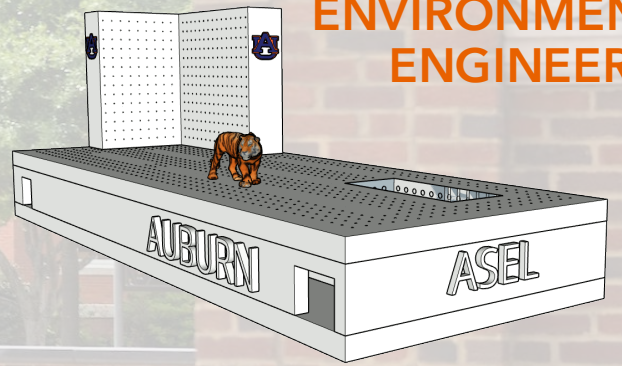
GeoVirginia



LESSONS LEARNED FROM 25 YEARS OF SOIL-STRUCTURE TESTING AT FULL SCALE

ADVANCED STUCTURAL ENGINEERING LABORATORY

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING



J. Brian Anderson, Ph.D., P.E.

AUBURN

LESSONS LEARNED FROM 25 YEARS OF SOIL-STRUCTURE TESTING AT FULL SCALE

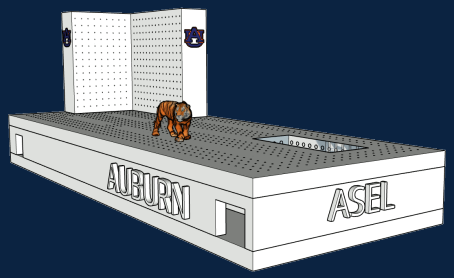




ROLE OF LOAD TESTING

- Research
  - Demonstrate behaviors to verify theoretical methods
  - Understand behaviors at scale
  - Calibrate numerical models
- Engineering/Construction
  - Design Phase
    - Collect pre-design information about load resistance
    - Gain competitive edge
  - Construction Phase
    - Verify design assumptions
    - Sleep better at night





RESEARCH LOAD TESTING

- Goals somewhat different than engineering/construction tests
- Budgets are limited
- Often impossible without partners providing direct support or in-kind assistance
- Less leverage of time and resources (see limited budgets)
- Personnel are often students (learners)
- We don't know the answers (unknown unknowns)
- Address as many questions as possible, but maybe not everything…



PRO TIPS

- Don’t try to conduct a load test unless you:
  - Can truly afford to provide at least the minimum equipment and instrumentation required
  - Know a thing or two about measurement fundamentals (precision, resolution, electricity, digital…)
  - Understand the risks, you are often pushing things to limits determine ultimate strength (safety)
  - Aren’t afraid to talk to structural engineers
- Know standards!
- Don’t get in a hurry, plan, be patient!
- Try not to push on a rope!
- Talk to people who have experience!
- Don’t be afraid to say STOP!





SOMEWHERE ALONG THE WAY…

- I completed my education at the time (~2000) when numerical models were maturing, and computers were evolving to handle larger and larger models in shorter amounts of time.
- I was engaged in soil-structure interaction research.
- There was a window of time when it was crucial to develop case studies of soil-structure interaction at full-scale to use to verification of computational methods.
- Spurred a career long thread of research load tests.



LESSONS LEARNED FROM 25 YEARS OF SOIL-STRUCTURE TESTING AT FULL SCALE

- Sharing some of my experiences from 25 years
- Successes
- Anecdotes
- ~~Failures~~ Lessons Learned







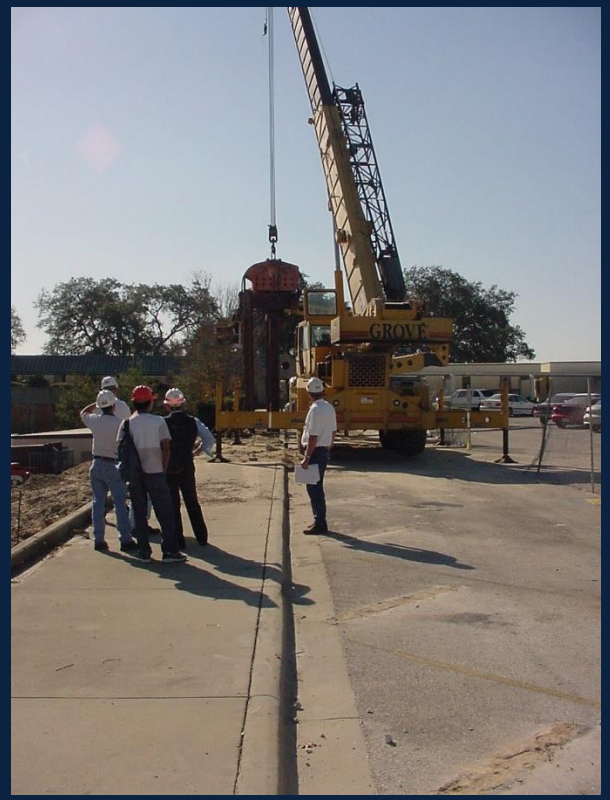


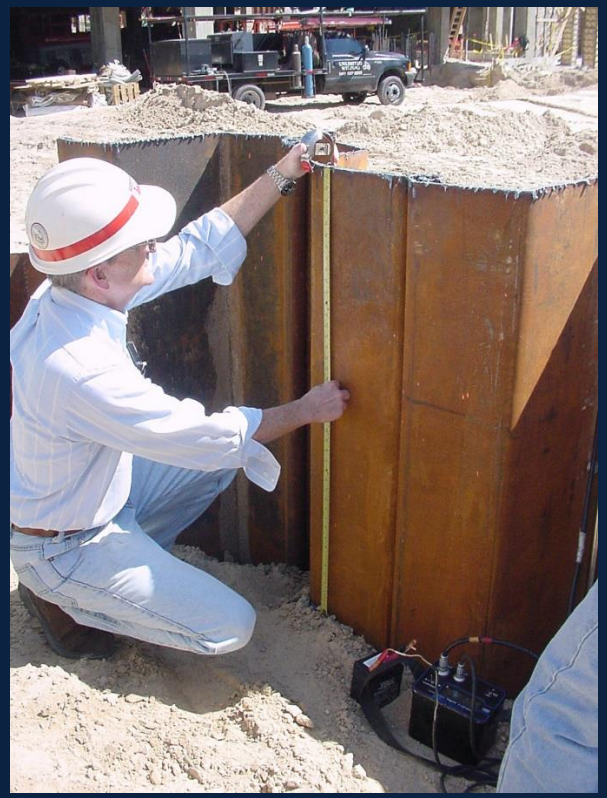
LOAD TEST CASES AND LESSONS LEARNED FROM EACH

- Sheet Pile Wall #1
- Shallow Footing
- Sheet Pile Wall #2
- Micropiles
- Segmental Arch Bridges
- Un-shored Trench Excavation
- H-Pile Bridge Bents
- Corrugated Metal Culverts
- Fabric Maintenance Shelter
- Lab - MSE Wall
- Timber Products
- Lab - Mast Arm Poles
- Lab – H-Pile Cap Fixity
- In-Situ Bridge



USF - SHEET PILE WALL



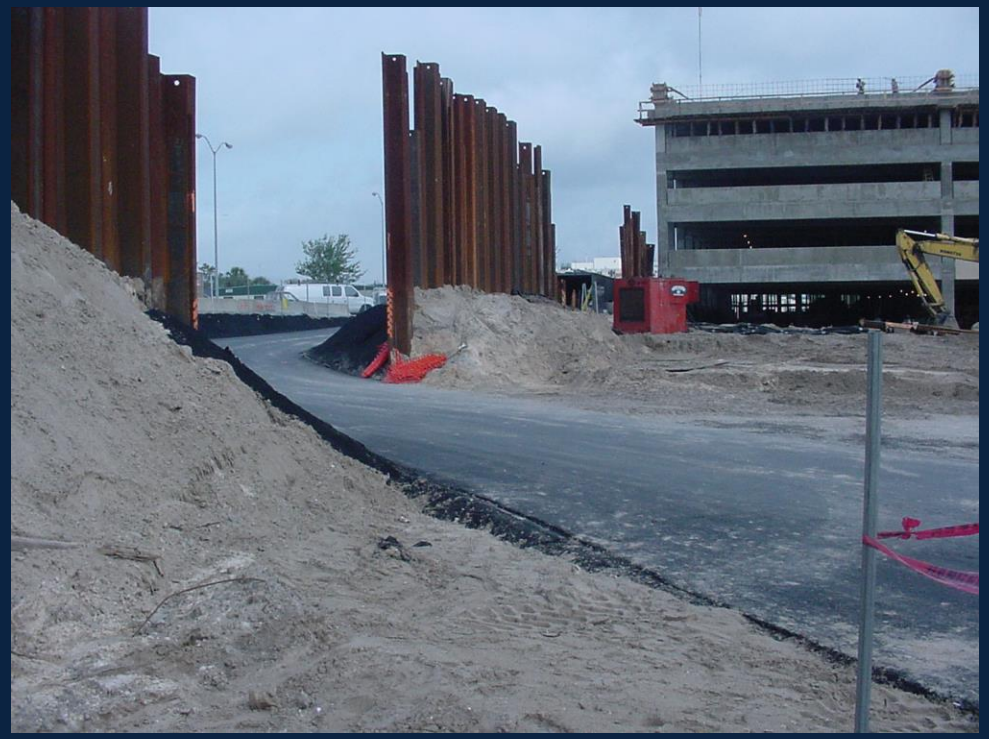


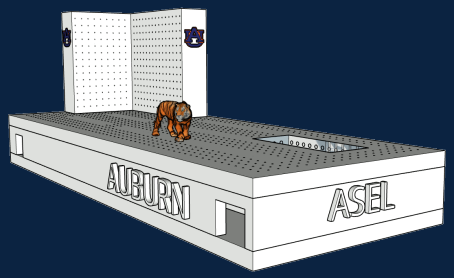




USF - SHEET PILE WALL







LESSON LEARNED

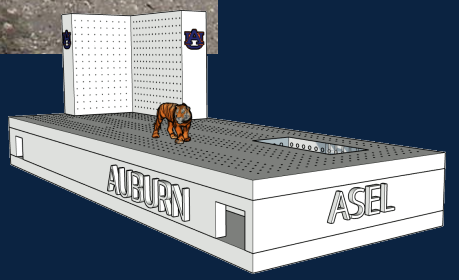
- Communicate.
- Be careful if your dissertation is contingent on a field load test under someone else's control.



SHALLOW FOOTING - GREEN COVE SPRINGS, FL







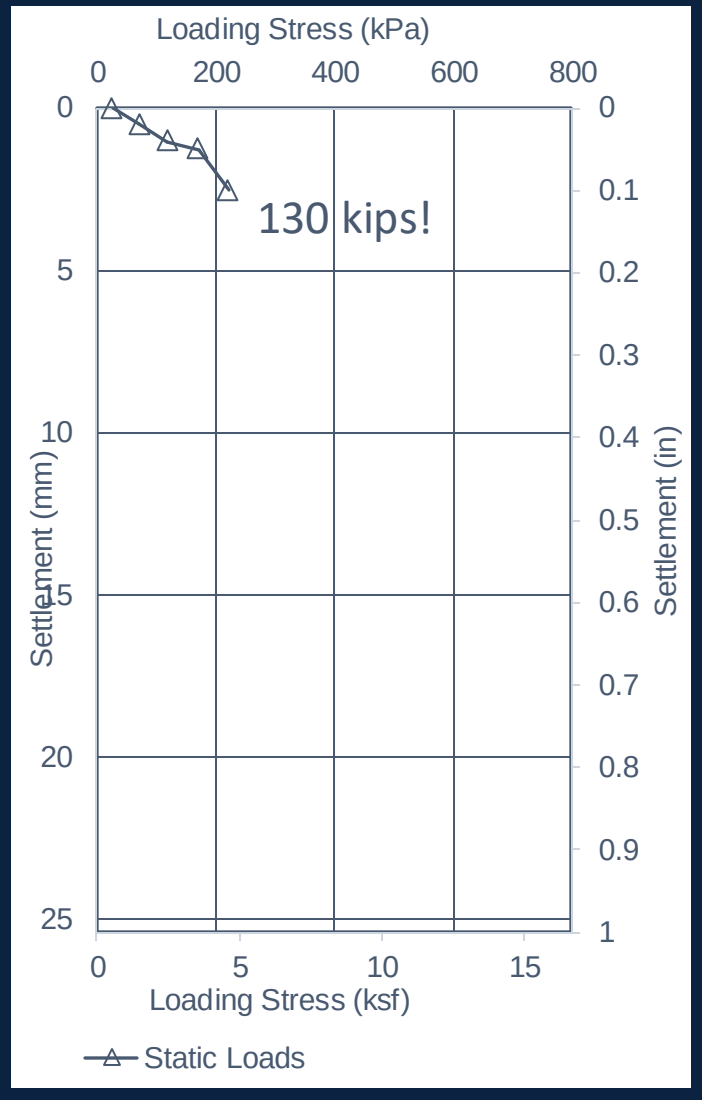
SHALLOW FOOTING - GREEN COVE SPRINGS, FL





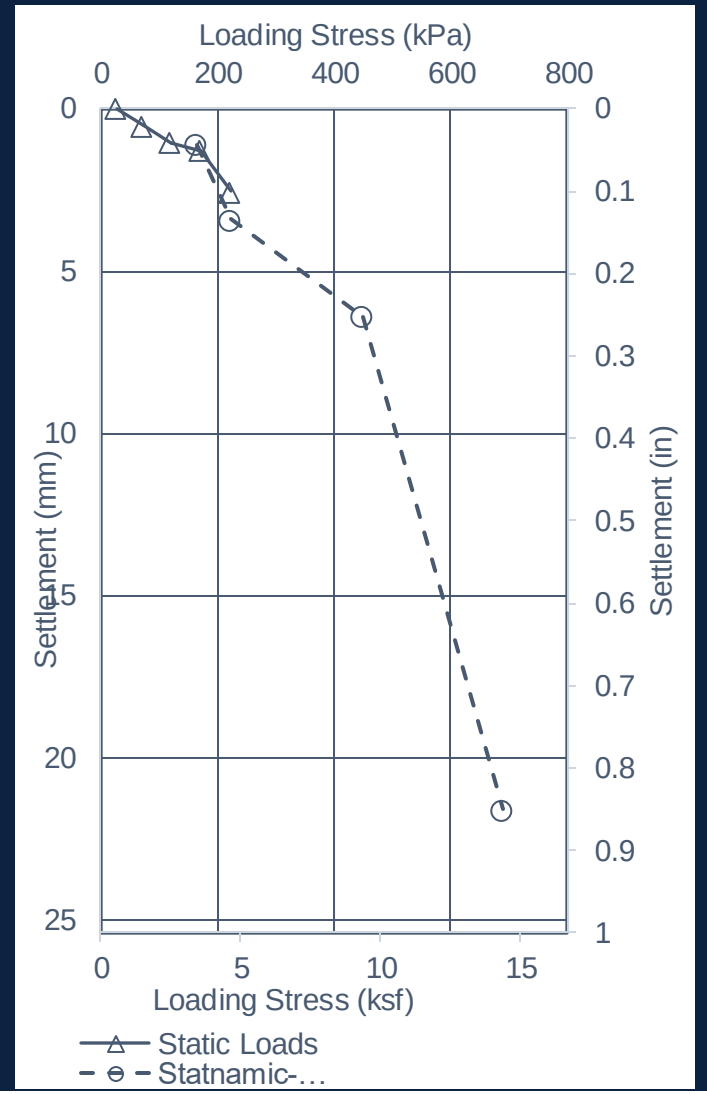






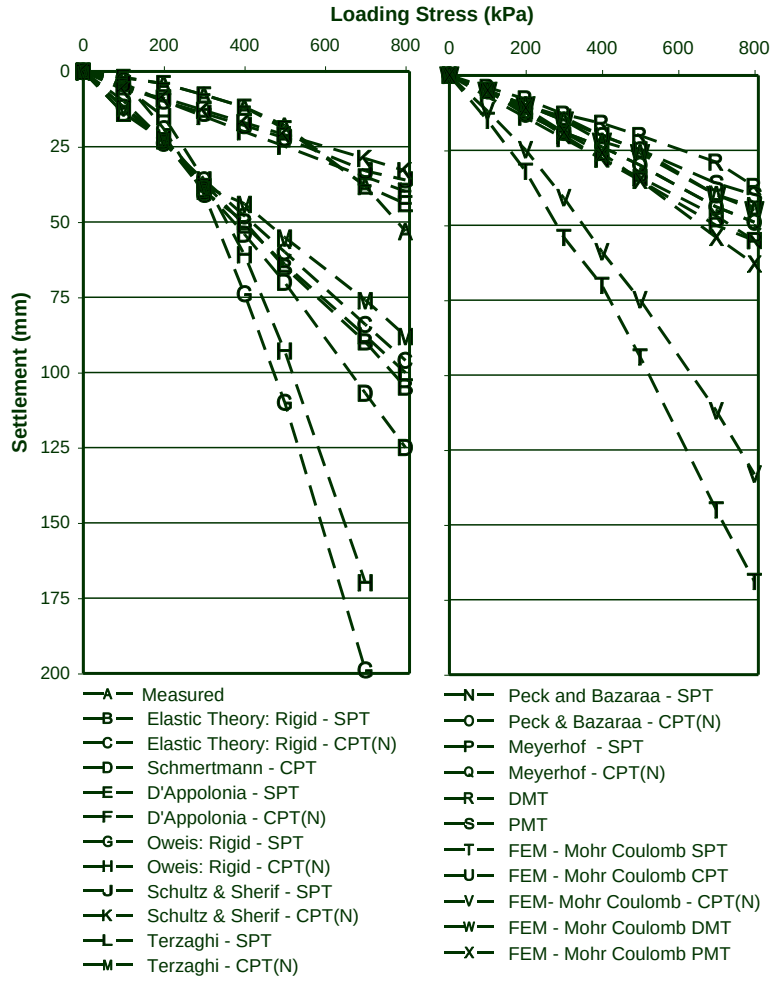
SHALLOW FOOTING - GREEN COVE SPRINGS, FL





SHALLOW FOOTING - GREEN COVE SPRINGS, FL

- Objective
  - Establish a load test case history for shallow foundation on sand
  - Use insitu test derived parameters to develop finite element model
- Outcomes
  - Conducted low-cost load test
  - Also conducted StatNAMIC load test
  - Compared all to classical methods and FEM models



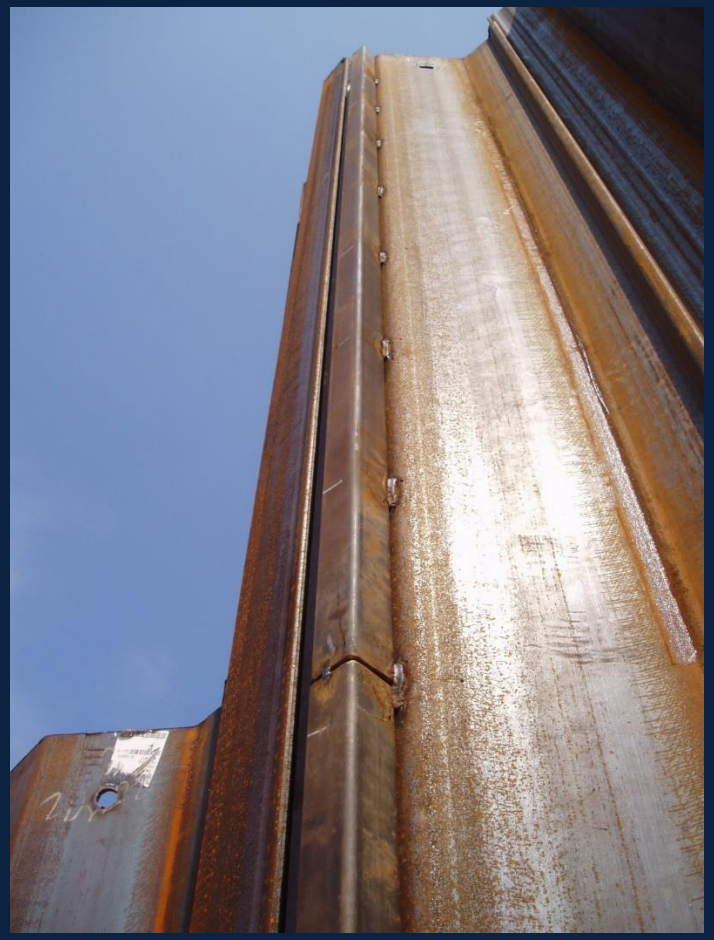
LESSONS LEARNED

- Shallow foundations are under utilized
- Most methods for estimating settlement for footings on sand are conservative
- Shallow footing load tests at full scale are achievable with access to equipment and simple instrumentation.
- Think outside of the box.
- You too can build a shallow foundation



