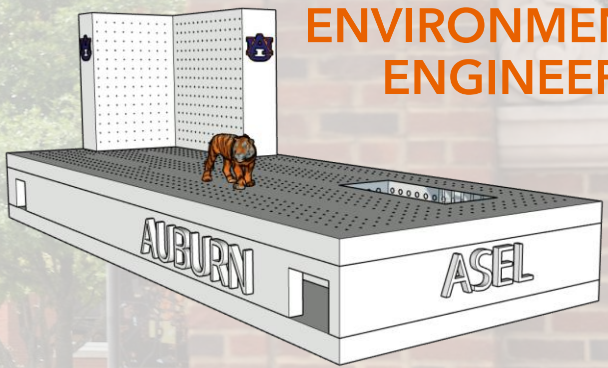
MECHANICALLY STABILIZED EARTH WALL – POOR FOUNDATION EXPERIMENT

ADVANCED STUCTURAL ENGINEERING LABORATORY

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING



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AUBURN

OUTLINE

- Introduction
- Motivation
- Objective
- Experimental Setup
- Construction
- Loading
- Results
- Conclusions

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INTRODUCTION

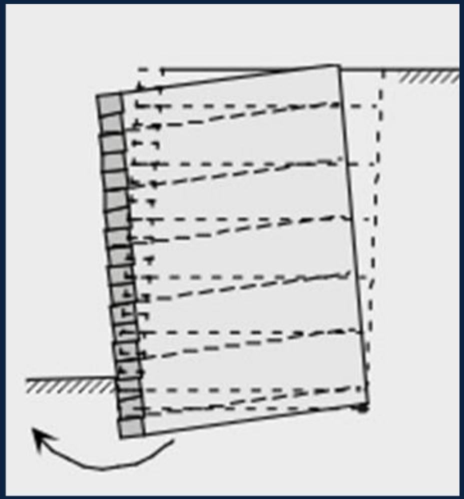
- Retaining walls are commonly used for grade separation in construction of new or expansion of existing highway.

- Mechanically Stabilized Earth (MSE) walls are created through the use of horizontal, linear reinforcing elements and compacted backfill material.

INTRODUCTION

- The largest loads from an MSE structure are often due to the mass of reinforced backfill.
- The foundation soils beneath the backfill must have sufficient bearing capacity so that the MSE wall and backfill meets both strength and serviceability limit states.

External stability – Bearing capacity



ADVANTAGES

- Ease of construction
- Up to 50% cost reduction
- Less construction time
- Less special skilled personnel
- Less construction space requirement
- Reduced right of way acquisition
- Incorporates architectural finishes
- Reduced carbon footprint

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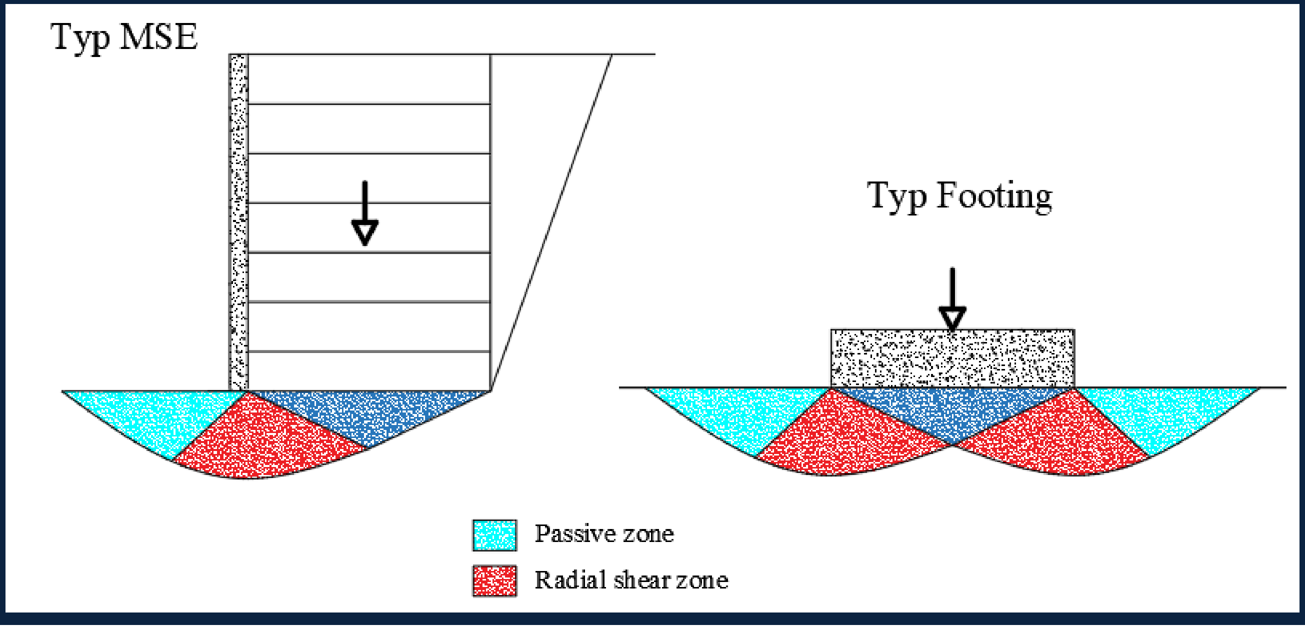
MOTIVATION

- In discussions with Bureau of Materials and Tests, there have been many recent cases where MSE walls required significant, costly foundation strengthening to meet bearing capacity requirements.
- The general feeling is that guidance from FHWA GEC 11 (Berg et al. 2009) is conservative and that the foundation stresses due to the MSE retaining structures are significantly lower than or the allowable bearing pressures are higher than those used in a design.

MOTIVATION

- While the design guideline mentions that the MSE is flexible and can be used even with poor bearing foundation, a strong foundation is still assumed.
- Foundation stress function assumes a rigid block and is based on eccentrically loaded rigid footing.



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OBJECTIVE

- The objective of this study is to assess the performance of a full scale MSE structure built on foundation with pockets of poor bearing zone.
- This is part of a research program to determine vertical stress distribution at the base of an MSE retaining structure and the magnitude and location of the resultant force.

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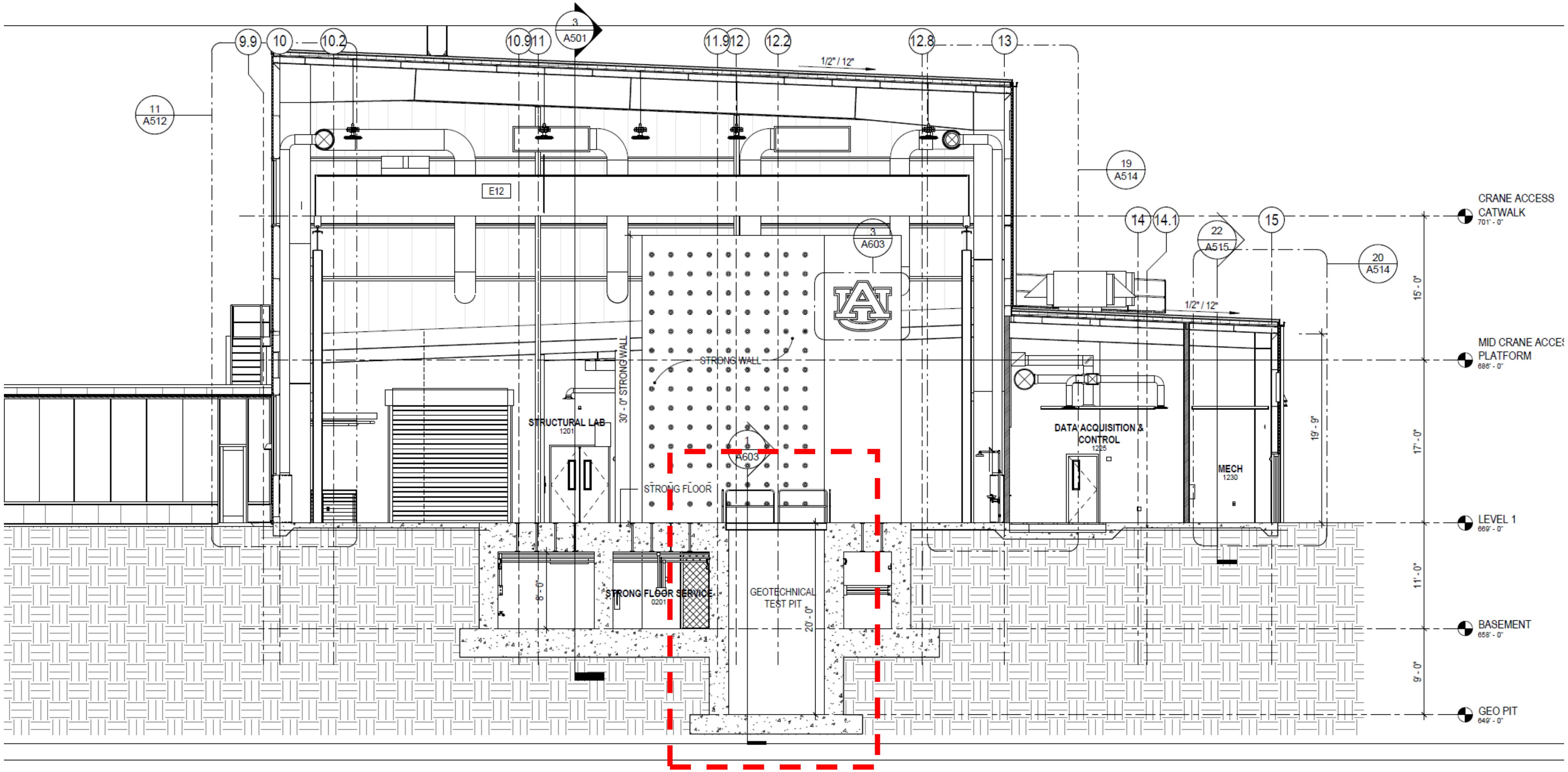
ASEL - ADVANCED STRUCTURAL ENGINEERING LAB

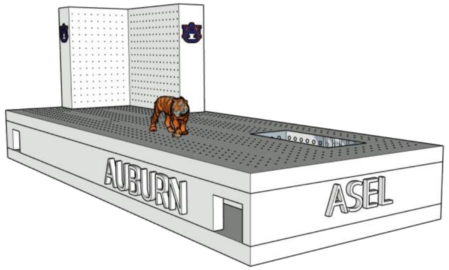
State-of-the-art facility for macro-scale experimental characterization and performance testing of infrastructure, engineering materials (concrete, metals, timber, soils, aggregates), structural components, structural systems, and integrated soil-structure systems.

- Vulcan Materials Company Laboratory
- Auburn University Concrete Materials Laboratory

GEOCHAMBER



STRUCTURAL LAB
1201
STRONG WALL
30' - 0" STRONG WALL
STRONG FLOOR
STRONG FLOOR SERVICE
0201
GEOTECHNICAL
TEST PIT
DATA ACQUISITION &
CONTROL
1225
MECH
1230
CRANE ACCESS
CATWALK
701' - 0"
MID CRANE ACCES
PLATFORM
686' - 0"
LEVEL 1
669' - 0"
BASEMENT
658' - 0"
GEO PIT
649' - 0"
1/2" / 12"
E12



