Ferguson Structural Engineering Lab Newsletter

THE UNIVERSITY OF TEXAS AT AUSTIN - STRUCTURAL ENGINEERING

Volume 9, Issue 2

October 03, 2017

Fall Semester Kickoff BBQ!

Ferguson Lab once again celebrated the return of a new school year with our Fall BBQ tradition. Research projects were on display, incoming students made introductions, and the beer and BBQ were plentiful. Oh, and did I mention the sidewalk chalk art?!

New Faces at FSEL

Xiaoyi Chen

I am a first-year PhD student working with Dr. Juan Murcia-Delso on the development of advanced computational and experimental techniques (DIC) to characterize the inelastic behavior of concrete structures. I received my BS from Shandong University, China and MS from Tongji University, China. During my Master's, I mainly focused on the structural dynamics and vibration control. I am very glad to be a member of FSEL and really looking forward to meeting everyone here! I enjoy photography and exercises, such as doing yoga, running and playing badminton.

Joseph Gilroy

I am a first year Master's student working with Dr. Clayton. I was born into a military family in Misawa AFB, Japan, until eventually moving to Schertz, Texas, near San Antonio. Last May I received my BS in Civil Engineering from UT Austin. My research involves evaluating the stability of moment frames utilizing fuse connection under seismic stresses. In my free time I enjoy playing billiards and visiting the lake for canoeing and kayaking.

Special points of interest:

- Flag Football Game October 27

Inside this issue:

Sedef Kockaplan

I received my Master's degree in Earthquake Engineering from Bogazici University, Kandilli Observatory and Earthquake Research Institute, Turkey. During my master's degree, I focused on developing methods to identify and calibrate analytical models of multi-story buildings from their vibration records, finite element modeling and earthquake resistant design. I am very glad to be working in FSEL and Dr. Clayton's research group. I am looking forward to meeting and working with everyone.

Stylianos Livadiotis

I come from Cyprus, a small island in the eastern Mediterranean. I got my Bachelors and Masters degrees in Civil Engineering from University of Cyprus and Drexel University respectively. I recently joined the smart structures research group under the supervision of Dr. Salamone. Working at the FSEL gives me a great opportunity to strengthen my knowledge on technical topics as well as getting to know and cooperate with a lot of talented students and professors. In my free time I enjoy watching tennis, soccer and football.

Matthew Moore

I grew up in Attleboro, Massachusetts, a small city just south of Boston. I received a Bachelor's degree in Civil Engineering from Wentworth Institute of Technology, and am currently pursuing my MS at UT. I am working with Dr. Helwig and Dr. Engelhardt on a NCHRP project that is focused on updating AASHTO provisions for analysis and design of cross-frames. In my spare time I enjoy reading, hiking, cooking, and snowboarding (which has been tough to do here in Texas).

Sunghyun Park

I'm a 2nd year PhD student from South Korea. I earned BS and MS in architectural engineering from Kyungpook National University in Korea. I'm interested in steel structure. This year I'm working on NCHRP project about stability and fatigue of cross-frame in steel I-girder bridges with Dr. Helwig and Dr. Engelhardt.

Yousun Yi

I was born and raised in Pohang a coastal city of South Korea. I recieved my BS degree in Chung-Ang university and MS degree in Seoul National University, and after received MS degree, I continued my research work as a research assistant in Seoul National University for one year. My research interests are reinforced concrete mechanics and its analysis, so I am really glad to pursue my PH.D degree at UT and start research work at FSEL. I enjoy watching movies, playing the guitar (basic level though), and traveling around with my wife in my free time.

Esteban Zecchin

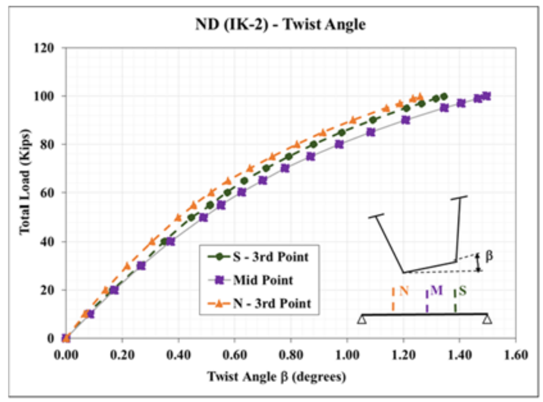
I am a MS student from Cordoba, Argentina. After receiving my Bachelor's degree in Civil Engineering at Universidad Nacional de Cordoba and working at a Structural Engineering Consulting Company for three years I came to UT Austin with a Fulbright Scholarship. I am particularly interested in Bridge Engineering and will be working with Dr. Helwig and Dr. Engelhardt during my time at UT. In my free time, I enjoy outdoor activities and meeting with friends. Being at UT and working at FSEL will be for sure an amazing experience both personally and academically.