SHEET PILE WALLS - STATESVILLE/MONROE, NC











SHEET PILE WALLS - STATESVILLE/MONROE, NC



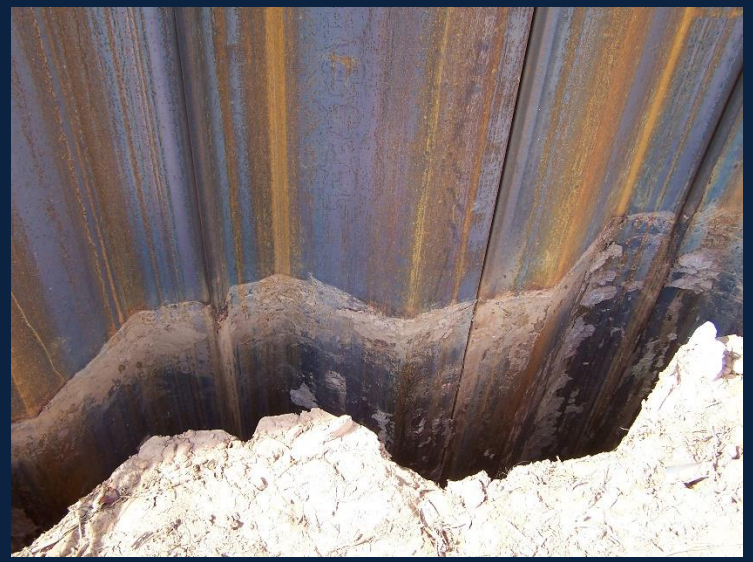






SHEET PILE WALLS - STATESVILLE/MONROE, NC



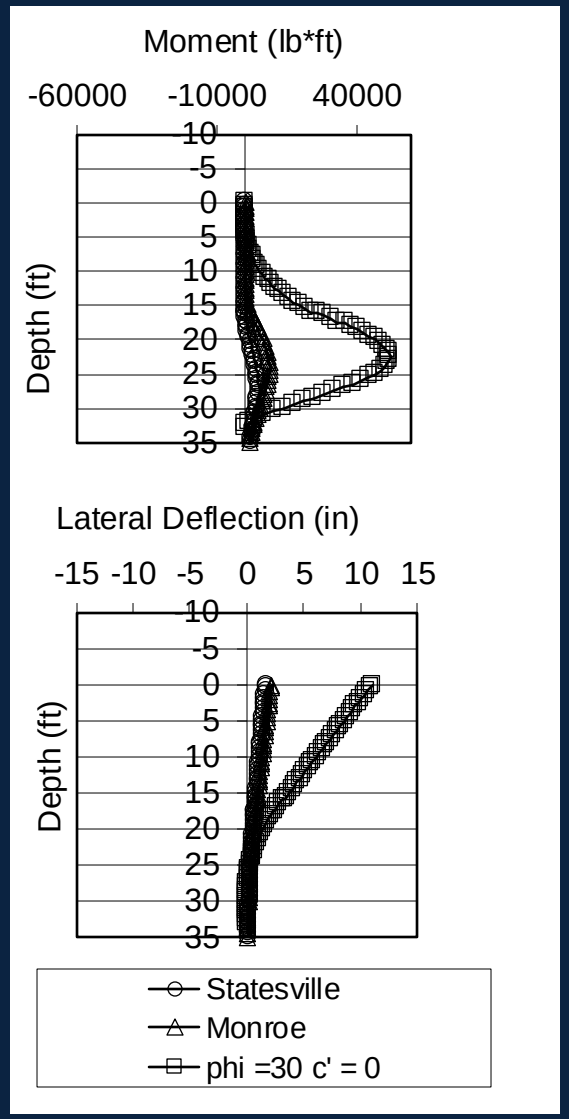


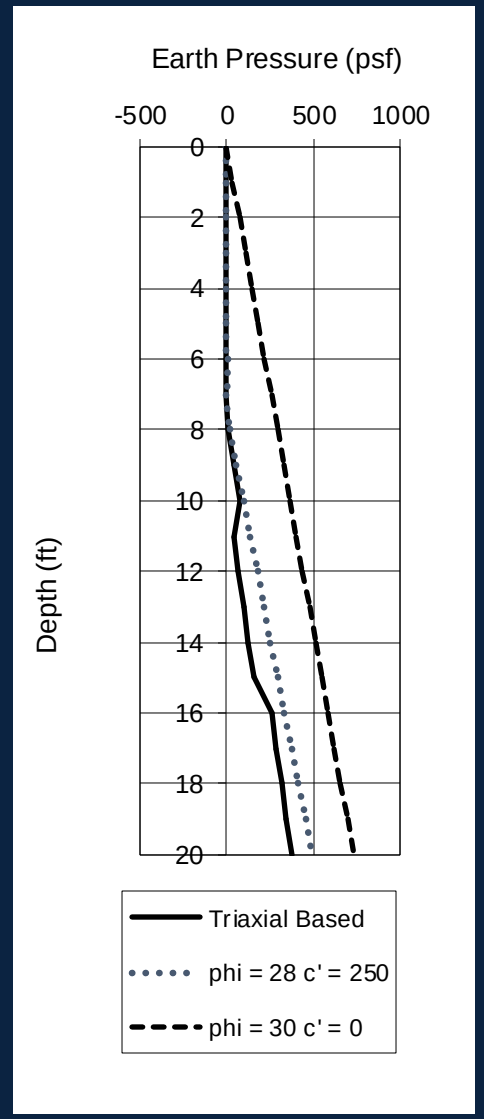


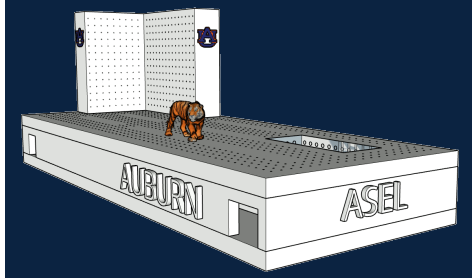


SHEET PILE WALLS - STATESVILLE/MONROE, NC

- Objective
  - Develop model for lateral earth pressure in piedmont residual soils
- Outcomes
  - Developed model based on laboratory parameters for lateral earth pressure in granitic residual soils in North Carolina







LESSONS LEARNED

- Piedmont residual soils exert less horizontal earth pressure than predicted by classical earth pressure theories
- Typical cohesive component of shear strength is ignored, and can have a substantial impact on earth pressure
- Back analysis of earth pressure from bending of sheet piles is possible using instrumentation (strain gages, inclinometers)
- Water remains the biggest enemy of retaining walls.
- And..





Most designs assume $\phi=0$ or $c=0$

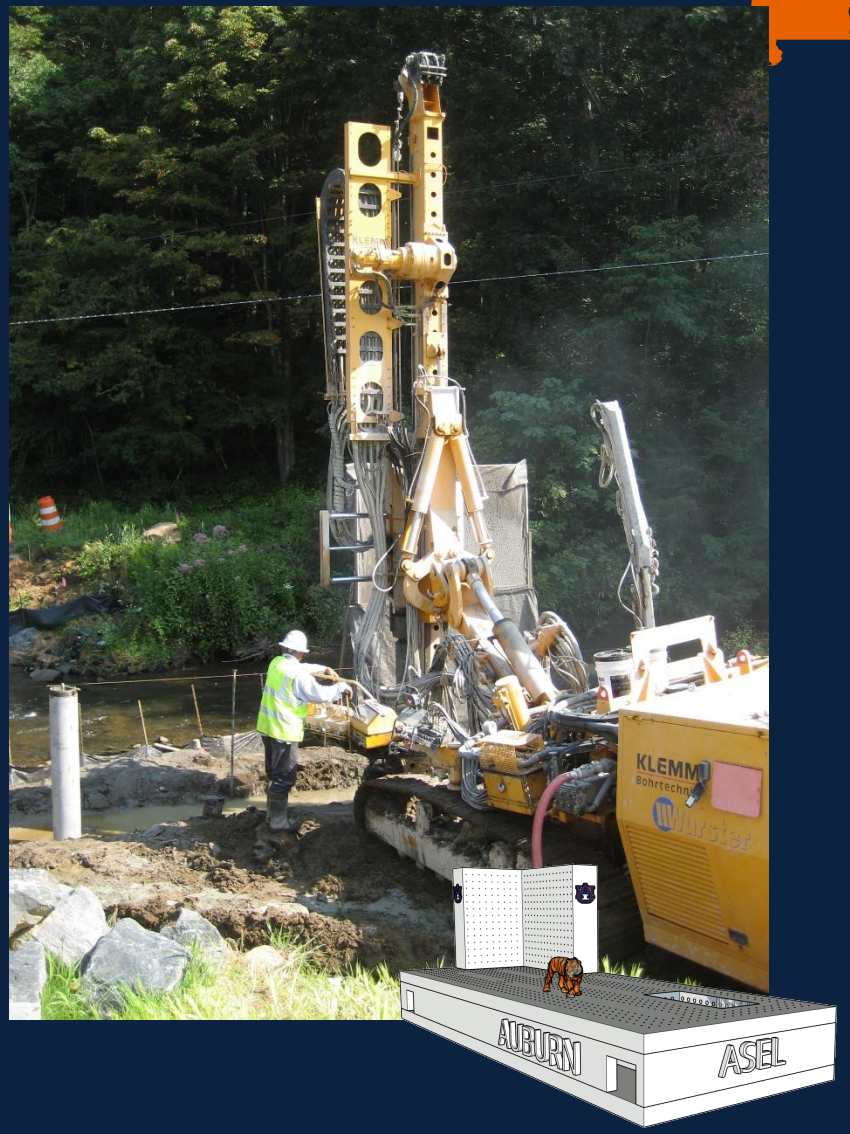
Residual soil has both ϕ and c





MICROPILES - ASHE COUNTY, NC



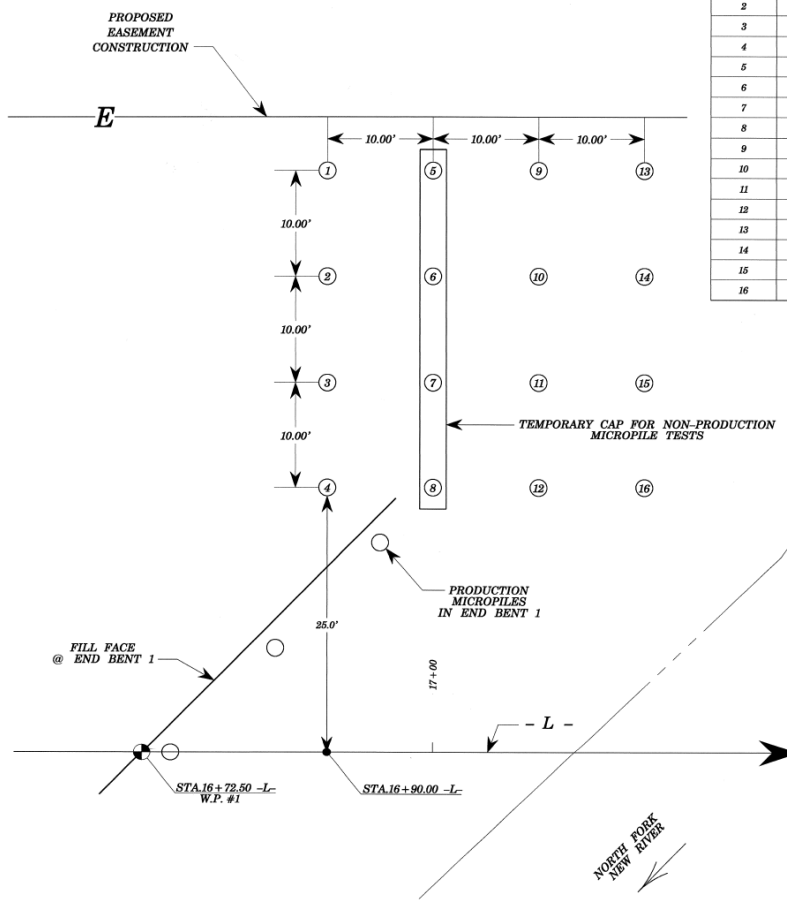


MICROPILES - ASHE COUNTY, NC

- What we wanted…

NON PRODUCTION MICROPILE TEST LAYOUT

DIMENSION LOCATING MICROPILES ARE SHOWN TO THE PILE CENTERLINE



NON-PRODUCTION MICROPILE SCHEDULE

NON-PRODUCTION MICROPILE	REQUIRED REINFORCING CASING PLUNGE IN CRYSTALLINE ROCK (FT)	BOND LENGTH (FT)	ESTIMATED TIP ELEVATION OF REINFORCING CASING	TOP ELEVATION OF REINFORCING CASING (FT)	ESTIMATED MICROPILE LENGTH (FT)	INTERNAL BAR REINFORCEMENT	EXPOSED REINFORCING CASING JOINT ABOVE GROUNDSURFACE
1	1	0	3109	3121	12	YES	NO
2	2	0	3108	3121	13	YES	NO
3	5	0	3105	3121	16	YES	NO
4	5	5	3105	3121	26	NO	YES
5	5	5	3105	3121	21	YES	YES
6	5	5	3105	3121	21	YES	YES
7	5	5	3105	3121	21	YES	YES
8	5	5	3105	3121	21	YES	YES
9	5	5	3105	3121	21	YES	YES
10	5	5	3105	3121	21	YES	YES
11	5	5	3105	3121	21	YES	YES
12	5	5	3105	3121	21	YES	YES
13	1	0	3109	3121	12	YES	NO
14	2	0	3108	3121	13	YES	NO
15	5	0	3105	3121	16	YES	NO
16	5	5	3105	3121	21	NO	NO

GEOTECHNICAL ENGINEER — SEAL 023480 ENGINEER — JOHN F. FARGHER — SIGNATURE DATE

ENGINEER — SIGNATURE DATE

NOTES:

1. NON-PRODUCTION MICROPILES SHALL BE INSTALLED USING DUPLEX DRILLING.
2. NON-PRODUCTION MICROPILES SHALL BE PAID FOR PER EACH. SEE MICROPILE SPECIAL PROVISION.
3. NON-PRODUCTION MICROPILES SHALL BE INSTRUMENTED WITH STRAIN GAGES ATTACHED TO THE REINFORCING CASING.
4. NON-PRODUCTION MICROPILES ARE TO BE TESTED LATERALLY BY THE NCDOT.
5. ASSISTANCE FROM THE CONTRACTOR WILL BE PAID FOR UNDER LATERAL LOAD TESTING ASSISTANCE. SEE LATERAL LOAD TESTING ASSISTANCE SPECIAL PROVISION.
6. THE CONTRACTOR WILL TAKE NECESSARY CARE NOT TO DAMAGE INSTRUMENTATION DURING MICROPILE CONSTRUCTION.
7. THE STRAIN GAGES WILL BE PROVIDED BY THE NCDOT.
8. NON-PRODUCTION MICROPILES SHALL BE CUT-OFF 2 FOOT BELOW GRADE AFTER COMPLETION OF THE LATERAL LOAD TESTING.

PROJECT NO.: B-4012
ASHE
STATION: 17+30.00 -L-

PREPARED BY: C. E. BURRIS — DATE: 01/08
REVIEWED BY: JOHN FARGHER — DATE: 01/08

GEOTECHNICAL ENGINEERING UNIT
☐ EASTERN REGIONAL OFFICE
☒ WESTERN REGIONAL OFFICE

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION
RALEIGH

NON PRODUCTION MICROPILE TEST LAYOUT

REVISIONS

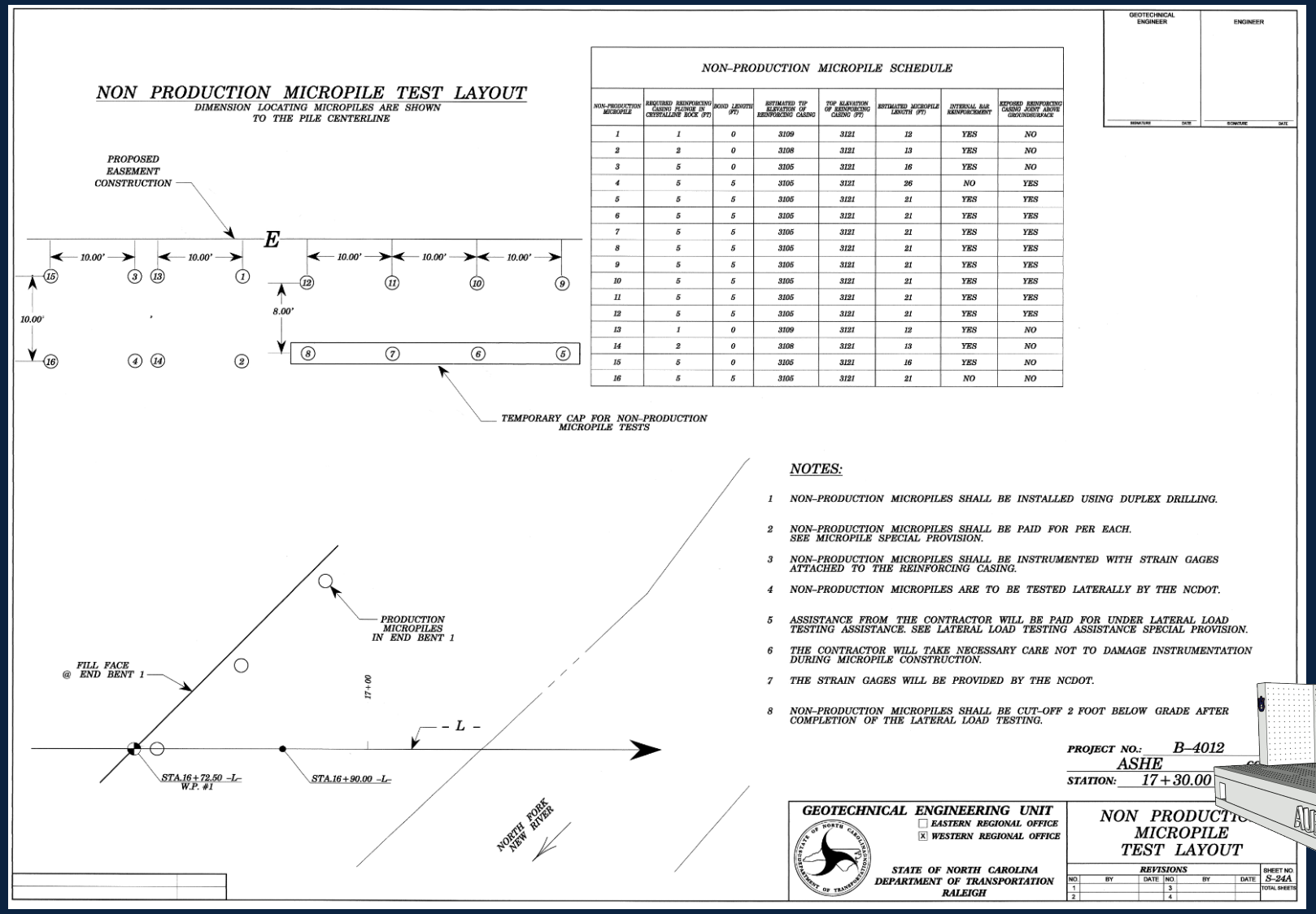
NO.	BY	DATE	NO.	BY	DATE
1			3		
2			4		

SHEET NO. S-24A
TOTAL SHEETS



MICROPILES - ASHE COUNTY, NC

- What was construct-ed…



NON PRODUCTION MICROPILE TEST LAYOUT

DIMENSION LOCATING MICROPILES ARE SHOWN TO THE PILE CENTERLINE

PROPOSED EASEMENT CONSTRUCTION

E

10.00' 10.00' 10.00' 10.00' 10.00'

8.00'

10.00'

