TIDC

Transportation Infrastructure Durability Center
AT THE UNIVERSITY OF MAINE

2020 TIDC Annual New England Transportation Infrastructure Durability Conference

PROGRAM

Wednesday, August 12, 2020

1865 THE UNIVERSITY OF MAINE

UMASS University of Massachusetts Lowell

AGENDA

8:00 am: Registration and Sign-in

8:30 am: Welcome: Dr. Habib Dagher, P.E., Conference Chair, TIDC Center Director and Executive Director, Advance Structures & Composites Center, University of Maine

8:40 am: Welcome: Dr. Joseph C. Hartman, P.E., UMass Lowell Provost & Vice Chancellor for Academic Affairs

8:45 am: Keynote Speaker: Dr. Jean-Louis Briaud, PE, President Elect, ASCE; Spencer J. Buchanan Chair Professor, Texas A&M University Q&A Moderated by Bill Davids, Ph.D., P.E., University of Maine

9:15 am: Session I Presentations – Moderator: Jonathan Rubin, Ph.D., University of Maine

Novel, Nonlinear Finite-Element Analysis Methods for Load Rating of Concrete Girder Bridges
Bill Davids, Ph.D., P.E., University of Maine

Structural Health Monitoring of a Bridge using Fiber Optic Sensing Textile
Andres M. BiondiVaccariello, University of Massachusetts Lowell

Bridge-Stream Network Assessments to Identify Sensitive Structural and Hydraulic Parameters for Planning Flood Mitigation
Rachel Seigel, University of Vermont

10:30 am: Coffee Break

10:40 am: Session II Presentations – Moderator: Bill Davids, Ph.D., P.E., University of Maine

Large Scale 3D Printed Thermoplastic Composite Forms for Precast Concrete Structures
Sunil Bhandari, University of Maine

Development and Testing of High / Ultra High Early Strength Concrete for Durable Bridge Components and Connections
Bijaya Rai, University of Connecticut

Study of Prestressed Concrete Crossties Using High-Performance Computing
Moochul Shin, Ph.D., Western New England University

Electromagnetic Detection and Identification of Concrete Cracking in Highway Bridges
Tzuyang Yu, Ph.D., University of Massachusetts Lowell

12:30 pm: Lunch Break

1:00 pm: Keynote Speaker: Stan Caldwell, Mobility21 Executive Director, Carnegie Mellon University

1:30 pm: Session III Presentations – Moderator: Aaron Gallant, Ph.D., P.E., University of Maine

Durability Evaluation of Carbon Fiber Composite Strands in Highway Bridges
Braedon Kohler, University of Maine

Optical-Based Structural Health Monitoring of Truss Bridges
Celso do Cabo, University of Massachusetts Lowell

Preliminary Material Testing and Analysis of Two Old Railroad Steel Bridges
Celso de Oliveira, University of Connecticut

Avalanches during Flexure of Early-age Steel Fiber Reinforced Concrete Beams
Ting Tan, Ph.D., University of Vermont

3:10 pm: Coffee Break

3:20 pm: Session IV Presentations – Moderator: Roberto Lopez-Anido, Ph.D., P.E., University of Maine

Lateral Spreading and Stability of Embankments supported on Unreinforced Fractured Columns over Soft Soils
Aaron Gallant, Ph.D., P.E., University of Maine

The Effect of Different Conditions at the Two Abutments on the Behavior of Skew Integral Abutment Bridges (IABs) under Thermal Loading
Susan Faraji, Ph.D., University of Massachusetts Lowell

Alternative Cementitious Materials (ACMs) for Durable and Sustainable Transportation Infrastructures
Hosain Haddad Kolour, University of Maine

Deterministic Optimization for Damage Identification Using Dividing Rectangles Algorithm
Yang Zhang, University of Connecticut

5:00 pm: Closing: Tzuyang Yu, Ph.D., Conference Co-Chair, University of Massachusetts Lowell

Keynote Speaker

Upcoming Transportation Infrastructure Challenges

Jean-Louis Briaud, Ph.D., P.E., D.GE, Dist.M.ASCE

ASCE President 2020

Jean-Louis Briaud, Ph.D., P.E., D.GE, Dist.M.ASCE, is a distinguished professor of civil engineering and director of the National Geotechnical Experimentation Site at Texas A&M University. He is also holder of the Spencer J. Buchanan chair at Texas A&M University's Zachry Department of Civil Engineering.

Briaud recently completed a three-year term on the ASCE board of direction and previously served as president of the Geo-Institute. He was also president of the Federation of International Geo-Engineering Societies. In 2014, Briaud was recognized as a Distinguished Member of ASCE.

Briaud started his career four decades ago as an assistant professor at Texas A&M University. He has also worked as a consultant on numerous projects, including highway embankments, oil tanks, dams, bridges, levees, shallow and deep foundations and soil erosion. He is a licensed professional engineer in Texas.

Additionally, he has written two books, "Geotechnical Engineering" and "The Pressuremeter", and published about 300 articles and reports. He has received the Ralph Peck Award from ASCE, the CGS Geoffrey Meyerhof Foundation Engineering Award from Canada and the Honorable Aitalyev Medal from Kazakhstan.

Briaud earned his Bachelor of Science at Ecole Speciale des Travaux Publics in Paris, France, a Master of Science at the University of New Brunswick in Fredericton, Canada, and a doctorate degree in geotechnical engineering at the University of Ottawa in Ottawa, Canada.