Improved Tub Girder Details - Yang Wang & Stalin Armijos Moya

Tub Girder Test Setup

Steel trapezoidal box girders, known as tub girders, are a popular alternative in systems with large torsional demands, such as horizontal curved bridges, because of the torsional stiffness of their closed section. The objective of the current research study is to improve the economy and structural behavior of steel tub girders by modifying tub girder proportions and the bracing details for the girders.

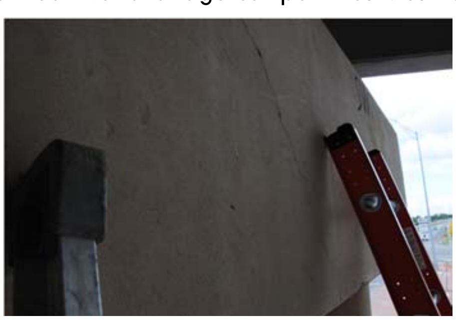
The activities during the Fall 2017 semester include experimental elastic-buckling tests of our third tub girder which has been built with shallow webs. The tub will be subjected to bending and combined bending with torsion to simulate demands on straight and curved girders, respectively. In order to measure the effectiveness of top lateral bracing and internal K-frame bracing systems, different bracing layouts will be tested on the same tub girder under the same loading conditions. On parallel, the results of the elastic-buckling tests of the first and second tub girder are been evaluated to calibrate finite element models. Finally, we will start adjusting our test setup to conduct ultimate capacity tests on each tub girder after placing a concrete deck over each one.



Torsional Response of Tub Girder with No Top Lateral Bracing

Damage Assessment of Decommissioned Reinforced Concrete Bent Caps - Bernardo Perez, Andrew Stam, Yousun Yi, and Jarrod Zaborac

The objective of this research is to assess two recently decommissioned reinforced concrete bent caps from Interstate Highway 20 and State Highway 351. This research will provide experimental results to provide insight into the performance of real-world bridge components under distributed loading conditions. The primary tasks associated with this research are: site inspection, lab inspection after removal, ultimate load testing, and data synthesis and analysis. Both site inspections have been completed and in-service damage has been recorded. Currently, the project team is working towards characterizing the mechanical properties of the bent caps, including compression tests and petrography. Additionally, the team is working towards preparing the bent caps and the test setup for ultimate load testing.



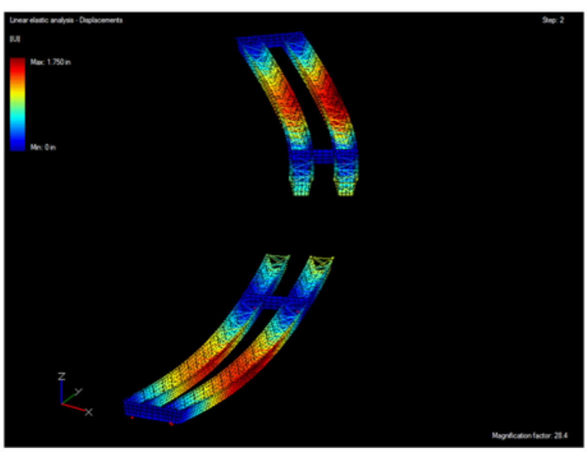
Additive Manufacturing in the Construction Industry - Daniel Delgado Camacho, Kee Young Jung

Additive Manufacturing (AM), commonly known as 3D printing, fabricates components in a layerwise fashion based on 3D models. Already being applied in many industries such as aerospace, automotive and healthcare for small scale, large scale 3D printing for construction is still in its infancy. AM requires interdisciplinary research. At UT, mechanical engineers will start to program a robotic arm for material extrusion. Materials engineers will work on a concrete mix design suitable for 3D printing. Construction engineers will work on the methods and applications for construction. Structural engineers will focus on large scale testing, scaling effects, customized connections, reinforcement techniques for AM processes, and non-destructive evaluation of components during printing and when completed.

