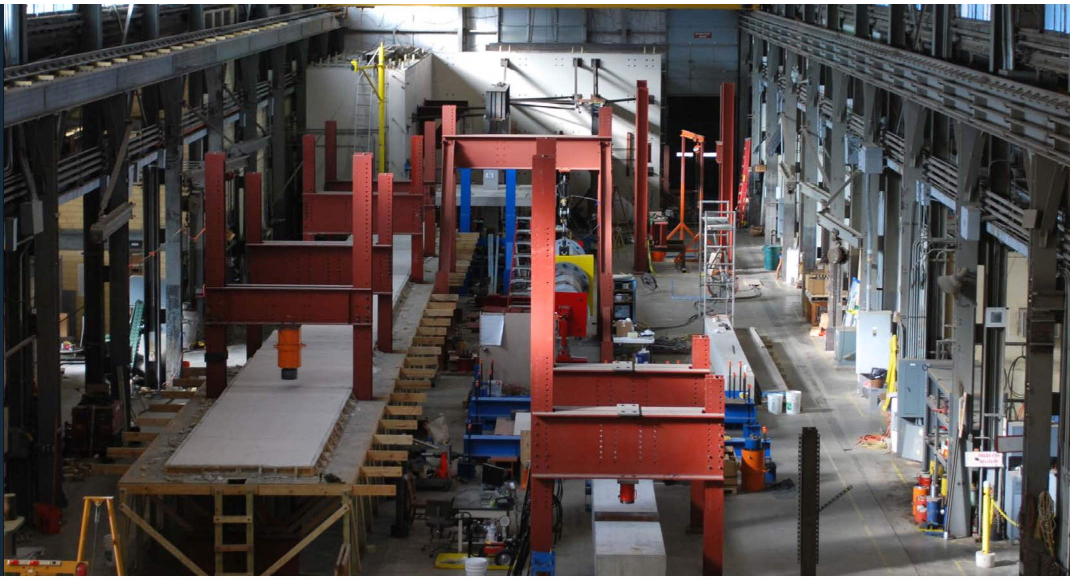
The University of Texas at Austin

FERGUSON STRUCTURAL ENGINEERING LABORATORY



FSEL NEWSLETTER

Volume 11, Issue 2, November 2020

FSEL

The Ferguson Structural Engineering Laboratory (FSEL) located on the Pickle Research Campus of The University of Texas at Austin is named after Professor Phil M. Ferguson, who was an inspirational teacher and a meticulous researcher.

We hope that you enjoy learning about our laboratory and ongoing research.

NEWS FROM **BUILDING 24**

CONGRATULATIONS!

We had several students graduate recently. Moreover, some of our postdoctoral researchers made big moves! We would like to congratulate the following folks:

- **JONGKWON CHOI** moved to Seoul, South Korea to become an Assistant Professor at Hongik University.
- **ARVIN EBRAHIMKHANLOU** moved to Socorro, New Mexico to become an Assistant Professor at New Mexico Institute of Mining and Technology.
- **APOSTOLOS ATHANASIOU** graduated with his PhD in Fall 2019.
- **RYAN BOEHM** graduated with her MS in Spring 2020.
- **BRENNAN DUBUC** graduated with his PhD in Spring 2020.
- **MATT REICHENBACH** graduated with his PhD in Summer 2020.
- **MELANIE SCHNEIDER** graduated with her MS in Summer 2020.
- **JOSH WHITE** graduated with his PhD in Summer 2020.

BUILDING 24 COMMITTEE ANNOUNCMENTS

The Building 24 Committee was re-launched at the beginning of this year. This student-run effort aims to increase productivity at FSEL through improved communication and collaboration of students, staff, and faculty.

During our bi-weekly meetings, students announce their project needs for the following weeks to plan and allocate material and human resources effectively. Moreover, presentations on the ongoing projects and mini-seminars on useful technical topics are given to fellow researchers.

Moreover, we implemented improved recycling practices at FSEL, according to the University's Zero Waste Program guidelines. Separate recycling and landfill waste bins were labeled and placed around the laboratory and student offices.

We hope next year we can organize traditional Ferguson Lab events such as the Fall Barbeque and the JNT Golf Tournament!