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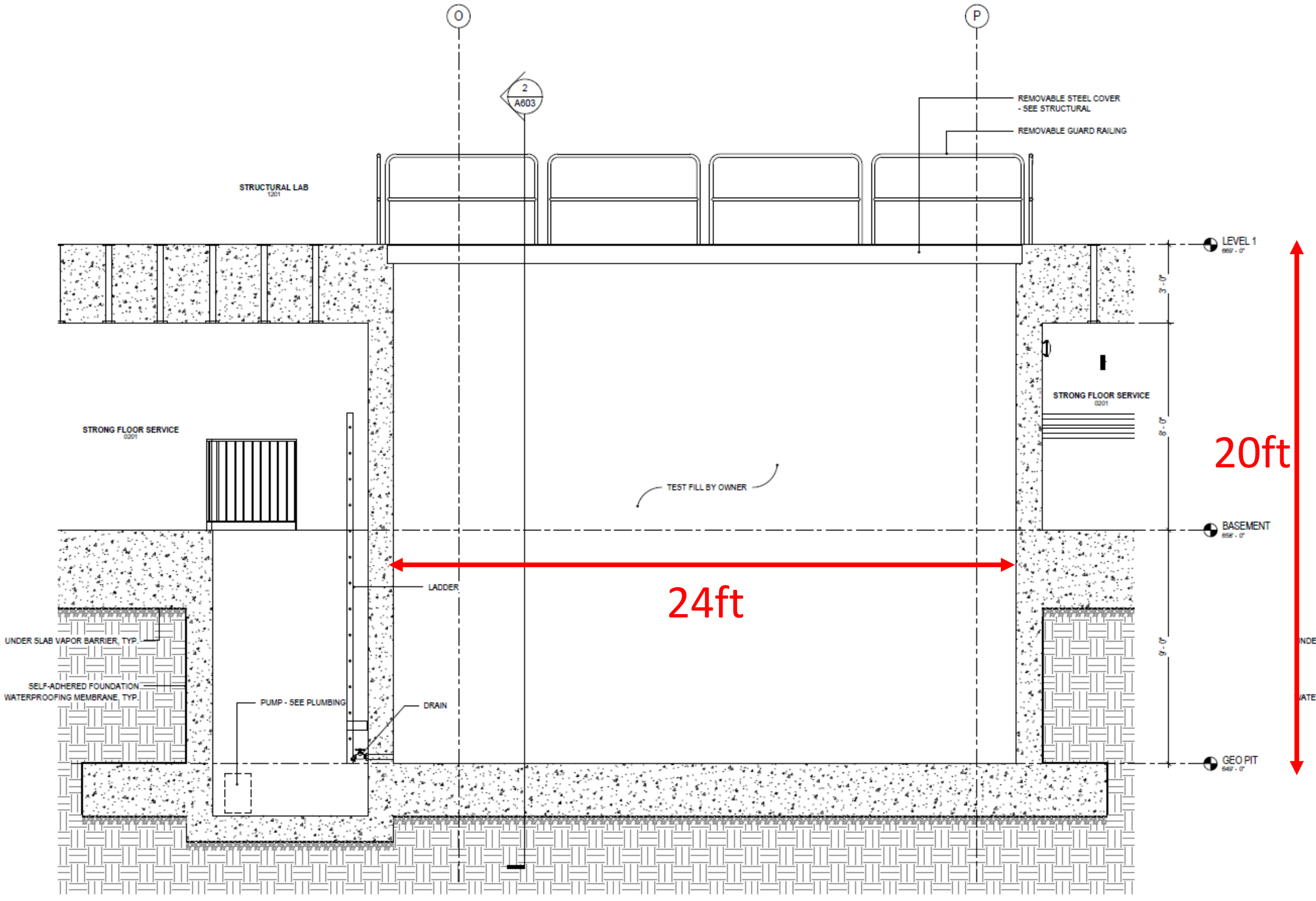
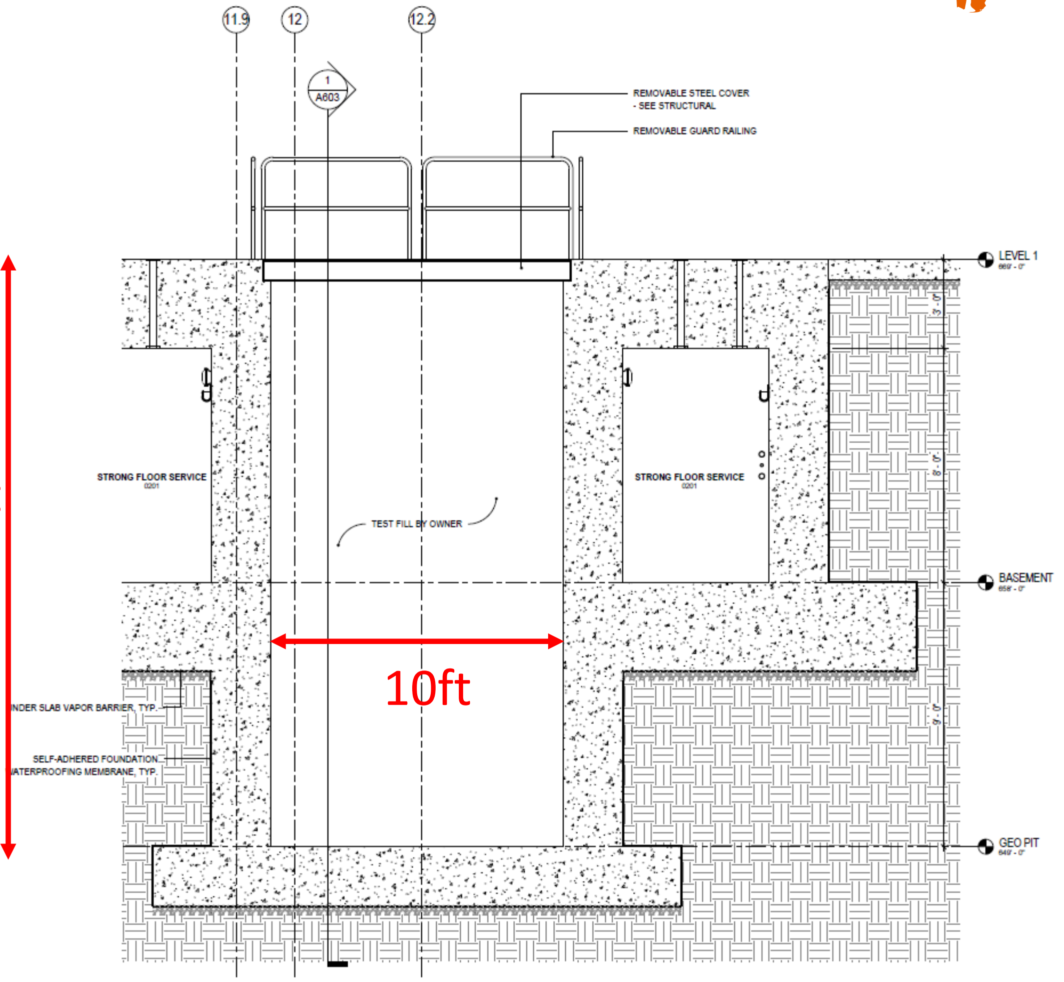
GEOCHAMBER DIMENSIONS

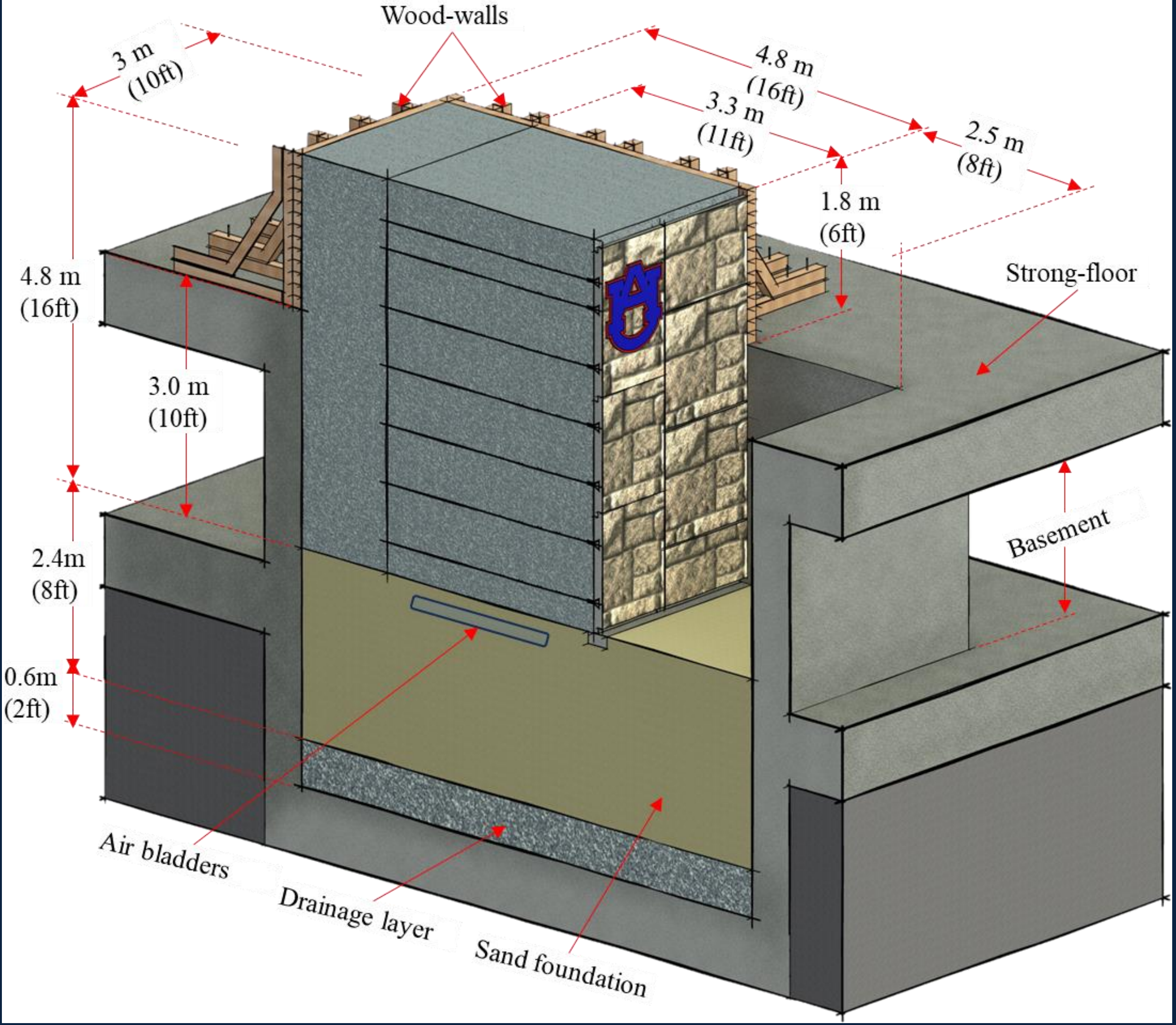


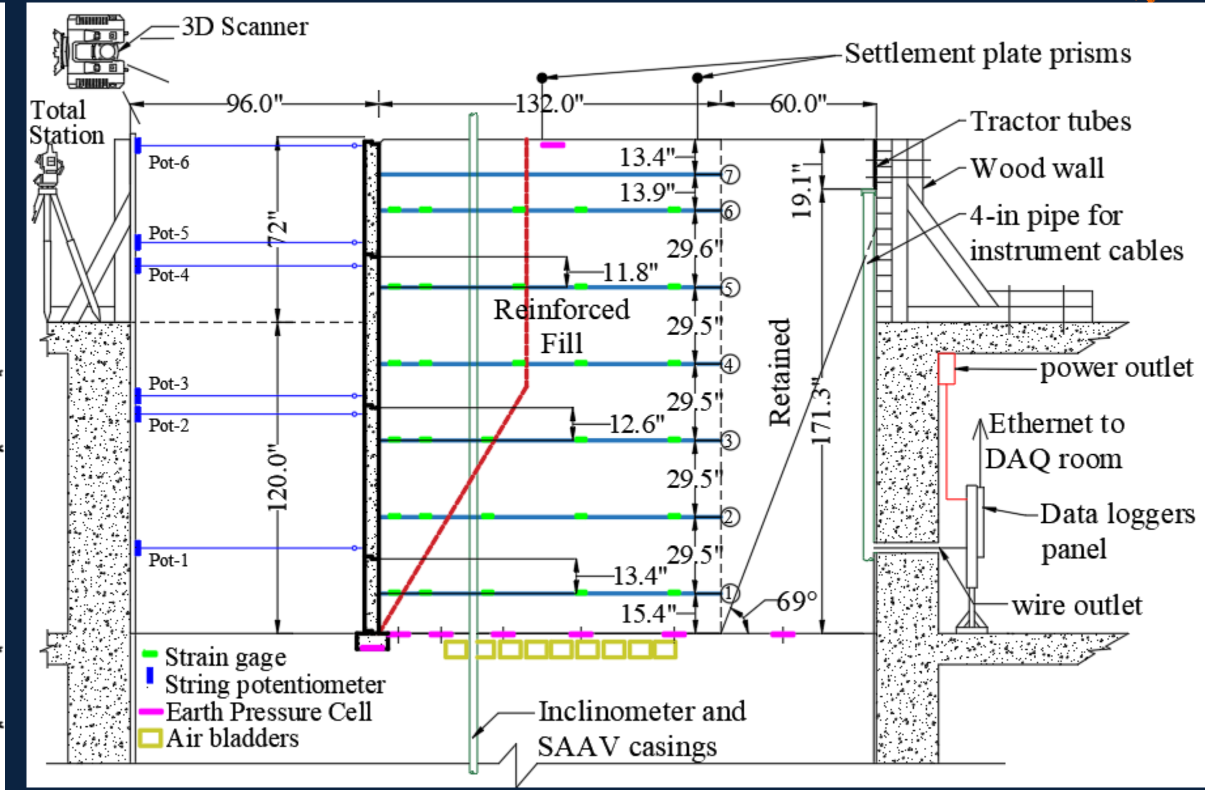
1 TEST CHAMBER SECTION 1
3/8" = 1'-0"