Optimized Column by XtreeE

Example of a Robotic Arm by MX3D

Partial Depth Precast Concrete Deck Panels on Curved Girders – Paul Biju-Duval and Colter Roskos



Analytical Model of Trapezoidal Girders

This research program is investigating the use of precast prestressed concrete panels (or PCPs) as bracing elements in curved bridges during the construction phase. This summer, the research team conducted experimental tests using a forklift in order to evaluate whether the connection detail from the PCPs to the steel girders can accommodate large displacements between adjacent girders. Parametric studies were also conducted to estimate the benefits of using PCPs on large-scale, realistic bridges. Next semester, the team will wrap up the parametric studies and propose design recommendations on the use of PCPs for curved systems. In addition, a new version of UT Bridge will be released, which will include curved trapezoidal box girders.

Fatigue Behavior of High Mast Illumination Poles (HMIPs) with Pre-existing Cracks – Ying-Chuan Chen, Xoab Perez and Ali Morovat

High Mast Illumination Poles (HMIPs) provide lighting along highways and at major interchanges. In recent years, several HMIPs have collapsed in states neighboring Texas. These collapses have been attributed to fatigue failure of the weld at the shaft-to-base-plate connection. Failure of these poles and the presence of pre-existing cracks from galvanizing processes have raised concern over the status of the nearly 5000 HMIPs in Texas. This project is therefore funded by TxDOT to study the fatigue of galvanized HMIPs with pre-existing cracks. To do this, fatigue tests are performed at stress ranges from 1 to 6 ksi to evaluate the fatigue strength of cracked poles (Figure 1). Additionally, HMIPs were instrumented and monitored throughout Texas to better understand the fatigue loading environment at the base of HMIPs (Figure 2). Results from fatigue tests and field studies will be used to estimate the remaining fatigue life of in-service HMIPs with pre existing cracks.

Figure 1: Test setup for fatigue tests.

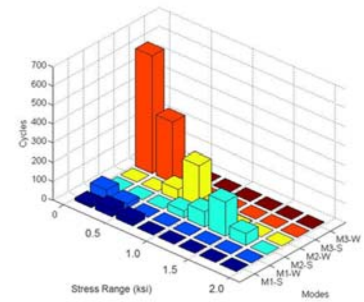


Figure 2: Stress range histogram (resulting from rainflow cycle counting using strain time series) – relationship between stress cycles and the corresponding vibration modes.

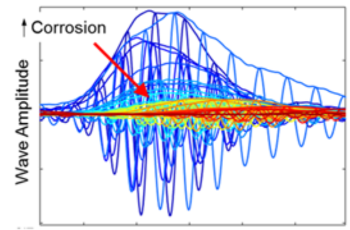
Influence of Uniformly Distributed Loading Conditions on the Performance of Flat Plate Slab-Column Connections – Gabriel Polo, Leandro Montagna

This experimental research focuses on studying the performance of flat plate slab-column connections subjected to Uniformly Distribute Loading conditions compared to slabs under Discretely Concentrated Loading conditions. Testing programs focused on examining the punching shear resistance of reinforced concrete slab-column connections have traditionally employed discretely located, and often heavily concentrated, slab loading conditions that have necessitated the need for test specimens containing large, and often unrepresentative, longitudinal reinforcement ratios in order to avoid flexure-controlled failure modes, and arguably do not represent the loading conditions experienced by actual slabs in the field. Four connections are being studied for this research: two connections subjected to uniform pressure applied on the surface of the slab, and two companion connections tested under concentrated load applied to the column, employing different longitudinal reinforcement ratios for each series. The results from the tests applying Uniformly Distributed Load will be compared with those obtained from more conventional testing programs involving Concentrated Loading conditions.