ONGOING RESEARCH AT FSEL

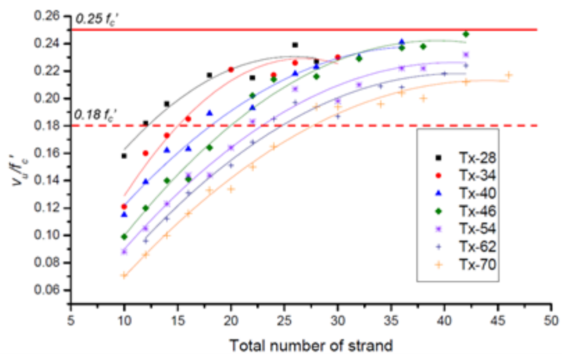
There are 42 student researchers working at FSEL, and this newsletter summarizes 15 of our ongoing projects. We hope you enjoy learning more about the exciting projects we have going on at FSEL.

ANALYZE SHEAR CAPACITY OF TEXAS STANDARD PRESTRESSED BEAMS FROM STRUT-AND-TIE MODELS OF BEAM ENDS

PROJECT TEAM: JONGKWON CHOI, ZACH WEBB, & HANSOL JANG

SUPERVISOR: OGUZHAN BAYRAK

According to AASHTO LRFD (2020), shear design stresses can exceed $0.18f'_c$, provided that the end region is appropriately detailed using strut-and-tie model (STM) procedures. Appropriate STMs by tie capacity-based approach and anchorage capacity were used to calculate the end region shear stress of Texas standard Tx-girders. The analyses indicate that the $0.18f'_c$ shear stress limit can be exceeded, and a new shear stress limit for Tx-girders can be proposed based in the figure below. Further, the three additional failure modes (node failure, horizontal shear failure, and lateral splitting failure) are investigated whether they would limit the capacity when the calculated shear stress exceeded the $0.18f'_c$ shear stress limit. The shear stress of all parts of the girder cannot exceed the $0.25f'_c$ shear stress limit derived from the Modified Compression Field Theory (MCFT). Therefore, in this study, the $0.25f'_c$ shear stress limit is the upper limit that can release the shear stress of the girder's end.



Schematic of deck test setup

DEVELOP GUIDANCE FOR STRUCTURAL BEHAVIOR OF TALL HAUNCHES IN TXDOT BEAM AND GIRDER BRIDGES

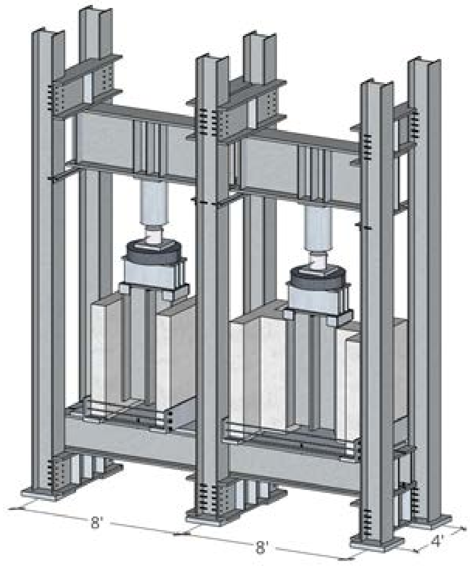
PROJECT TEAM: NIDHI KHARE & ZHENGHAO ZHANG

SUPERVISORS: ERIC WILLIAMSON, TODD HELWIG, & OGUZHAN BAYRAK

The haunch is the region between the top of a bridge girder and the bottom of the concrete deck and is used to help maintain a uniform deck thickness. Tall haunches (≥ 6 inches) are often encountered in steel or prestressed bridge girders. Current TxDOT detailing practices for tall haunches have not been thoroughly tested. The goal of this research is to verify the effectiveness of currently used tall haunch details and establish improved design methods based on the results of large-scale push-out tests.

Modified push-out tests (shown in the figure at the top of p. 3) that can accommodate tall haunches will be performed for ultimate shear capacity testing of haunches in steel and prestressed girders. This work will include testing of 30 specimens for both steel and prestressed girders. The test program will include variable haunch heights (up to 15 inches) and detailing strategies.

The research will also include analysis of data and modeling to create guidelines for a range of applicable haunch designs. A parametric study will represent the range of dimensions encountered for the vast majority of Texas bridges.