In his free time, he enjoys tennis, soccer and rugby, and he plays piano jazz at the amateur level.

Keynote Speaker

Managing Disruptive Transportation Technologies

Stan Caldwell

Executive Director, Traffic21 Institute & Mobility21 National University Transportation Center

Stan serves as Executive Director of Carnegie Mellon's Traffic21 Institute and of the US DOT designated Mobility21 National University Transportation Center. These centers fund and coordinate faculty from across the University in interdisciplinary technology-focused transportation research and education. The research centers maintain a primary focus on deploying transportation research and technology in the community and work with public and private partners to use Pittsburgh and the region a smart transportation test bed. Through the work of these centers, Stan has taken a nationally active role in the emerging intelligent transportation industry and serves on the Leadership Circle of the Intelligent Transportation Society of America and developed the industry recognized Traffic21 Blog. He serves on the executive committee of the Council of University Transportation Centers, the Pennsylvania Autonomous Vehicle Policy Task Force and the Smart Belt Coalition.

Additionally, Stan has an appointment in Carnegie Mellon's office of Government Affairs as Director of State Relations where he interfaces with state and local officials and community organizations.

Prior to joining Carnegie Mellon, Stan was serving as Executive Director of US Senator Arlen Specter's Pittsburgh Office and served as political director for the Senator's 2010, 2004, and 1998 re-election campaigns. For 17 years, he worked in both official and political capacities for Pennsylvania elected officials including Supreme Court Justice Sandra Shultz Newman, Superior Court Judge John Bender, US Senator Rick Santorum, and various candidates. Stan also founded a consulting company that focused on community organizing where he developed and managed initiatives such as the "RAD Works Here" campaign in 2000 to build community support for the Allegheny Regional Asset District.

Stan has also worked for the Southwestern Pennsylvania Commission, the Southern Alleghenies Conservancy and the US Department of the Interior, National Park Service.

He received his Master of Public Policy and Management degree from the University of Pittsburgh and a Bachelor of Science degree from Slippery Rock University of Pennsylvania.

Presentation Abstracts

Development of novel, nonlinear finite-element analysis methods for load rating of concrete girder bridges

Presenter: Bill Davids, PhD, PE, Professor and Chair, Civil & Environmental Engineering, University of Maine

By: Bill Davids and Andrew Schanck
University of Maine

Abstract: Maine's bridge inventory includes a significant number of reinforced concrete T-beam bridges. Many of these bridges were built in the first half of the 20th century for design loadings much lower than those considered today, causing a significant number of them to have low flexural rating factors. Despite this, these bridges continue to carry modern levels of loading with little to no apparent distress, and many are in good condition. This observation has prompted efforts to better understand the behavior of these bridges and to develop new methods of analysis to better predict their true capacities.

In the summers of 2017 and 2018, 10 reinforced concrete T-beam bridges were non-destructively live-load tested to update their rating factors and to observe their load-strain responses. Five bridges were un-skewed and five were skewed between 15° and 35°. The test results permitted increasing the flexural rating factor to a value greater than one for 7 of these 10 bridges. However, load levels used in diagnostic live load tests cannot exceed service load levels, and diagnostic testing therefore cannot capture inherent structural ductility and load redistribution that will increase rating factors further.

To address these shortcomings, the novel, nonlinear finite element technique, Proxy Finite Element Analysis (PFEA), was developed. PFEA represents the complex material and system behavior of a bridge using proxy girder models whose nonlinear flexural behavior closely matches that of an actual girder, but whose constitutive properties and geometry are straightforward to implement in 3D FE models using commercial software. These 3D PFEA models simulate realistic levels of ductile, inelastic deformation in heavily loaded girders and the resulting load redistribution that occurs before capacity is reached.

PFEA simulations indicated that all 10 bridges have rating factors greater than one. PFEA proved to be especially valuable at capturing the effect of unusual bridge geometry, which diagnostic live load testing failed to do. The results of the diagnostic live load testing and PFEA have been used by the MaineDOT to increase official bridge rating factors, ultimately extending bridge service life and eliminating the need to post, strengthen or replace these critical structures. PFEA's capabilities have also been extended to allow the determination of girder shear rating capacities and the load rating of simple-span prestressed girder bridges.

Preliminary material testing and analysis of two old railroad steel bridges

Presenter: Celso de Oliveira, Ph.D. Student, Civil Engineering

By: Mark Castaldi, Sachin Tripath, Celso Cruz De Oliveira, and Ramesh B. Malla
University of Connecticut

Abstract: Most of the railroad (RR) bridges currently under operation in the United States, especially in the New England region, were constructed a more than a century ago. It is imperative to determine their material properties and remaining life expectancy for passenger safety. This paper presents the current status of the material properties of the critical members of two with more than 115 years old long-span open deck truss RR bridges, Cos Cob (Fig. 1) and Devon Bridges in Connecticut. These two bridges lie in the North East Corridor (NEC), the busiest passenger train railroad line in the U.S. Tensile tests have been conducted in accordance with ASTM E8-16 standard.