2 TEST CHAMBER SECTION 2
3/8" = 1'-0"

EXPERIMENTAL SETUP

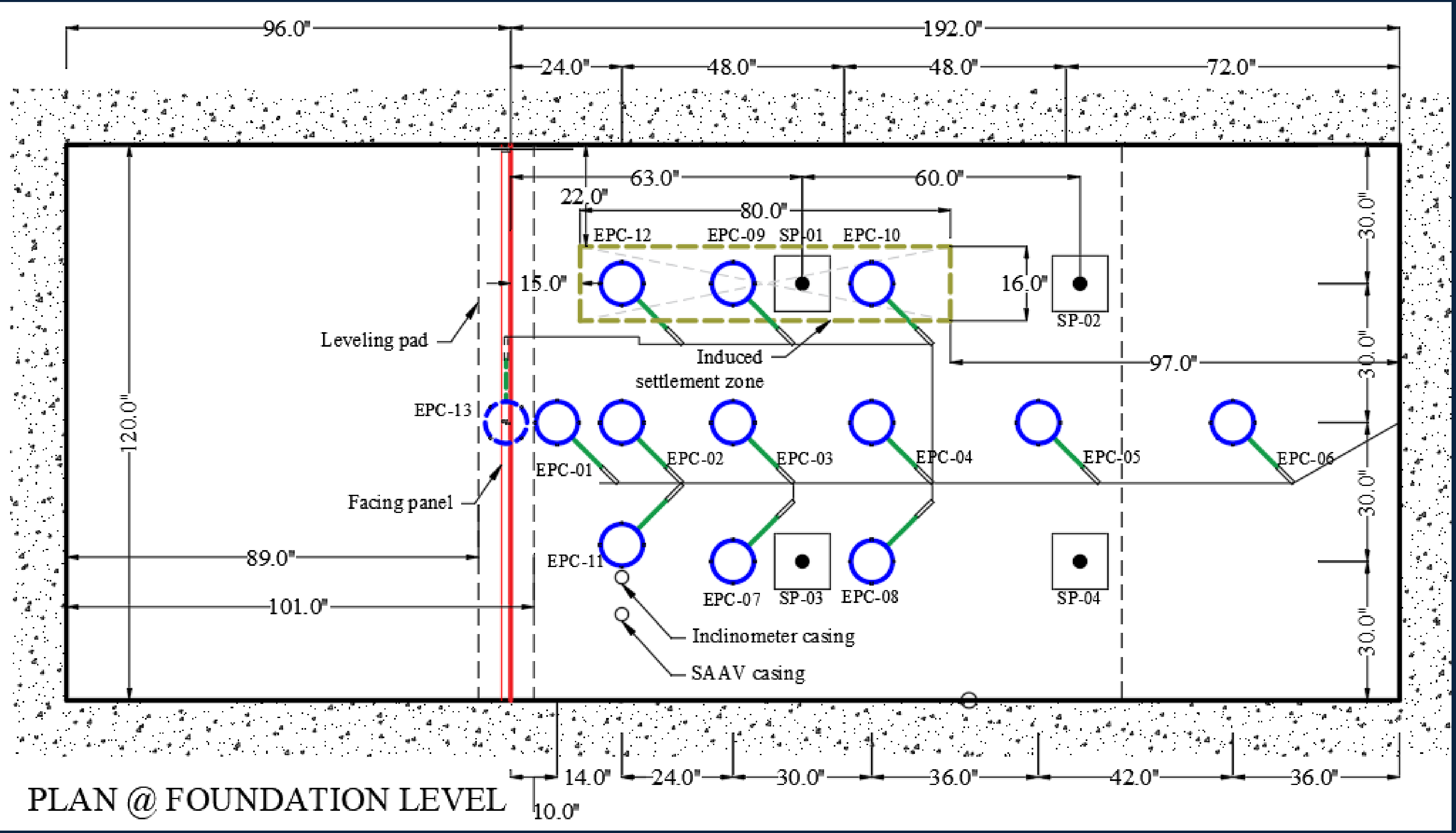




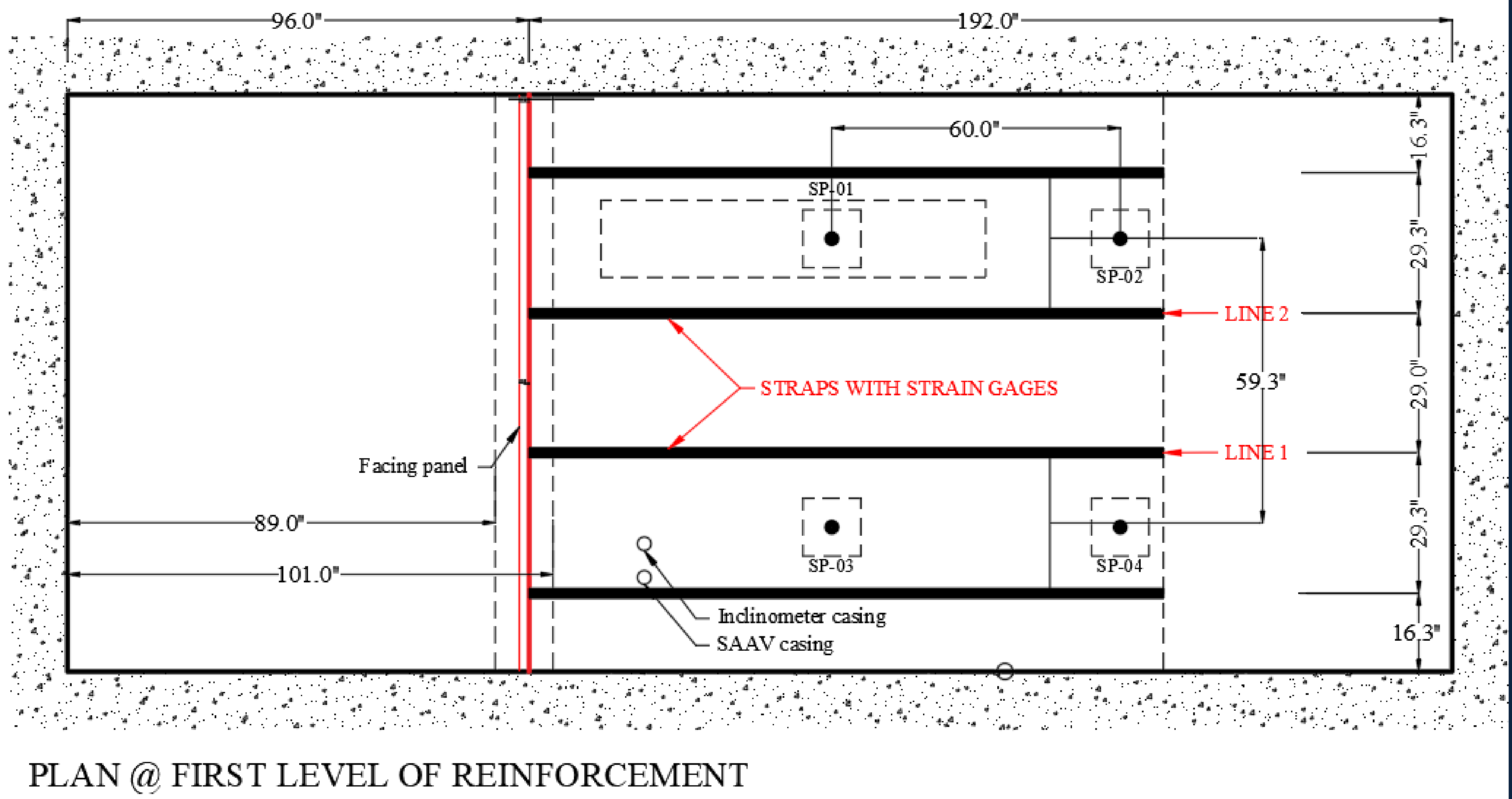
INSTRUMENTATION

- Vibrating wire earth pressure cells
- Foil resistance strain gages
- Settlement plates
- Slope inclinometer
- Shape array (SAAV)
- Draw wire potentiometer
- 3D laser scanner
- Total station

EXPERIMENTAL SETUP



EXPERIMENTAL SETUP



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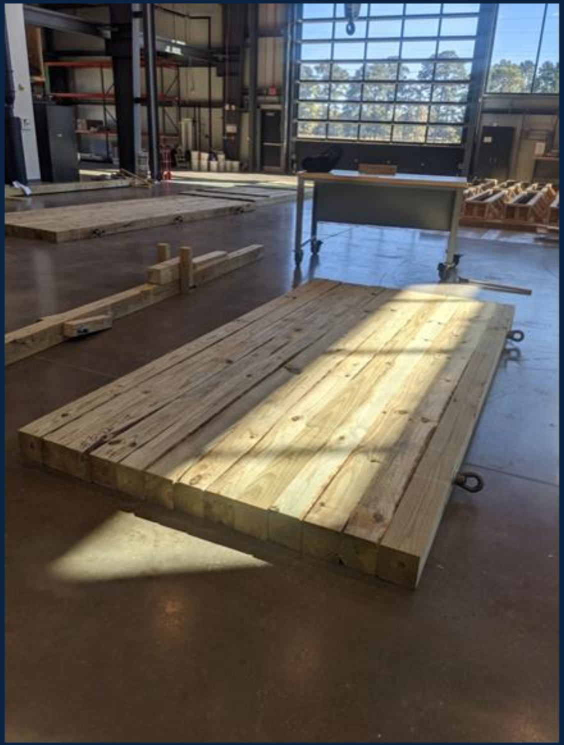
CONSTRUCTION

Materials

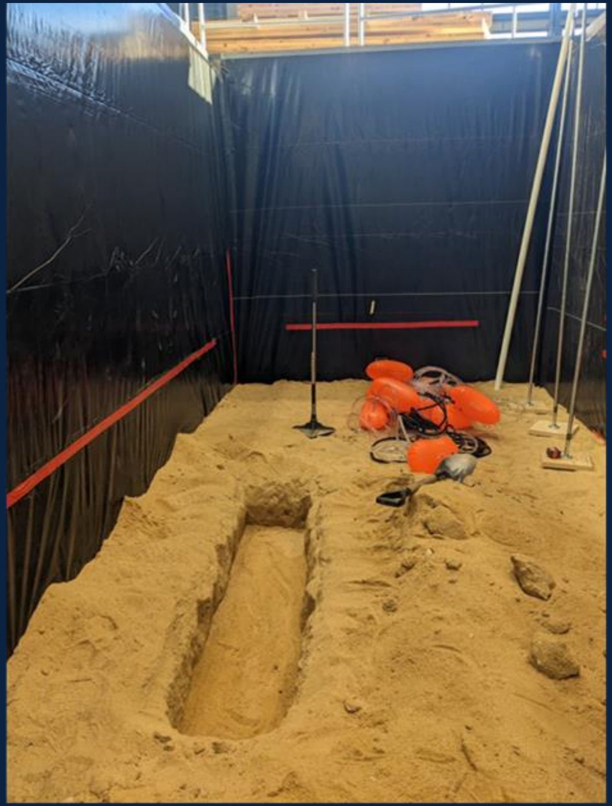
- Drainage layer
- Foundation sand
- #57 crushed stone
- Precast panels
- Steel straps

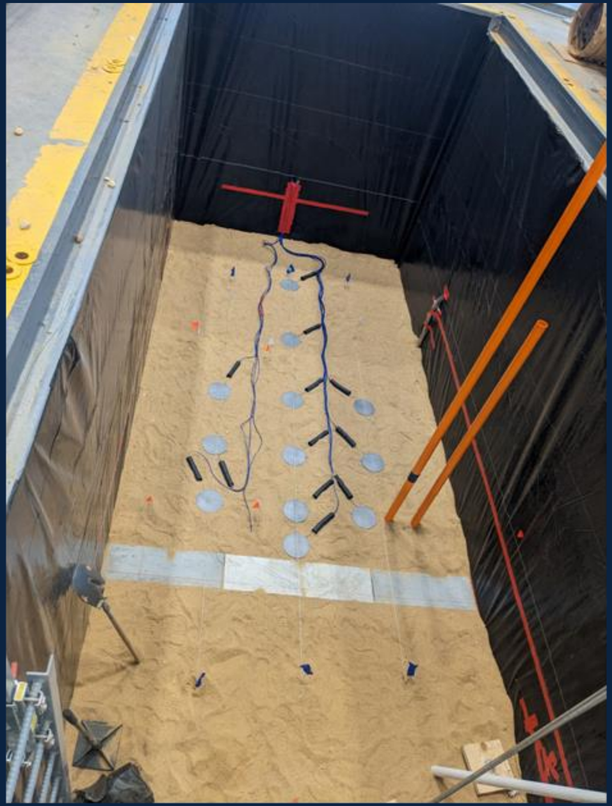
FABRICATING TIMBER SUPPORT WALLS

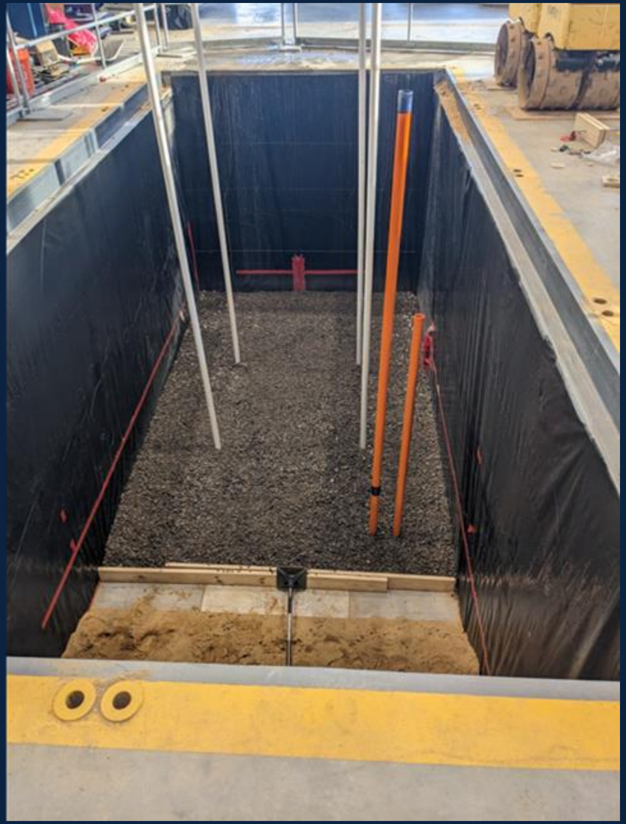


PLACING FOUNDATION LAYERS

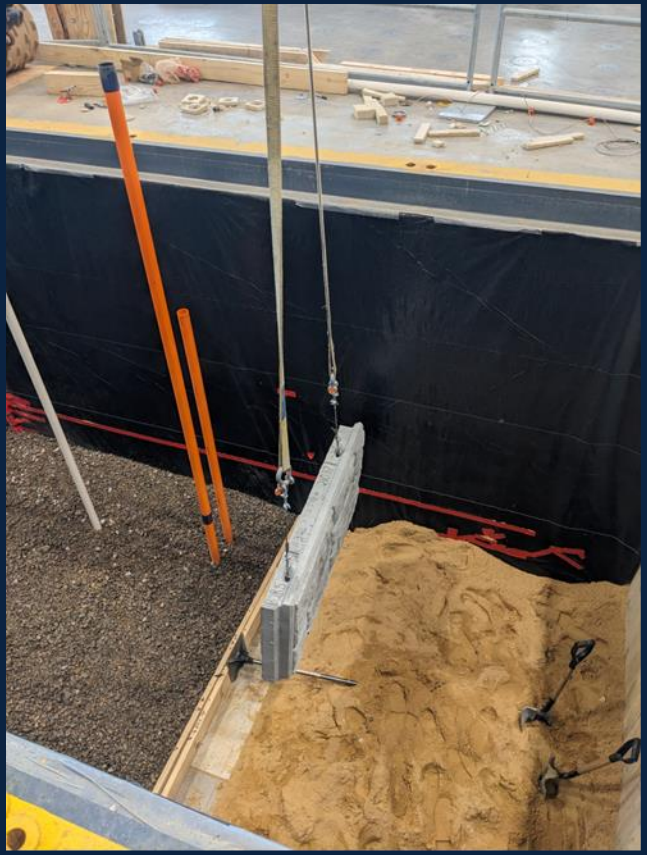
INSTRUMENTATION INSTALLATION AND SABOTAGE