Push-out test setup for steel girders

DEVELOP NEXTGEN TEXAS BRIDGE DECK

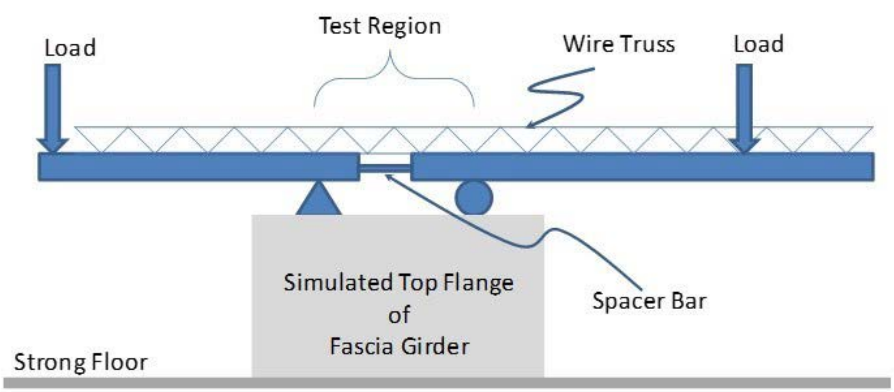
PROJECT TEAM: ZACH WEBB & DYLAN GENTRY

SUPERVISOR: OGUZHAN BAYRAK

Texas bridge decks are commonly built using partial-depth precast concrete panels as stay-in-place formwork for a cast-in-place topping. Typically, the panels are about half of the bridge deck depth and are prestressed transversely. The system is widely used because it significantly improves cost efficiency, speed of construction, and worker safety.

Currently, the overhangs of the bridge decks are generally constructed as a full-depth cast-in-place section with wood formwork and falsework. This system of constructing the overhang is costly in terms of labor and time. The goal of TxDOT Project 0-7041: Develop NextGen Texas Bridge Deck is to develop a design standard for the use of partial-depth precast concrete panels that can span the entire bridge superstructure, including the overhangs. The panels make use of "lattice girders," steel trusses made of rebar and wire, to resist negative moments over the fascia girder. This system is inspired by a similar system currently used in Spain.

Next month we will begin a series of 24 tests to simulate the negative moment generated during construction in the overhang panels over the fascia girder.



Conceptual test setup for NextGen Bridge Deck over fascia girder during construction phase

IN THIS ISSUE

DEVELOPMENT OF KNOWLEDGE IN THE APPLICATION OF STRUT-AND-TIE MODELING

PROJECT TEAM: ANAS DAOU, ZACH WEBB & JONGKWON CHOI

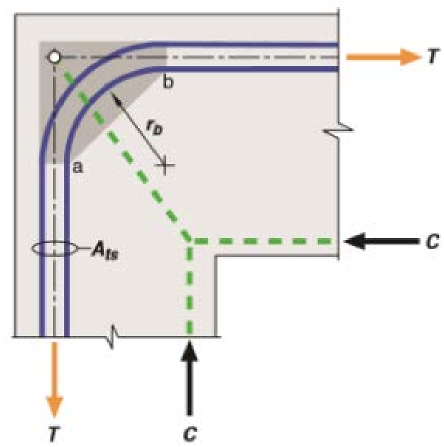
SUPERVISOR: OGUZHAN BAYRAK

The origins of strut-and-tie modeling (STM) are over a century old and many developments to refine this technique and broaden its application took place over the past 120 years. However, there are gaps in knowledge for applying strut-and-tie modeling. TxDOT designs can significantly benefit, if these knowledge gaps can be filled.

A finite element model was developed to show that a hooked bar creates significant nodal stresses. The tighter the radius of the bend, the higher these stresses are. While the AASHTO LRFD Bridge Design Manual does not specifically require checking the stresses in this type of node, it is good engineering practice. Often when you have hooked reinforcement, there are multiple mats of reinforcing, as often seen on cantilevered bents. There have been no attempts at determining the stress effects of nested hooked bars. Designing based on the current state of practice may lead to over stressing these areas.

For example, in a beam-column joint of a straddle bent, the internal actions at the joints are transferred between the elements of the frame through the bend of the reinforcing steel bars at the outside corners, as depicted in the following Figure. STM method of analysis indicates that stress concentrations in these regions can be critical; however, development of design recommendations in AASHTO LRFD has not yet occurred due to lack of supporting test data.

The current task of the research project will examine the mechanics of load transfer at a curved bar node to address this knowledge gap.



