Ferguson Structural Engineering Lab Newsletter

THE UNIVERSITY OF TEXAS AT AUSTIN - STRUCTURAL ENGINEERING

Volume 5, Issue 2

July 30, 2013

A New Face at FSEL!

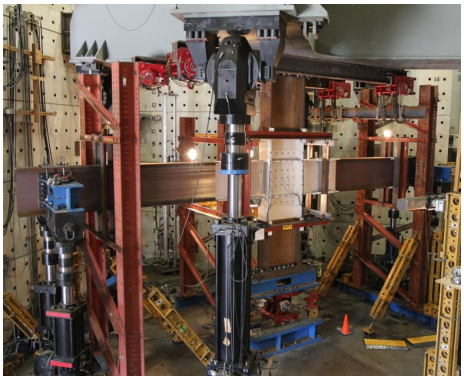
Helen Wang

I'm from a small place out west of Houston called Katy, TX. After leaving Katy, I spent four years in Berkeley, CA where I earned my Bachelors degree in Architecture and minored in Civil Engineering. I came home to Texas in 2011, started my Masters program here at UT, and joined FSEL this past spring semester. On my own time, I love doing things like exploring Austin on my bike, being outdoors on random adventures, and finding time to be back in the SF Bay from time to time.

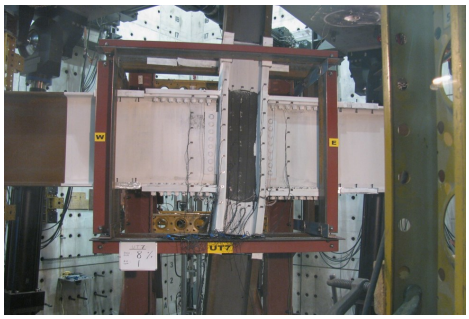
Inside this issue:

Seismic Behavior of Steel Beam-Column Connections - Sungyeob Shin

Cyclic loading tests were conducted on ten large-scale interior steel moment connections to study the seismic performance of connections in special moment frames. The key variables for the tests were panel zone strength, beam and column size, beam -to-column connection detail, and column axial stress. Nine of the ten test specimens performed well and met the acceptance criteria of the current AISC *Seismic Provisions* (AISC 341-10). The other specimen failed by fracture of column flange just prior to achieving the required 0.04 radian story drift angle. The specimens with weak panel zones showed excellent performance, achieving large story drift angles without strength degradation. A specimen constructed using a bolted flange plate moment connection with a weak panel zone achieved a story drift angle of 0.07 radians before failure. High axial tensile stress in the column did not cause initial fracture in the column flange of a weak panel zone joint.



Test setup



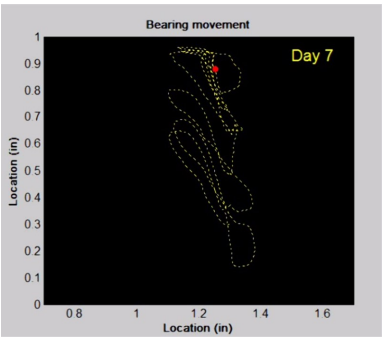
Bolted flange plate moment connection with weak panel zone at 8% story drift

Congratulations to the 2013 FSEL Spring Graduates!!

Spring 2013

- Jeremiah Fasl (PhD)
- Lindsay Hull (MS)
- Andrew Kilduff (MS)
- Jin-Young Kim (PhD)
- Nancy Larson (PhD)

Extending Use of Elastomeric Bearing Pads to Higher Demand Applications - Kostas Belivanis, Liwei Han & Daniel Sun



The movement trace of a bearing over a week, not a drunken person's walk...

Steel girders are often used in Texas for moderate- to long-span bridge applications that usually include skewed supports and/or horizontally curved geometry. Those geometries result in significant demands on the bearings at the supports to accommodate the rotations and complex bridge movements from both thermal loads and daily truck traffic.

The elastomeric bearing pads that are routinely used in medium-demand systems generally provide a reliable means of accommodating translations, and the pads are significantly cheaper than pot bearings. The use of elastomeric bearings in higher demand steel bridge applications will result in systems that are easier to fabricate, erect, and maintain while also improving the long-term bridge behavior. Results from this research study will provide valuable insight into the behavior of large elastomeric bearing pads for use in high-demand applications.

At this phase of the study, a bridge is being instrumented (electronically and mechanically) and test setups for material and specimen testing are being designed.