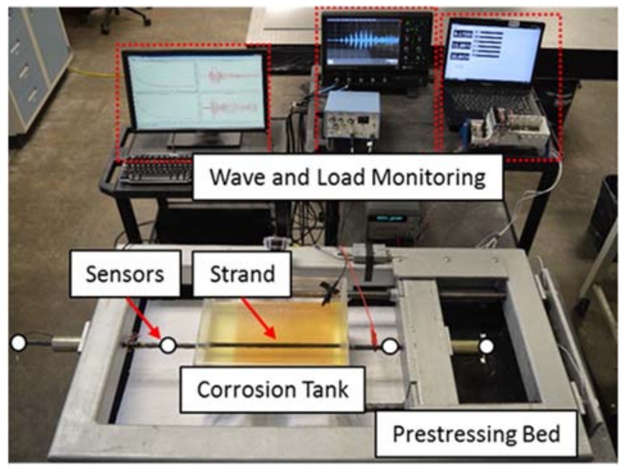
Uniformly Distributed Load Test Configuration

Corrosion Monitoring of Prestressing Strands Using Guided Ultrasonic Waves (GUWs) - Brennan Dubuc, Arvin Ebrahimkhanlou

This project examines the suitability of a monitoring system based on guided ultrasonic waves (GUWs) for detecting the initiation and growth of corrosion damage in prestressed concrete beams. The objective of this project is to design, implement, and validate the use of an innovative monitoring system for the nondestructive evaluation of prestressed steel strands. The proposed monitoring system is based on low profile piezoelectric sensors, which have the capability of transmitting and receiving GUWs and can localize damage. The effects of accumulating corrosion and resulting prestress losses on GUW characteristics are studied, such as wave amplitude and velocity. Experiments on unbonded strands under accelerated corrosion have been carried out. Upcoming experiments are also planned for studying the accelerated corrosion of small-scale prestressed concrete blocks.

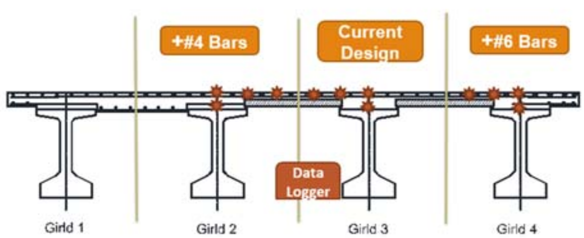


Record GUW signal in prestressing strand as corrosion accumulates.



Experimental setup for controlled accelerated corrosion of a loaded prestressing strand. GUWs transmitted and recorded between sensors to monitor corrosion.

Designing for Deck Stress Over Precast Panels In Negative Moment Regions - George Ge



Field Monitoring with Vibrating Wire Gages on Bastrop Bridge

One of the problems faced by designers for continuous girder systems is the lack of clear guidance in the AASHTO LRFD Specifications on the reinforcing requirements in the concrete deck, for both steel and prestressed concrete girders.

This research study will provide a comprehensive set of design guidelines and recommended details for the reinforcing steel to be utilized in the design and construction of continuous bridge systems that utilize partial depth precast concrete deck panels. The research methods that are to be employed in this study consist of field monitoring, full-scale laboratory testing and parametric finite element modeling of the PCPs on a variety of continuous bridge systems commonly used in Texas.

End-Region Behavior of Pretensioned Concrete Beams with 0.7-inch Prestressing Strands – Rodolfo Bonetti, Hyun Su (Dennis) Kim, and Alistair Longshaw

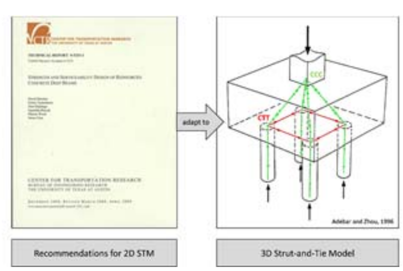
This project aims to evaluate the serviceability and shear strength implications of using 0.7-in. strands in pretensioned Texas bulb-T girders (Tx-girders). This is accomplished through a series of parametric studies on the design of bridge girders, nonlinear finite-element simulations, and experimental studies on full-scale specimens.