The specimens were tested using 150 kN ADMET (Fig. 2) and Instron machines. Out of 7 tensile test specimens from Cos Cob bridge and 6 tensile test specimens from Devon bridge, two specimens for each bridge were simply loaded to failure at the nominal speed provided by ASTM standard. The remaining test specimens from each bridge were loaded/unloaded in their elastic and yield regions at different strain rates. This was done to evaluate the linear elastic region, potential effect of different strain rates on the results, and to determine the parameters to conduct hysteresis test. After the material is loaded to the yield point at the first time, yield shelf was observed. Once unloaded, when specimens were reloaded monotonously until failure, yield shelf was not observed. Moreover, interestingly, yield strength was observed to be increased compared to the first trial. This might be related to the crystallographic defects and dislocation of the grain structure subjected by test specimens during plastic deformation at first trial. The material has maintained their elastic, yielding, plastic deformation, and strain hardening characteristics. From the current testing of limited number of specimen, Devon bridge material has maintained its ultimate tensile strength (UTS, Fig. 3) while Cos Cob exhibited lower UTS (Fig. 4) in comparison to ASTM A7 material specifications. The UTS is related to the remaining fatigue life from the constant amplitude fatigue limit (CAFL), which is equal to half of UTS (AREMA 2015, AASHTO 2018).

This paper presents the material properties and remaining life estimation of two more than 115 years old railroad (steel bridges. Tensile tests have been conducted to determine the status of the materials. Similarly, strain-based life estimation, concept has been used to determine the remaining life of the bridge. The results from the research has potential to provide information on the overall health of the bridge and ensure the safety.

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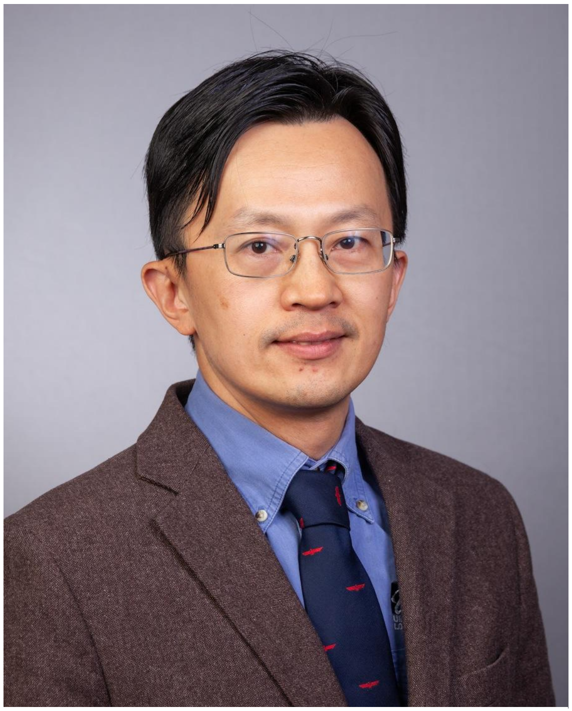
Electromagnetic detection and identification of concrete cracking in highway bridges



Presenter: Tzuyang Yu, Ph.D., Associate Professor, Civil & Environmental Engineering

By: Tzuyang Yu, Sanjana Vinayaka, Ahmed Alzeyadi, Qixiang Tang, Jianing Wang, and Ronan Bates
University of Massachusetts Lowell

Abstract: The research problem we are trying to solve is the structural assessment of aging concrete bridges (reinforced and prestressed) in New England, targeting at concrete cracking and degradation. Our approach includes near-field (contact) and far-field (remote) electromagnetic (EM) sensors. Near-field EM sensors such as ground penetrating radar (GPR) are commercially available and have been widely used in practice. Far-field EM sensors such as synthetic aperture radar (SAR) offer efficient inspection but have not been commercialized. In this project, we have developed i) an EM database for remotely quantifying concrete cracking, ii) a procedure to correlate an SAR sensor with a commercial GPR, and iii) a portable, wireless SAR imaging sensor for field bridge inspection. Since concrete cracks on real structures cannot be verified without destructive examination, we have extensively utilized laboratory specimens (panels, beams) to develop a thorough understanding on how a concrete crack generates its electromagnetic scattering (remotely or near-field).

From the laboratory and field test results, we have found that all EM sensors are sensitive to background noises in concrete structures, such as moisture content. Variation of moisture content in concrete leads to a global change of scattering pattern, while the presence of concrete cracks only leads to a local change of scattering pattern. Quantification of global and local changes of scattering patterns allows us to separate local scattering pattern from global scattering pattern for damage detection. We have developed several algorithms for such radar image quantification in this project.

- Concrete cracks with regular geometry – To investigate the EM scattering effect of concrete cracks with regular geometry, we manufactured five concrete panel specimens with two groups of crack designs; a through crack and three finite cracks. Fig. 1 shows five concrete panels and their SAR images.
- Concrete cracks with random geometry – To verify the performance of our image-based crack detection approach, we inspected two real cracks on a concrete bridge in Lowell, MA. Fig. 2 shows a photo of two real concrete cracks and their radar images.