Monitoring Stresses in Prestressed, Precast Concrete Arches - Hossein Yousefpour

Arch transportation using Self Propelled Modular Transporters (SPMTs)

During the spring semester, the final stages were performed in the precast yard, and all of the arches were made ready for transportation. The 300-ton arches were then transported over a distance of almost half a mile and were installed on new piers. Over the last 11 months, the instrumentation has been a valuable tool to ensure of the safety of the innovative arches and has also contributed to making decisions in critical stages of construction.

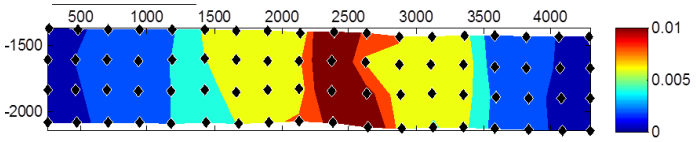
Since most of the key stages of monitoring process are finished, the activities in this project are now focused on extensive data processing and finite element modeling. Additional tests on slender unbonded post tensioned concrete elements will also be performed in the lab during the summer to obtain more knowledge of the complex second order behavior of such elements.

Debonding Mechanism of CFRP - Wei Sun, Will Shekarchi, Nawaf Alotaibi & Helen Wang

Above: Anchor failure mode

Right: FRP rupture failure mode

This research focuses on the transfer of force from CFRP (carbon fiber reinforced polymer) to concrete using anchors. Around 40 unreinforced 6x6x24" concrete beams have been built and strengthened by either 3" or 5"wide CFRP sheets to increase their flexural capacity. CFRP anchors have been applied to ensure that the sheets reach their full capacity, instead of prematurely debonding before rupture. The debonding process and results are recorded and collected by a visual system. These results are then compared with numerical results from ANSYS simulations.



Strain contour of CFRP strips around ultimate load

Spliced Prestressed Concrete I-Girders - Andy Moore, Chris Williams, Dhiaa Al-Tarafany & Josh Massey

The spliced girder team is nearly finished testing the fifth of eight large-scale beam specimens in their investigation of the shear performance of post-tensioned bridge girders. The vision system developed at FSEL was used during a recent test to capture the expansion of the beam web due to the presence of the post-tensioning duct (see picture). The team hopes to use the data to better understand the shear failure mechanism of the beam specimens.

An industry survey focusing specifically on the design and construction practices of the cast-in-place splice region of spliced I-girder bridges was recently conducted. The responses from the survey will aid in selecting splice details that will be proof tested at the lab. Planning for these splice region tests is currently underway.

Failure of girder 5 showing vision system targets

Improved Cross Frames - Anthony Battistini & Sean Donahue

As many of you have noticed, the improved cross frames team has added a sense of ambience to the lab- the sweet smell of grinding steel, loud bangs that we try to time on the hour, and some groaning noises from the cross frames when they begin to crack (or is that the sound of anguished graduate students?). To date, the team has tested 18 cross frames in fatigue and has made some interesting discoveries. We found that the Z frames, although offering superior stiffness behavior, have trouble in fatigue due to large bending stresses that develop at the welded connections. The K frames and X frames offer adequate fatigue performance, and we will be making some recommendations on the width of the gusset plates to improve the life of the details. We have also performed one stiffness test and two fatigue tests on X frames using unequal leg angles, which have a reduced member eccentricity.

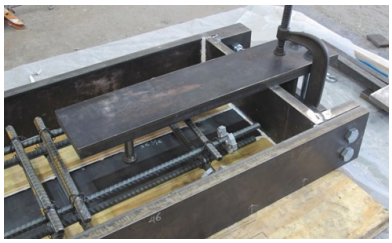
Z frame HSS fatigue cracks show stress concentration at connection

Cross frame stiffness test setup with unequal leg X frame

Elevated Temperature Performance of Shear Connectors for Composite Beams - Sepehr Dara

A test setup is being designed and constructed to determine the load-slip behavior of shear connectors at elevated temperatures. Experiments on small steel-concrete composite specimens will be conducted at several temperatures ranging from room temperature up to 800°C. Thermocouples will be installed over the thickness of the slab and along the shear stud length to capture the thermal behavior of the specimens. It is possible that spalling of the concrete at very high temperatures will present a challenge in performing the tests!