STM due to closing moment at a frame corner

DEVELOPMENT OF NON-FRACTURE CRITICAL STEEL BOX STRADDLE CAPS

PROJECT TEAM: ESTEBAN ZECCHIN , CHEN LIANG , MATT REICHENBACH, & EMMA WILLIAMS

SUPERVISORS: TODD HELWIG, MICHAEL ENGELHARDT, & ERIC WILLIAMSON

Steel box straddle caps (SBSCs) are an efficient solution when the use of conventional piers is unfeasible. However, they are categorized as fracture critical (AASHTO LRFD, 8th Ed.), which imposes more stringent design and inspection requirements, hence increasing the long-term costs of these caps. This project aims to develop internal redundancy details for the SBSCs to avoid being classified as fracture critical.

The first set of test specimens have already been designed and fabricated, and comprise two internal redundancy approaches: (i) a conventional welded box section with the addition of longitudinal high-strength PT bars anchored to the section, and (ii) a box section with the bottom flange bolted to the webs.

The test load will be applied to a pre-cracked specimen while subjected to lower-shelf temperatures to minimize the steel's toughness. Wedges may be driven into the cracks to increase stress concentration and achieve a brittle crack propagation. Internal redundancy will prove effective if the faulted straddle cap is still capable of carrying the test load. Currently, the test protocol is being assessed on a pilot specimen before moving on to the full-scale testing phase.


Pilot Specimen (Left) and Full Size Specimen (Right)

EVALUATION OF DEEP BEAMS WITH INSUFFICIENT WEB REINFORCEMENT

PROJECT TEAM: JONGKWON CHOI & JARROD ZABORAC

SUPERVISOR: OGUZHAN BAYRAK

Beam during test with motion capture system

The goal of this project is the advancement of crack-based assessment procedures with an emphasis on deep, reinforced concrete beams that contain less-than-minimum crack control reinforcement. Traditional crack-based assessment procedures typically rely on pre-established crack measurement limits and do not provide guidance to account for member-specific properties, such as geometry and reinforcement layout. A testing program of ten beams was completed at the end of the summer. Data processing, analysis, and writing is ongoing. Ultimately, the project team will make recommendations for levels-of-approximation in crack assessment and novel mechanics-based assessment procedures using the detailed crack and strain measurements taken during the testing.

EVALUATION OF SEAMLESS BRIDGES

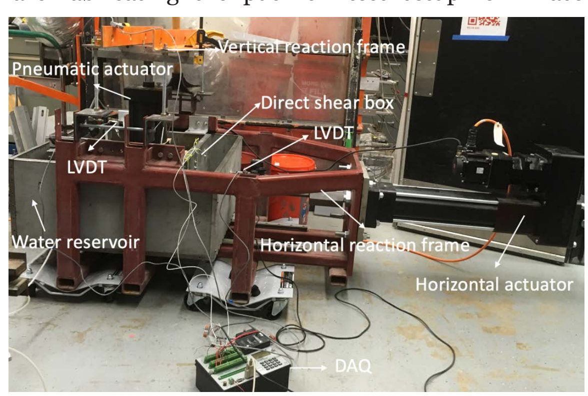
PROJECT TEAM: XIAOYI CHEN & JAY HEMENDRA MALVIYA

SUPERVISORS: JUAN MURCIA-DELSO, TODD HELWIG, & JORGE ZORNBERG

The primary goal of this project is to develop design guidelines for implementing seamless connections between bridges and continuously reinforced concrete pavement (CRCP) in Texas. We have a two-phase laboratory experimental program to characterize the interaction between the concrete slab and different base and interface materials. Phase I comprises unit-cell direct shear tests to determine the interface shear strength for different bases and to evaluate the effectiveness of several bond breakers. In Phase II, push-off tests will be conducted to verify the interface friction characteristics in full-scale slab segments and to study the effects of cyclic displacement histories caused by expansion-contraction cycles.

In Phase I, we have examined the interfaces between a precast concrete block and AASHTO Gravel No. 8 without bond breaker/ Grade 3 Aggregate without bond breaker/Grade 3 Aggregate with two layers of polyethylene sheets. The shear resistance versus relative displacement relationship was obtained. The friction coefficient and cohesion were determined.

For Phase I, we will continue to conduct tests to evaluate the interface between concrete and hot-mixed asphalt/cement stabilized base without or with bond breakers, such as woven/non-woven geotextile, one or two layers of polyethylene sheets. At the same time, we are fabricating the push-off test setup for Phase II.