Structural health monitoring of a bridge using fiber optic sensing textile

Presenter: Andres M. BiondiVaccariello, Ph.D. Student, Electrical & Computer Engineering

By: Andres M. BiondiVaccariello[a], Xu Guo[a], Rui Wua[a], Jingcheng Zhou[b], Qixiang Tang[c], Jianing Wang[c], Tzuyang Yu[c], Balaji Goplan[d], Thomas Hanna[d], Jackson Ivey[d], Steven Youschak[e], Nick Ray[e], Xingwei Wang[a*]
University of Massachusetts Lowell

Abstract: Structural Health Monitoring (SHM) of large civil infrastructure has been the focus in on the latest research. The ability to determine the deterioration status of an infrastructure brings economics advantages and the possibility to early detect damages in the structure. . Distributed sensors have played an important role in developing a reliable monitoring system. This project develops a fiber optic sensor embedded in a textile and demonstrates its feasibility to be installed in bridges for SHM. The interrogation system is based on Brillouin Optical Time Domain Reflectometry (BOTDR) measurement. The sensing system was installed at the Salmon Fall River Bridge located at South Berwick in New Hampshire (Fig.1). This sensing structure monitored the strain variation while the Amtrak service trains transited the bridge.

Before the deployment, the sensors were calibrated in the laboratory. This calibration procedure consisted in obtaining the temperature and strain coefficients that provided the conversion factor to obtain the true value of temperature and strain from the Brillouin frequency shift. In addition, the temperature cross-sensitivity effect was investigated. A temperature compensation technique was proposed and applied, using a section of the fiber as a thermometer to obtain the environmental temperature. Fig 2 shows the final system, which was installed on the bridge. The importance of this research is the impact that has on the civil infrastructures' maintenance. With the development of this system, a better understanding of the current conditions of the structures will allow us to plan for the respective maintenance and repairs reducing cost and the possibility of structural failure. The realization of this project was possible, thanks to the collaboration between the University of Massachusetts Lowell and our industry partners: (1) Saint-Gobain, who was in charge of developing the sewing techniques for embedding the fiber in the textiles, and (2) American Rail Engineering Corporation, who provided the assistance and the equipment for the installation of the sensors at the bottom of the bridge. Advanced Functional Fabrics of America (AFFOA) provided additional funding for this research.

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Deterministic optimization for damage identification using dividing rectangles algorithm

Presenter: Yang Zhang, Graduate Student, Mechanical Engineering

By: Yang Zhang and Jiong Tang
University of Connecticut

Abstract: Damage such as material degradation and geometry changes in structures adversely affect the system's performance. In this research, an optimization-based damage identification framework is proposed to analyze piezoelectric admittance data for structural health monitoring.

We first establish finite element simulation of admittance information of piezoelectric transducer integrated to an underlying structure. Structural damage generally causes the change of admittance information which is then used to infer damage location and severity. Damage identification is achieved by comparing measured to simulated admittance change. Since the sampling range in admittance change is limited, it means that the inverse analysis is under-determined problem, to tackle this problem we cast the damage identification process into an optimization problem to minimize the difference between measured admittance change with respect to model prediction with assumed damage scenarios. Meanwhile, we take advantage the fact that the damage index vector is sparse in nature which corresponds to minimized l_0 norm. Subsequently, we formulate a multi-objective optimization problem to solve for the damage index vector. The optimization model is:

$$\begin{cases} \text{find} & \boldsymbol{\alpha} \in \boldsymbol{E}^{n} \\ \min & \left\| \Delta A - \Delta A_{meas} \right\|_2 \\ \min & \left\| \boldsymbol{\alpha} \right\|_1 \\ \text{s.t.} & \alpha_l \le \alpha_i \le \alpha_u \end{cases}$$

where α_l and α_u are lower and upper bounds of the design variables respectively. n is the numbers of design variables. $\boldsymbol{E}$ is design space. $\|\cdot\|_p$ denotes the l_p norm. Note that the multi-objective optimization model is built rather than a composite function because the selection of weights for the two objectives are usually ad-hoc due to the undetermined importance of objective.

Dividing Rectangles algorithm (DIRECT) is employed to solve the inverse identification problem. DIRECT is a deterministic global optimization algorithm and divides the search space into rectangles and calculates objective values at the centers. The algorithm has less tunable parameters compared to most of stochastic global optimization methods. The relationship between input and output of the system is complex which includes many local minima. Thus, DIRECT is capable of tackling the damage identification problems and finding the global minimum. Three cases with different numbers of damage are considered and discussed. Results confirm that the proposed approach can deal with various damage scenarios.

Avalanches during flexure of early-age steel fiber reinforced concrete beams

Presenter: Ting Tan, Ph.D., Associate Professor, Civil & Environmental Engineering

By: Zhuang Liu[1], Robert Worley II[2], Fen Du[3], Courtney D. Giles[2], Mandar Dewoolkar[2], Dryver Huston[1], Ting Tan[2*]
University of Vermont

In this work, we studied stress variations occurring during flexure of early-age steel fiber reinforced concrete beams. By preparing beams with different fiber volume ratios, four-point bending tests were performed to evaluate the specimens at different loading rates. A new experimental system was created to collect the stress-time curves collected at 100 kHz sampling rate so that temporal profiles of stress drops were analyzed in high resolution. Meanwhile, stress drops were modeled as avalanches due to interactions between steel fibers and cement matrices during flexure. Good agreement on avalanche statistics and dynamics was obtained between measurements and the predicted power law exponents and scaling functions from the mean field model. The observations of different avalanche types also illustrated the essential failure features evolved during flexure of steel fiber reinforced beams.