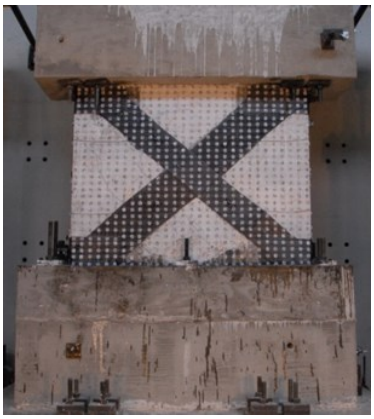
The results from these tests will be used in finite element analyses to specify the temperature-dependent load-slip relationship for spring elements, which represent the shear connectors. The simplification of modeling the shear connectors as springs will allow for advancement from member level to structure level analysis.



Composite specimen before (above) and after (below) concrete casting

Seismic Rehabilitation of RC Structures - Guillermo Huaco

Retrofitted column (above) and masonry wall (below) after testing



Innovative materials and devices can be used to strengthen reinforced concrete members for improved seismic performance. Laboratory tests were conducted on full scale reinforced concrete columns and a masonry wall which were retrofitted using new techniques after suffering severe damage. CFRP sheets and anchors were used to provide additional shear capacity and ductility. These sheets were applied both as column jackets and as diagonal ties on the masonry walls. Mechanical splices were used to provide continuity to the reinforcement and to replace buckled bars in areas of heavy damage.

The performance of the retrofitted members was found to be comparable to that of similar members strengthened using more conventional techniques. The mechanical splices behaved well under the axial load and moments applied through the lateral cyclic loading applied to the columns. The CFRP materials confining the hinge region at the column base provided a large amount of ductility. The CFRP sheets and anchors allowed the columns and wall to carry higher shear loads than the original structures. The feasibility of these innovative strengthening methods for a particular case depends on the degree of damage, the cost of replacement, and the performance requirements of the strengthened structure.

Air-Coupled NDT Methods - Xiaowei Dai & Yi-Te Tsai

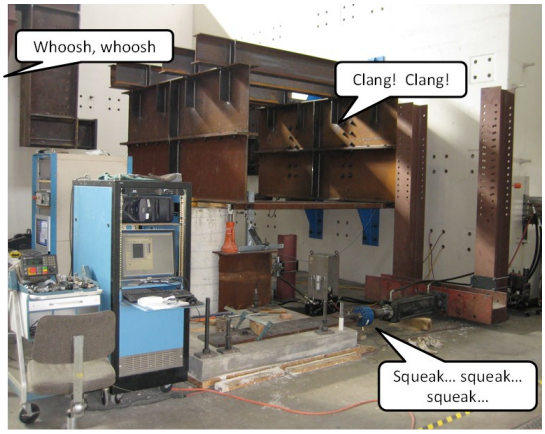
Air-coupled impact-echo testing equipment

The air-coupled impact-echo system works well when employed in through-transmission tests, i.e. when the spark source and the microphone are positioned on opposite sides of the concrete slab test specimen. However, when the source and the receiver are located on the same side of the specimen, the noise generated by the spark tends to overshadow the useful impact-echo signal, which is radiated through the air from the concrete slab. This makes it difficult to extract the impact-echo frequency and interpret the results. To resolve this issue, two approaches are proposed: (1) reducing the noise level by using an acoustical muffler, and (2) optimizing the reflector geometry to generate a stronger airborne impact-echo signal.

During the past semester, an acoustical muffler was developed and studied numerically using finite element modeling. This muffler "smears" the noise by breaking its energy into small pieces and distributing it over a longer time period, making the impact-echo frequency easier to determine. The TexasKZK code, which can properly simulate the focused spark source, has been employed to help carry out a parametric study to determine the optimal geometry for an ellipsoidal reflector. To further verify the theoretical results, several new nylon ellipsoidal reflectors have been made using selective laser sintering (SLS). A series of calibration tests are being conducted in the anechoic chamber in the ECJ basement. Recent results indicate these smaller reflectors will generate weaker pressure at the focal point, which may present our next challenge in the quest to transform the air-coupled system into a hand-held NDT device.