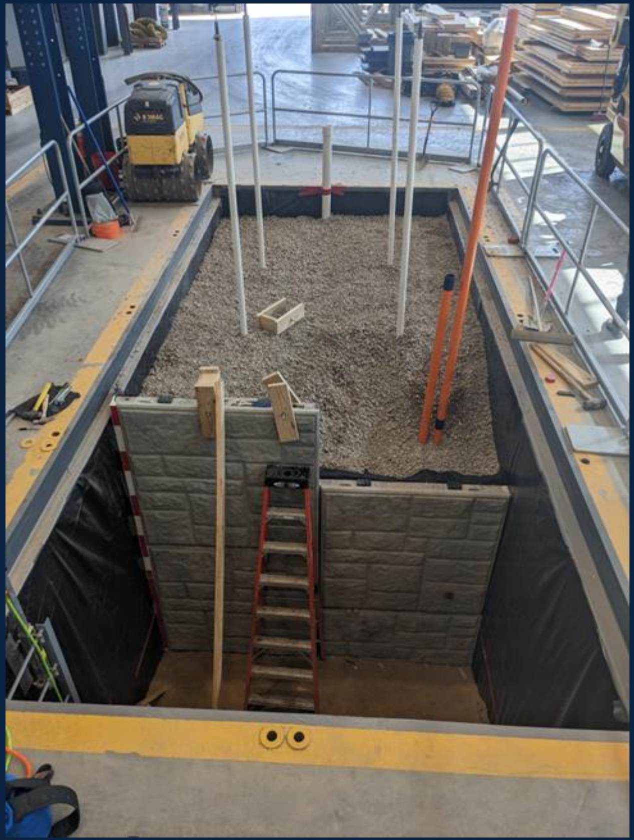


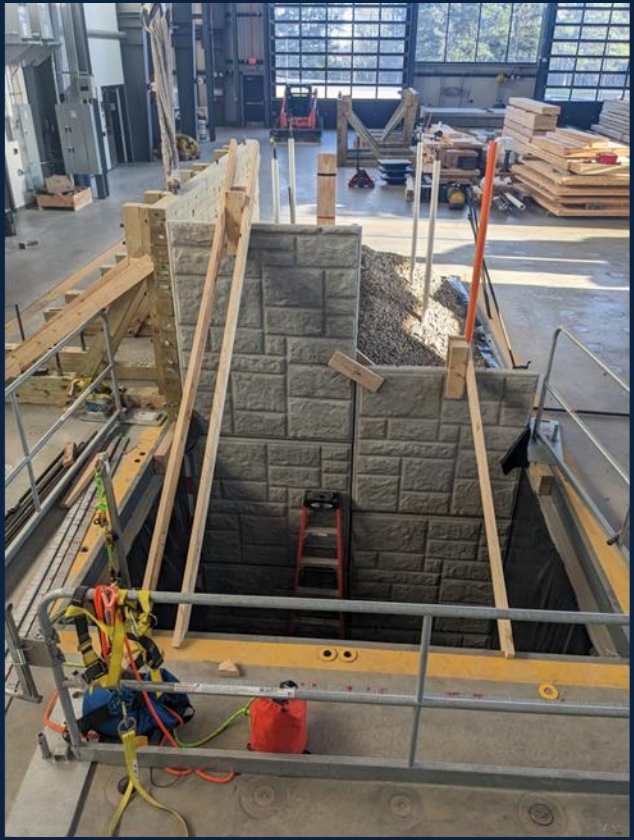


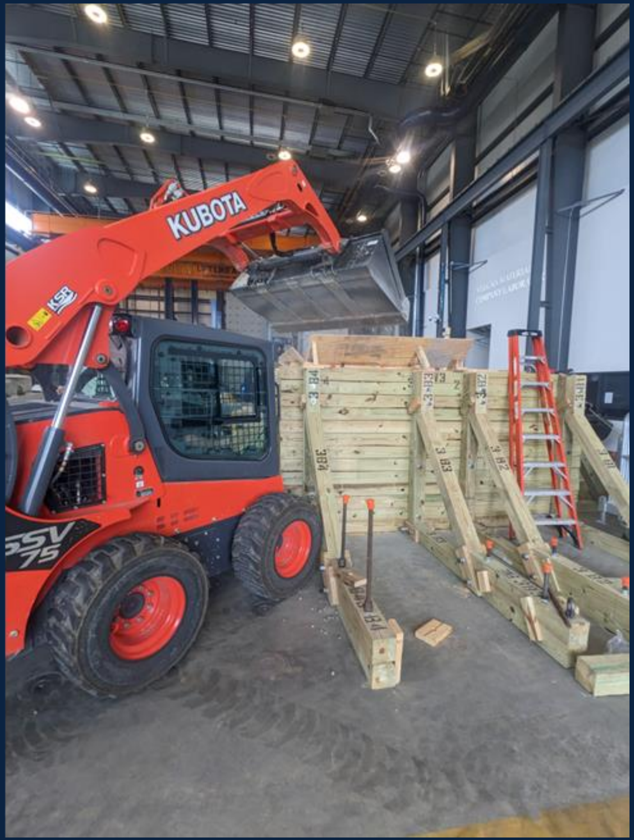
PLACING WALL AND MSE STRAPS



INSTALLING TIMBER WALLS AND CONSTRUCTION ABOVE FLOOR







TOPPING OUT

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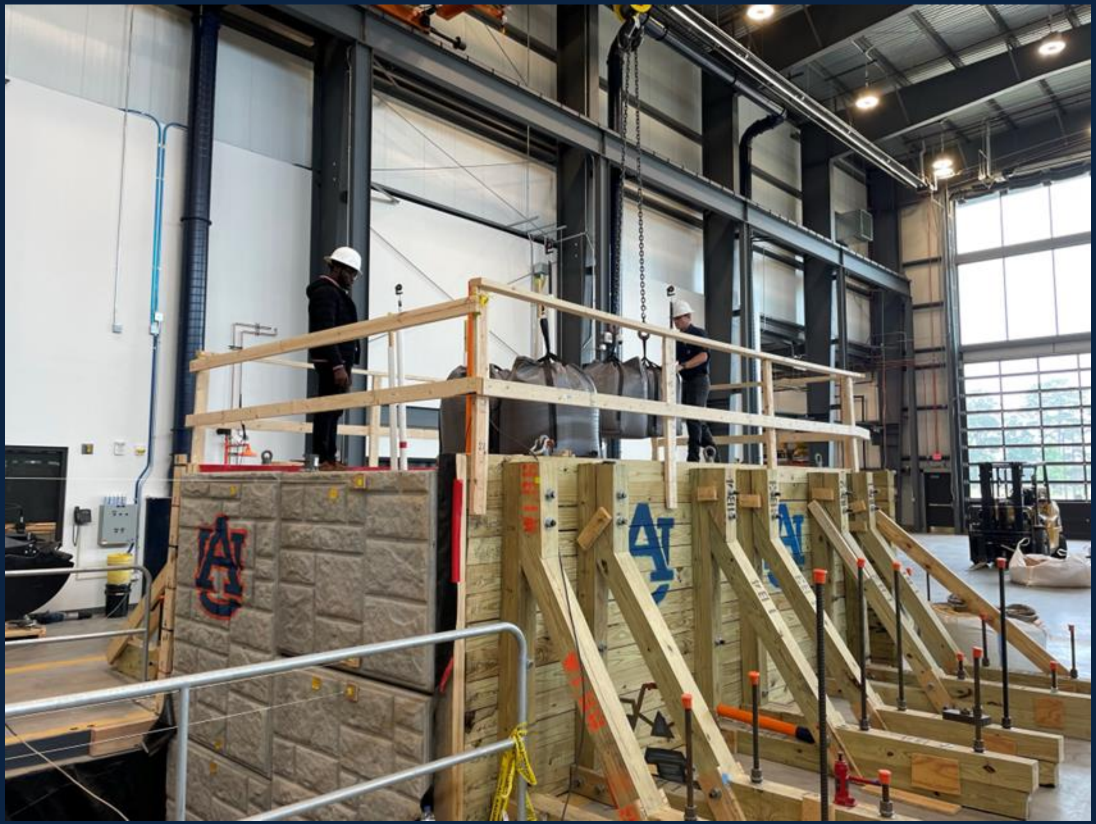
HIGHWAY SURCHARGE



ADDITIONAL OVERLOAD

TESTING SUMMARY

Test Stage	Description
1	End of Construction
2	Induced loss of foundation support by deflating air bladders
3	Traffic surcharge (q=2 psi)
4	Increased surcharge (q= 3.8 psi)
5	Increased surcharge (q= 6.3 psi)
6	Increased surcharge (q= 7.5 psi)

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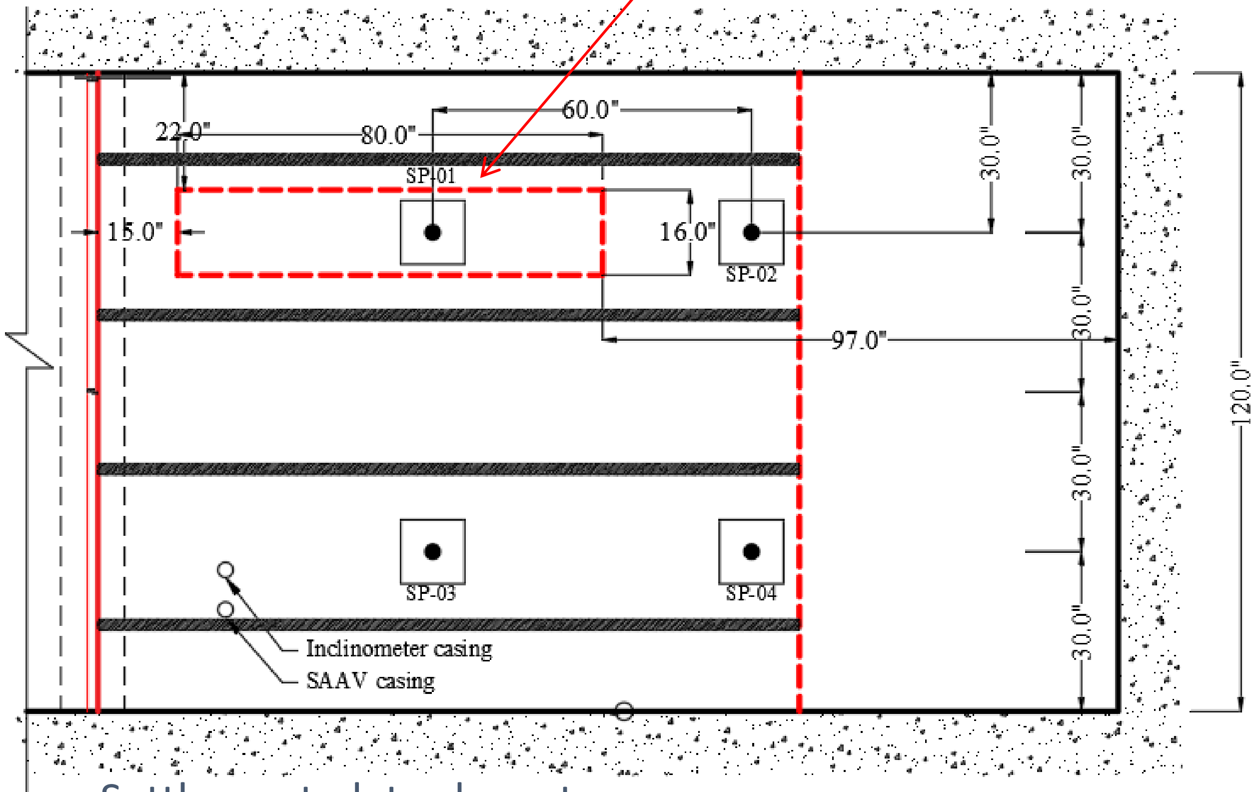
RESULTS