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Large Scale 3D Printed Thermoplastic Composite Forms for Precast Concrete Structures

Presenter: Sunil Bhandari, Ph.D. Student, Civil Engineering

By: Sunil Bhandari[1,2], Roberto A. Lopez-Anido[*,1,2], and James Anderson[1]
University of Maine

3D printed parts are gaining wider acceptance as tools in formative manufacturing process. Molds have been made using polymer-extrusion based 3D printing technology for vacuum assisted resin transfer molding (VARTM) boat hulls, casting polymer medical implant, and small scale stamp forming of mechanical parts. Recently, forms for precast concrete structures were made using polymer extrusion-based 3D printing technology. Recent advances in large-scale 3D printing and thermoplastic composite materials with bio-based fillers and reinforcements have great potential for expanding the possibilities of making forms for precast concrete structures. The 3D printing technology for making molds, forms and tooling for precast concrete is expected to reduce labor cost and minimize waste. 3D printed forms allow design optimization of precast concrete parts since the additive manufacturing cost is only function of thermoplastic material weight and is independent of part complexity. Additionally, 3D printed forms can become and asset, since thermoplastic composite materials can be reprocessed. Ingersoll Masterprint multi-station was used for the study. The large-scale 3D printer has a 60′ (18.3m) long, 22′ (6.7m) wide, and 10′ (3m) high build envelope.

A 16.5 m long 3D printed form for the precast concrete pier cap of a highway bridge replacement project was selected for demonstration. The design and manufacturing of 3D printed forms for casting concrete encompass three steps, as follows: 1) Prediction and reduction of shrinkage effects during manufacturing; 2) Structural design for strength and stiffness requirements; and 3) Model slicing, part printing, and surface finishing. The type of surface finishing and the dimensional stability and durability of the thermoplastic material selected for concrete forms are examined. The lessons learned from projects using large-scale 3D printing technology for formwork are discussed. The project explores the feasibility of designing forms for durable and lightweight precast concrete structures.

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Development and Testing of High / Ultra-High Early Strength Concrete for Durable Bridge Components and Connections

Presenter: Bijaya Rai, Ph.D. Student, Civil & Environmental Engineering

By: Bijaya Rai and Kay Wille
University of Connecticut

Abstract: Aging of infrastructure is one of the major problem in the US. About 25% of bridges are already 50 years or older and about 9.1% have already been classified as structurally deficient as per ASCE Report card 2017. Increasing traffic loads along with aging accelerates the deterioration process of the infrastructure. The challenge is to find cost-efficient ways a) to increase the service life of existing structures and b) building new structures with enhanced service life. This is in line with the Connecticut DOT's long-term goal. In pursuit of this the Connecticut DOT is working on an updated concrete specification to enhance the concrete's performance and thus the service life of major structural components, such as bridge decks and parapets. Recently they introduced the concept of low permeable concrete to reduce maintenance cost and enhance service life. The solution for this is to design low permeable, high strength, and highly durable concretes tailored to the New England area.

The development and testing of high and ultra-high performance concrete (UHPC) using local available materials have a significant potential to address the aforementioned concerns effectively and efficiently. UHPC uses a relatively high binder ratio, a water to cementitious ratio (or water to binder ratio) less than 0.2, is tailored towards a very high particle packing density which results in a compressive strength in excess of 150 MPa (22 ksi) and most importantly a significant higher durability compared to conventional concrete. Although the incorporation of discontinuous fibers significantly increases the material cost, these are needed to allow for small crack widths and high ductility properties.

The proprietary nature, increased quality control and high material costs have hindered an accelerated and wide spread use of UHPC in the U.S. infrastructure. Addressing these concerns, this research provides methodical recommendations for the design of UHPC in regards to material efficiency by using locally available materials available in the New England area. The basic principles of UHPC design includes: high particle packing density (low porosity), high material quality (low impurity), cement hydration chemistry (high density calcium–silicate–hydrate [C–S–H]), pozzolanic reactions and filler effect of supplemental materials (C–S–H formation and low porosity), high particle dispersion quality (low porosity and enhanced workability), optimized particle to high range water reducer (HRWR) interaction (enhanced particle dispersion) and excess paste (enhanced workability and robustness).

In close coordination with the Connecticut DOT, the research team has made contacts with local material suppliers such as Lafarge Holcim, Lehigh White Cement, GCP Applied Technologies, and Tilcon Connecticut. Within the University of Connecticut, the research team actively co-ordinates the experimental research with the Advanced Cementitious Materials and Composites (ACMC) lab, the Institute of Material Science (IMS at UConn) - Mechanical Testing Lab, and the Structures Lab.

Durability Evaluation of Carbon Fiber Composite Strands in Highway Bridges

Presenter: Braedon Kohler, Mechanical Engineering

By: Braedon Kohler[1,2], Keith Berube[1,3] , Andrew Goupee[1,2] and Roberto A. Lopez-Anido[1,4]
University of Maine

Abstract: The goal of this project is to further advance our knowledge regarding the durability of carbon fiber composite cable (CFCC) strands used in transportation infrastructure. For this reason, we aim to improve the structural health monitoring capabilities of CFCC strands placed within the stays of the Penobscot Narrows Bridge. The bridge is a "living laboratory" in which there are already sensors in place in six strands at two locations throughout the bridge that monitor strand response that were installed in 2007.