TEMPORARY CAP FOR NON-PRODUCTION MICROPILE TESTS

NON-PRODUCTION MICROPILE SCHEDULE

NON-PRODUCTION MICROPILE	REQUIRED REINFORCING CASING PLUNGE IN CRYSTALLINE ROCK (FT)	BOND LENGTH (FT)	ESTIMATED TIP ELEVATION OF REINFORCING CASING	TOP ELEVATION OF REINFORCING CASING (FT)	ESTIMATED MICROPILE LENGTH (FT)	INTERNAL BAR REINFORCEMENT	EXPOSED REINFORCING CASING JOINT ABOVE GROUNDSURFACE
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12	5	5	3105	3121	21	YES	YES
13	1	0	3109	3121	12	YES	NO
14	2	0	3108	3121	13	YES	NO
15	5	0	3105	3121	16	YES	NO
16	5	5	3105	3121	21	NO	NO

GEOTECHNICAL ENGINEER

ENGINEER

PRODUCTION MICROPILES IN END BENT 1

FILL FACE @ END BENT 1

17+00

- L -

STA 16+72.50 -L- W.P. #1

STA 16+90.00 -L-

NORTH FORK NEW RIVER

NOTES:

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PROJECT NO.: B-4012

ASHE

STATION: 17+30.00

GEOTECHNICAL ENGINEERING UNIT

☐ EASTERN REGIONAL OFFICE

☒ WESTERN REGIONAL OFFICE

STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION RALEIGH

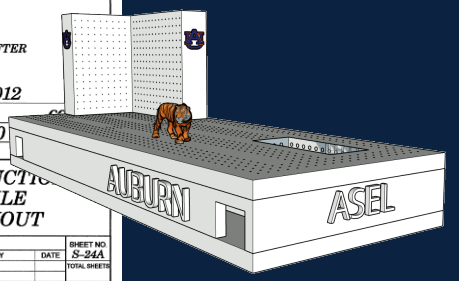
NON PRODUCTION MICROPILE TEST LAYOUT

REVISIONS

NO.	BY	DATE	NO.	BY	DATE
1			3		
2			4		

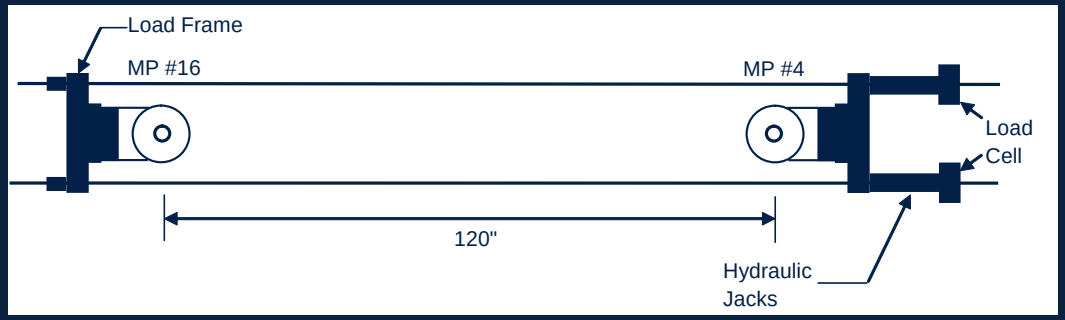
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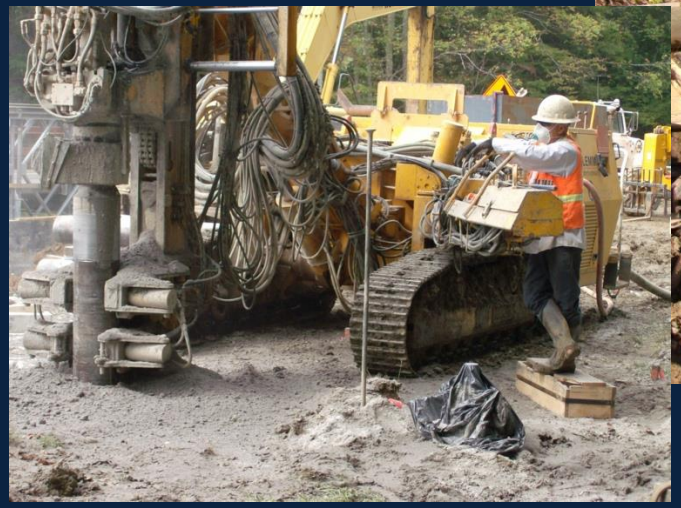
TOTAL SHEETS



MICROPILES - ASHE COUNTY, NC













MICROPILES - ASHE COUNTY, NC







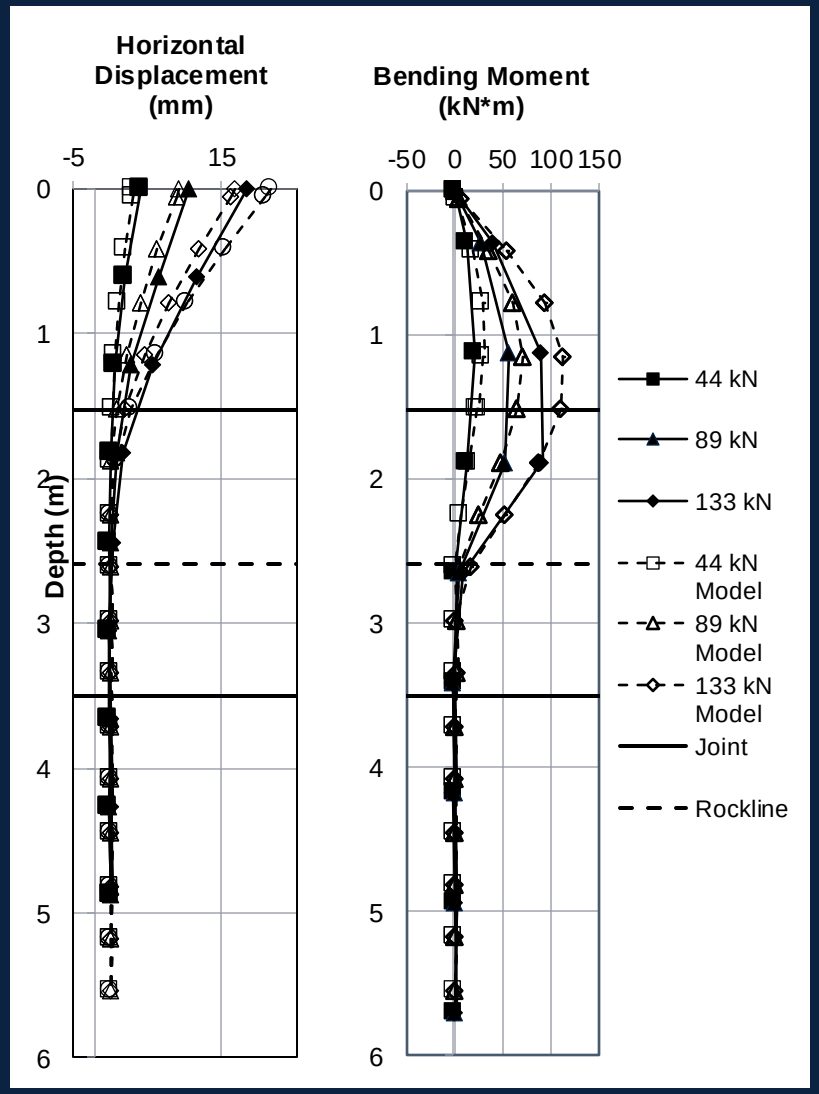


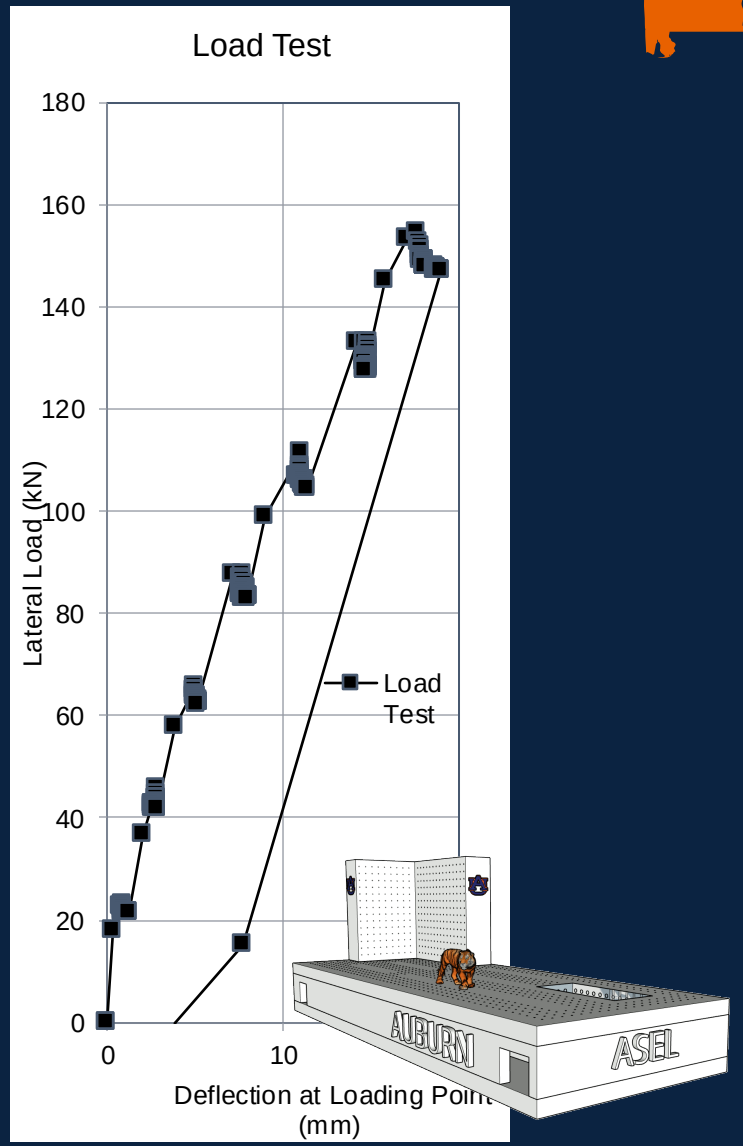




MICROPILES - ASHE COUNTY, NC

- Objective
  - Determine lateral load capacity of micropiles with threaded joints
  - Determine longitudinal lateral resistance of micropile bent
- Outcomes
  - Developed jointed micropile model
  - Verified lateral capacity of micropiles





LESSONS LEARNED

- Sometimes, you are not in control of all constraints on a test and must improvise
- Micropiles in this case carried 7-8x the lateral loading estimated for design.
- High capacity, brittle failure
- Threaded casing joints can be easily modeled using a reduced cross section.
- Weather is not always your friend
- Tell your spouse when you are planning to test late night outside of cellular reception in the winter darkness…



SEGMENTAL ARCH CULVERTS - CONCORD, NC AND AUBURN, AL

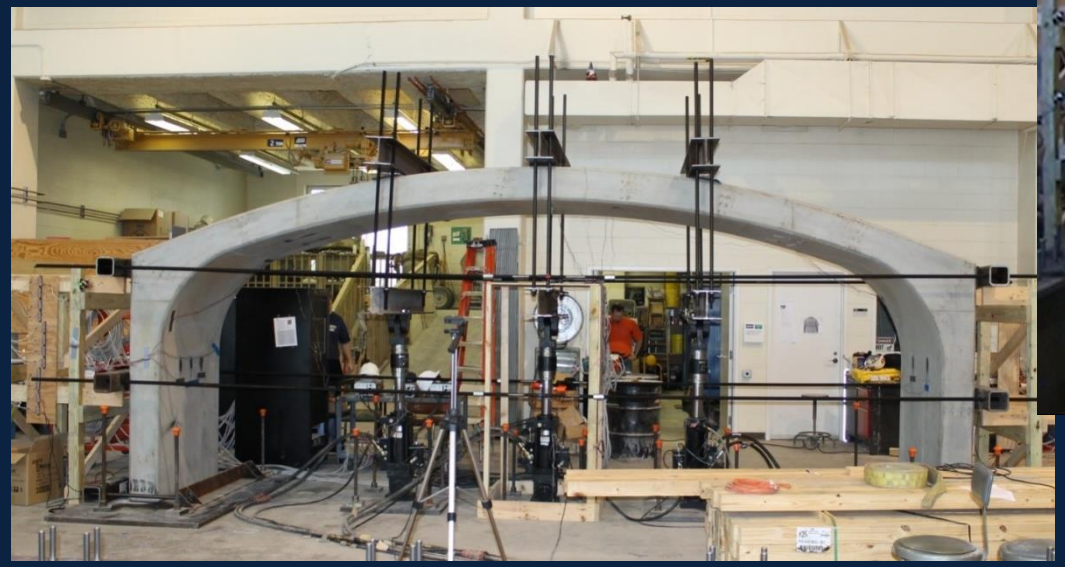






DID SOMEONE ORDER A BRIDGE?



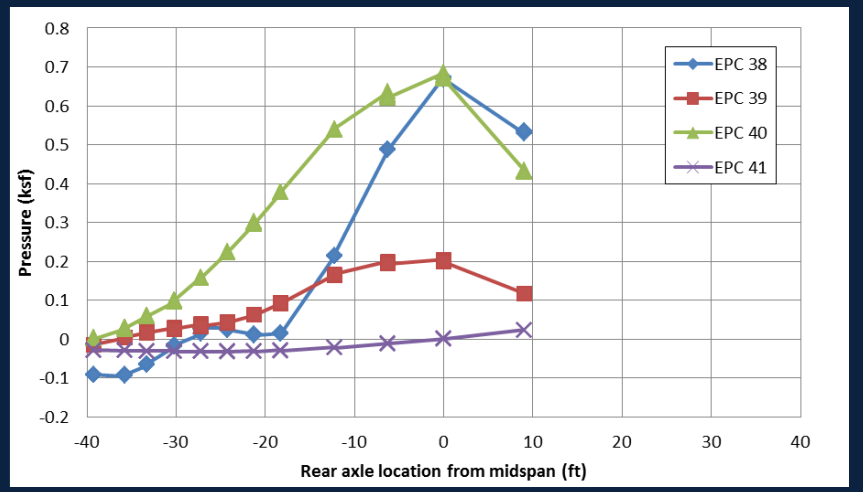


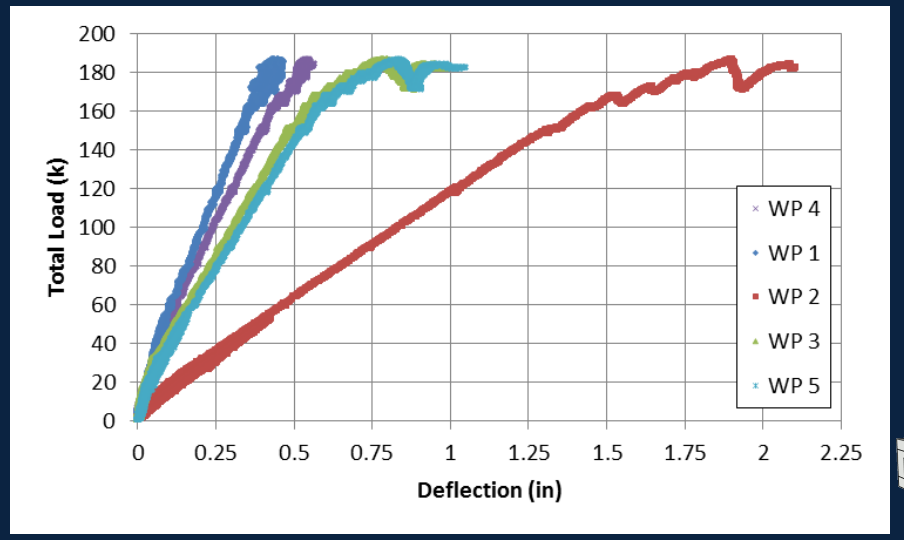




SEGMENTAL ARCH CULVERTS - CONCORD, NC AND AUBURN, AL

- Objective
  - Determine load carrying capacity of segmental arch culvert using field and laboratory load tests
- Outcomes
  - Verified design assumptions for segmental arch culverts
  - Load tested segments to failure







LESSONS LEARNED

- Segmental arch bridges founded on rock are strong and stiff structures.
- Communicate with the casting yard, or you will get a section that is too stiff and strong!
- Be sure you can move a specimen into your lab!
- Route your instrumentation wires neatly, or the neighbors think you are working with a demolition crew.



NGES EXCAVATIONS - OPELIKA, AL



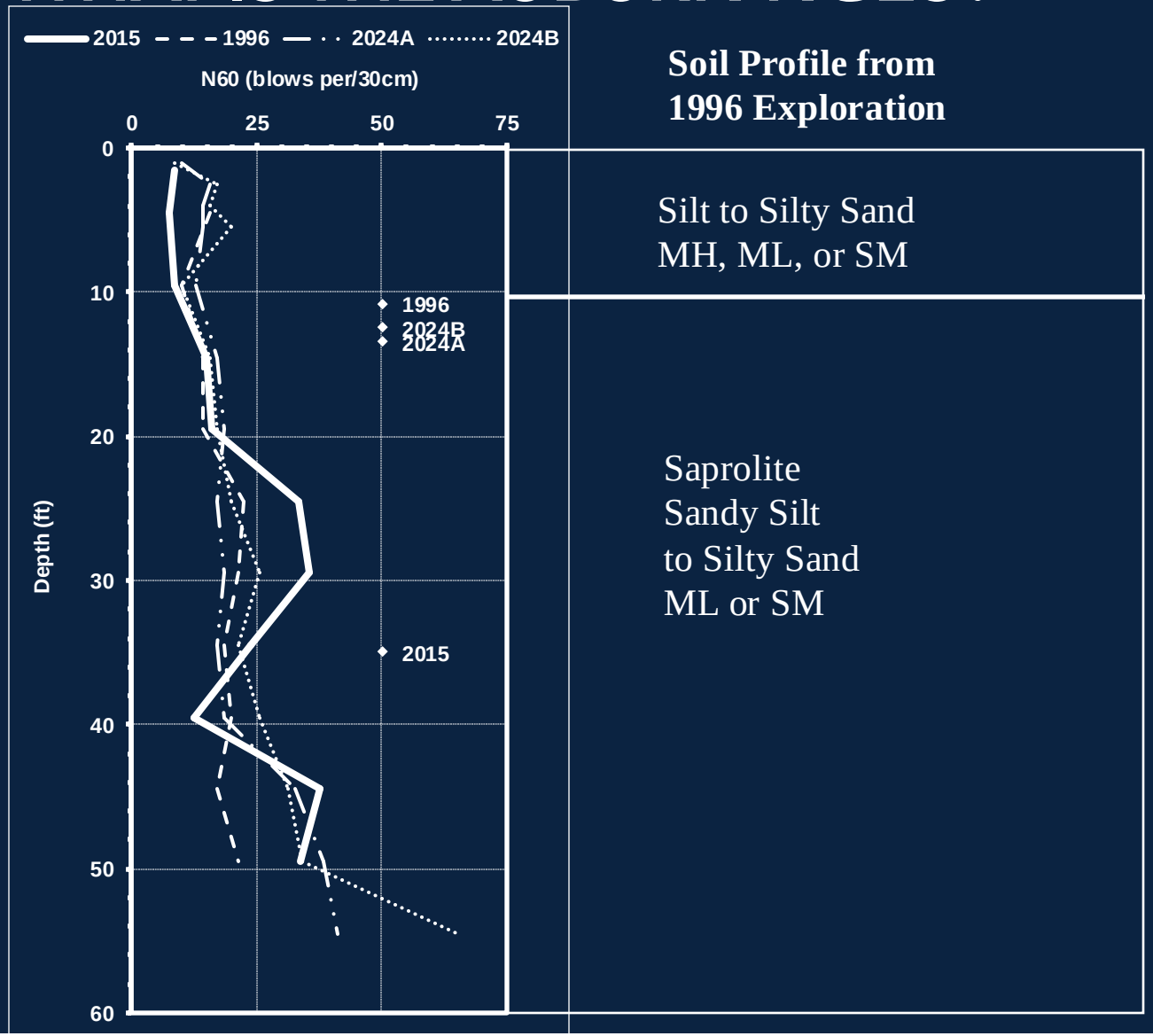








WHAT IS THE AUBURN NGES?