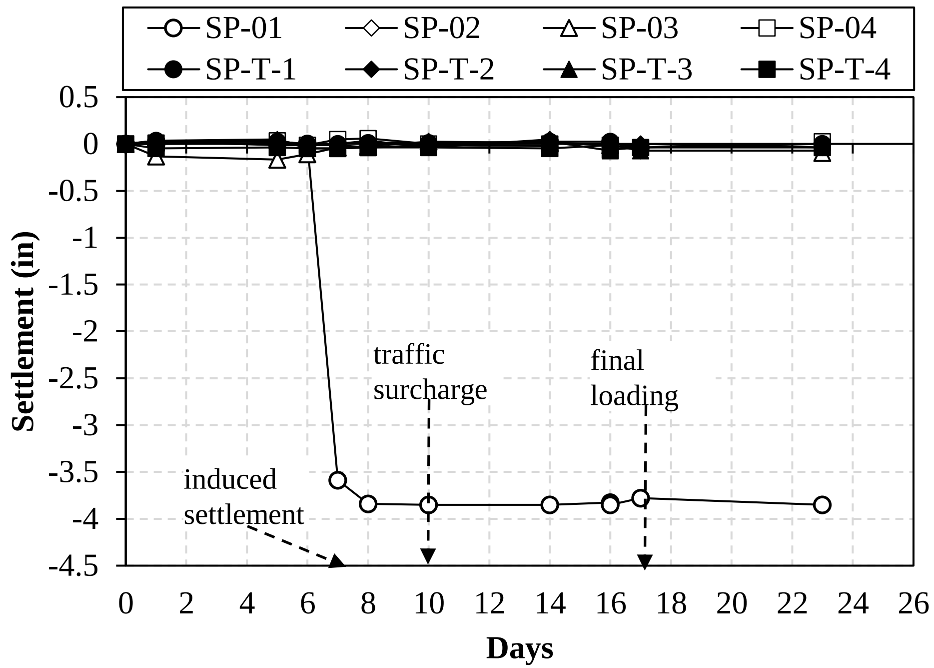
Induced soft spot with air bladders

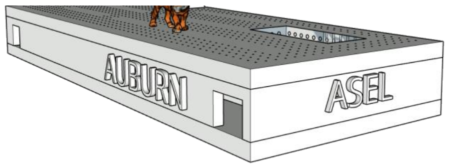


Settlement plates layout

Total station survey results

- SP-01 settled about 4 inches





RESULTS

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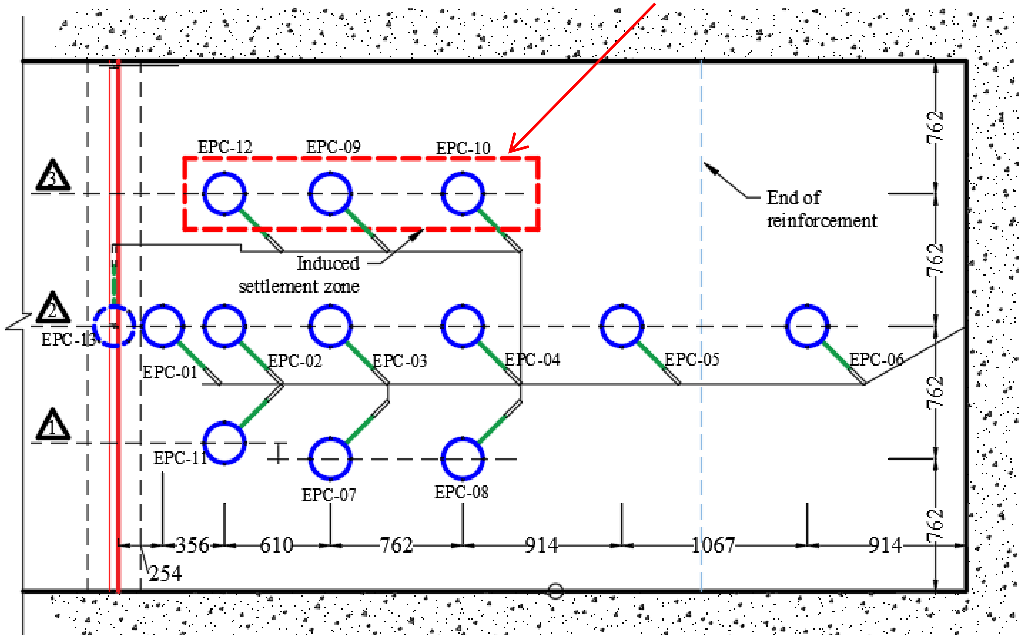
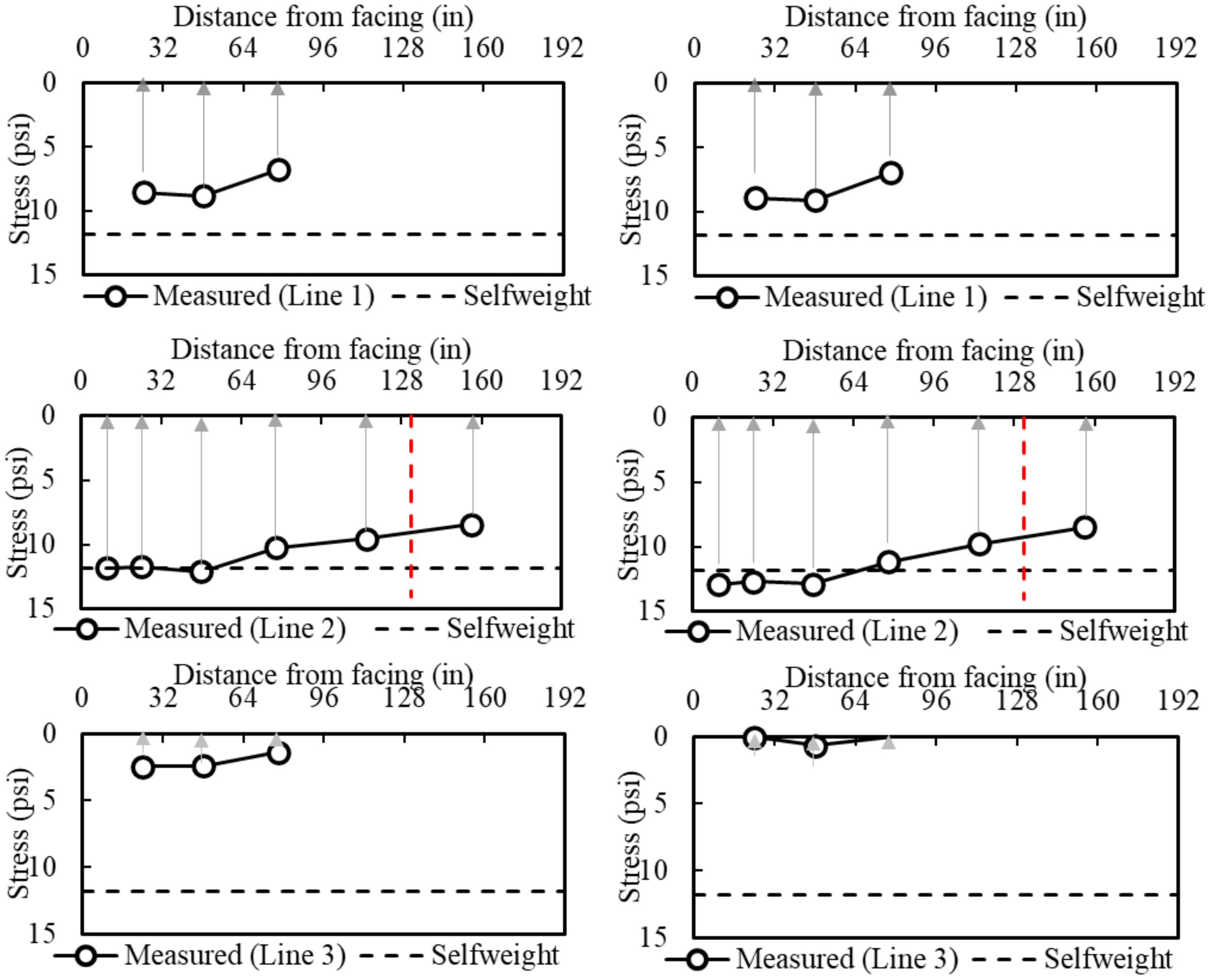


Before inducing settlement | After 4-in diff settlement

Line 1

Line 2

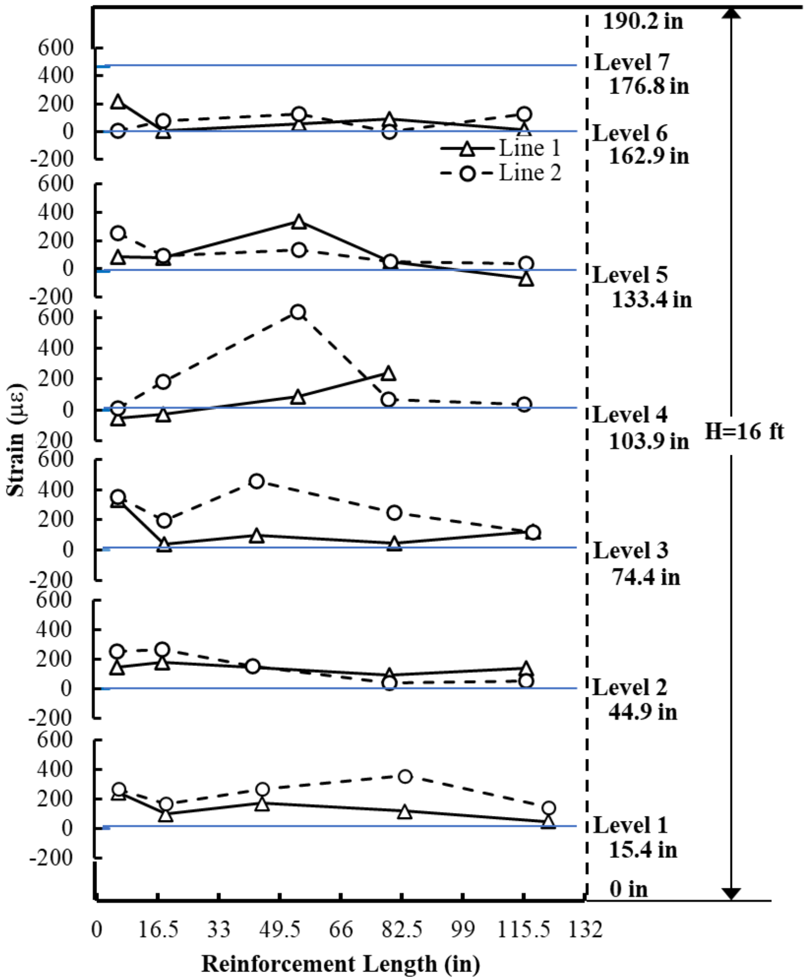
Line 3



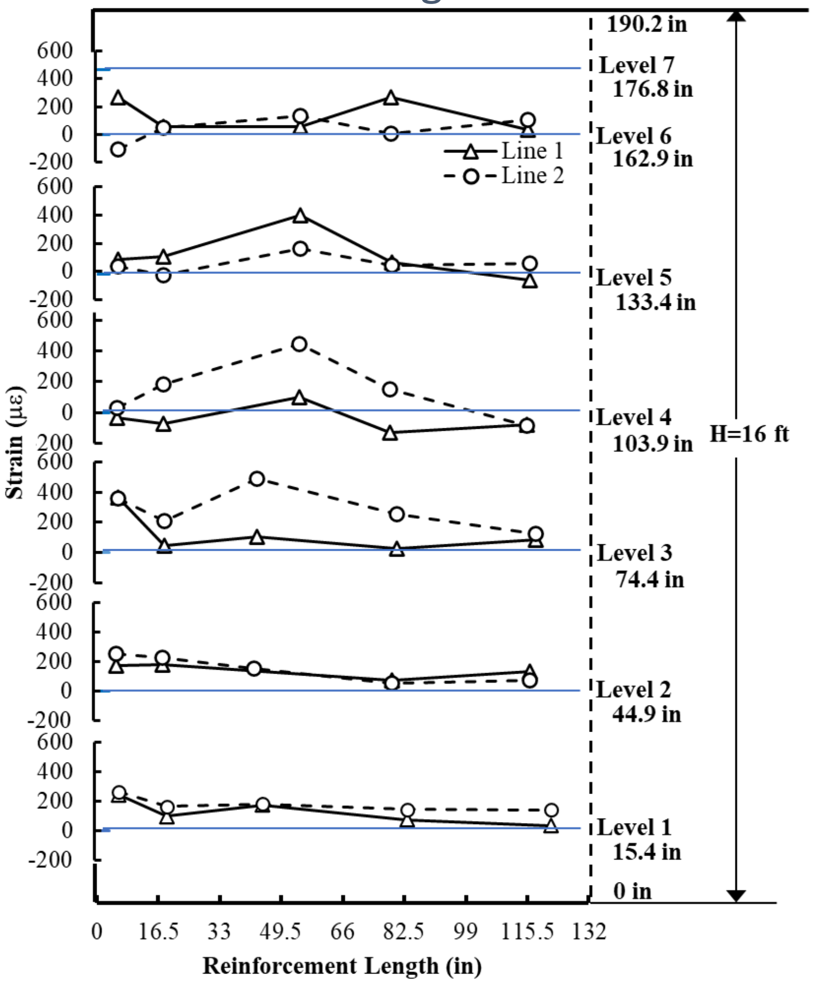
- **Measured stresses are closer to self-weight than design assumptions**