CFCC strands have high corrosion resistance, low thermal expansion coefficients, high modulus to weight ratio, and high strength to weight ratio. Due to the corrosive environments of highway bridges these strands have the potential to outperform steel cables when used for post-tensioning concrete decking and in cable-stayed bridges. The tasks of this project are: a) to implement a wireless system in the bridge to allow remote and continuous data acquisition at the Penobscot Narrows Bridge; b) to evaluate CFCC durability related to long-term response of the strands and anchorages; c) to demonstrate the value in collecting continuous CFCC strand force data; d) to develop a thermoelastic model for numerical simulation of the CFCC response and validate it with collected data; and e) to apply the model to predict CFCC strands long-term response.

Using an array of sensing equipment forces and strains in the strands, along with the ambient temperature, have been monitored for the past twelve years. Using a thermoelastic model, the acquired temperature data at the bridge will be used to predict the long-term CFCC strand response. In an effort to streamline this process, a wireless data acquisition system will be implemented such that data will be collected and processed remotely. In addition, a new weather station will be installed to acquire temperature, wind speed, humidity, and barometric pressure.

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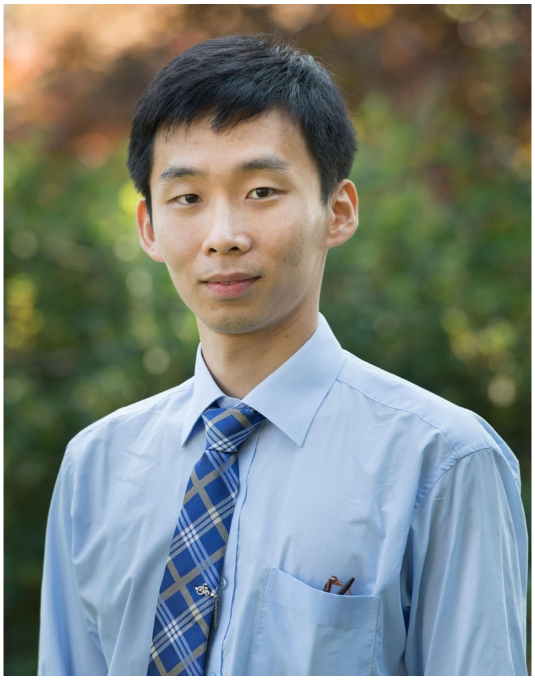
Study of Prestressed Concrete Crossties Using High-Performance



Presenter: Moochul Shin, Ph.D., Associate Professor, Civil & Environmental Engineering

By: Abdoulay Diallo, Moochul Shin, JaeHyuk Kwack, and ChangHoon Lee
Western New England University

Abstract: This study focuses on exploring the feasibility of using high-performance computing to examine the structural performance of prestressed concrete ties with respect to various types of prestressing wires. Prestressing wires have different indentation patterns, volumes, and depths, which results in a wide range of structural performance such as splitting propensity, transfer length, and different bond characteristics. Recent studies have demonstrated that volume/depth of indentation types are highly correlated with splitting/bursting performance of prestressed concrete prisms. In order to study the geometrical variations of prestressing wires such as the shape, volume, and depth of indentations, realistic 3D numerical models are developed for finite element analysis (FEA). This requires high computing power to handle a large number of degrees of freedom. Since the traditional direct solver would be inefficient, this study utilizes a parallel computing algorithm and present an advanced numerical study framework. An in-house FEA code is developed and a speed-up test is carried out successfully to estimate an optimal number of CPUs with respect to the size of the problems. The in-house code is capable of varying the number of cores for the analysis after the model is partitioned to a specific number. 4 ~ 1000 cores are used to solve a problem with the size of 21 million degrees of freedom. The numerical results by a commercial FEA software and the in-house code are compared and indicate the robustness of the in-house code with great efficiency. In addition, a concrete of 6000 psi compressive strength at 14 days is developed and a series of the pull-out test on 2”x4” cylinders with three different wires are carried out. The experimental results clearly indicate that the prestressing wire with the deeper indentation reaches the bond strength much at smaller displacement than other wires. The study demonstrates that the different effects of geometrical parameters of prestressing wires on the bond characteristics of the prestressed concrete crossties.

The Effect of Different Conditions at the Two Abutments on the Behavior of Skew Integral Abutment Bridges (IAB) under Thermal Loading

Susan Faraji, Ph.D., Professor, Civil & Environmental Engineering

By: Susan Faraji
University of Massachusetts Lowell

Abstract: When integral abutments are located on skew their behavior is more complicated than that of non-skew bridges. Non-skew bridges experience uniformity when the temperature is increased and the lateral soil pressure behind the abutment wall near the deck level tends toward the passive pressure limit state.

Skewed integral abutment bridges experience a rotation in the horizontal plane under thermal loading, which causes a redistribution of soil pressure acting on the abutment walls and so a non-uniform soil pressure behind the wall. Rotation tends to decrease translation at the acute corner and increase translation in the obtuse corner. Therefore, the deformation pattern for skew bridge may differ substantially from the non-skew state and produce unanticipated local cracking.

To study the impact of different soil conditions at the abutments on the behavior of rotation of skew IABs under thermal loading, a closed form analytical solution for a symmetrical skewed rigid plate. With restraining springs acting on two sides of the plate subjected to a uniform thermal loading was generated for (a) restraining symmetrical springs and (b) restraining non-symmetrical springs.