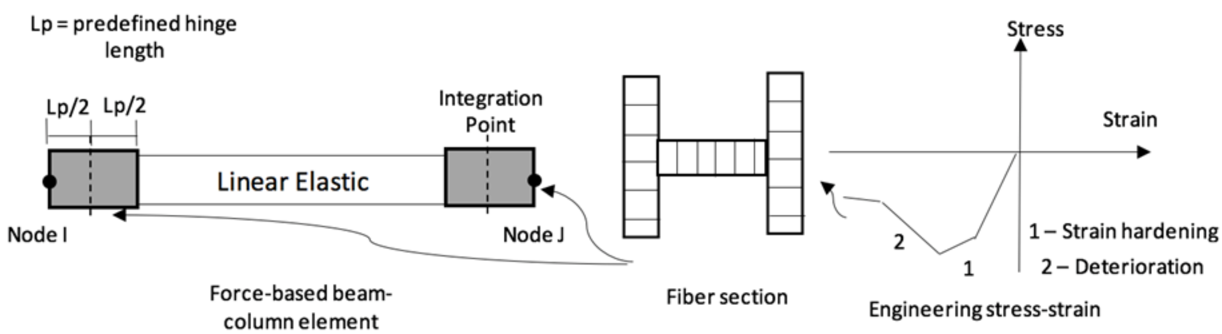
Evaluation of Seamless Bridges—Phase I Direct shear test setup layout

FIBER-BASED MODELLING OF POST-TENSIONED BEAM TO COLUMN CONNECTIONS FOR COLLAPSE PERFORMANCE ASSESSMENT

STUDENT: SEDEF KOCAKAPLAN

SUPERVISOR: PATRICIA CLAYTON

Self-centering steel moment resisting frames with post-tensioned (PT) beam-to-column connections have been proposed as damage-mitigating alternatives to conventional steel moment resisting frames used in seismic design of structural systems. The self-centering capability of properly designed PT connections proves to be an effective tool for improving resilience of a building following an earthquake; however, the rocking behavior of PT beam-to-column connections could result in excessive compressive forces at the contact surfaces between beams and columns. These concentrated compressive forces can cause local buckling in the beams, which causes plastic shortening of the beam and loss of connection moment-resisting capacity. For assessing collapse risk of these systems, it is necessary to understand the strength degrading behaviors associated with beam local buckling. For system level analysis, simplified beam element models are preferred over computationally demanding shell element models. This study focuses on developing fiber-based elements for modelling strength degrading behavior of PT beam-to-column connections under earthquake loads due to beam local buckling. The strength degrading behavior of the PT-beam-to-column connections are characterized based on a parametric finite element study. Finite element model was validated with experimental results of large-scale PT connections that exhibited local buckling under cyclic load.



Fiber-based modeling of post-tension beam-to-column connections

INVESTIGATION OF BOND IN UNREINFORCED CONCRETE INTERFACES FOR PARTIAL DEPTH REPAIRS AND PRECAST CONSTRUCTION

STUDENT: MAGGIE BECKER

SUPERVISOR: JUAN MURCIA-DELSO

The design for horizontal shear transfer at an interface between concrete placed at two different times occurs in several scenarios in new construction and repair applications. The ACI 318-19 and ACI 562-16 design requirements for interface shear transfer limit the nominal strength of an intentionally roughened, unreinforced interface to 80 psi. When interface areas are large, requirements to add interface reinforcement and/or intentional roughening result in considerable time and expense or, in some cases, the decision that some other approach is needed. Previous research studies suggest an 80 psi nominal limit for interface shear stress without interface reinforcement is overly-conservative, and may be substantially reducing the cost-effectiveness of topping slab designs and partial depth repair solutions in some situations.

The goal of this research is to provide suggestions for defining horizontal shear provisions for unreinforced interfaces in partial depth repairs and precast construction. This was done by establishing shear bond strength values for a range of unreinforced interfaces. The use of direct shear (guillotine) on concrete cores was explored to estimate interface shear strength and to compare with direct tension pull-off strengths. The core strengths are then to be correlated to the horizontal shear strength in flexural members (beam tests). The goal is to develop a performance-based limit for horizontal shear capacity of unreinforced interfaces.