We have fabricated a total of seven specimens in the test program and investigated their behavior at the time of prestress transfer and under shear-critical loading since the project commenced. Four specimens were fabricated based on the standard Tx-girders details, while the end-region detailing of the last three specimens were modified to improve end-region behavior at the time of prestress transfer and more effectively confine the bottom flange. Results from the seven specimens investigated so far have shown relatively satisfactory performance for Tx-girders with 0.7-in. strands at prestress transfer. Atypical shear failure characteristics, most importantly strand slip, were observed in almost all specimens. However, the capacities of the specimens were conservatively estimated using AASHTO LRFD specifications. These findings were reported to TxDOT in the summer semester.

The team pictured with the seventh specimen after failure

Strut-and-tie modeling and design of drilled shaft footings - Andrew Stam, Yousun Yi

The design and detailing of reinforced concrete footings supported by a grid of drilled shafts varies greatly on a state, district, and even municipality basis due to the continued use of legacy; sectional design method. Therefore, a full transition to strut-and-tie modeling is required for uniform design and detailing of shaft-supported footings. This project hopes to refine the STM guidelines for 2D structures to those for 3D structures; shaft-supported footings through experimental and analytical approaches for it. For this purpose, the team is going to establish an experimental database by reviewing domestic and international technical publications within this fall. In addition, several unique shaft-supported footing plans will be reviewed to determine parameters for the experiments of this project.



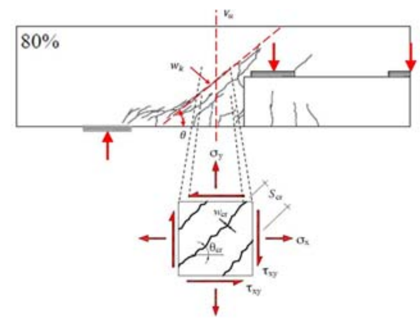
3D STM design from 2D STM refinement

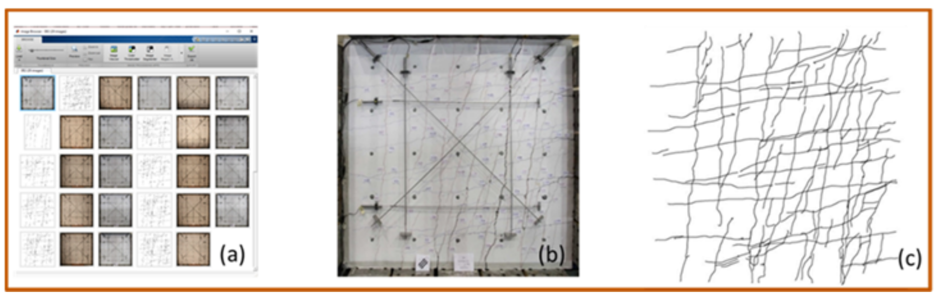
Evaluation of Diagonally Cracking in Reinforced Concrete Bridge Members - Apostolos Athanasiou and Jarrod Zaborac

The objective of this research is to develop crack-based shear strength assessment procedures for reinforced concrete (RC) bridge members. There are two methods which are being investigated currently: a RC mechanics-based approach and a crack pattern quantification approach.

The RC-mechanics based approach estimates stress-strain states based on crack width, spacing, and inclination. Preliminary results for the RC mechanics-based approach have shown proof-of-concept for estimating residual capacity. Current work on the mechanics-based procedure include incorporating additional parameters (e.g., confinement, slip, time-based effects) and plasticity methods.

The research team has also developed an approach to estimate the damage of a RC element based on the distribution of the surface crack patterns (i.e., crack pattern quantification). Using the image of a cracked concrete element as input, the user can predict how much the elements stiffness has reduced, based on the shape of the multifractal spectrum. The current goal is to investigate the applicability of this method on RC bent caps.





The Use of Precast Panels to Improve the Torsional Capacity of Concrete U-Beams - Sean Donahue, Colter Roskos

Failure of Closure Pour Strip due to Poor Confinement at Corners

Prestressed Concrete U-beams are a popular choice for bridge designers across the country. However, the open shape of their design can leave them ill-suited for handling the torsional loads that often occur in the deck placement of a multiple U-beam bridge. The Prestressed Concrete Institute has designed a detail to address this, by placing precast concrete panels on top of the U-beams, and casting a closure pour strip along the interface, to create a torsionally strong closed shape. However, this detail has not been experimentally evaluated, and its true stiffness and capacity are unknown. Testing is underway at the lab to evaluate the shear performance of this connection, both to understand the behavior of this connection, and to identify the demands on the structural elements in the hopes of refining the detail for better constructability.