The use of restraining symmetrical springs is representative of identical substructure conditions at both abutments. On the other hand, the use of restraining non-symmetrical springs is representative of different conditions at the abutments, such as variations in the soil pressure behind the abutment walls, the HP piles inertia, the length of the HP piles, and wing wall type.

The analytical solution indicates that the rigid plate experiences a rotation in the horizontal plane under the thermal loading. The rotation depends on the tangential relative stiffness parameter, β , the skew angle, θ , and the length /width ratio, a/b.

In addition, the analytical solution indicates that the impact of different conditions at the abutments should not be ignored. It might have major impact on redistribution of soil pressures acting on the abutment walls. Therefore, we shall design accordingly.

Optical-Based Structural Health Monitoring of Truss Bridges

Presenter: Celso T. do Cabo, Graduate Student, Mechanical Engineering

By: Celso T. do Cabo, Nicholas A. Valente, and Zhu Mao
University of Massachusetts Lowell

Abstract: Optical sensing techniques are an effective approach to extract system dynamics information for structural health monitoring (SHM). Traditional sensing hardware, such as accelerometers, require a large amount of time and monetary expense for the installation. Moreover, such permanently installed data acquisition system demands a high cost of maintenance given its in-situ operational nature. Thus, non-contact sensing is a good alterative due to its better portability compared to traditional sensors. In particular, sensing through video cameras can obtain full-field information, permitting the extraction of dynamic information at any pixel of interest, while accelerometers and other noncontact sensors such as laser Doppler vibrometers can only provide simultaneous measures at sparse locations. To process the camera data, phase-based motion estimation (PME) and magnification (PMM) have been investigated, which aim to extract and amplify subtle (invisible) motions that cannot be seen clearly without processing.

This paper aims to identify the shift of natural frequencies and change of the operational deflection shapes of truss bridges due to damage and load conditions using PMM. For this purpose, experiments on a laboratory-scale truss bridge was carried out under the collaboration with Prof. Tzuyang Yu from Civil Engineering at UMass Lowell. To observe the difference of the bridge behavior under different types of excitation, a mass-loaded cart is adopted and impact excitation at the sides of the bridge is applied too. With the intention of simulate diverse damaged scenarios, the damages were divided into severe damaged and light damages. The damage started from changing a truss element with varying cross section properties, which led to a loss of stiffness, and the damage ended as severe as taking away a whole truss on the bridge. It was feasible to identify the shifted natural frequencies from damaged cases which deviate from the healthy structure. Complementarily, a real truss bridge test was done and had a good dynamic response, allowing the identification of the first few bending modes of the structure. It was also possible to identify nonlinear higher harmonics with 4Hz modulations, which may be induced by the nonlinear coupling with traffic loading or wind/scour excitation. Therefore, PME and PMM proved to be a powerful tool for dynamic information extraction, and frequency shift with the change of the operational deflection shapes shows great potential for damage detection.

On Lateral Spreading and the Stability of Embankments Supported on Fractured Unreinforced Rigid Columns over Soft Soils

Presenter: Aaron Gallant, Ph.D., P.E., Assistant Professor, Civil & Environmental Engineering

By: Aaron Gallant and Danilo Botero-Lopez
University of Maine

Abstract: Over the past decade, the construction of embankments supported on unreinforced rigid (i.e. grouted) columns over soft soil has become common practice to accelerate construction for highway, railway, and bridge applications. Arching is largely responsible for transferring the embankment load through the columns to more competent ground at depth, thus reducing stress applied to underlying soft foundation soils. In some cases, a geosynthetic-reinforced load transfer platform (LTP) is constructed above the columns to increase the efficacy of load transfer, though the foundation soils ultimately share some of this load. Differential settlement mobilizes arching in the fill and engages the geosynthetic reinforcement. The mechanics behind vertical load transfer are well understood. However, column bending and yielding that arises from unbalanced loads near the perimeter of an embankment or MSE wall, and associated lateral spreading, remains a salient concern.

There is currently no established method to assess lateral spreading of column-supported embankments (CSEs). Simplified limit equilibrium methods to assess lateral spreading and deeper-seated global instabilities neglect the redistribution of stresses in the embankment fill and foundation soils due to mobilization of vertical load transfer mechanisms. In this study, 3D finite element analyses, which incorporate a discrete-crack method to account for column-yielding and the cessation of bending resistance associated with fracture of brittle columns, thus providing a more faithful assessment of the system, were performed to examine the influence of column fracturing on lateral spreading and basal stability. The numerical analyses are complimented with field performance data from full-scale column-supported systems.

Based on the observations from this study, column yielding attributed to bending does not necessarily exacerbate lateral spreading, and is controlled, in large part, by the subsurface conditions at shallow depths. The results of the study will allow practitioners to develop more economically efficient column configurations and area replacement ratios based on subsurface conditions rather than subscribing to criteria that preclude column yielding of unreinforced elements—a debate currently underway as industry considers codifying a design methodology for CSE systems. The implications are of practical importance to DOTs, designers, and contractors.