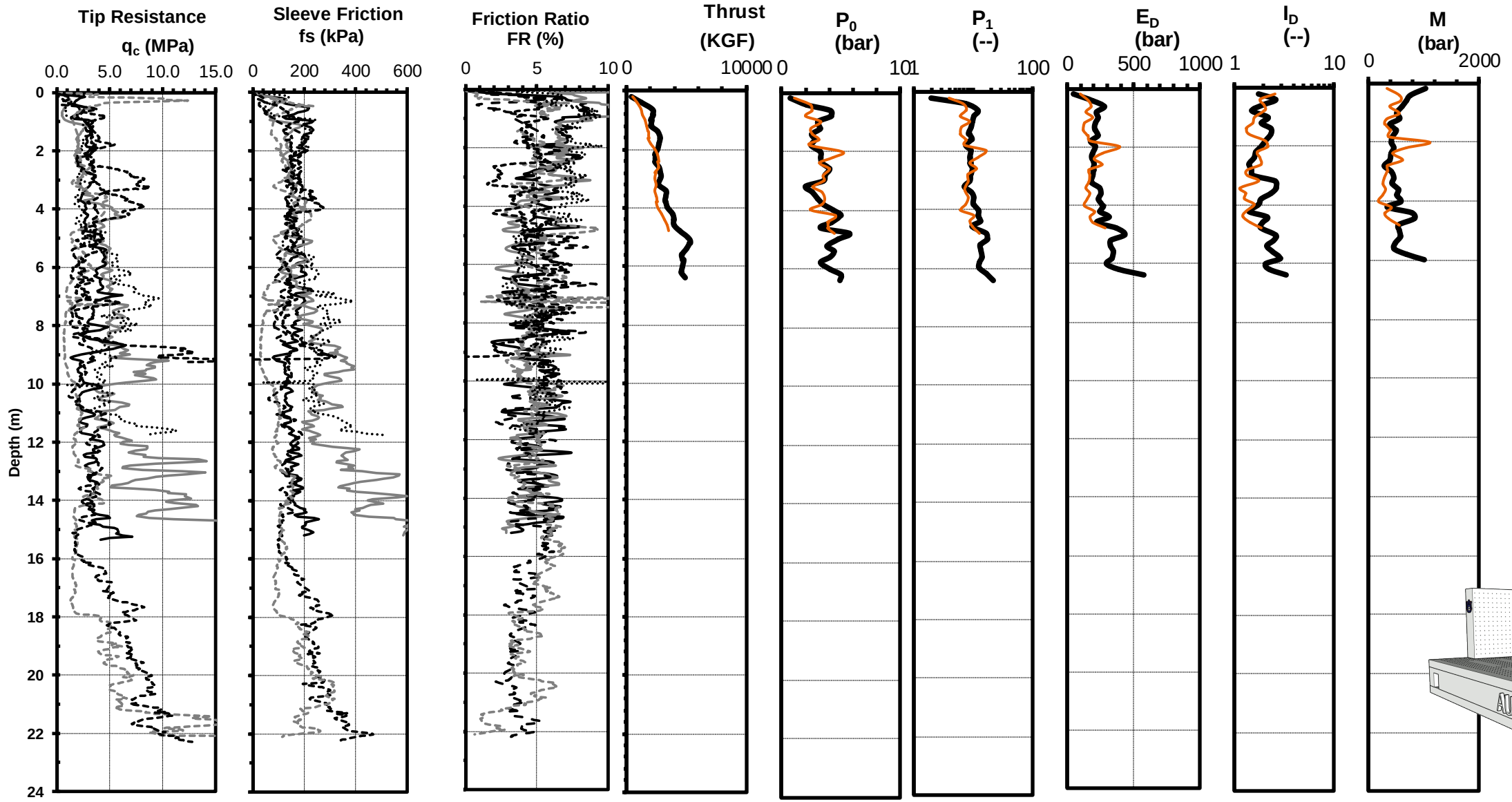


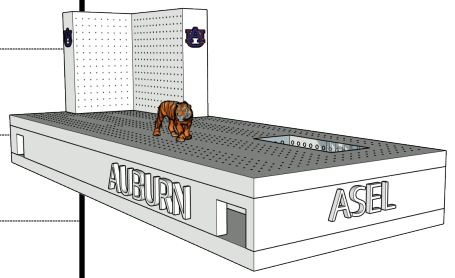


- National Geotechnical Experimentation Site
- Just east of Auburn in Opelika, AL
- Co-located with the National Center for Asphalt Technology Test Track Facility
- Well characterized site consisting of thick layer of Piedmont Residual Soil



WHAT IS THE AUBURN NGES?





NGES EXCAVATIONS- OPELIKA, AL

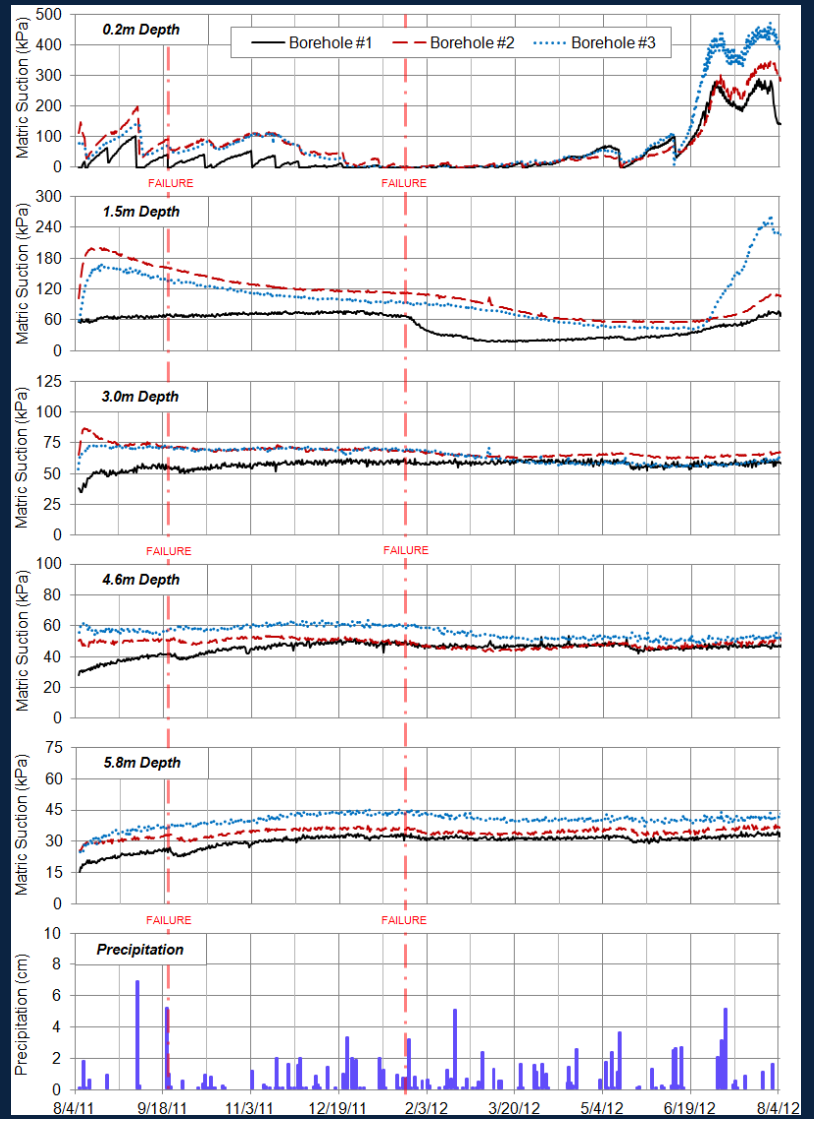


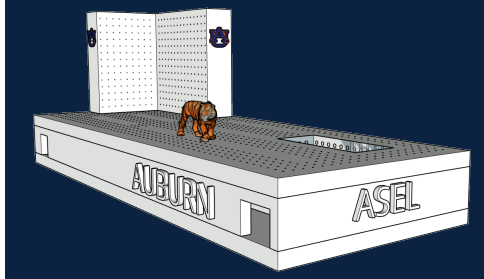




NGES EXCAVATIONS - OPELIKA, AL

- Objective
  - Determine long term stability of open cuts in Piedmont Residual soil
- Outcomes
  - Observed failure of two test excavations
  - Determined contributing factors including unsaturated behavior



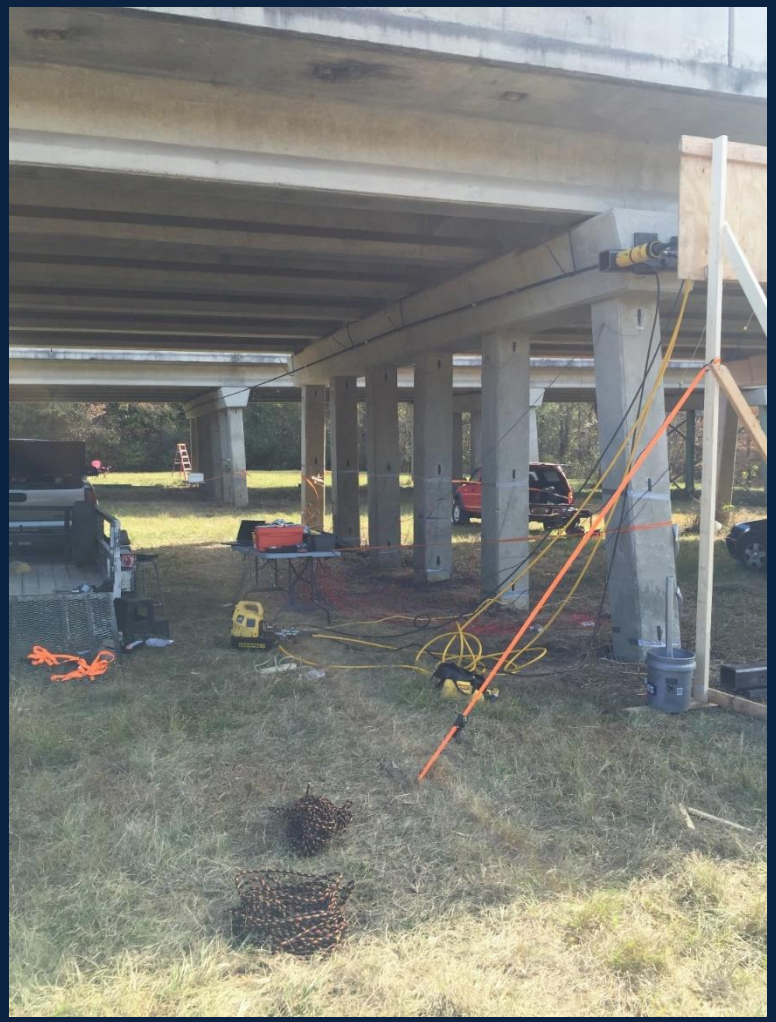


LESSONS LEARNED

- Excavations in piedmont residual soil fail from the bottom up with a face slough that is shaped like a thin logarithmic spiral.
- A simple experiment is possible when you have access to an open site and a student equipment operator.



H-PILE BENTS - SHORTER AND MONTGOMERY, AL



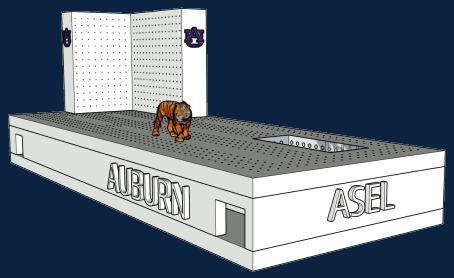




H-PILE BENTS - SHORTER AND MONTGOMERY, AL

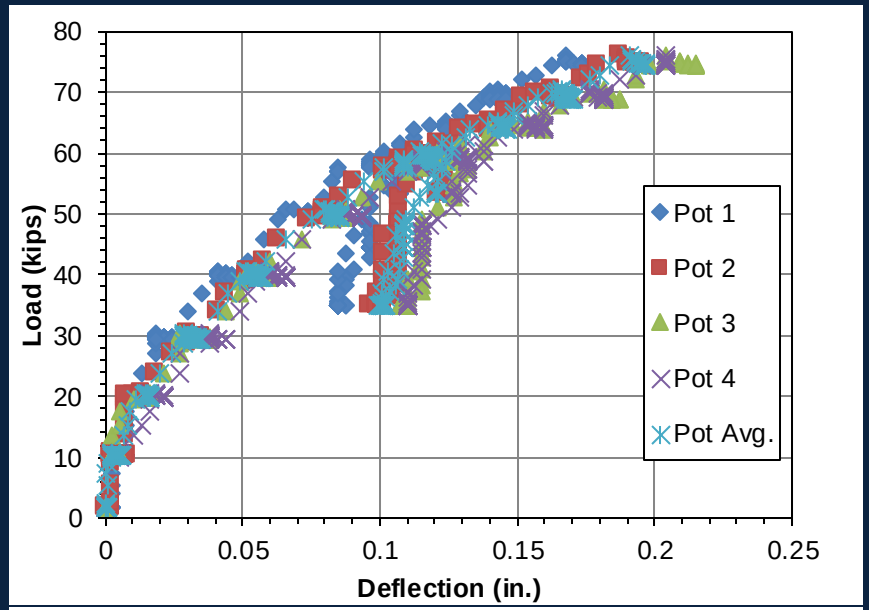


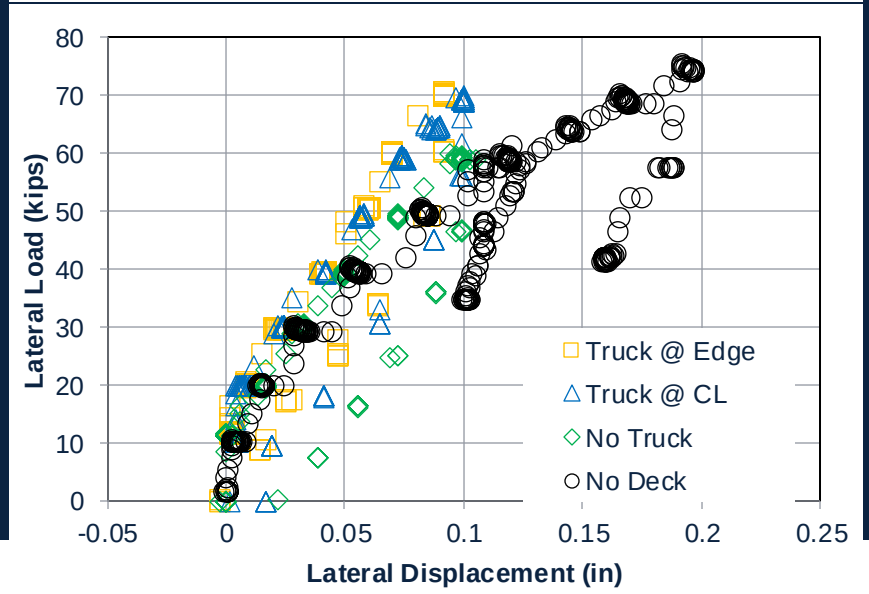


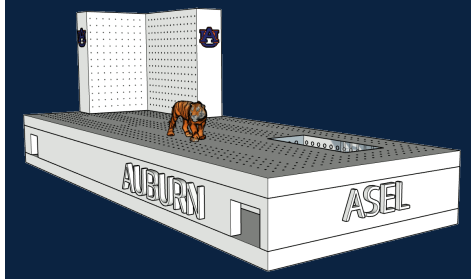


H-PILE BENTS - SHORTER AND MONTGOMERY, AL

- Objective
  - Determine load path in steel H-pile bents through load testing in the weak axis
- Outcomes
  - Conducted 3 lateral load tests
  - Determined load path and also deck load effects on stiffness







LESSONS LEARNED

- Testing an in service southbound bent bridge using the northbound bridge as a reaction is feasible.
- Dead and live load have a noticeable impact on load deflection response.
- Concrete encasements and scour protection measures (rip rap) provide significant stiffness to pile bents, even though ignored in design.



NGES PILE BENTS - OPELIKA, AL





NGES PILE BENTS - OPELIKA, AL



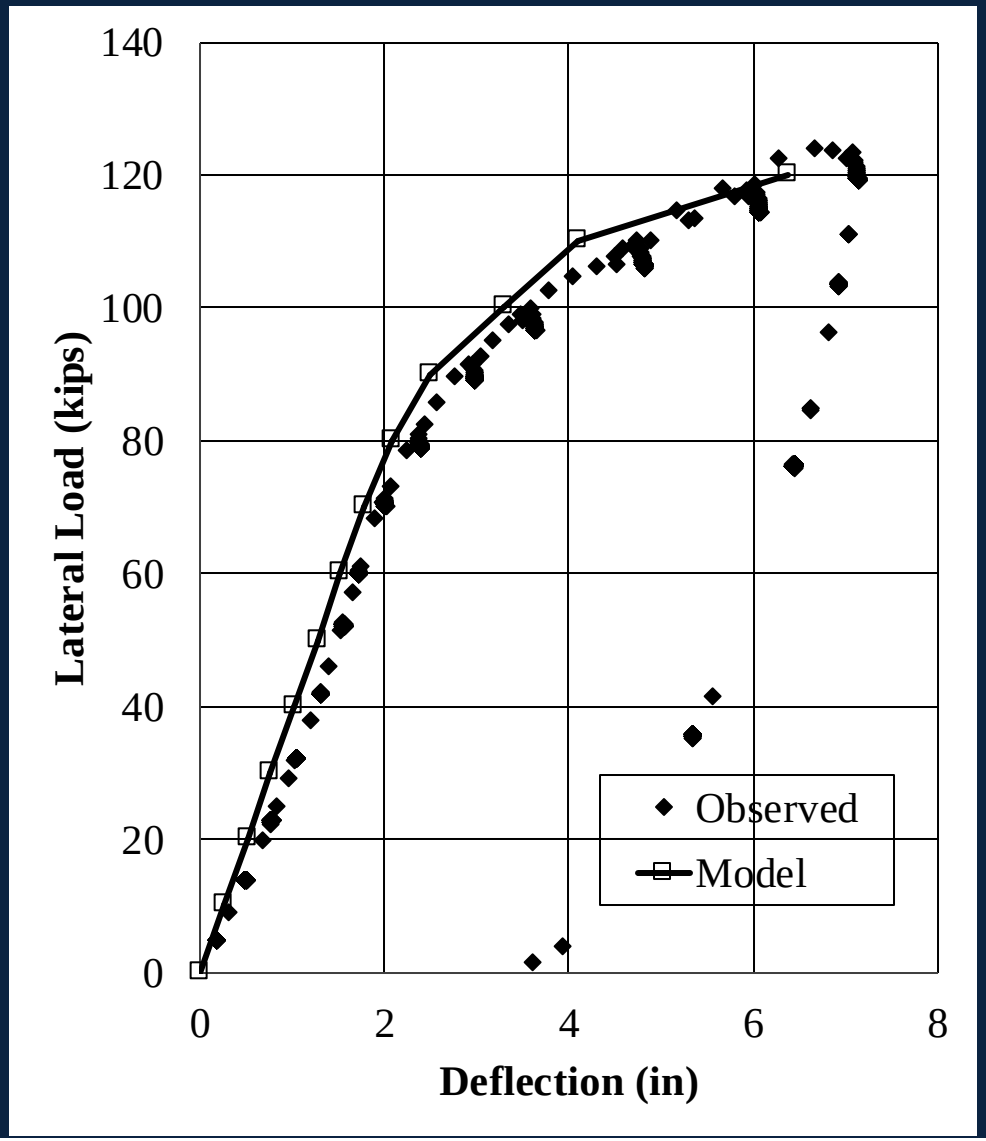








NGES PILE BENTS - OPELIKA, AL



- Objective
  - Conduct lateral load tests on vertical and battered steel h-pile bents to structural failure
- Outcomes
  - Conducted and documented two lateral load tests to structural failure at over 6 inches displacement

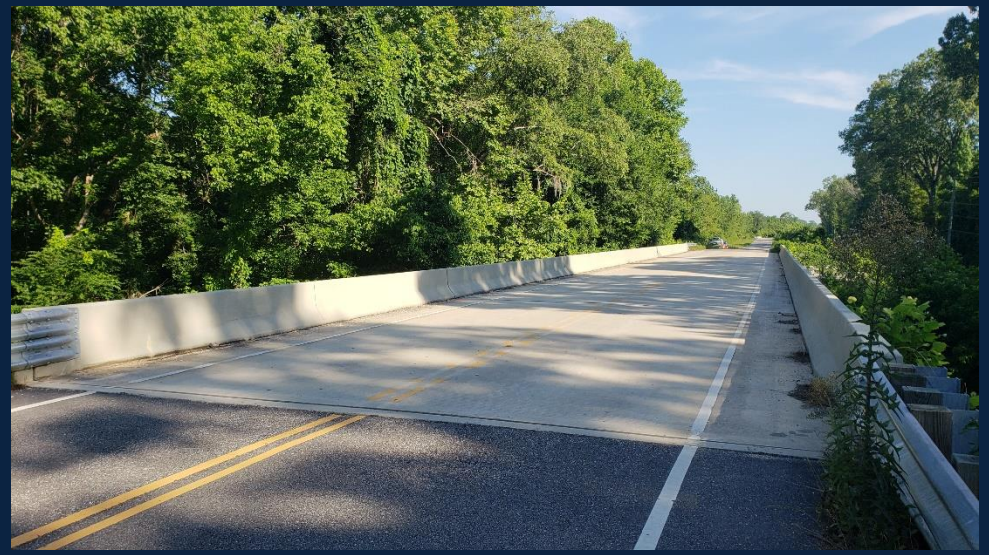


LESSONS LEARNED

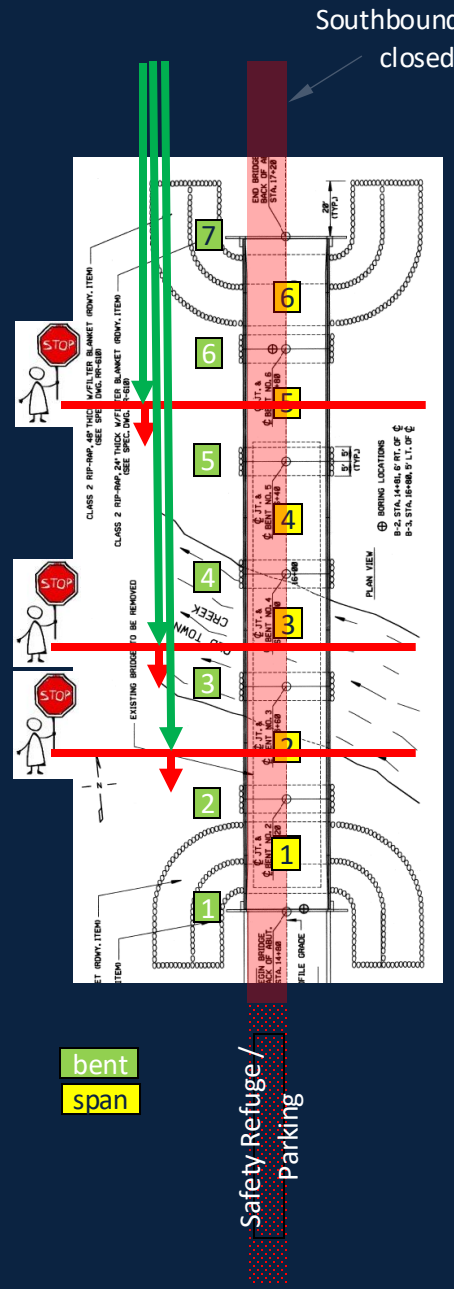
- Vertical pile bents are just as effective as battered pile bents for small bridges and much easier to construct.
- Battered pile bents incur more damage at the pile cap during overload than vertical pile bents.