Seismic Vulnerability of Masonry Facades in the Central and Eastern United States - Jennifer Kurkowski

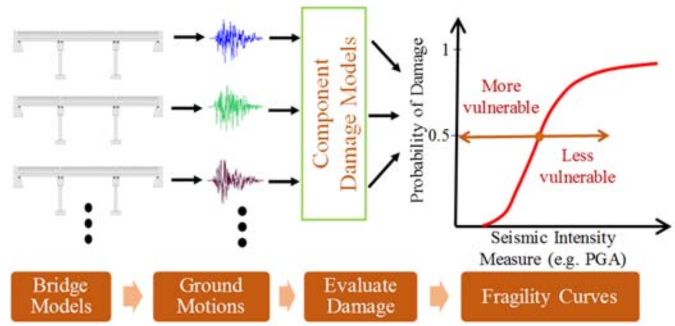
The goal of this project is to better understand the behavior and fragility of masonry facades, in North Texas and Oklahoma, due to potentially human-induced seismic activity. Currently this is to be accomplished mainly through computer modeling using OpenSEES software.

This project was started in the spring semester, which consisted mostly of literature review and investigating previous research and modeling methods. We came up with an optimal plan to build a masonry wall in OpenSEES and subject it to synthetic ground motions that had commonly been used in past studies. This allows us to validate our own model by comparing the results to those of previous research projects.

The summer focused on building an OpenSEES masonry modeled that was tailored to our needs and future analysis plans. Currently, this model is undergoing the dynamic analysis portion of the project. This will include a parametric study of installation and construction methods used for this type of wall as well. After this initial analysis phase, we will then be developing fragility curves to allow us to study the vulnerability of masonry facades to these different construction parameters.

Seismic Vulnerability of Texas Bridges to Natural and Induced Hazards - Farid Khosravikia, Andy Potter, and Vyacheslav Prakhov

The primary objective of this project is to study the effects of natural and induced seismic hazards on Texas bridges. The motivation for this research stems from the significant increase in the number of earthquakes greater than magnitude 3.0 in Texas over the past five years. Texas is historically known as a non-seismic region; therefore, this significant increase in seismicity raises concerns over the safety of infrastructure designed with little to no consideration of seismic demands. The bridge population is characterized by different classes, and for each class, computationally efficient nonlinear models are implemented for simulating damage in non-seismically detailed bridge components. The damage level is evaluated based on deformations of bridge components, and fragility functions representing the probability of exceeding each damage state are generated for various bridge classes. This information will be used to inform post-earthquake inspection plans and identify the most vulnerable bridge types and components.



The Role of Gravity Framing in Seismic Response of Structures - Sean Donahue

Typical seismic design for steel structures assumes all the lateral strength of a building is provided by the moment frames or braced frames, with the remaining gravity connections having no effective lateral resistance. Although composite gravity connections are known to have significant flexural strength, the nature of their response is currently not well understood. This research examined the response of typical gravity framing under earthquake loads. Previous testing, focused on the local response of the connections, had suggested that gravity framing was generally too weak to contribute significantly to the seismic resistance of a structure. Testing done as part of this research with a greater emphasis on simulating the boundary conditions of a full structure has shown that the floor system as a whole can significantly enhance the capacity of the connections, reaching moment capacities of over 50% of Mp, and sustaining this capacity at up to 9% interstory drift.

Test Setup at 9% Inter-story Drift

Proposed Modifications to AASHTO Cross-Frame Analysis and Design - Matthew Moore, Sunghyun Park, Matthew Reichenbach, Joshua White, and Esteban Zecchin

The project began on June 1st 2017. Recent developments have created a need for improvements to cross-frame design and analysis for steel I-girder bridges. Previously, cross-frame design was based on standard designs. The goals of this project are:

Improving guidelines for the calculation of fatigue design forces in cross-frames in straight and horizontally curves I-girder bridges as well as with normal and severely skewed supports,

Improving guidelines for the calculation of cross-frame strength and stiffness requirements for stability of I-girders during construction and in-service conditions,

Developing improved methods to account for the influence of end connection details on cross-frame stiffness,