Strengthening Continuous Steel Bridges with Post-Installed Shear Connectors - Kerry Kreitman, Hemal Patel & Amir Ghiami

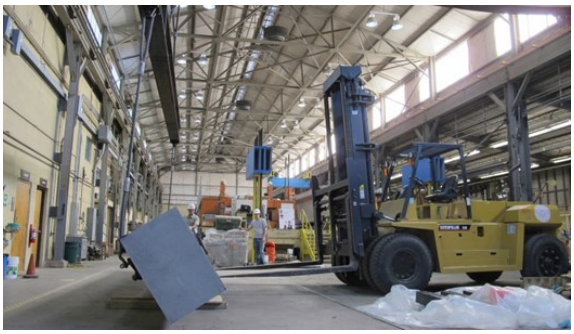
The goal of this project is to investigate a method of strengthening older non-composite steel girder bridges by "post-installing" shear connectors (high strength threaded rods or bolts) to create composite action. We recently "completed" our small scale fatigue tests on single post-installed adhesive anchor shear connectors, but plan to follow up with some additional testing both to supplement our existing data and to continue contributing to the pleasant harmonies echoing from the three fatigue tests at the south end of the lab. We are also in the planning stages for some large-scale, 2-span composite beam tests, which will be used to evaluate fatigue, service, and ultimate load behavior of a strengthened bridge. In particular, the limit state of shakedown, or excessive deformations due to repeated yielding, will be explored using the composite beam tests.



Free concerts at the south end of the lab!

ASR Affected Walls - Gloriana Arrieta, David Wald, Nick Dassow, Trey Dondrea & Alissa Neuhausen

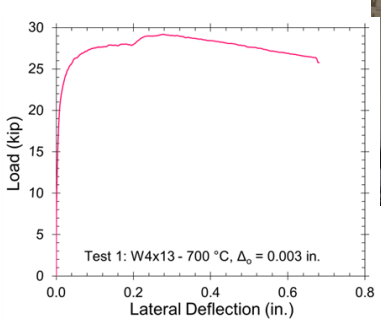
The ASR Walls team is hard at work fabricating beams which will be tested in the future to determine shear and anchorage capacity after long-term, high temperature and humidity conditioning in the greenhouse just outside of the lab. We have constructed four beams so far and are on pace to cast many additional beams (one every other week) over the course of the summer. By the beginning of fall, we expect to fabricate and test our first control specimens.



Specimen cast as a wall being rotated to later be tested as a beam

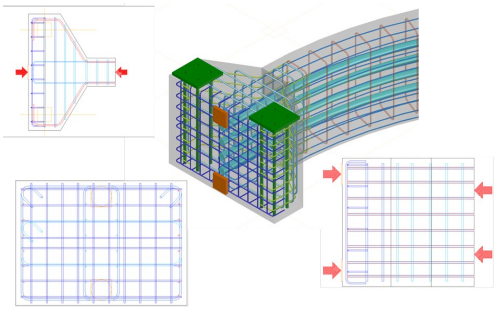
Creep Buckling Due to Fire - Ali Morovat

This research focuses on studying the creep buckling behavior of ASTM A992 steel columns subjected to fire. The objectives of this project are to better understand the phenomenon of creep buckling and to develop methods to predict creep buckling behavior. Material characterization tests have been conducted at temperatures up to 1000°C to evaluate tensile and creep properties of ASTM A992 steel at elevated temperatures. The buckling tests on W4×13 wide flange columns are currently underway and will be continued through summer. As an example, the deformed shape of a pin-ended column following a buckling test at 700°C is shown in the picture. The corresponding load-deflection curve is also shown. As can be seen in the load-deflection plot, a small increase in the crosshead displacement rate has resulted in a jump in this curve. This observation further illustrates the time-dependent buckling behavior of steel columns at elevated temperatures.

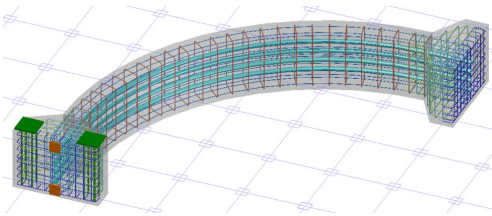


Buckled column at 700°C (above) and corresponding load-deflection plot (left)

Delamination of Curved Post-Tensioned Structures - Jongkwon Choi



Details of future test specimens



The goal of this research study is to develop an improved understanding of the behavior and design of curved post-tensioned concrete structures. The effect of member thickness on the delamination of curved post-tensioned structures without radial reinforcement is of particular interest.

The recent failure and loss of a containment structure at a Florida nuclear power facility was attributed to low quality concrete and an improper de-tensioning sequence. It is also likely, though unattributed, that the analytical models used by the responsible engineers did not account for size effect in the concrete tensile response. This research study will provide the experimental data necessary to more accurately model the effect of size on the tensile strength and delamination of curved post-tensioned structures.