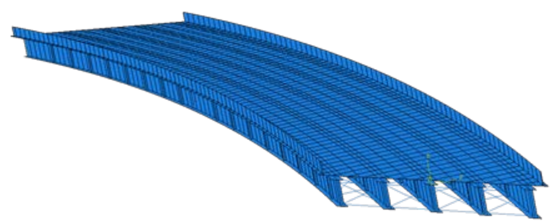
Beam specimens with various interface conditions

PROPOSED MODIFICATION TO AASHTO CROSS-FRAME ANALYSIS AND DESIGN

PROJECT TEAM: SUNGHYUN PARK, MATT REICHENBACH, & JOSH WHITE

SUPERVISORS: TODD HELWIG & MICHAEL ENGELHARDT

NCHRP Project 12-113 aims to improve the design and analysis of cross-frame systems in steel I-girder bridges. Cross-frames have traditionally been detailed and fabricated based on general rules-of-thumb. In recent years, however, developments in highway bridge design and analysis have necessitated the modernization of cross-frame design and analysis practices. More specifically, the appropriate design criteria for fatigue and stability bracing are investigated. Through a series of field experiments and finite element parametric studies, quantitively-based modifications are proposed for implementation into AASHTO LRFD Bridge Design Specifications. The research team is proud to announce that the final project report was submitted in September 2020. Although accomplishing this major milestone, there is still significant work remaining. The team will continue to prepare ballots to be presented to the AASHTO Highway Subcommittee on Bridges and Structures in 2021.



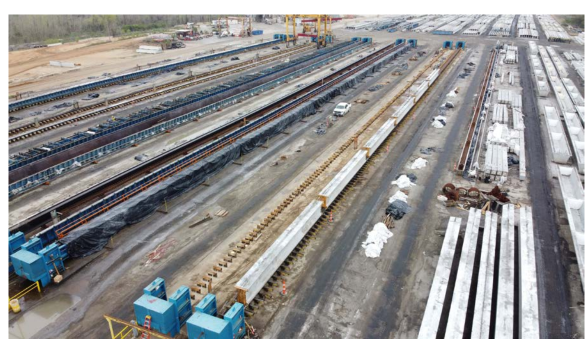
Sample 3D finite-element analysis model of a horizontally curved system used in the parametric study

SHEAR BEHAVIOR OF SPLICED POST-TENSIONED GIRDERS WITH UNGROUTED TENDONS

PROJECT TEAM: JONGKWON CHOI, ZACH WEBB, & SANGYOUNG HAN

SUPERVISOR: OGUZHAN BAYRAK

The objective of this project is to test the used, ungrouted tendons of spliced girders and to investigate the effect of the ungrouted tendon on the shear capacity of post-tensioned I-girders. For more detailed information about this project, please reference the previous FSEL Newsletter (Feb. 2020). Since February 2020, six test specimens were successfully fabricated at Valley Prestress Products, who have greatly contributed to this project. Also, many excellent students volunteered. It was tough for everyone due to the hard work and hot weather (YOU know we are in Texas!), so they will never forget that time. We just conducted the structural testing on one test specimen out of six. The structural testing made a nice dominant shear crack that we expected and a huge sound with a bunch of crushed surfaces. We are so happy about this testing because there were no issues, as well as no accidents. We still have many things left to complete on this project. However, we had a good start and are enjoying this moment.



Fabrication at Valley Prestress Products

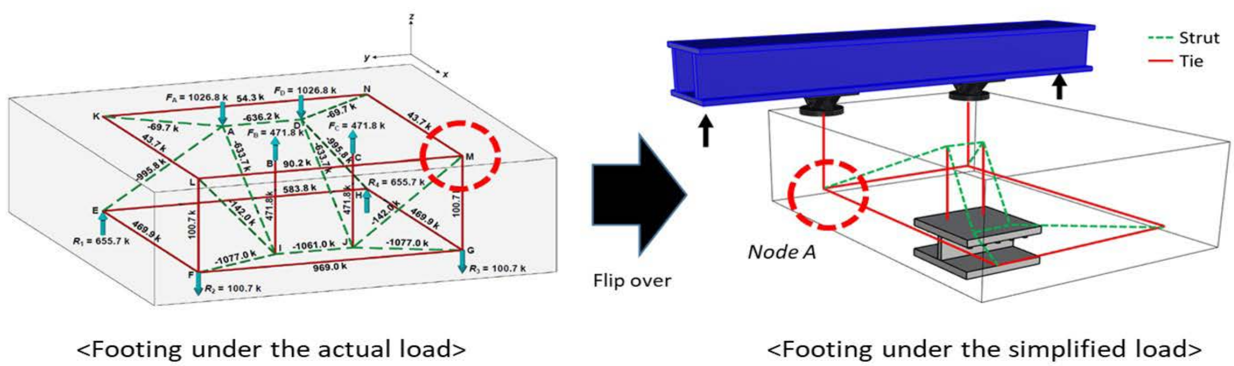
STRUT-AND-TIE MODELING AND DESIGN OF DRILLED SHAFT FOOTINGS

PROJECT TEAM: YOUSUN YI & DENNIS KIM

SUPERVISORS: OGUZHAN BAYRAK & JUAN MURCIA-DELSO

The design and detailing of reinforced concrete footings varies greatly on a state, district, and municipality basis due to the continued use of legacy (sectional) design methods. Therefore, a full transition to strut-and-tie modelling (STM) is required for uniform design and detailing of shaft-supported footings. This project aims to refine the STM guidelines for 2D structures to those for 3D structures through testing almost half-scale footing specimens under various loading conditions.