RESULTS

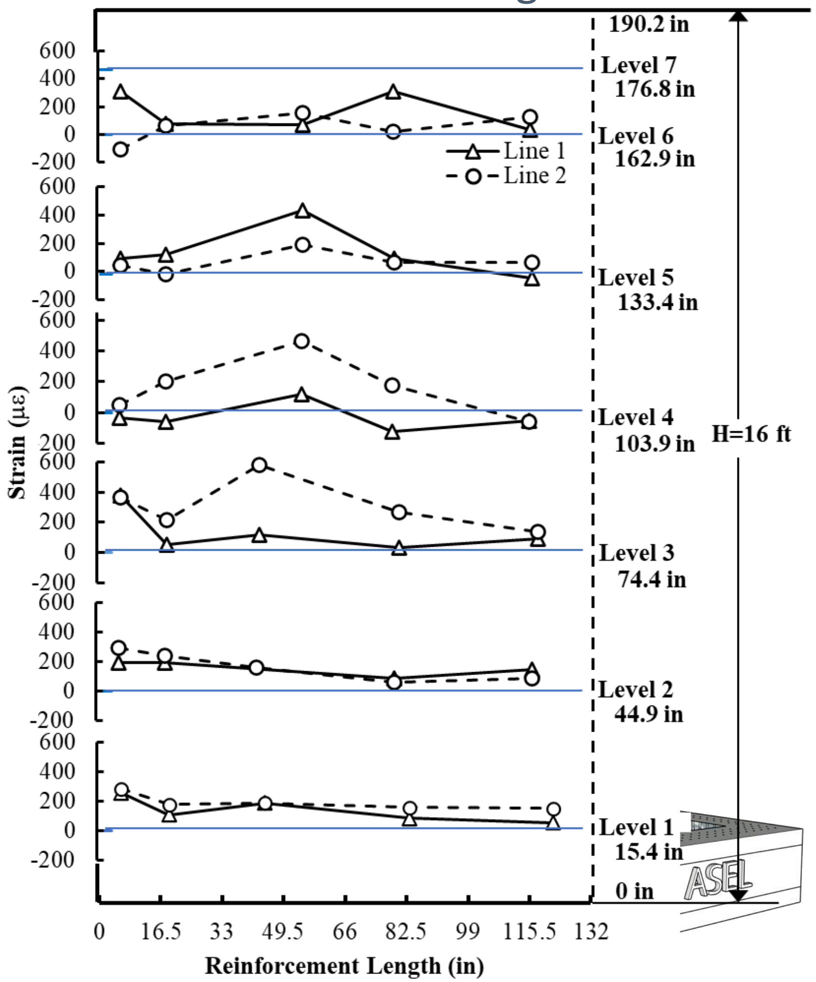
- Maximum strain = 635 $\mu\varepsilon$
  - End of construction



  - Before testing



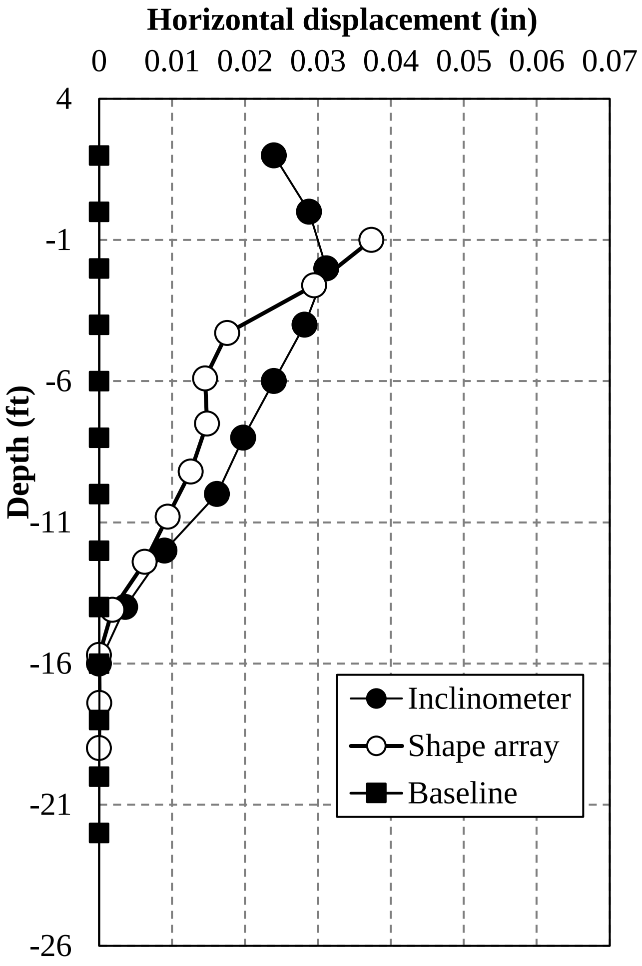
  - After load testing



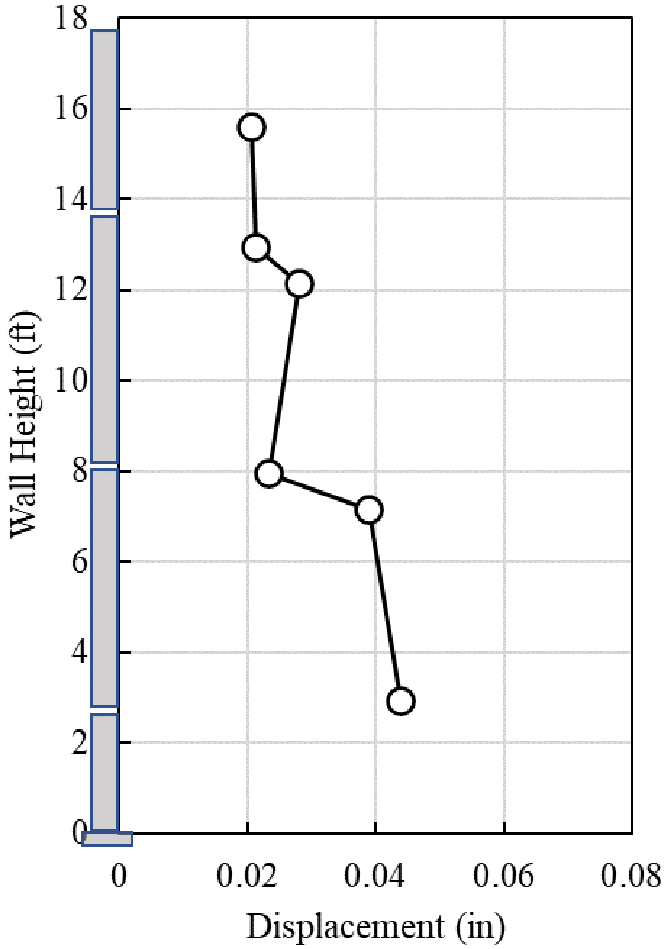
RESULTS

- **No significant lateral displacement**

Within reinforced mass

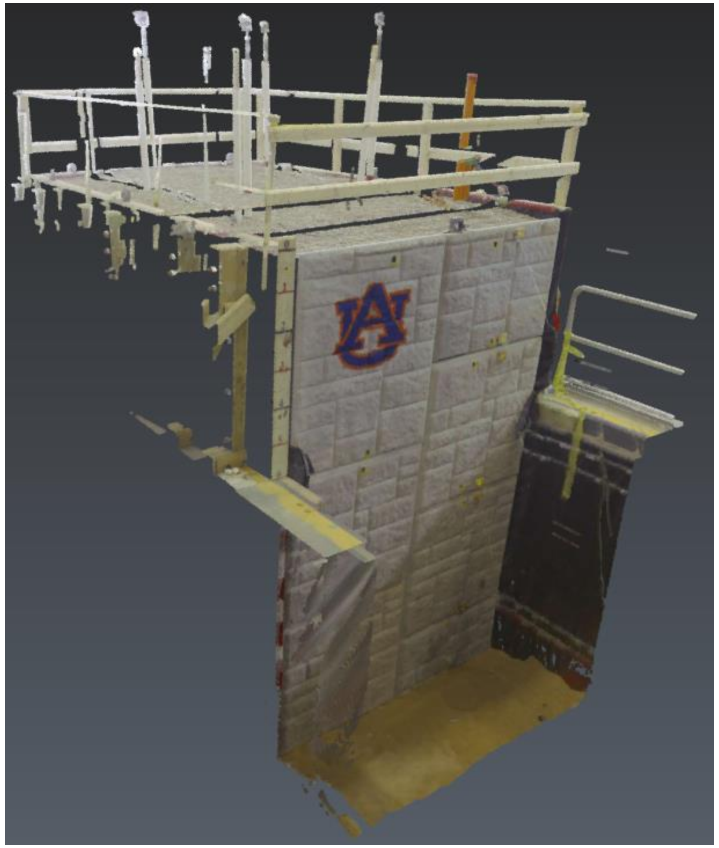


At facing panel

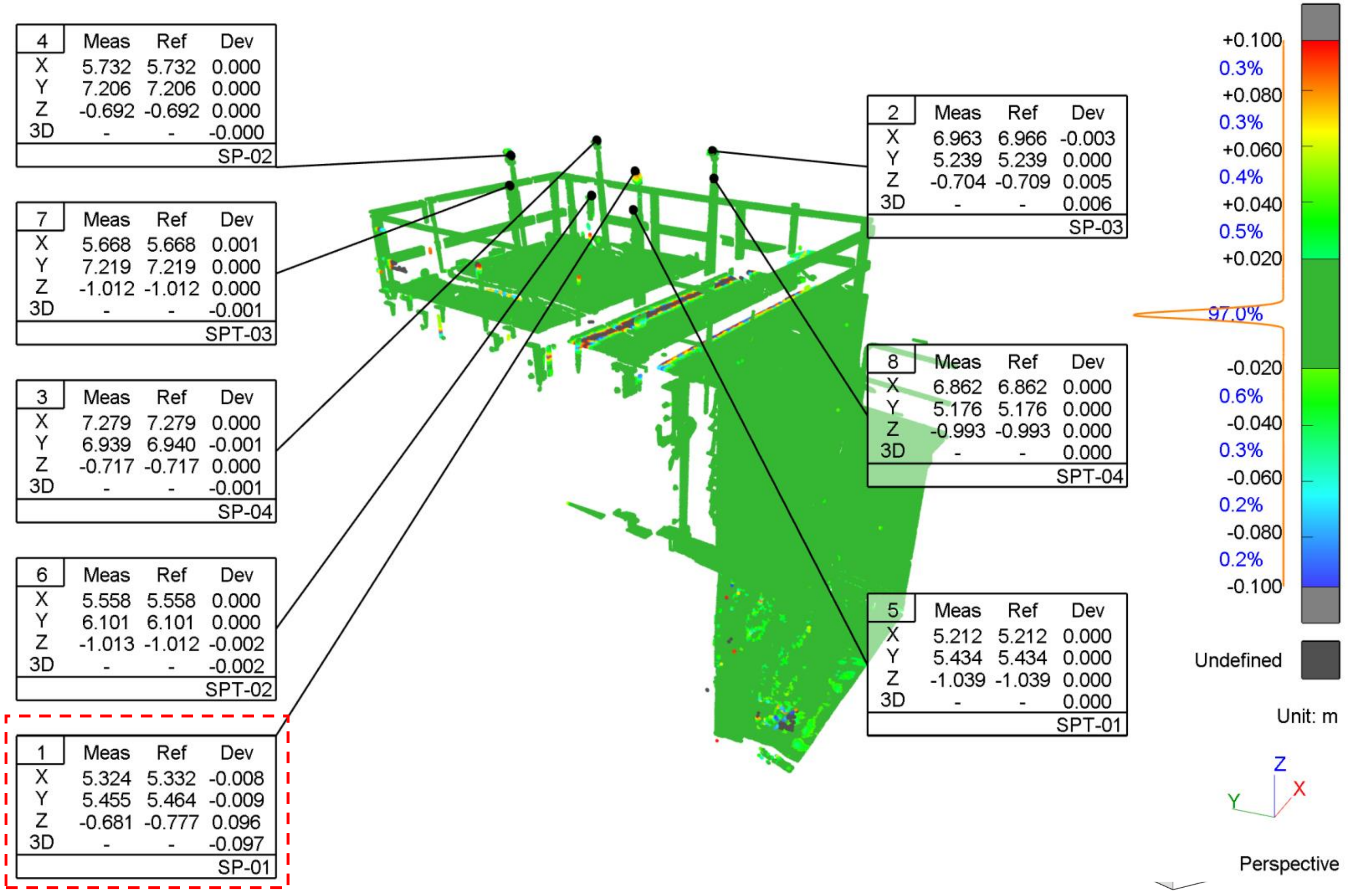


RESULTS

- SP-01 showed 3.8 in (0.096 m) settlement.
- Wall facing panel showed no real deviation.
- 97% of scan surface within 0.4 in (0.01 m)



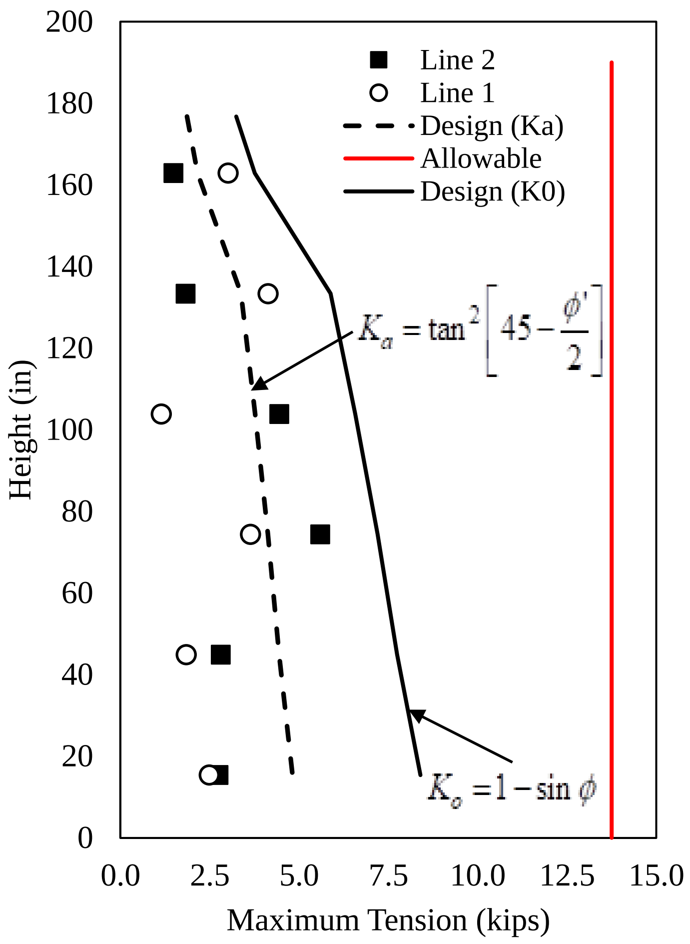
Point cloud analysis comparing scans before and after deflating air bladders

