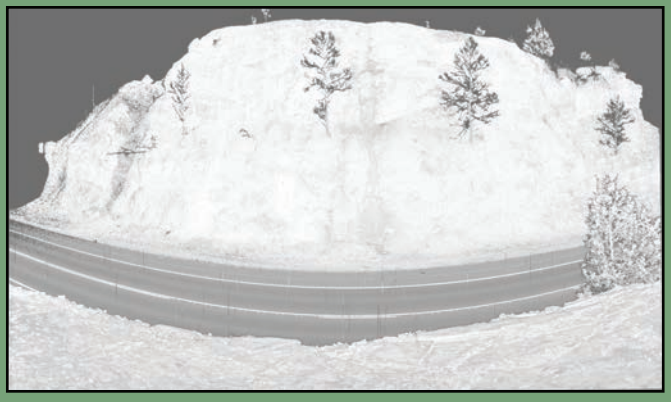

Figure 2.
LIDAR scan of the Highway 63 north site.

FEATURED PROJECT:

Missouri S&T formula electric racing

- Ryan S. Hutcheson, Asst. Teaching Professor, Mechanical and Aerospace Engineering, Missouri S&T

Figure 1. The Missouri S&T Formula Electric Racing Team.

Thanks to the support of CTIS and its other sponsors, Missouri S&T Formula Electric Racing is well on its way to competing in its first race. The team is currently building their entry for the 2014 Formula SAE Electric competition (http://students.sae.org/cds/formulaseries/electric/). This Society of Automotive Engineers sponsored student design competition will host 20 teams from universities across the world. The teams will compete in dynamic events with their electric racecars including a single lap autocross-style race, a figure 8 skidpad to test lateral acceleration, a standing acceleration event and most significantly a 20km endurance race. The team must also compete in static events including a design review with industry and racing professionals, a cost and manufacturing analysis and a business presentation.

The S&T team has completed mechanical and electrical design for their 2014 entry and is busy manufacturing their frame and chassis systems. Acquisition of all major components and materials has been completed. The team has received their 100 kW electric motor (which has to be limited to 85 kW per competition rules), motor controller and lithium polymer battery pack components. Battery pack construction will begin once classes resume in the spring 2014 semester.

- Continued Next Page -

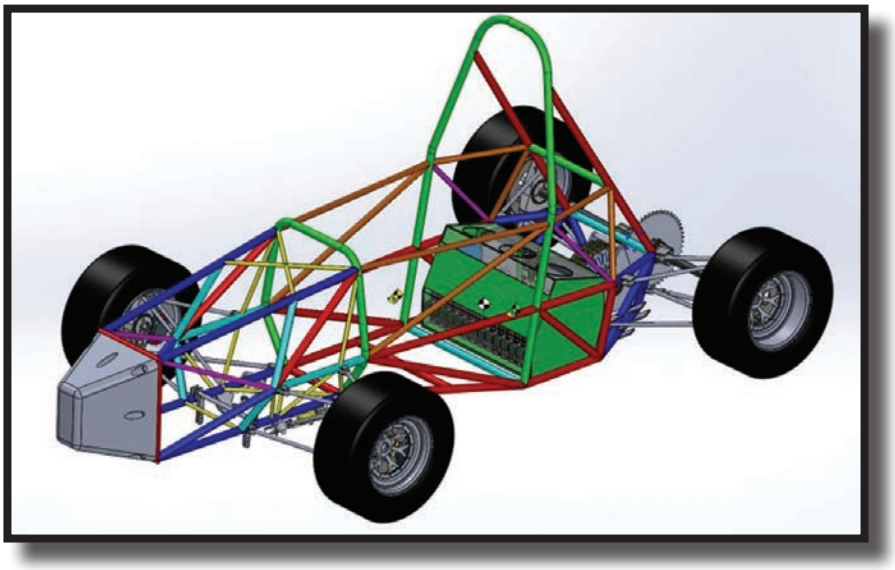

Figure 2. The 2014 Design Model.

The team expects to be driving the electric racecar during late March. Driver training, vehicle setup and endurance testing will continued up to the 2014 competition to be held June 18-21 in Lincoln Nebraska.

In addition to the design and construction of their 2014 car, the team has been busy promoting awareness of electric vehicle technology through a series of design seminars to undergraduate students and a summer camp for high school students. The 2013 Formula Electric Summer Camp hosted 30 students from high schools across the United States. The students were instructed in the basics of electric vehicle design and were required to design and construct a prototype frame for an electric racecar.