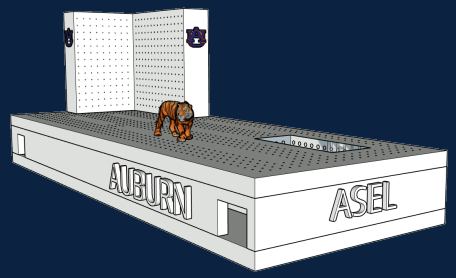


BRAKING FORCE - SHORTER, AL



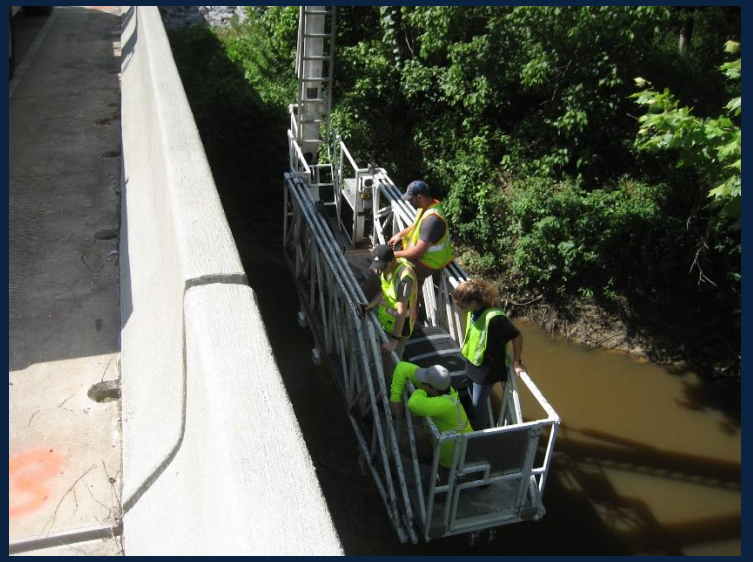


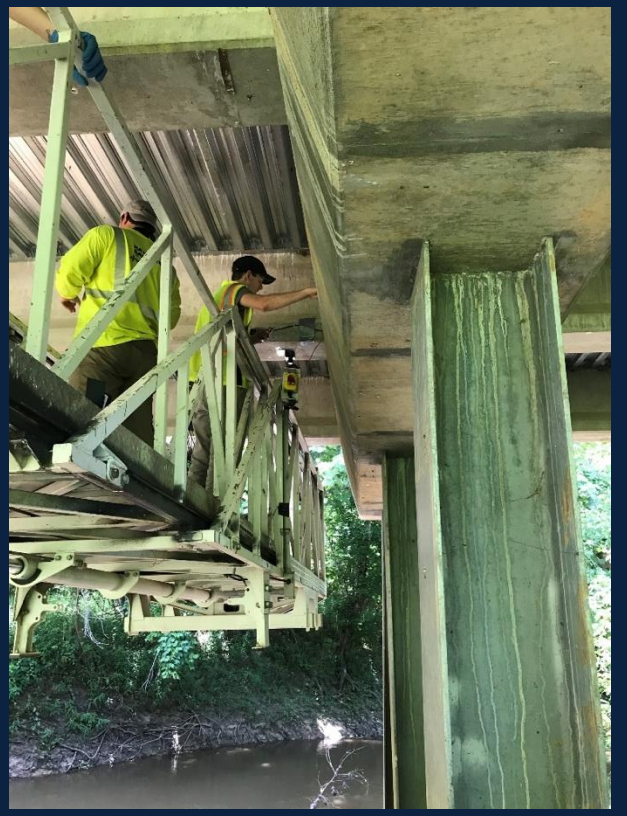




BRAKING FORCE - SHORTER, AL







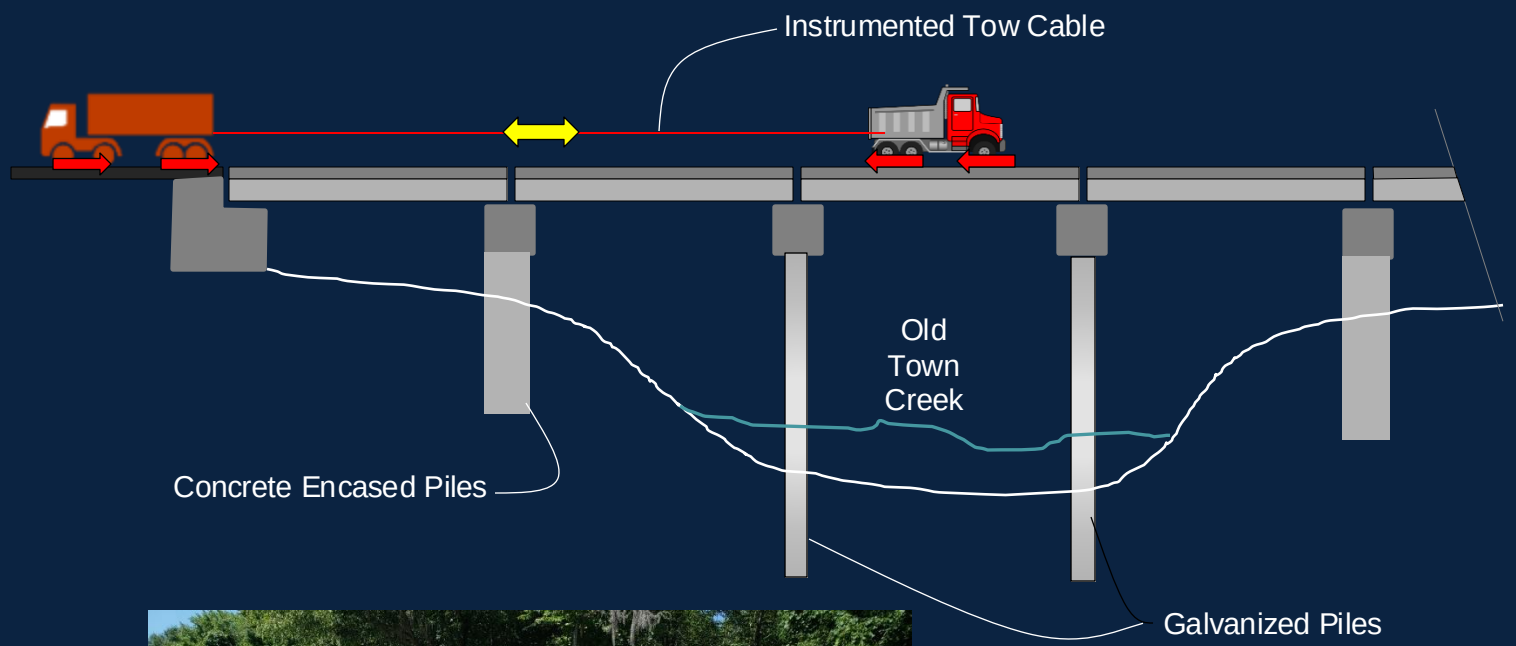




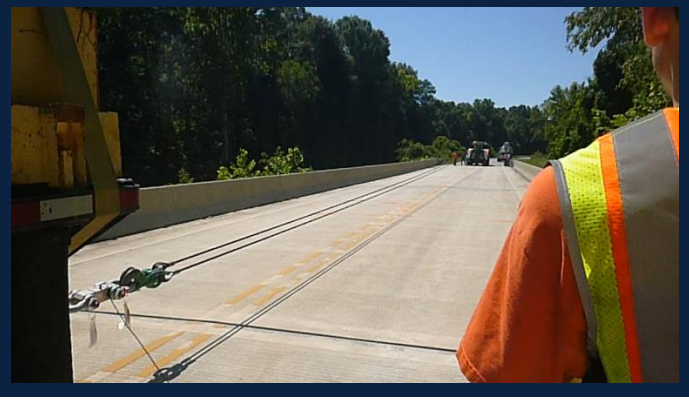


BRAKING FORCE - SHORTER, AL



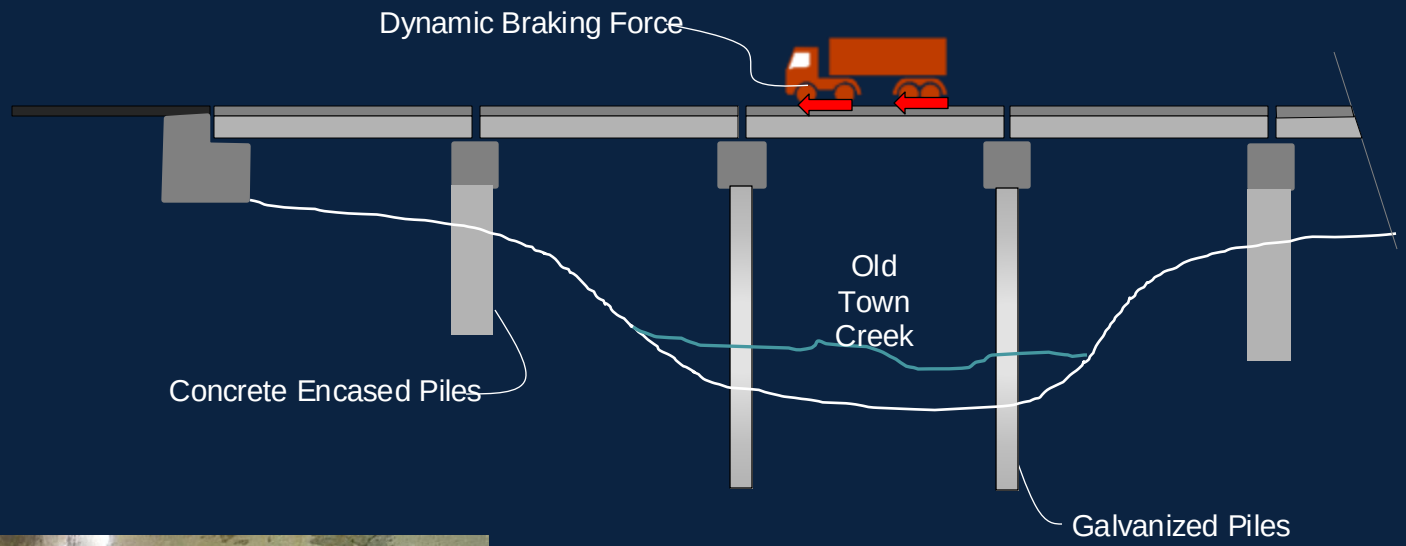








BRAKING FORCE - SHORTER, AL

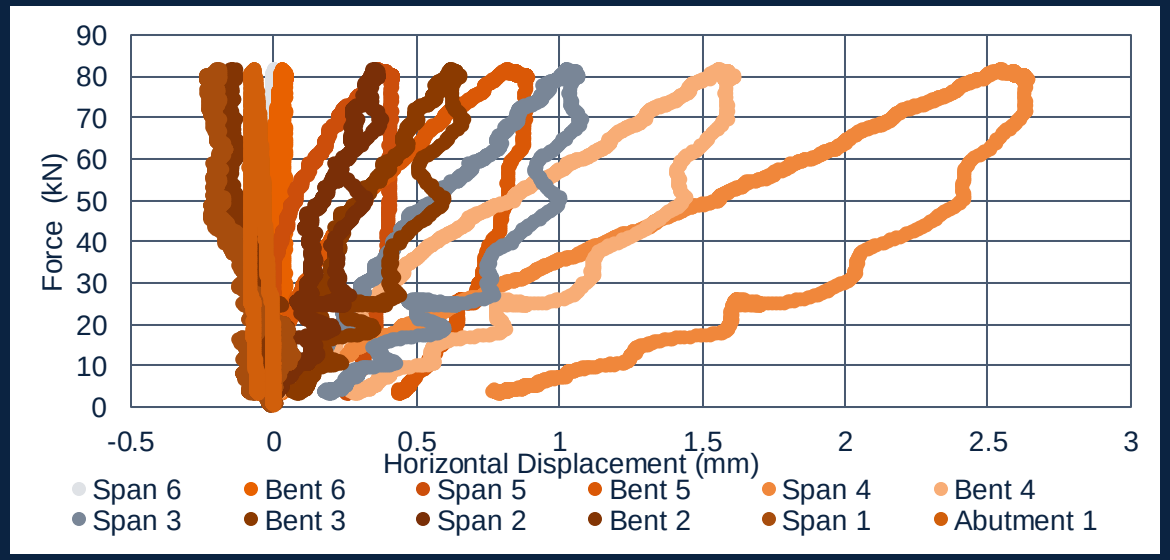


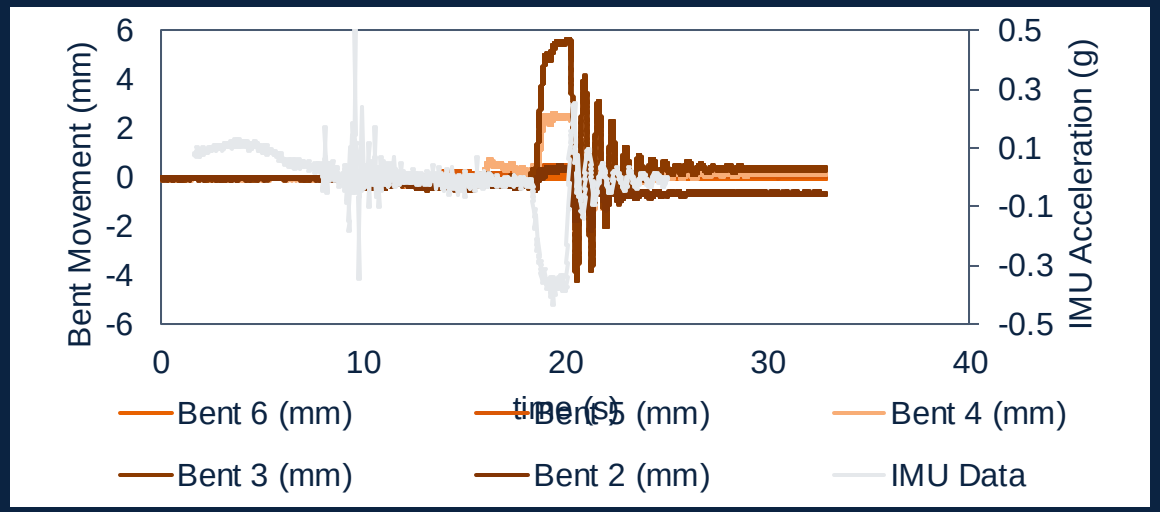




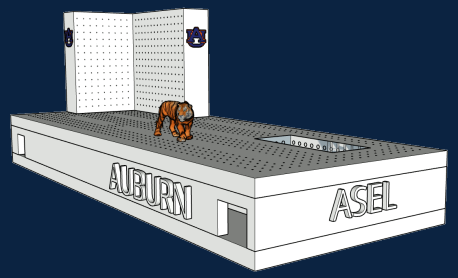


BRAKING FORCE - SHORTER, AL





- Objective
  - Determine longitudinal load transfer during heavy vehicle braking
- Outcomes
  - Provided load path from truck braking to abutments and pile bents



Load Displacement Response for Static Test at Center of Span 4

Displacement Response with Time for Dynamic Test at Center of Span 2

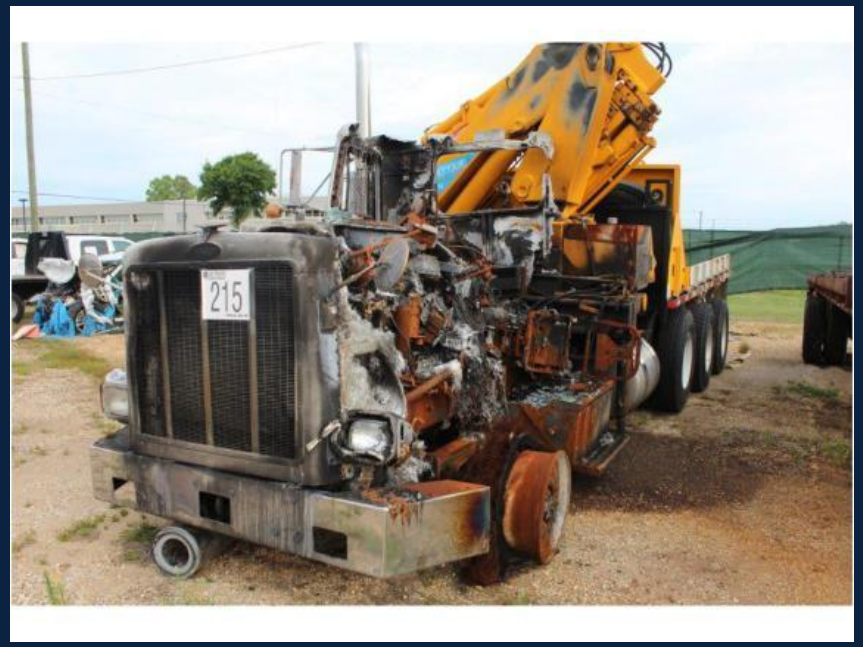
LESSONS LEARNED

- Tropical storms can threaten even before hurricane season in the south
- Significant braking forces are transferred to the end bents (bridge abutments)
- Braking force distribution is impacted by the relative stiffness of the bridge substructure (pile bents).
- 25% of vehicle weight as a guide for braking force (per AASHTO) is reasonable.
- And sometimes, things don't always go as planned…