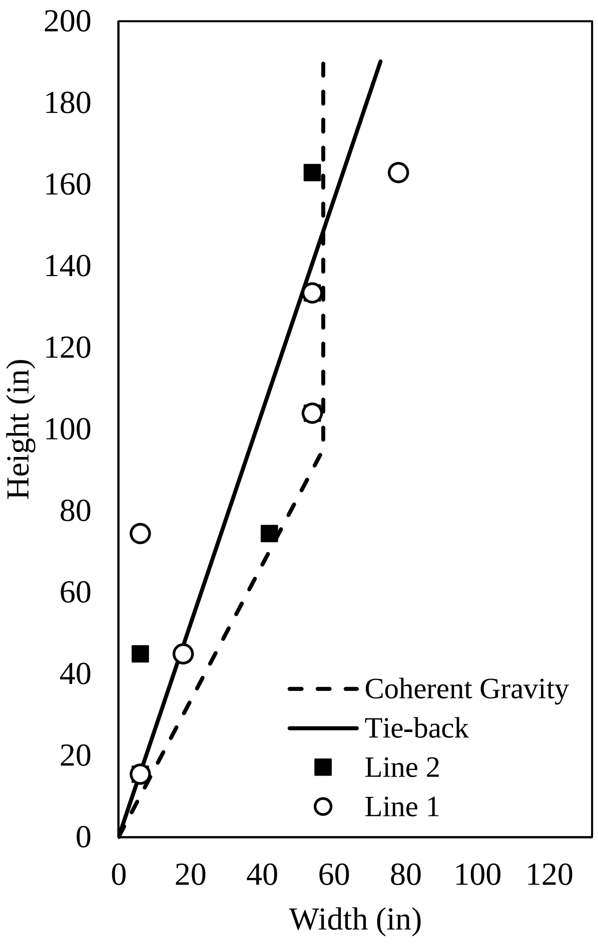


RESULTS

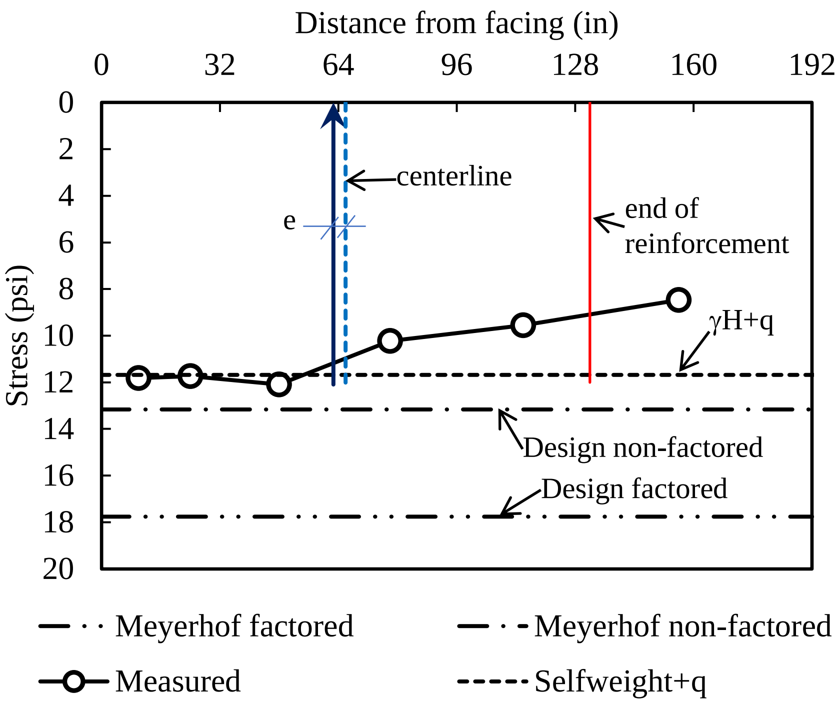
- Reinforcement tension for maximum surcharge (7.5 psi) are within design limits

- Location of maximum tension in reinforced mass closely follows the bi-linear coherent gravity failing wedge

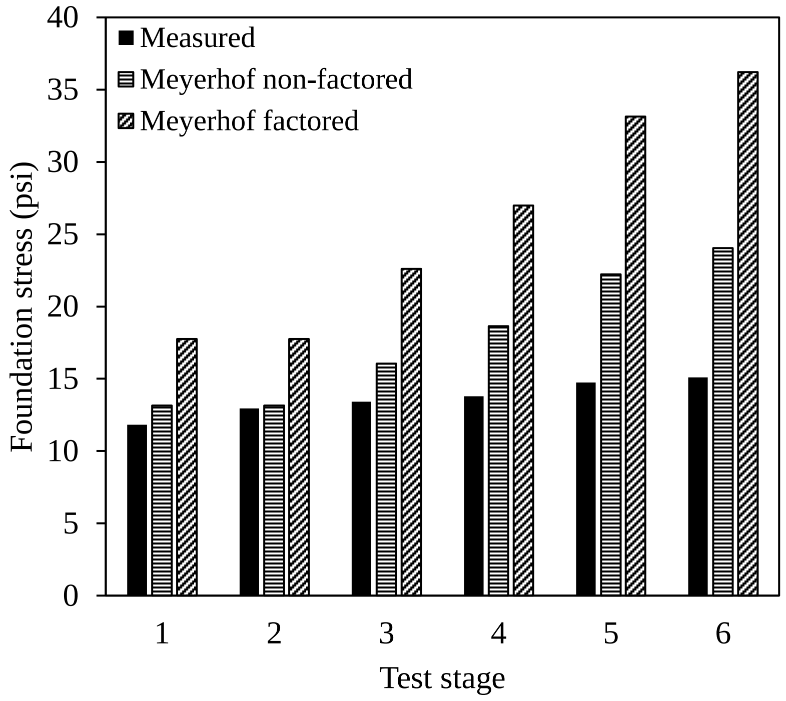




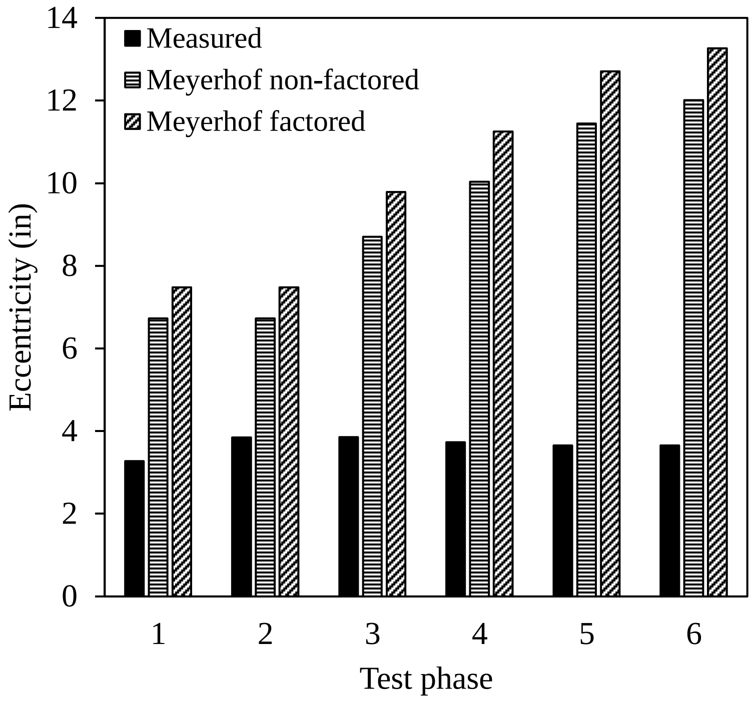
RESULTS



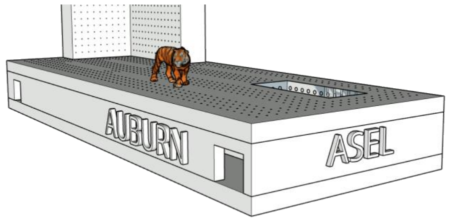
Distance from facing (in)
0
32
64
96
128
160
192
Stress (psi)
0
2
4
6
8
10
12
14
16
18
20
centerline
e
end of
reinforcement
γH+q
Design non-factored
Design factored
Meyerhof factored
Meyerhof non-factored
Measured
Selfweight+q



Measured
Meyerhof non-factored
Meyerhof factored
Foundation stress (psi)
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6
Test stage



Measured
Meyerhof non-factored
Meyerhof factored
Eccentricity (in)
0
2
4
6
8
10
12
14
1
2
3
4
5
6
Test phase



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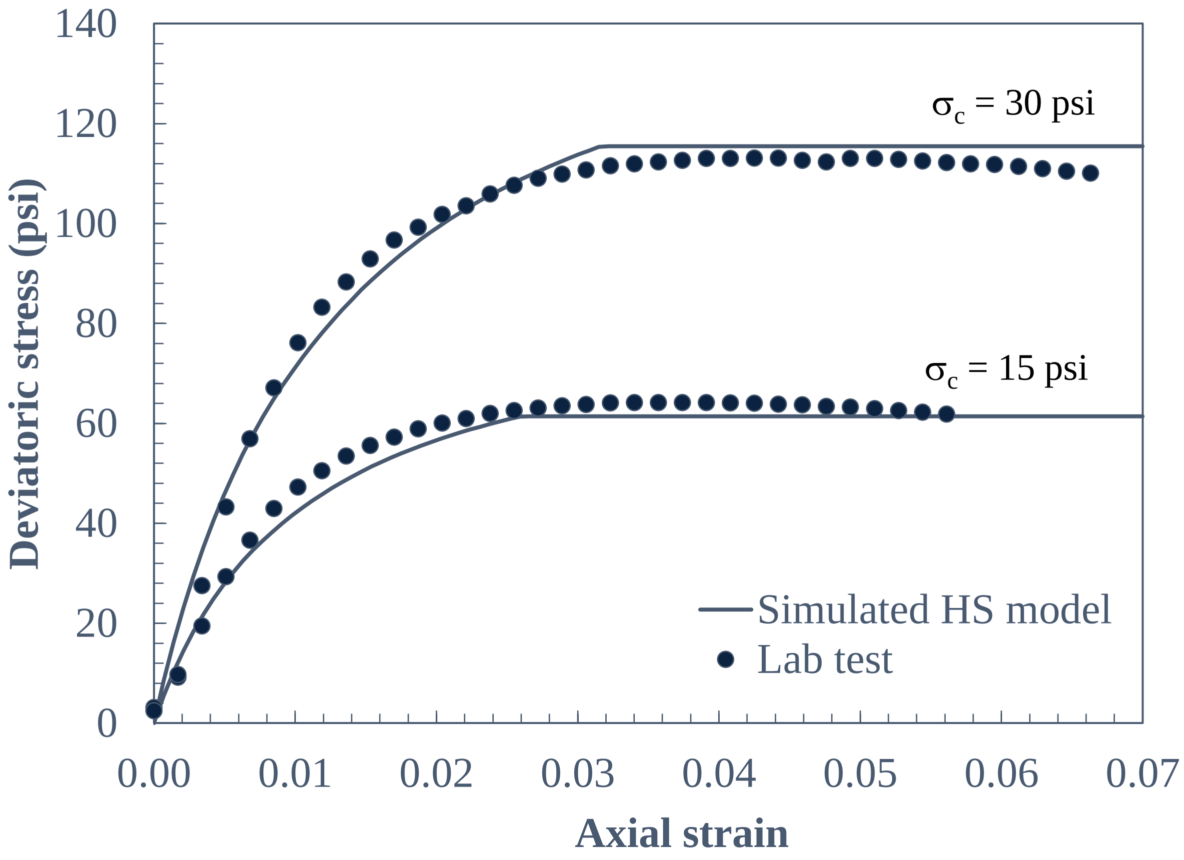
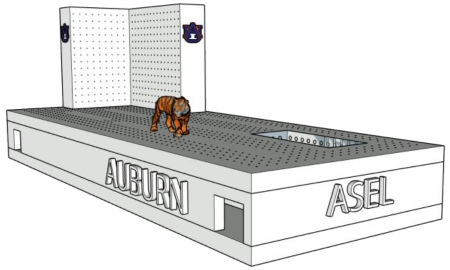
NUMERICAL MODELING