The team appreciates the support of all its sponsors, and looks forward to a successful 2014 competition. More information about the team can be found at their website: minerracing.com.

Figure 3. 2013 Formula Electric Summer Camp.

Local Transportation News:

Fall Advisory Committee Meeting

The Missouri Local Technical Assistance Program is located at Missouri University of Science and Technology and operates on funding provided by the Missouri Department of Transportation (MoDOT) and the Federal Highway Administration. Missouri S&T's National University Transportation Center also supported the efforts of Missouri LTAP by providing 1:1 match funds to aid in MO-LTAP's services and deliverables through December 2013.

The Missouri LTAP team met with its Advisory Committee for the second time in 2013 on November 22 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, Patrick Bonnot, Mike Geisel, Stuart Haynes, Sean McGonigle, Bonnie Prigge, Bill Stone, Marc Thornsberry, and Skip Wilson. MO-LTAP was represented by Heath Pickerill, Director, Kristi Barr, Program Specialist, Doreen Harkins, Administrative Asst., and Nicole Annis, Graduate Assistant.

See the complete list of committee members on the next page.

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 everyone. Pickerill then gave a summary of 2013 center activities. A total of 162 classes were offered, which was an increase from 134 classes in 2012. A total of 6,469 people attended training throughout the year. New classes offered included Communicating Effectively in the Workplace (Advanced Communication Skills), Comprehensive Winter Planning, Construction Documents 101, and Fall Protection & Personal Protective Equipment. Utility Road Zone Training was also offered in partnership with MoDOT in the northwest district. A second training is planned for February 2014 in the northeast district. In addition, a chip seal showcase

Fall LTAP Advisory Committee Meeting

Local Transportation News:

Fall Advisory Committee Meeting (con't)

was offered in three locations, which included Lebanon, Jefferson City and Chillicothe. The partnering program with MoDOT included a one to two hour classroom discussion led by Mike DeGraff with Vance Brothers Asphalt and a one to two hour on-site demonstration. The showcases were free to local agencies. Finally, there were several new Road Scholar Program Level I graduates in 2013 bringing the total to 129. There are now 404 participants representing 46 agencies.

A few of the discussion highlights from the meeting included training plans for 2014, the National LTAP/TTAP Conference being held in St. Louis July 21-24, and some new training ideas. Some of the new classes planned for 2014 include Bucket Truck Operation & Safety, Confined Spaces, Introduction to Materials: Concrete, Asphalt & General Materials, Forklift Operation & Safety and Trenching & Shoring. MO-LTAP will also partner with MoDOT to offer a right-of-way training. A few of the suggested topics for future training included blood borne pathogens, lockout/tag out, and low cost improvements for rural roads.

The meeting concluded with closing comments from each committee member. Several members commented on the increase in training numbers for 2013. It was also suggested to increase the number of consulting firms, city and county clerks, other administrators and private agencies that are contacted as a way of promoting the upper levels

Advisory Committee Meeting

of the Road Scholar Program. A copy of the minutes can be found under the About Us >> Committees link on the website, www.moltap.org. The next meeting will be held in spring 2014. If anyone has an interest in serving on the Advisory Committee, please contact Heath Pickerill at pickerillh@mst.edu or 573-341-7637. For more information on Missouri LTAP please visit the MO-LTAP website.

Current LTAP Advisory Committee

Benz, Larry
Cole County Public Works & MACTO
Bonnot, Patrick
MIRMA
DeLong, Tony
University of Missouri Extension
Foster, Ken
FHWA Missouri Division
Gano, Johnathan
City of Springfield
Geisel, Mike
City of Chesterfield Public Works & Missouri Chapter APWA
McCord, Bonnie
Vernon County
McGonigle, Sean
Missouri Association of Counties
Miller, John P.
MoDOT
Prigge, Bonnie
Meramec Regional Planning Commission & MACOG representative
Ross, Dan
Missouri Municipal League
Haynes, Stuart – alternate –
Sager, Greg
Platte County Public Works
Scheipeter, Gary
City of Clayton & APWA representative
Stone, Bill
Construction and Materials, MoDOT
Thornsberry, Marc
FHWA Missouri Division
Voss, Kenny
MoDOT
Cremer, Jeff – alternate –
White, Randy
Pioneer Trails Regional Planning Commission & MACOG representative
Wilson, James
District 3, MoDOT