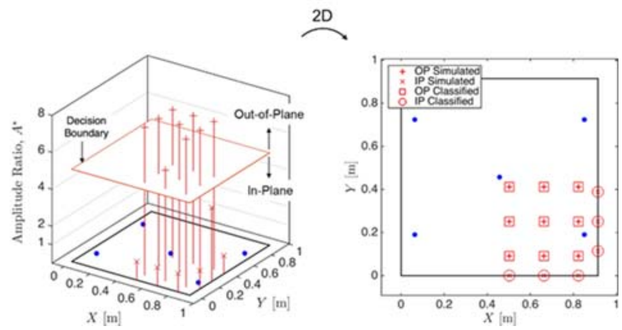
Because the project recently began, we are still in the early stages of the project. So far, we have conducted a literature review, distributed a survey to all 50 state Departments of Transportation (DOTs) to collect information about cross-frame design, and identified the specific gaps in knowledge we will aim to fill.

Once we have finished the background and planning tasks for the project, we will be instrumenting three bridges around Texas. The data collected will be used to validate FEA models that will be used in the next phase of the project.

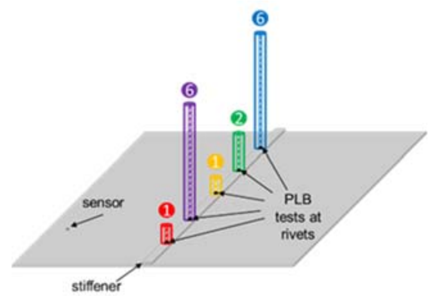
Figure 1: Cross-frames in Horizontally Curved I-girder Bridge (Direct connector between SH 71 and SH 130 in Austin Texas)

Integrated Structural Health Monitoring Systems for Navy Structures - Arvin Ebrahimkhanlou, Brennan Dubuc

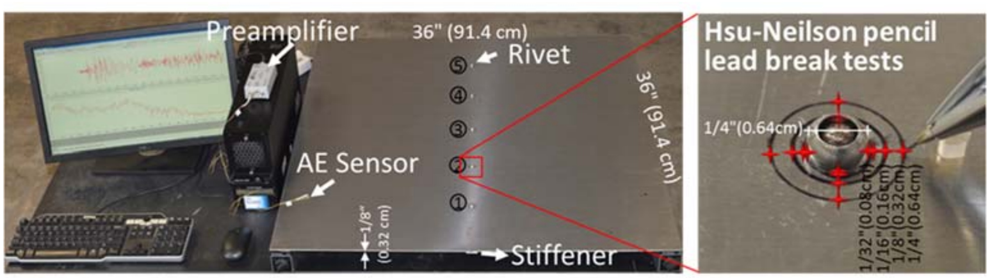
Metallic plates have numerous applications in aerospace and civil structures. Aircraft wings and fuselages, as well as bridge girders and gusset plates, are some common examples. The goal of this research is to monitor and localize the fatigue cracks of plate structures. These cracks emit high frequency (mainly ultrasonic) stress waves that could be used to find their location and mechanism. This physical phenomenon is called acoustic emission (AE). Recently, the group has used a *deep learning* approach to find the location of AE sources in plate structures using only a single sensor. In this work, only one sensor is used for a plate that has geometric features, such as a stiffener and rivet holes. This is particularly important because such geometric features make localization challenging. In addition, in any structural health monitoring system, the number of sensors and thus the cost associated with them and data acquisition channels are important. In addition, the group has used a *sparse reconstruction* method to not only localize but also characterize the AE sources. Specifically, a classification is used to determine whether an AE source has an out-of-plane or an in-plane mechanism.



Damage Classification and Localization Results with Sparse Reconstruction



Damage Localization Results using Deep Learning



Experimental Setup

New Student vs Old Student Flag Football!!

Come join us Friday, October, 27th as the incoming Structures grads once again challenge the returning students to game of flag football!

- Kickoff is at 4pm on the Commons Soccer field
- Free BBQ Dinner provided by Walter P Moore
- Bring your game face!!

Congratulations to FSEL 2017 Spring and Summer Graduates!!

- John Kintz (MS)
- Keaton Munsterman (MS)
- Heather Wilson (MS)
- David Wald (PhD)

Feedback
Andrew Stam
E-mail: andrew.stam@utexas.edu