Bridge-Stream Network Assessments to Identify Sensitive Structural and Hydraulic Parameters for Planning Flood Mitigation

Presenter: Rachel M. Seigel, Graduate Student, Civil & Environmental Engineering

By: Rachel M. Seigel, Arne Bomblies, Donna M. Rizzo, and Mandar M. Dewoolkar
University of Vermont

Abstract: The 2011 Tropical Storm Irene resulted in considerable monetary damages to infrastructure and property in Vermont and neighboring states, including damages to and failure of hundreds of bridges. The northeastern United States is experiencing a trend of more frequent and persistent extreme precipitation events. As a result, infrastructure must now be able to withstand more extreme flood events of greater magnitude. Satisfying the rigorous hydraulic demands of these floods on all bridges and structures is not feasible, so prioritizing resources to minimize flood damage in a watershed is critical for efficient rehabilitation projects. The interactions among rivers, hydraulic structures and the surrounding hydrogeological features are not well-established or understood at the river network scale. Studies are often limited in scope to steady-state analyses in the immediate vicinity of a specific structure or feature, and the far-reaching impacts up- and downstream are often not considered. This is complicated by the fact that specific structural or hydrogeological features may attenuate and/or intensify hazards on the network scale. In this work, we attempt to quantify the dynamic interactions between a river and its surrounding infrastructure under high-risk, transient conditions to help assess a number of flood mitigation strategies, such as bridge widening, lowering of approaches, and adding culverts. Two-dimensional HEC-RAS models, developed for three Vermont rivers ranging from very low to high gradients, each with numerous bridges and culverts, are used for the analysis. Multiple model simulations are performed over a variety of flood events ranging from 25 to 500 years. The analysis results are compared and contrasted across the three study sites in an attempt to develop a framework for assessing flood mitigation of a bridge-stream network.

Alternative Cementitious Materials (ACMs) for Durable and Sustainable Transportation Infrastructures

Presenter: Hosain Haddad Kolour, Postdoctoral Research Associate in Cement-Based Materials

By: Warda Ashraf, Rakibul I. Khan, Eric Landis, and Hosain Haddad Kolour
University of Maine

New-generation binding systems, known as the Alternative Cementitious Materials (ACMs), can be used for producing concrete with enhanced durability and improved mechanical properties compared to those made with ordinary Portland cement (OPC). Simultaneously, carbonation (curing with CO_2) has been used for producing concretes with denser microstructure. In this work, the effects of grade 120 Ground Granulated Blast Furnace Slag on workability, compressive strength, and electrical resistance of concrete against the penetration of chloride (using rapid chloride penetrability test, RCPT), were investigated. 6 batches with constant binder content of 600 kg/m^3 and variable slag content (0%, 20%, 45%, 65%, 80%, and 100% slag replacement) in 3 groups with different curing procedure were prepared and tested. 28 days in moist room was the curing procedure in first group. The second curing method was 3 days in moist room followed by 4 days in carbonation chamber and 21 days in moist room. Third procedure was 7 days in carbonation chamber followed by 21 days in wet room. Standard slump tests were performed to measure workability. Slump test showed a decrease in the workability of fresh concrete due to the increase in slag content for all batches except 20% slag replacement which showed increase in workability. The results of the compressive strength tests for all specimens were collected for 3, 7, and 28 days. For all curing procedures, 45% and 65% slag replacements showed the best improvements after 28 days. RCPT results showed that chloride penetration decreased with an increased slag content. This shows that adding slag and using carbonation curing procedure, leads to denser concrete microstructure. Results suggest that combining pozzolanic reaction (due to slag addition) and carbonation reaction (due to curing with CO_2) with existing hydration reaction (due to cement) has a good potential to be considered as a method for improving concrete performance and obtaining denser microstructure (higher compressive strength and lower permeability).

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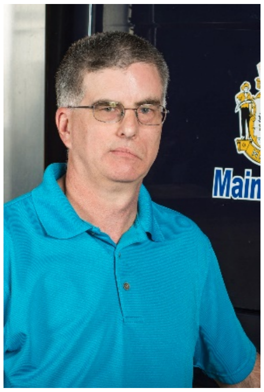

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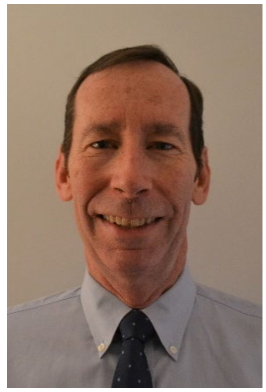

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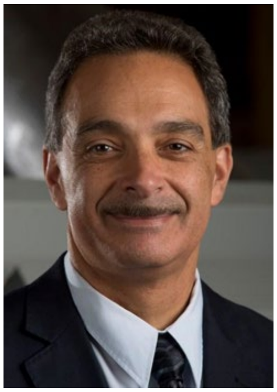

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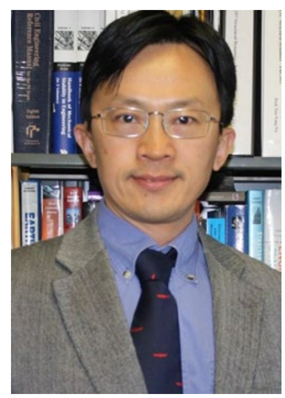

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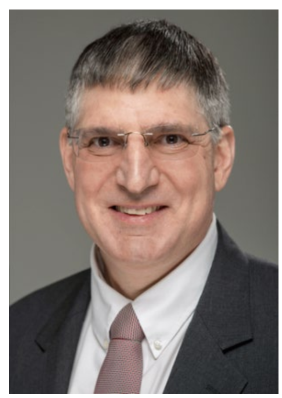

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