LESSON LEARNED





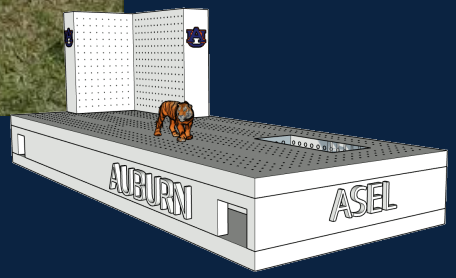


CORRUGATED METAL CULVERTS - ANNISTON, AL



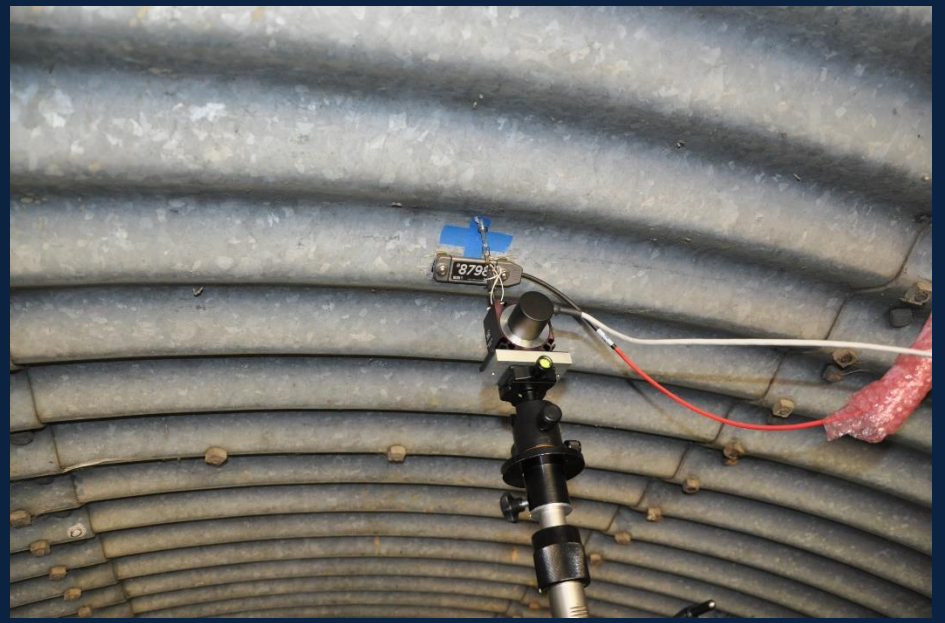




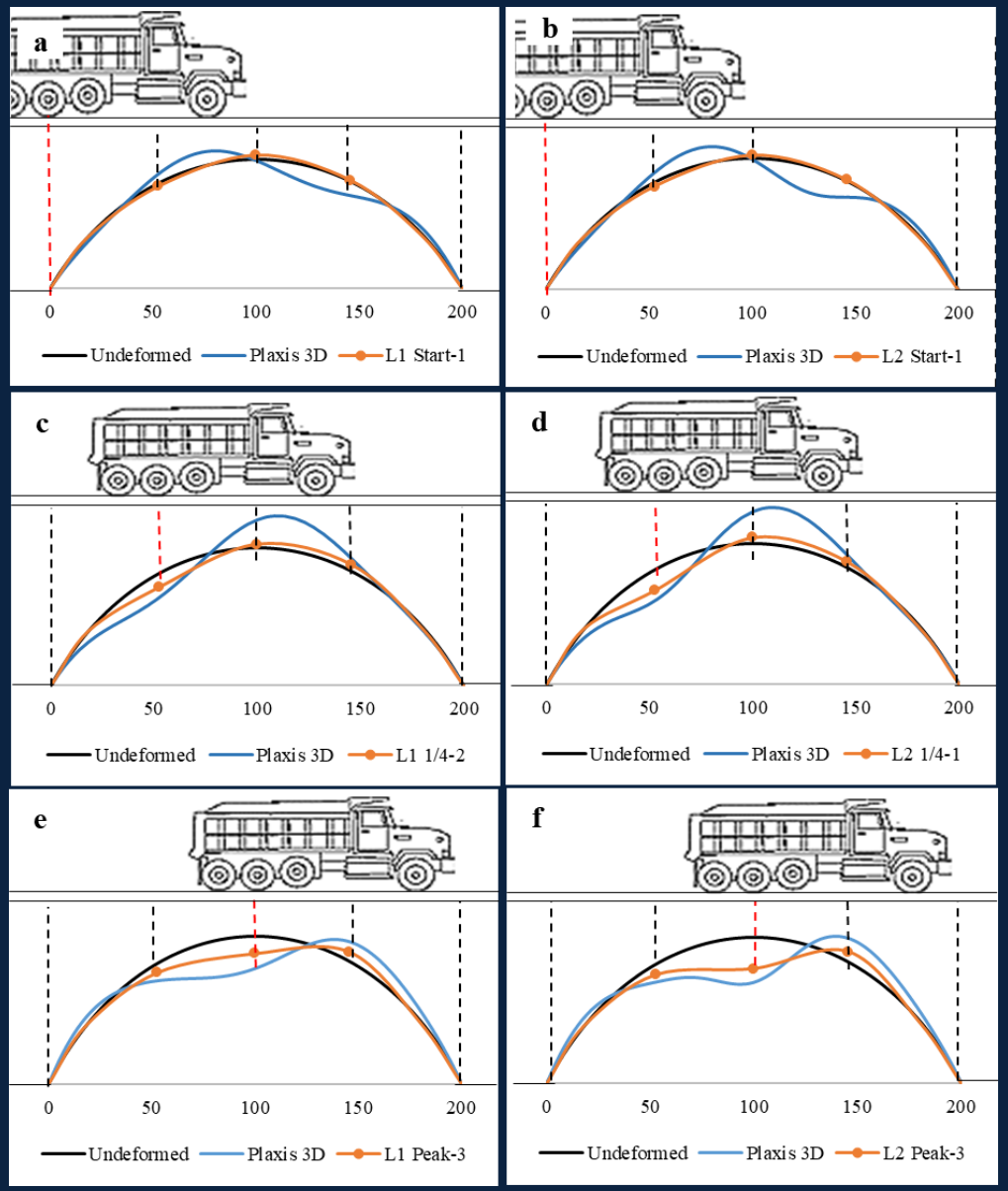


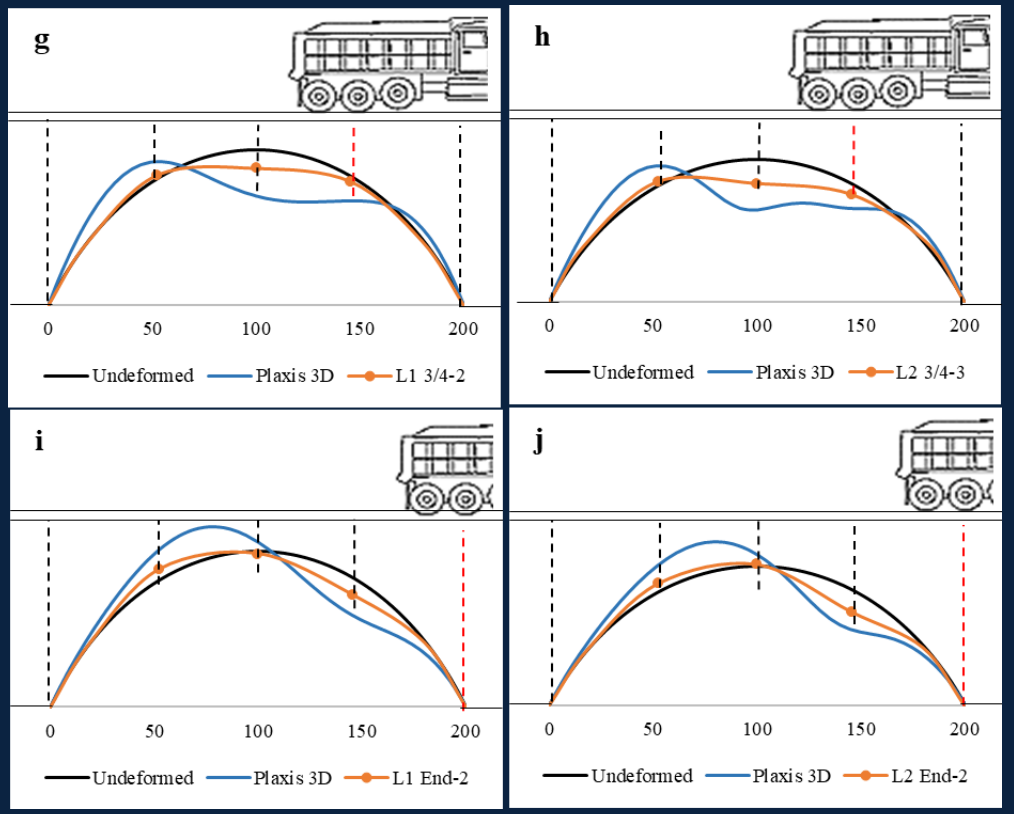
CORRUGATED METAL CULVERTS - ANNISTON, AL








a
0 50 100 150 200
Undeformed Plaxis 3D L1 Start-1
b
0 50 100 150 200
Undeformed Plaxis 3D L2 Start-1
c
0 50 100 150 200
Undeformed Plaxis 3D L1 1/4-2
d
0 50 100 150 200
Undeformed Plaxis 3D L2 1/4-1
e
0 50 100 150 200
Undeformed Plaxis 3D L1 Peak-3
f
0 50 100 150 200
Undeformed Plaxis 3D L2 Peak-3


g
0 50 100 150 200
Undeformed Plaxis 3D L1 3/4-2
h
0 50 100 150 200
Undeformed Plaxis 3D L2 3/4-3
i
0 50 100 150 200
Undeformed Plaxis 3D L1 End-2
j
0 50 100 150 200
Undeformed Plaxis 3D L2 End-2




AUBURN
ASEL

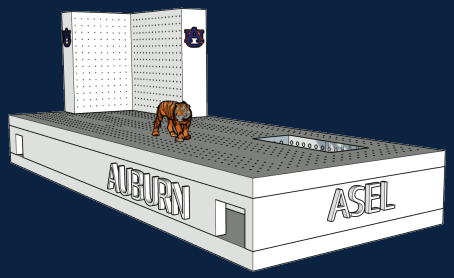
CORRUGATED METAL CULVERT - ANNISTON, AL

- Objective
  - Conduct field load testing to load rate corrugated metal culverts
- Outcomes
  - Proved culverts could carry truck loads much higher than would be expected
  - Collected information to amend analytical load ratings



LESSON LEARNED

- Arch culverts with thin soil cover should not necessarily default fail load rating
- A load truck or a heavy vehicle with known axle loads, can be used with simple displacement measurements to assess performance
- Be confident in analytical and numerical models before attempting!



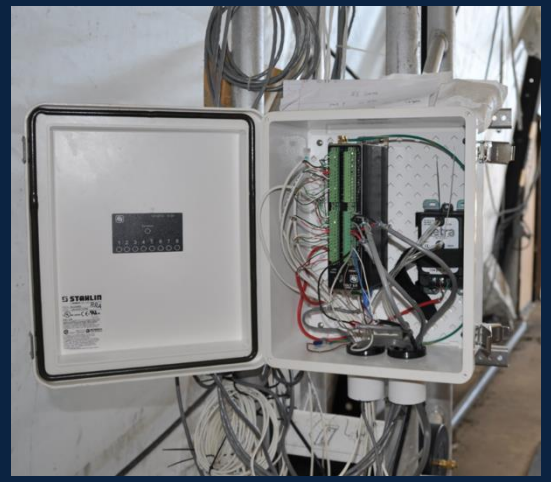
MAINTENANCE SHELTER





MAINTENANCE SHELTER







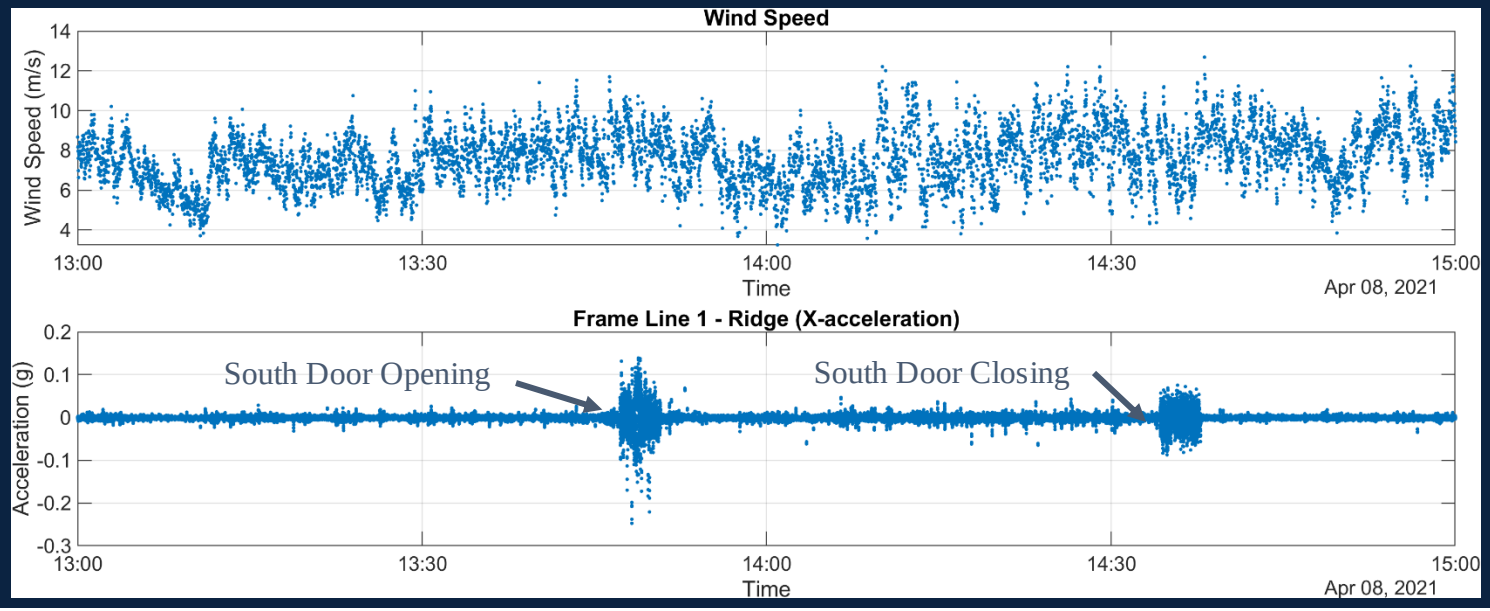


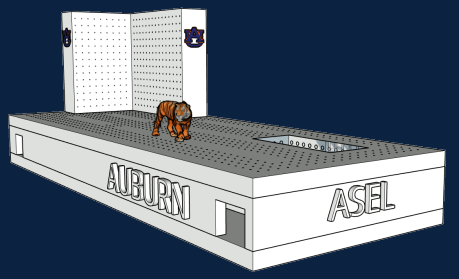




MAINTENANCE SHELTER

- Objective
  - Collect weather data and structure / fabric response to high wind events
- Outcomes
  - Two high wind events occurred during active monitoring period
  - Provided guidance to owners regarding load paths and structure / fabric response





LESSONS LEARNED

- Modern distributed data acquisition systems can reduce expensive cabling and consolidate measurements into a single system.
- Sometimes, new hardware isn't quite ready for deployment.
- It's easy to work outside during a pandemic but challenging to stay in hotels and work with agencies who are all working from home.



NEW LAB ALERT!

- What if we could:
  - Control the soil profile?
  - Have access to loading jacks and fixtures?
  - Plentiful clean electricity and bathrooms on site?
  - Remove weather from the equation?
  - Reduce the number of unknown unknowns…

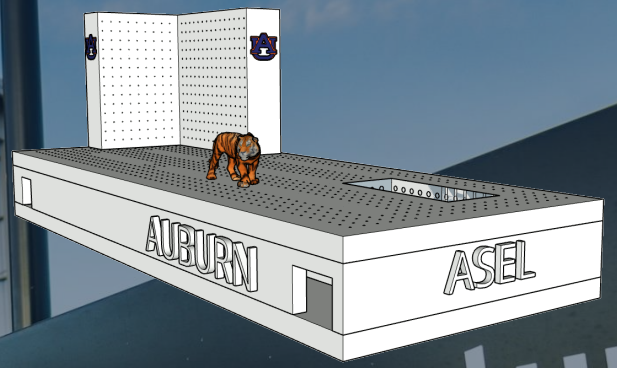


ASEL - ADVANCED STRUCTURAL ENGINEERING LAB

State-of-the-art facility for macro-scale experimental characterization and performance testing of infrastructure, engineering materials (concrete, metals, timber, soils, aggregates), structural components, structural systems, and integrated soil-structure systems.

- Vulcan Materials Company Laboratory
- Auburn University Concrete Materials Laboratory





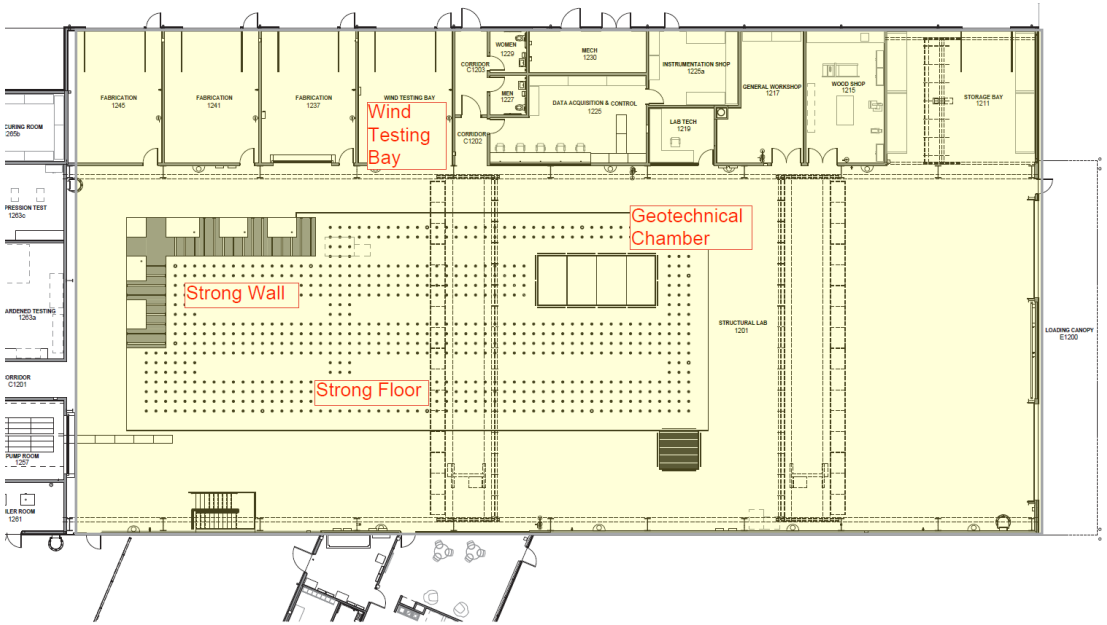
Advanced Structural Engineering Laboratory