During the past semester, the research team focused on design of the curved post-tensioned specimens. Design loads, boundary conditions and reinforcement details were modified and will be further refined to ensure highly applicable and useful test results. Design loads were increased to cover uncertainties related to various failure modes (bearing, shear, buckling, etc.) of the specimens. The boundary conditions were also simplified to ensure that the specimen response would mimic the actual behavior of a curved concrete structure.

Two curved wall segments will be constructed later this summer. The behavior of the wall segments (8 and 16 inches thick) will be monitored during application of the post-tensioning force. Results of the two tests will be used to validate and improve models within ABAQUS and VecTor.

Passive Wireless Corrosion Sensors - Ali Abu Yousef

Uncorroded (left) and corroded (right) specimens

Corrosion… Detected

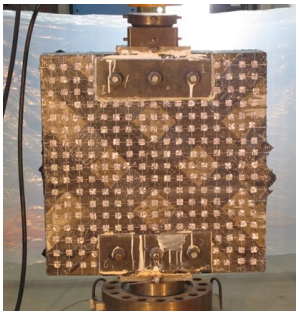
A set of 32 non-contact corrosion sensors were embedded in four reinforced concrete specimens resembling sections of bridge decks. The sensors were fabricated using sacrificial washers of different thicknesses, and the specimens were exposed to different levels of chlorides. The response of the sensors was used to assess their reliability at detecting corrosion initiation in the steel reinforcement. In addition, electrochemical evaluation techniques were used to assess the corrosion activity within the concrete slabs.

The non-contact sensor successfully detected the corrosion damage within the concrete slabs. The reliability of the sensors was assessed with respect to the observed condition of the reinforcement. Nine of the embedded sensors switched to the corroded state and corrosion was present in the adjacent rebar sections. Furthermore, negligible to no corrosion damage was observed in the vicinity of the sensors that remained in the uncorroded state. Only one sensor exhibited an erroneous false negative signal, which was attributed to the unique distribution of cracks

*Committee Vision: Increase **productivity** at Ferguson Laboratory through improved **communication** and **collaboration** of students, staff, and faculty*

Bi-Directional Application of CFRP - Changhyuk Kim

The objective of this study is to demonstrate the feasibility of using bi-directional CFRP strips for shear strengthening of large bridge I- and U-beams. Tests of deep beams with both uni-directional and bi-directional CFRP strips have indicated that the use of bi-directional strips leads to significantly greater increases in shear capacity. A total of nineteen panels, with and without CFRP anchors, have been tested under compressive forces applied over a restricted area. Such loading generates a bottle-shaped compressive strut between the loading and reaction points. As more panel test results become available, we will focus subsequent tests to target the most influential parameters, such as CFRP strip inclination and amount of CFRP anchorage. We are using the vision system to determine strain distributions and principal stresses.



Test setup showing a panel with CFRP strips

Special points of interest:

- Ice cream social, August 13, Large Conference Room
- FSEL Welcome BBQ, September TBD

Progressive Collapse Capacity of Composite Floor Systems - Michalis Hadjioannou, Lindsay Hull, Georgios Moutsanidis & Umit Can Oksuz

A second large-scale test was carried out in May 2013 (see picture). The purpose of the test was to characterize the response of a composite floor slab under a perimeter column loss scenario. The specimen was an isolated portion of a prototype building that was designed and constructed using typical practices found in the US and worldwide. This second test further supported the idea that steel-framed structures have significant capacity following a simulated column failure. The test data and observations from both tests are being analyzed to quantify the resiliency of these structural systems. Current work focuses on identifying the main components and mechanisms that contribute to the increased capacity that has been observed in both tests. Both computational simulations and mechanics-based methods are being used to model the response of the test structures. It is envisioned that a simple approach can be developed to evaluate the vulnerability of new and existing structures following a column loss.

The floor slab at the moment of collapse

Information about the Newsletter

The goal of this publication is to keep those working at FSEL aware of the status of ongoing projects around them. In addition to projects, we may also highlight special events, people, or news of interest. The newsletters will come out once a semester, three times a year.

In this second issue of 2013, sixteen research projects at FSEL are summarized. Hopefully you will learn something new about each project so as to initiate more discussions with your fellow researchers.

Feedback
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