During the Fall 2020 semester, footing specimens for the last test phase will be tested to investigate the behavior of three different anchorage details (straight, hooked, and headed bars) of shaft reinforcement in the footing. In order to induce a tensile reaction at two of four supports, a load combination of uniaxial compression and severe bending moment needs to be applied to the footing specimen. Therefore, the research team simplified the loading condition for safety by applying uplifting force to shaft reinforcement directly maintaining the strut-and-tie configuration at the bottom end node (Node A in below figure) of the vertical tie element which is affected by the anchorage detail of the shaft reinforcement. From the testing results, a proper anchorage detail for the shaft reinforcement will be suggested and exploited for updating the 3D STM guidelines.



Actual and simplified loads with associated STM

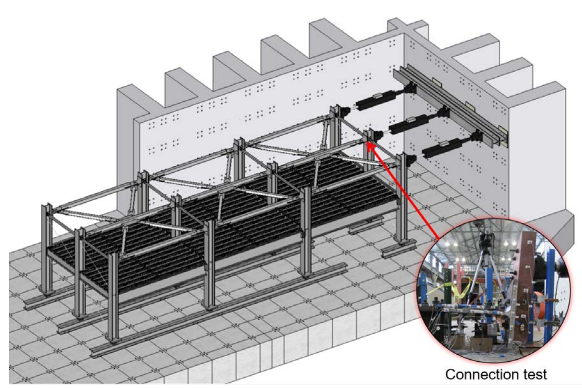
SYSTEM LEVEL SEISMIC PERFORMANCE OF STEEL GRAVITY FRAMING

PROJECT TEAM: SANGWOOK PARK & ADAM SCHULZ

SUPERVISORS: PATRICIA CLAYTON, MICHAEL ENGELHARDT, TODD HELWIG, & ERIC WILLIAMSON

The overall goal of the project is to investigate the role of gravity framing systems on the seismic performance and collapse resistance of steel buildings. The project focuses on the contribution of the metal decking and the restraint provided by surrounding framing bays on the connection behavior at large inter-story drifts. The test program includes two composite steel gravity framing system specimens to simulate realistic boundary conditions and restraint to frame expansion provided by neighboring bays.

As the first step, a simple connection test representing the connection at the top floor idealized as a pin has been conducted to explore the inelastic behavior of the connection under the cyclic loading. The main specimen will be built on the strong floor from the northmost location by assembling components that have been fabricated at the laboratory.



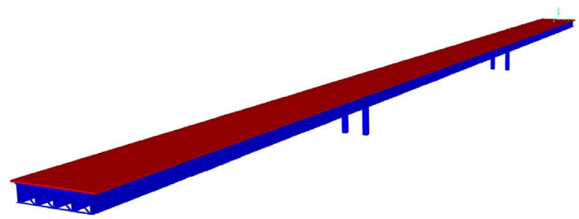
Steel gravity framing system specimen

USE OF LARGER DIAMETER SHEAR STUDS FOR COMPOSITE STEEL BRIDGES

PROJECT TEAM: LU WAN, YUCEL ALP, XIANJUE DENG & JEONG-HWA LEE

SUPERVISORS: MICHAEL ENGELHARDT, TODD HELWIG, & ERIC WILLIAMSON

The main objective of this project is to investigate the feasibility of using larger diameter shear studs up to 1-1/4 in. in bridge design, which can reduce almost half of the number of shear studs according to the redesign of TxDOT bridges. A literature review has been conducted and the research team is now doing the preliminary design studies and stud welding investigations. The research team is studying in detail the design of the shear studs in three typical TxDOT bridges designed with 7/8 in. diameter studs. These three bridges are then redesigned with 1 in., 1-1/8 in. and 1-1/4 in. diameter shear studs to evaluate the reduction in the required number of shear studs when the larger diameter shear studs are used. Future tasks including push-out tests, a large-scale beam test, and FEM parametric studies to investigate the static and fatigue behavior of larger diameter shear studs.