1170 West Samford Avenue

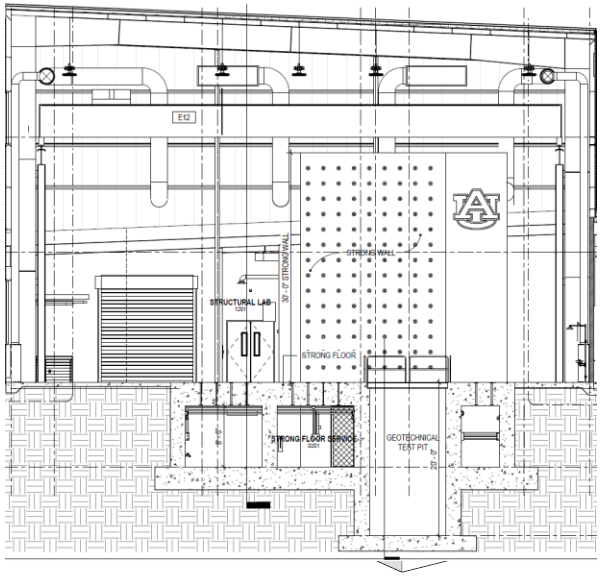
Vulcan Materials Company Laboratory

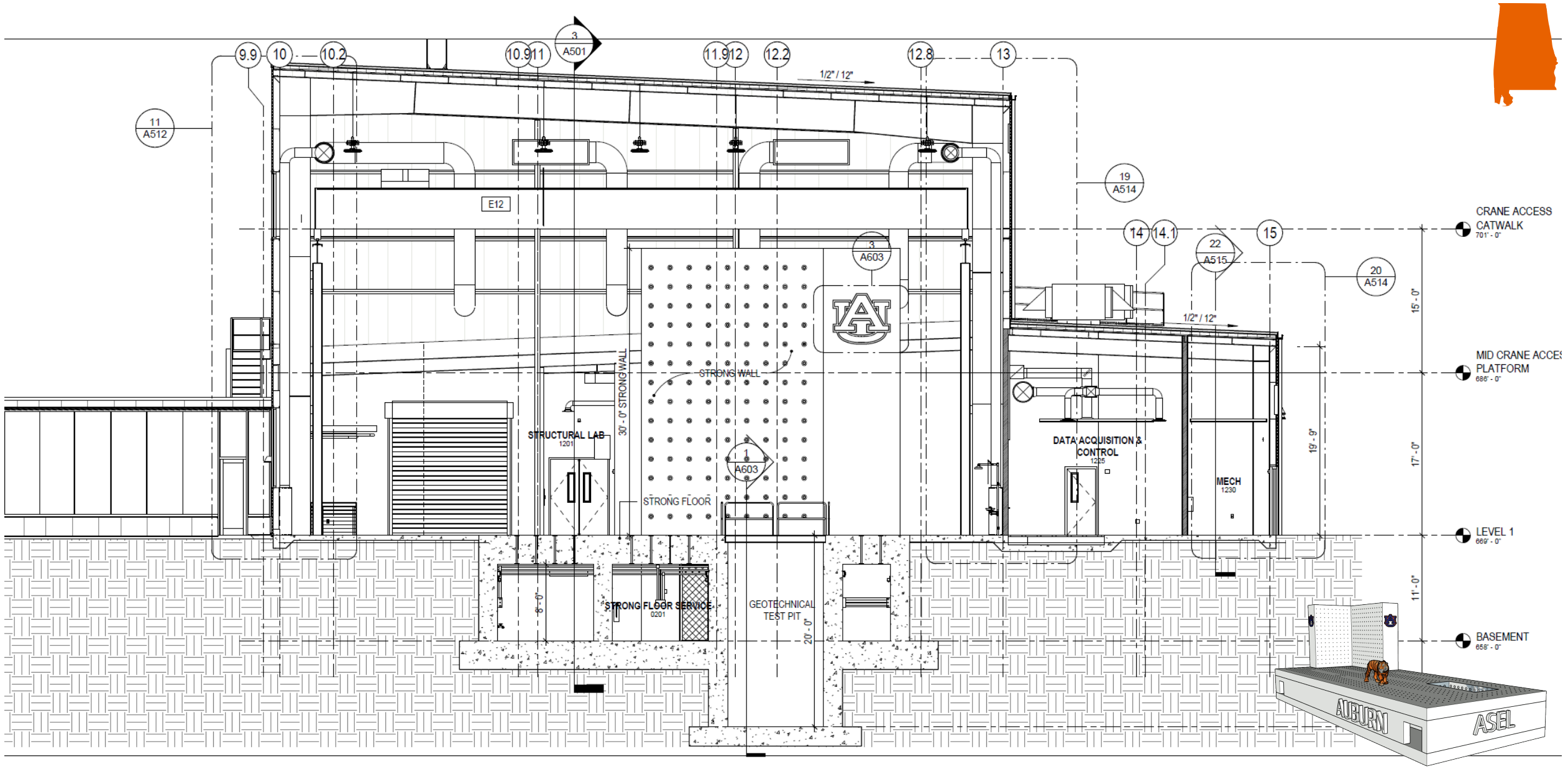
- Main laboratory footprint of 200ft x 73ft and 32ft from floor to crane level.
- Dual overhead 60 kip cranes
- 120 ft x 45 ft (5400 ft^2) strong floor and a 30 ft tall L-shaped strong wall with orthogonal leg lengths of 19 ft and 31 ft.
- Geotechnical chamber 20 ft deep is contained *within* the strong floor with plan dimensions of 24 ft x 10 ft.
- A 180 gpm MTS hydraulic pump powers the 3,000 psi hydraulic system. Nine hydraulic actuators that range in capacity from 52 kips up to 446 kips can be used for both static and dynamic loading.
- Two dynamic Universal Testing Machines (UTMs), one 22 kip (100 kN) and one 225 kip (1000 kN) capacity.
- The 22 kip UTM has an environmental chamber for high and low temperature testing (-200 F to 1000 F).
- 27 ft x 20 ft wind testing bay is includes two Pressure Loading Actuators (PLAs) capable of replicating hurricane level dynamic wind loads on structural components and systems.

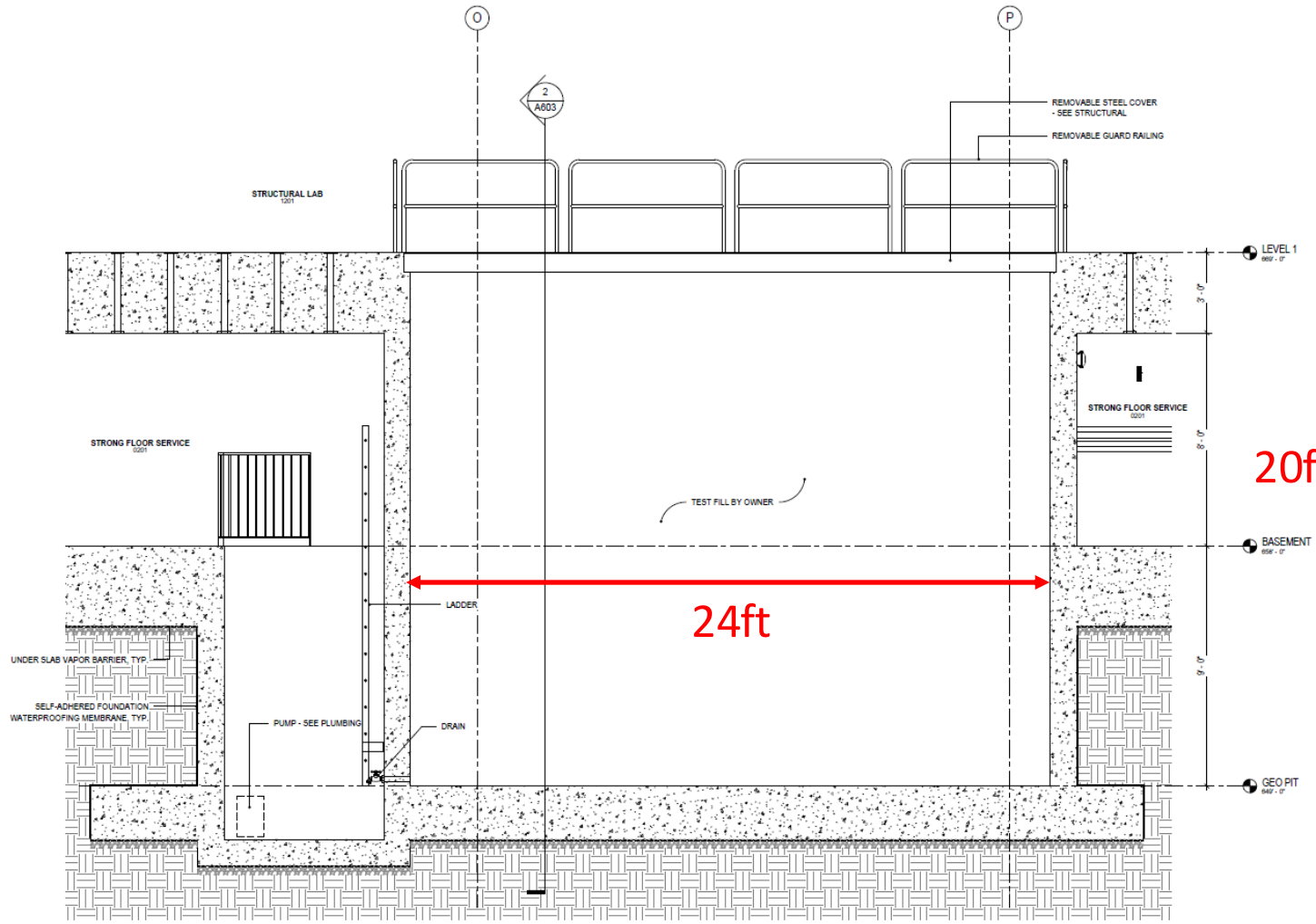




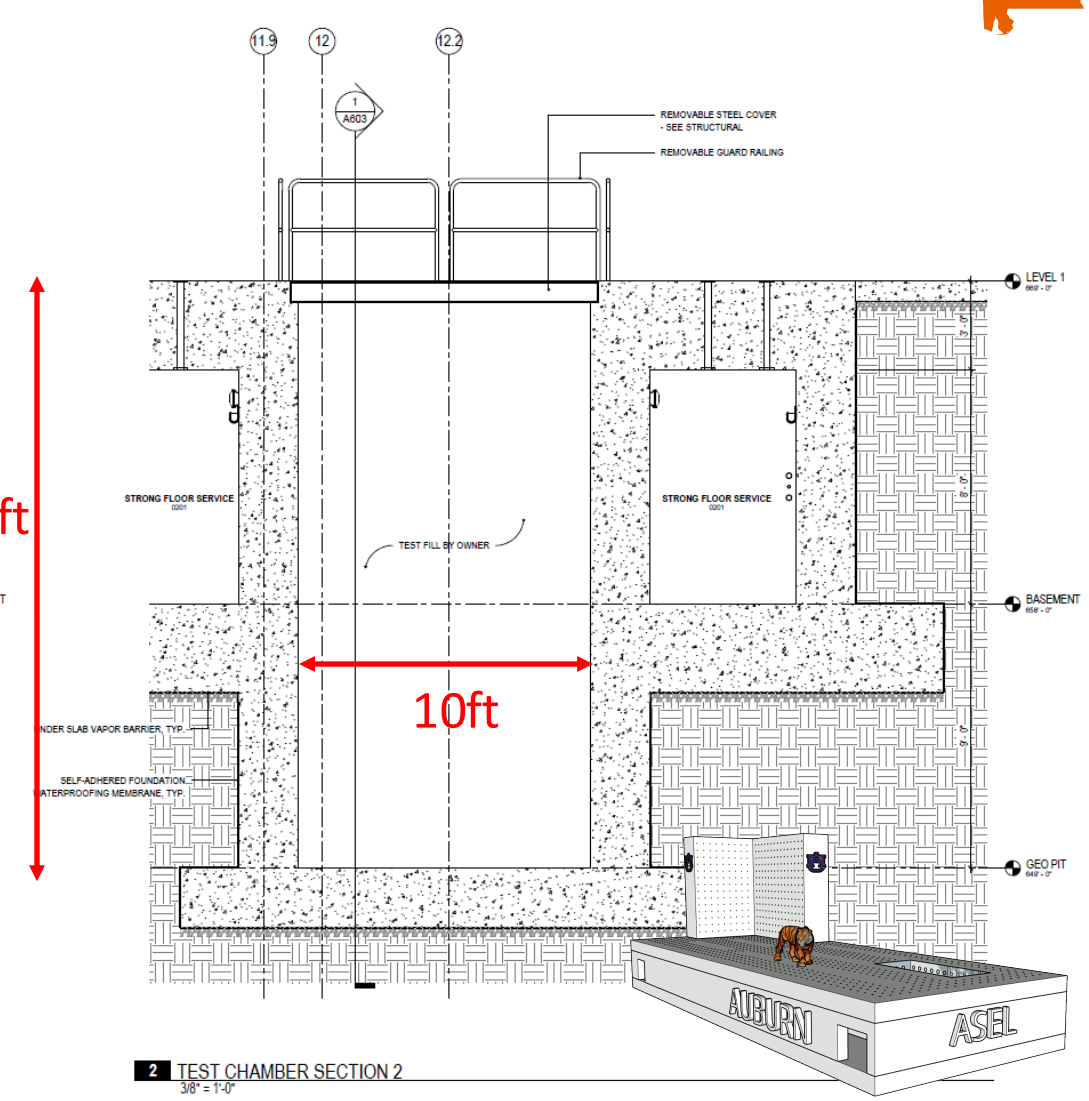





9.9
10
10.2
10.9
11
11.9
12
12.2
12.8
13
14
14.1
15
3
A501
11
A512
19
A514
20
A514
22
A515
3
A603
1
A603
E12
1/2" / 12"
1/2" / 12"
CRANE ACCESS CATWALK
701' - 0"
MID CRANE ACCES PLATFORM
686' - 0"
LEVEL 1
669' - 0"
BASEMENT
658' - 0"
15' - 0"
17' - 0"
19' - 9"
11' - 0"
STRONG WALL
30' - 0" STRONG WALL
STRUCTURAL LAB
1201
STRONG FLOOR
STRONG FLOOR SERVICE
0201
GEOTECHNICAL TEST PIT
8' - 0"
20' - 0"
DATA ACQUISITION & CONTROL
1225
MECH
1230
AUBURN
ASEL



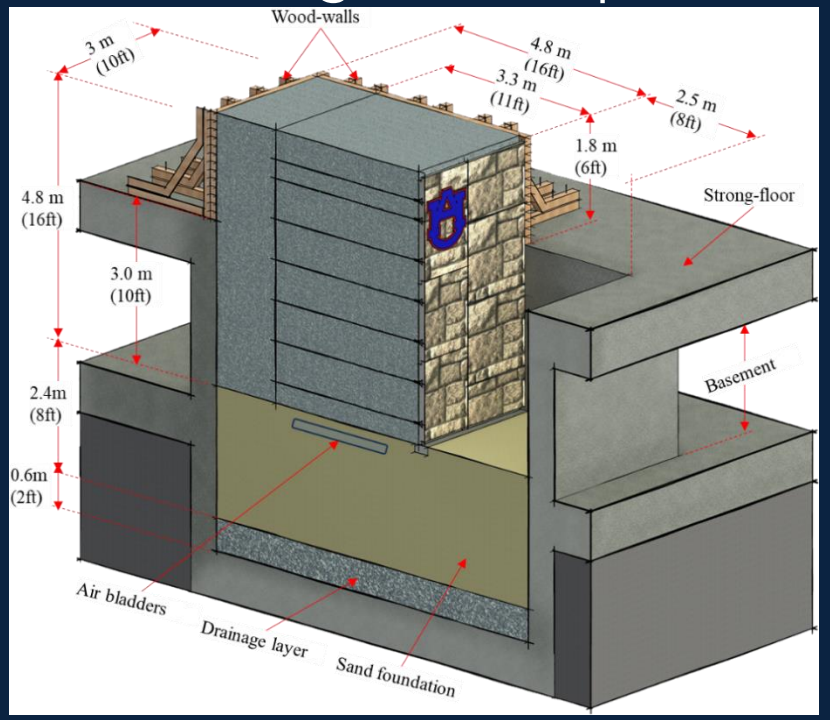
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3/8" = 1'-0"

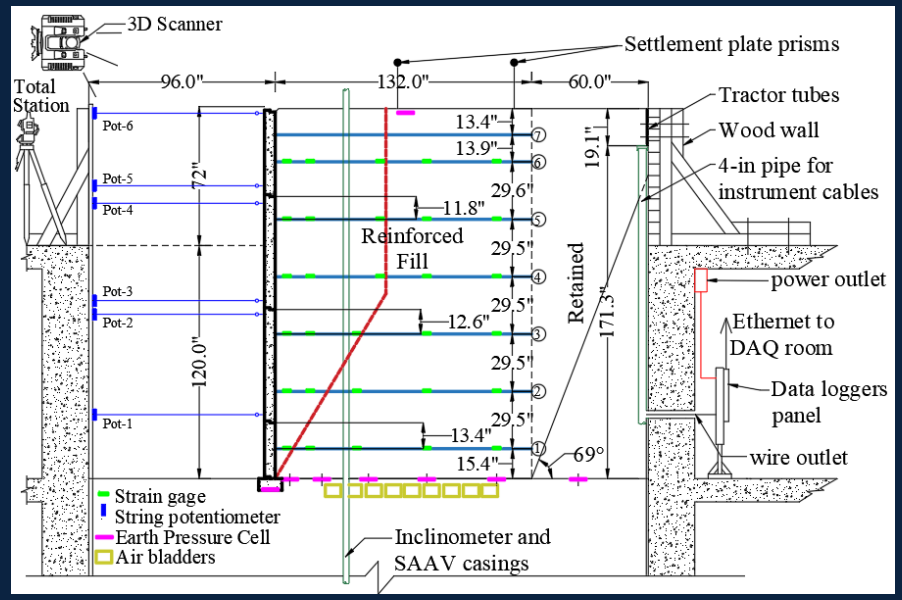


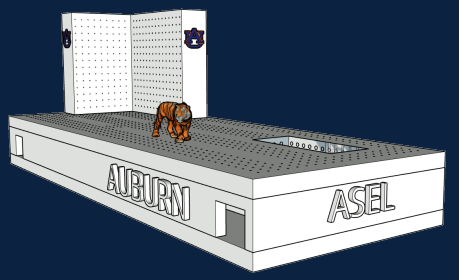
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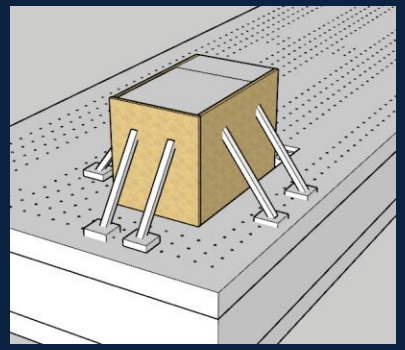
MSE WALL - ASEL, AUBURN

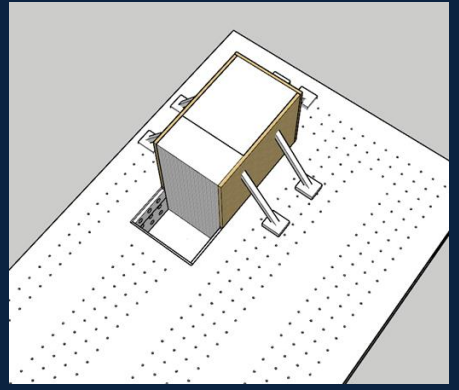
- Construct and instrument MSE Structures
- Measure bearing pressure and settlement when foundation defective
- Evaluate design assumptions and propose bearing stress distribution



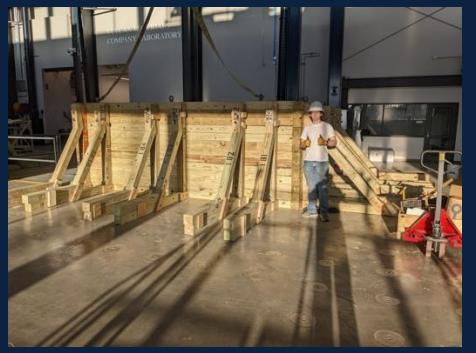










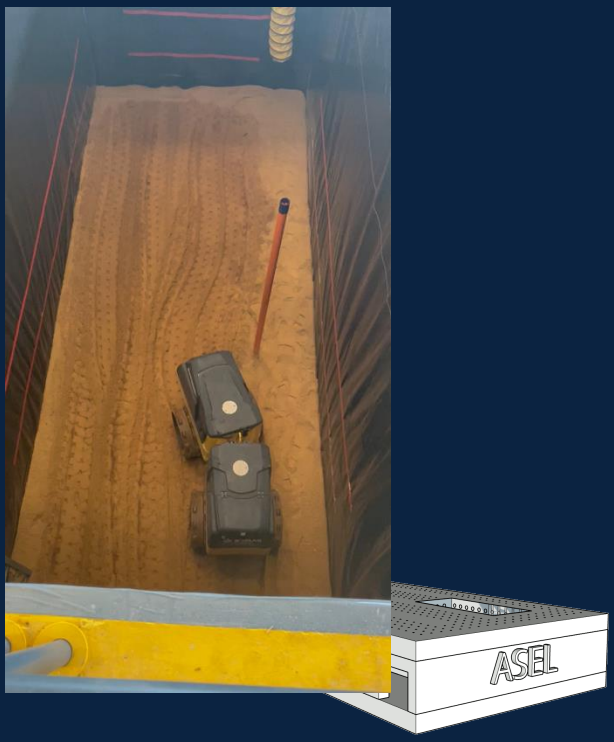


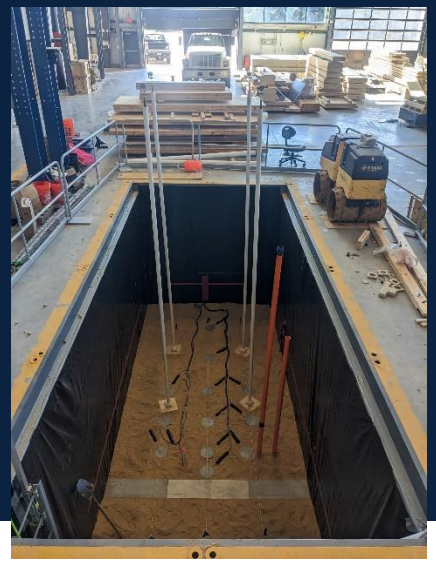


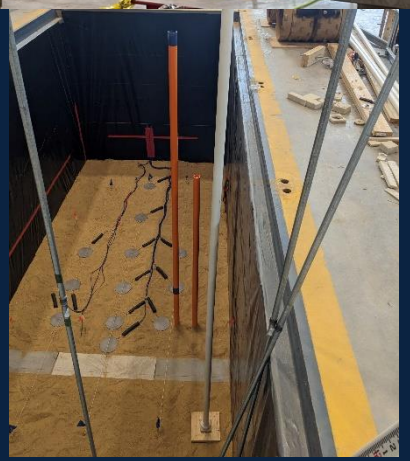

KUBOTA



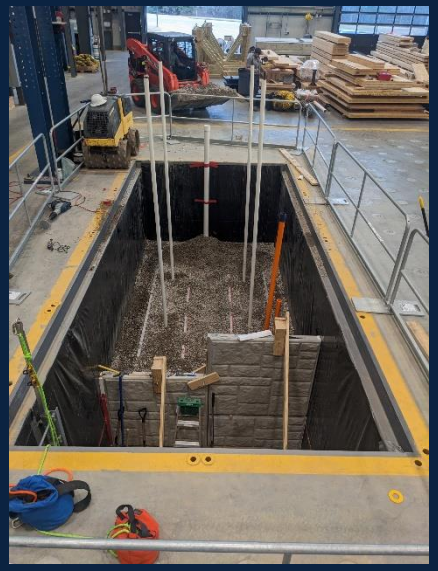


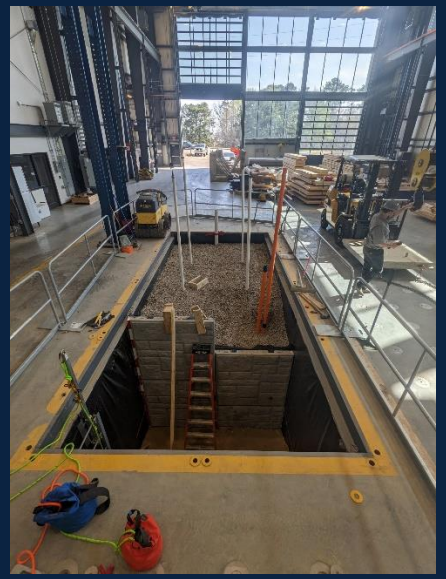

ASEL

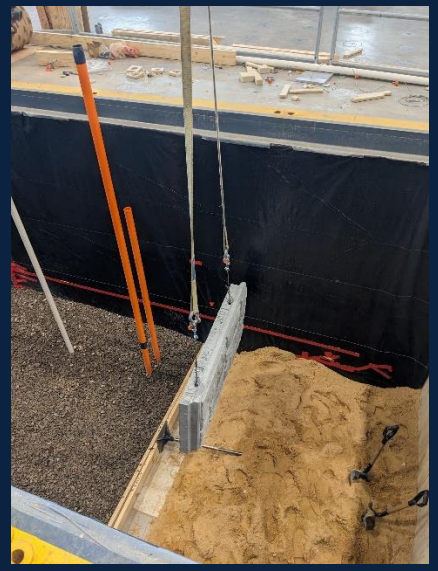


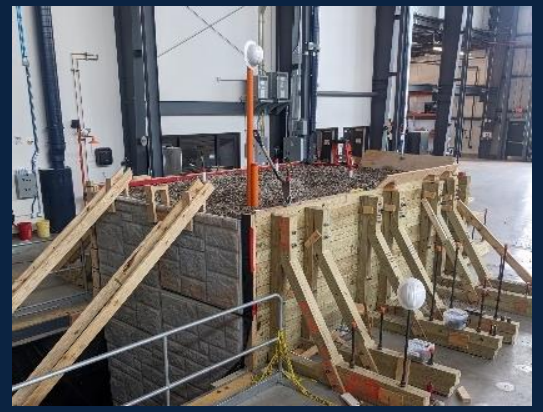


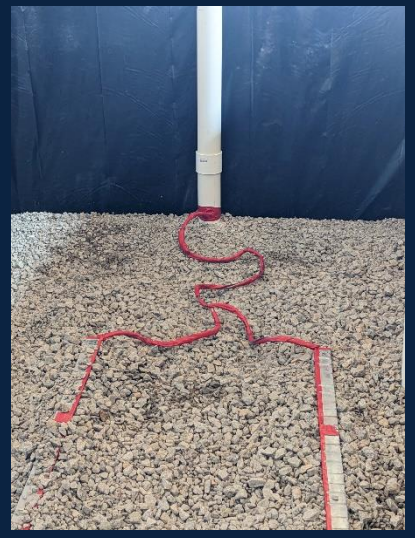


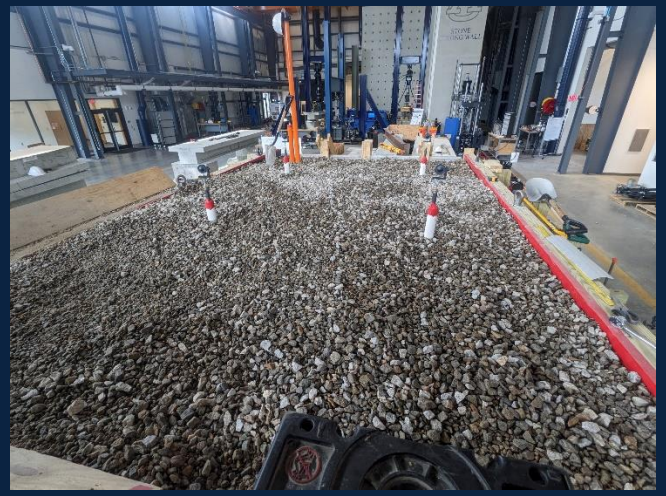




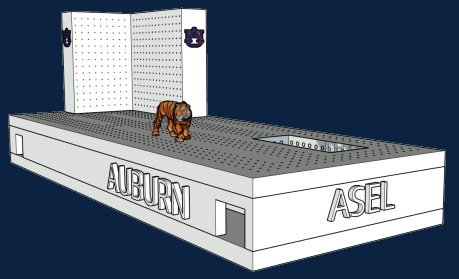











AUBURN
ASEL

HIGHWAY SURCHARGE WITH SAND BAGS…



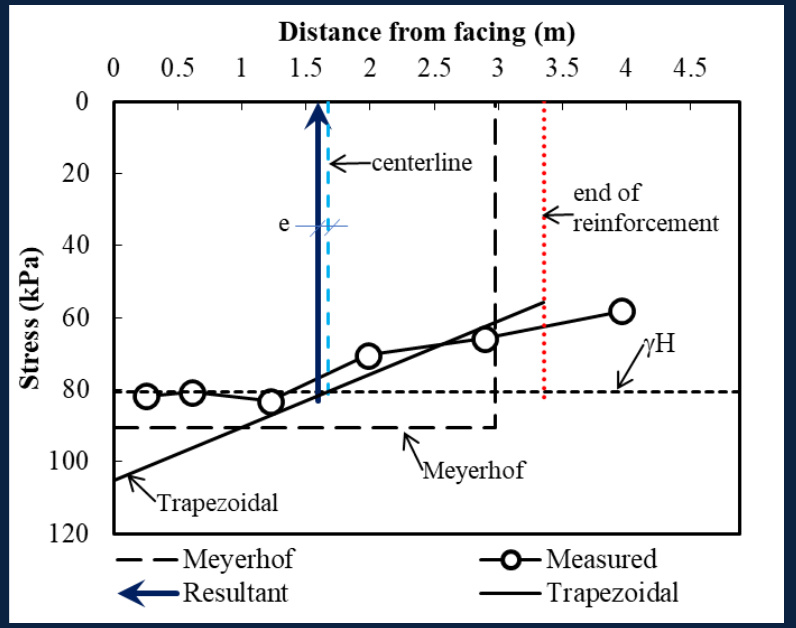


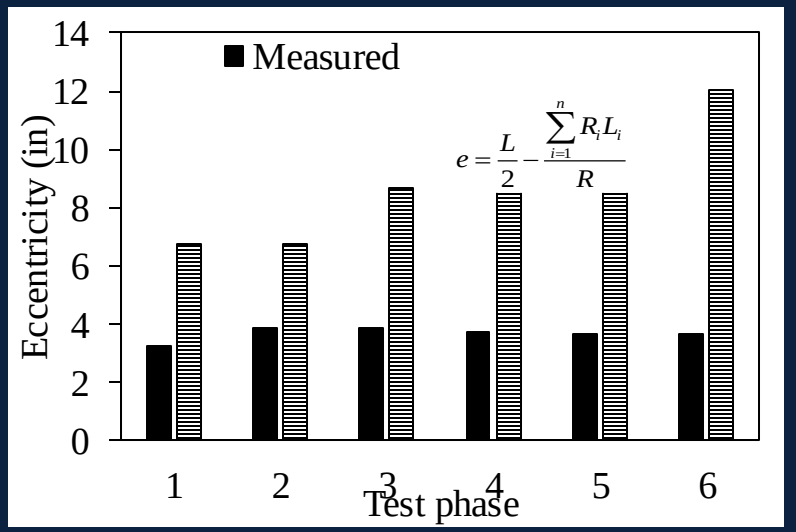
Why not overload…

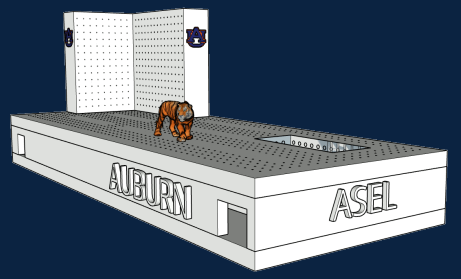


MSE WALL - ASEL, AUBURN

- Objective
  - Determine bearing stress distribution under MSE structure
  - Simulate poor foundation in laboratory test
- Outcomes
  - Measured bearing stress well below the recommended Meyerhof
  - Verified minimal eccentricity of resultant foundation load
  - Demonstrated the stress redistribution with foundation defect







LESSONS LEARNED

- Verified by experiment that MSE walls redistribute bearing stresses and are conservatively designed.
- Safety is key, but sometimes we have to accept a little risk in order to conduct any work at all.
- We know how to build MSE walls that do not move.
- Laboratory tests will always come with limitations that must be acknowledged and accounted for.



WHAT'S NEXT – LOAD TESTING OF LAMINATED TIMBER SHALLOW AND DEEP FOUNDATIONS – NGES OPELIKA, AL







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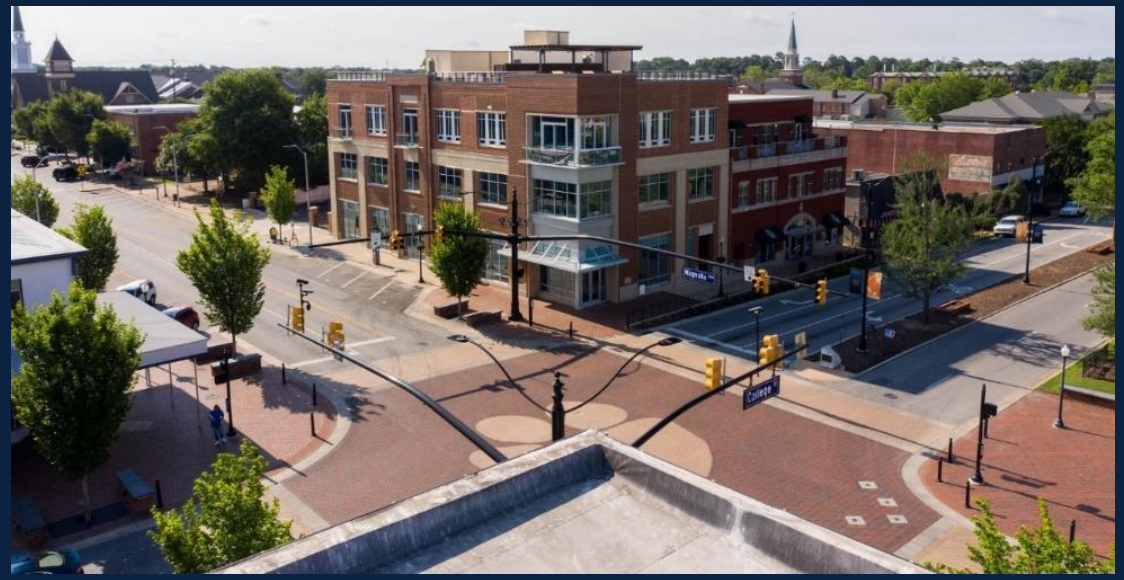


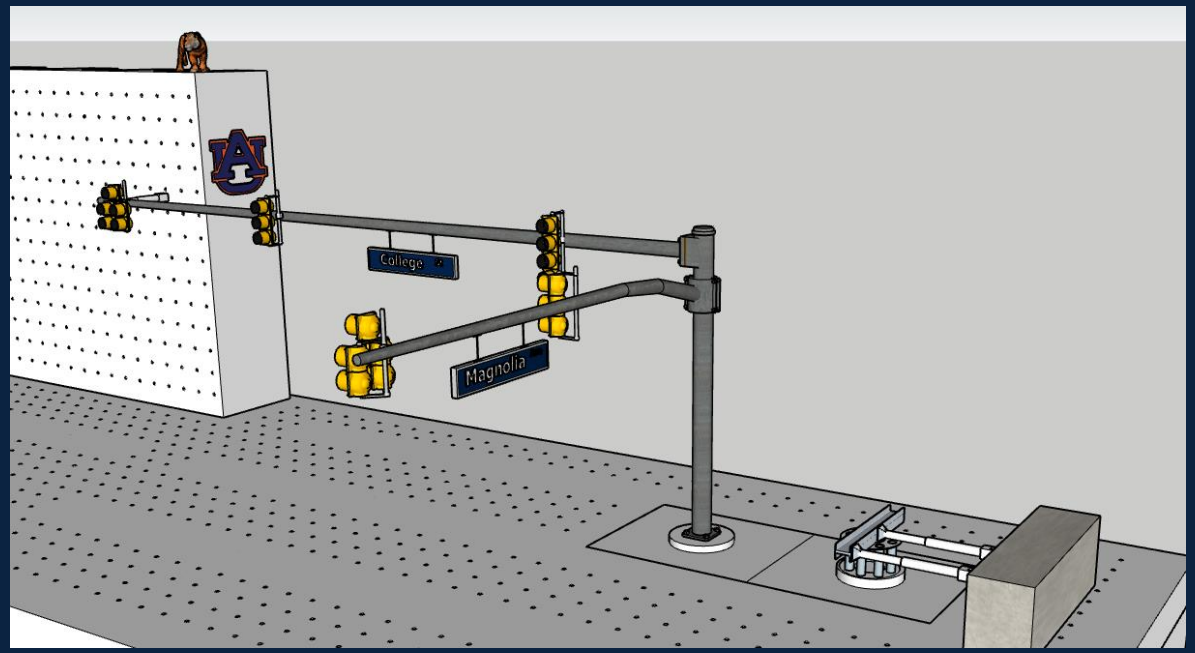






WHAT'S NEXT? – FULL SCALE TESTING OF MAST ARM STRUCTURES AND FOUNDATIONS @ ASEL





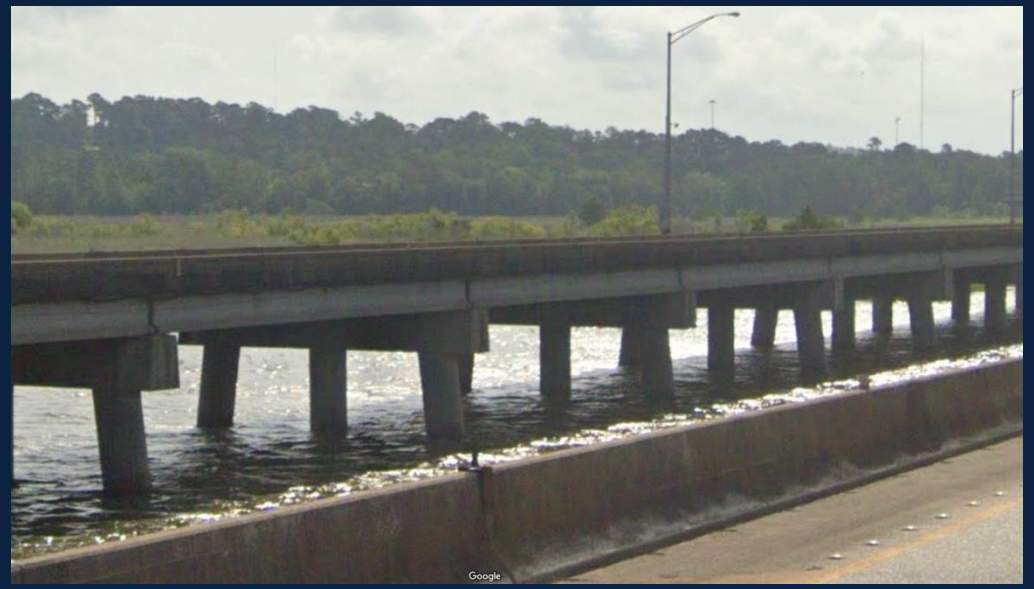


WHAT'S NEXT? – FULL SCALE SIMULATION OF H-PILE EMBEDMENT TO DETERMINE ROTATIONAL FIXITY @ ASEL





WHAT'S NEXT – PLANNING FOR FUTURE LOAD TESTING PROGRAM ON THE DECOMMISSIONED MOBILE RIVER BAYWAY







OVERALL LESSONS LEARNED

- In the vast majority of cases, most tests exhibited better (stronger, stiffer) than predicted.
- Real performance can be controlled by factors that are not captured well in models.
- Appreciate and respect limitations of large tests, but don't necessarily use them as reasons not to test.
- Communicate!
- Safety first, always.





OVERALL LESSONS LEARNED

- Prepare, prepare, and prepare some more. Then, go back and prepare.
- Be patient, do not force things to happen (no pushing on ropes).
- Time is money.
- Leverage as many resources as you can. Perform multiple tests if possible.
- Having your own test site and laboratories makes as tests like these possible.
- Great contractor friends are a huge benefit as well!





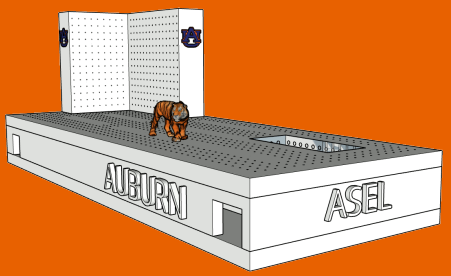
ACKNOWLEDGEMENTS

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- Florida DOT
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- Scott Bridge Company, Opelika AL
- Applied Foundation Testing, Green Cove Springs, FL
- City of Anniston, AL
- Auburn University Highway Research Center
- Cambell Scientific, Geokon, GPE Inc.



WAR EAGLE!



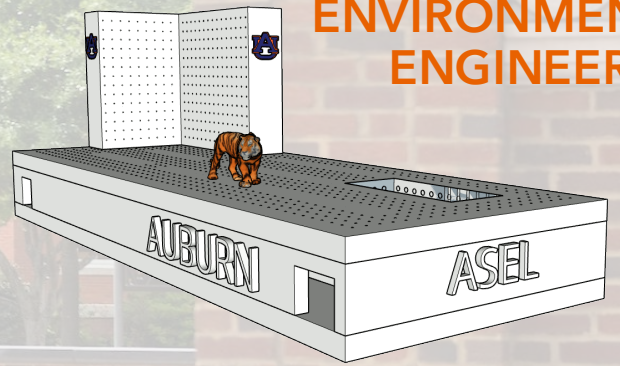


GeoVirginia

LESSONS LEARNED FROM 25 YEARS OF SOIL-STRUCTURE TESTING AT FULL SCALE

ADVANCED STUCTURAL ENGINEERING LABORATORY

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING



J. Brian Anderson, Ph.D., P.E.

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