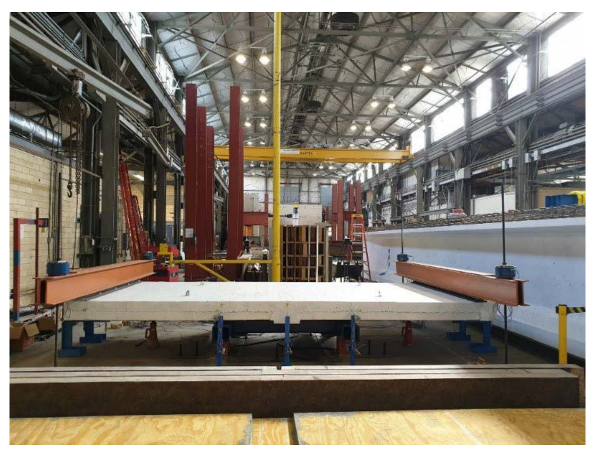
The CSI bridge model for a TxDOT bridge

UTILIZING STEEL FIBERS AS CONCRETE REINFORCEMENT IN BRIDGE DECKS

PROJECT TEAM: JONGKWON CHOI, THANOS DRIMALAS, ZACH WEBB, SOON KWANG JEONG, & JARROD ZABORAC

SUPERVISORS: OGUZHAN BAYRAK, JUAN MURCIA-DELSO, & KEVIN FOLLIARD

Precast, prestressed concrete panels (PCPs) as a stay-in-place formwork is the method widely used in Texas. PCPs support the weight of the cast-in-place (CIP) top half of the concrete and the loads from traffics. Bridge decks often experience cracking during the service. Bridge decks are susceptible to deteriorations from cracks and are commonly repaired elements. Steel fiber reinforced concrete (SFRC) can improve concrete cracking behavior. This project develops improved SFRC mix design and optimized reinforcement details. Deck strip tests evaluate crack control and load-resisting performance under idealized flexural loading condition. Nonlinear finite element analysis in conjunction with deck strip tests will give agreeable design specification for full-scale testing. Full-scale test with four different optimized reinforcements will be tested to examine the system level performance of SFRC bridge decks. During Fall 2020, Task 5, which is experimenting cracking behavior of top mat concrete for longitudinal and transverse direction will be performed.



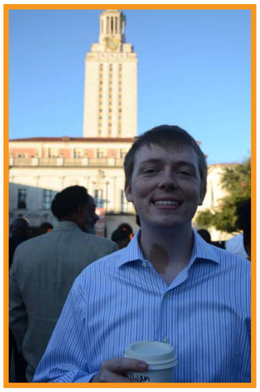
Deck strip test setup

NEW FACES AT FSEL

The FSEL family grows every year. Join us in welcoming these new faces. You can see a full list of our current students, staff, and faculty on our website.

SOON KWANG JEONG. I was born and raised in South Korea. I received my Bachelor's degree from Korea University and Master's degree from Texas A&M University. My current research focuses on the performance of the structure incorporating the fiber reinforced concrete. I mostly use my free time to do the workout. These days, I am learning the piano.

Editor's note: I screwed up and missed Soon Kwang's bio in the last edition of the newsletter. He has been with us for about a year now. Sorry Soon Kwang!—JZ



DYLAN GENTRY. I'm a Texan from birth and an Austinite since 14 years of age. I attended UT Austin for my Bachelor's in Architectural Engineering, and I was so blown away by the stellar engineering program that I didn't want to leave. Now I'm a Structural Engineering Master's student, performing research in precast panel solutions for Texas bridge decks under Dr. Bayrak.

YIBIN SHAO. I am a first-year master student from Fuzhou, China. I graduated from UT with a BS in Civil Engineering. With my meaningful undergraduate research experience at Ferguson, I decided to return. I am currently working with Dr. Bayrak on Strut and Tie Modeling. I am an outdoor person. Therefore, I like anything outdoor, such as hiking, camping, shooting, and motorcycling.

EMMA WILLIAMS. I grew up in Santa Cruz, California and lived there until I came to Austin for school. I graduated with a BS in Architectural Engineering from UT Austin in May of 2020, and I'm now pursuing a master's degree in structural engineering. I am very excited to be working with Dr. Helwig and Dr. Engelhardt on the study of non-fracture critical straddle caps. In my free time I enjoy traveling, running, and baking.

CONTACT US

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