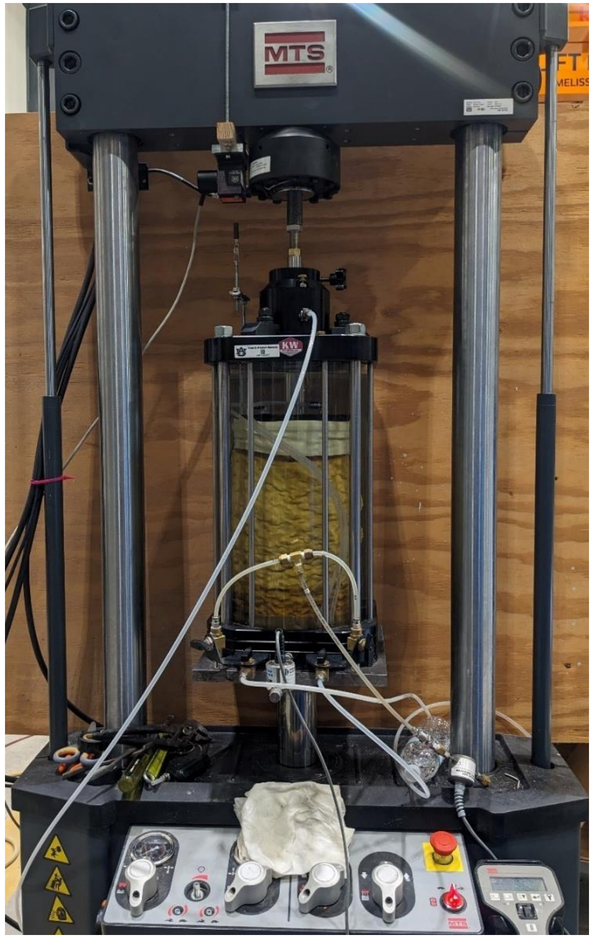
- **Material Calibration**
  - Foundation sand

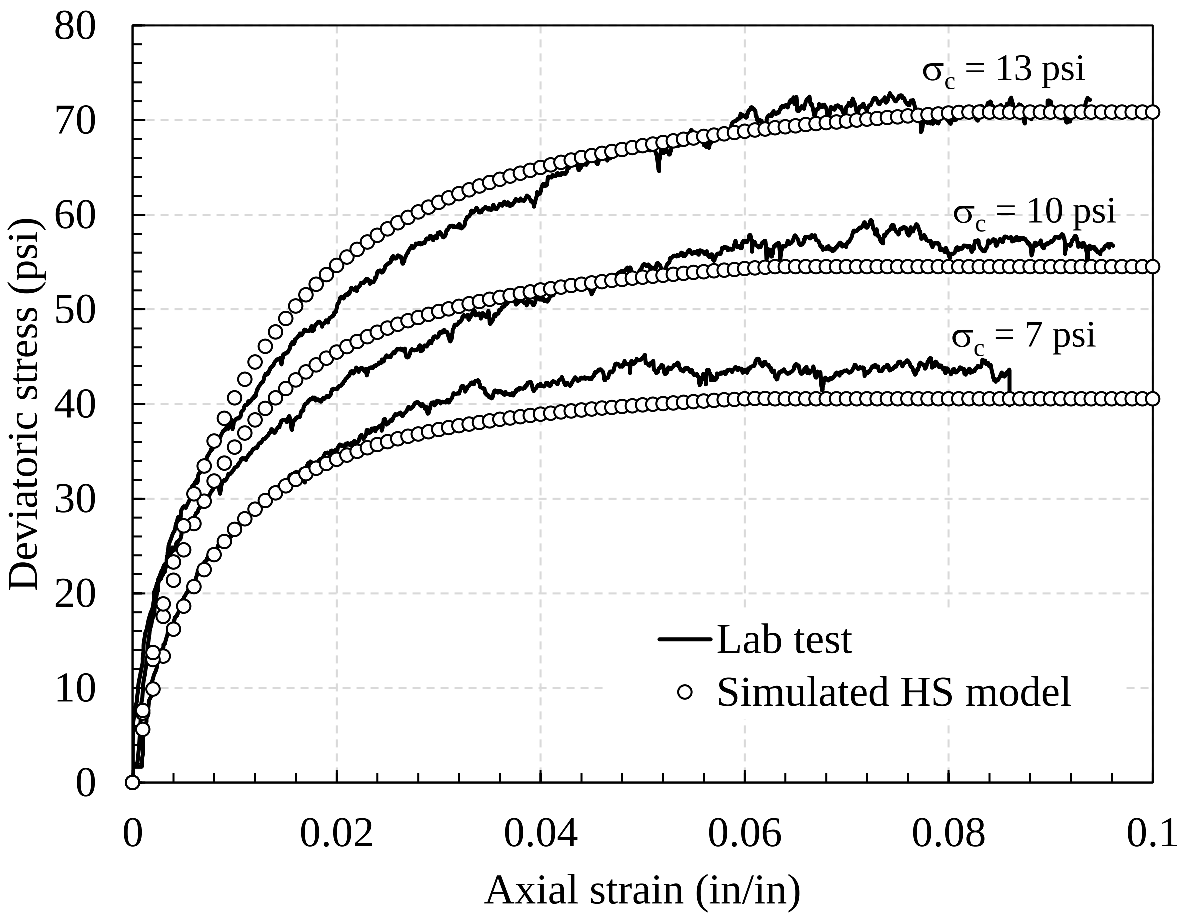


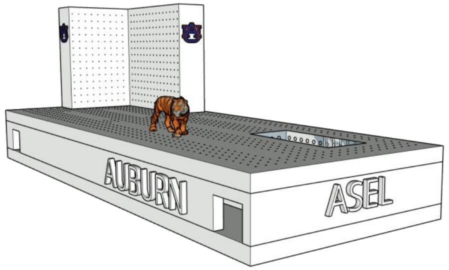


NUMERICAL MODELING

- **Material Calibration**
  - #57 Stone (Large scale triaxial test)



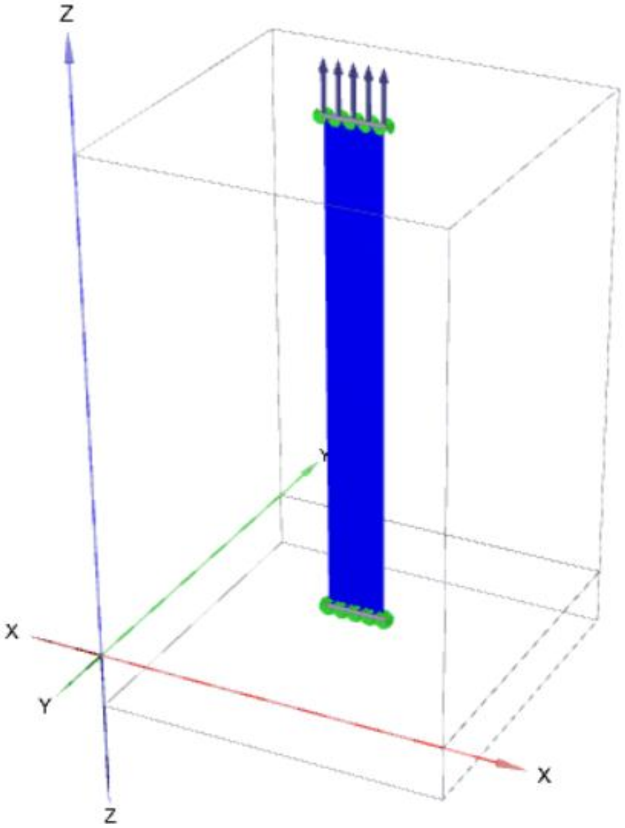


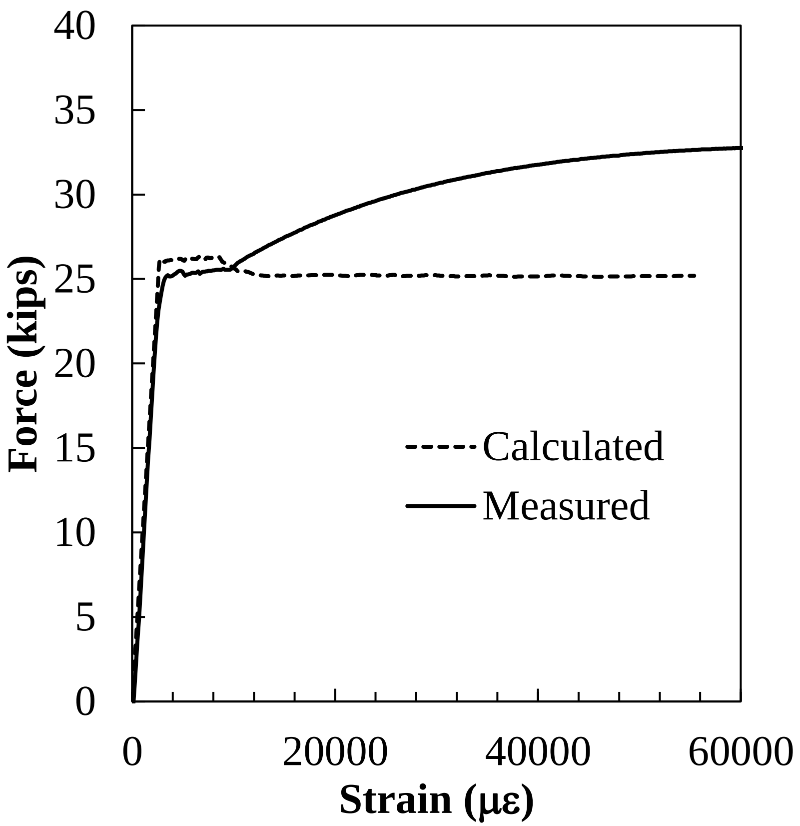


NUMERICAL MODELING

- **Material Calibration**

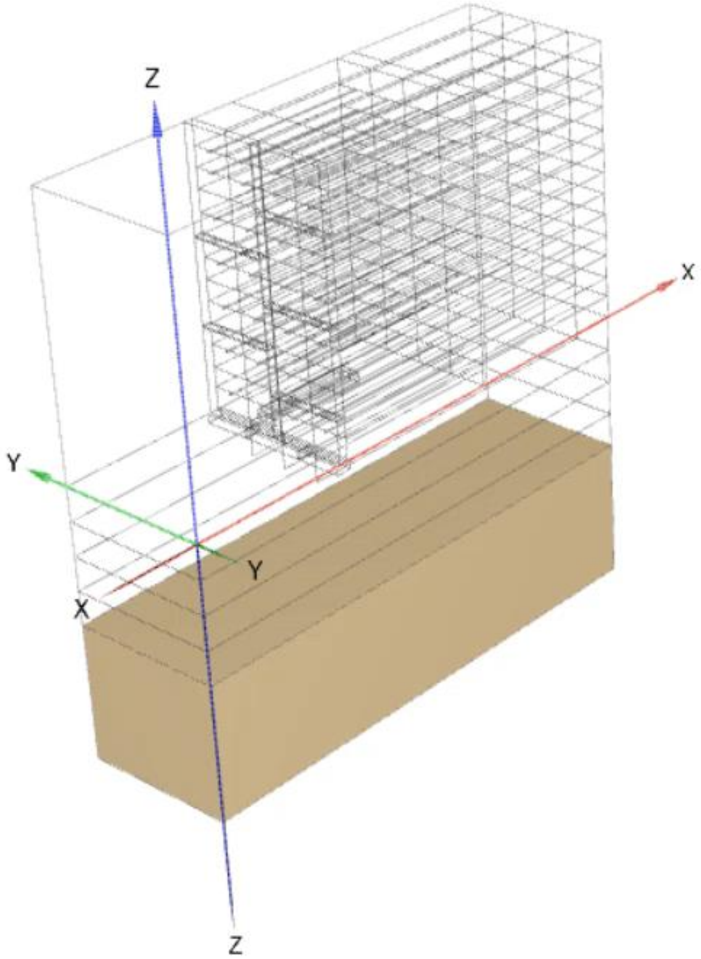
- Steel tensile test

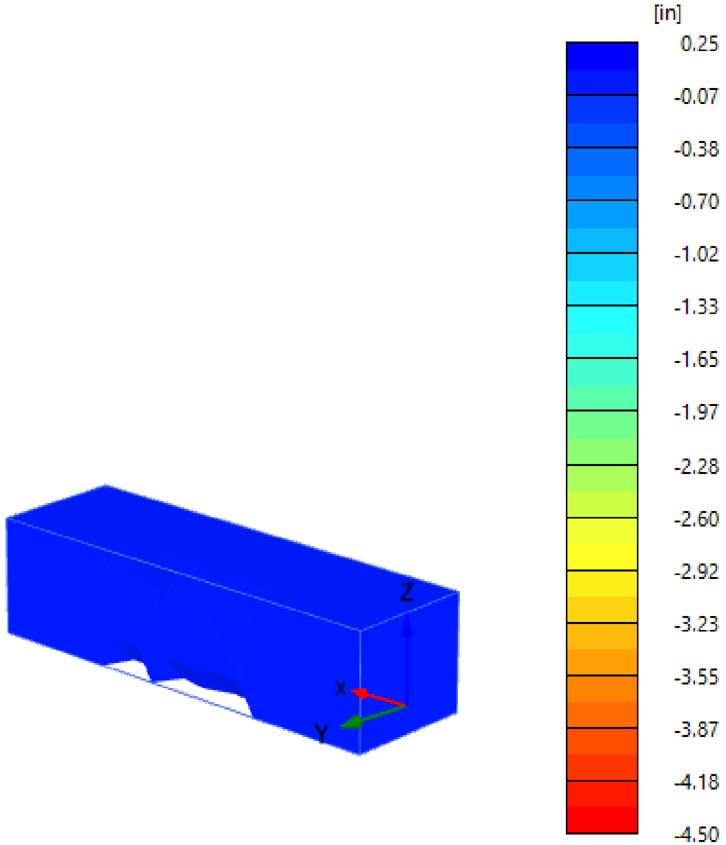


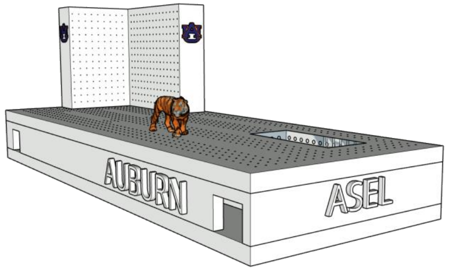


NUMERICAL MODELING

- Staged construction

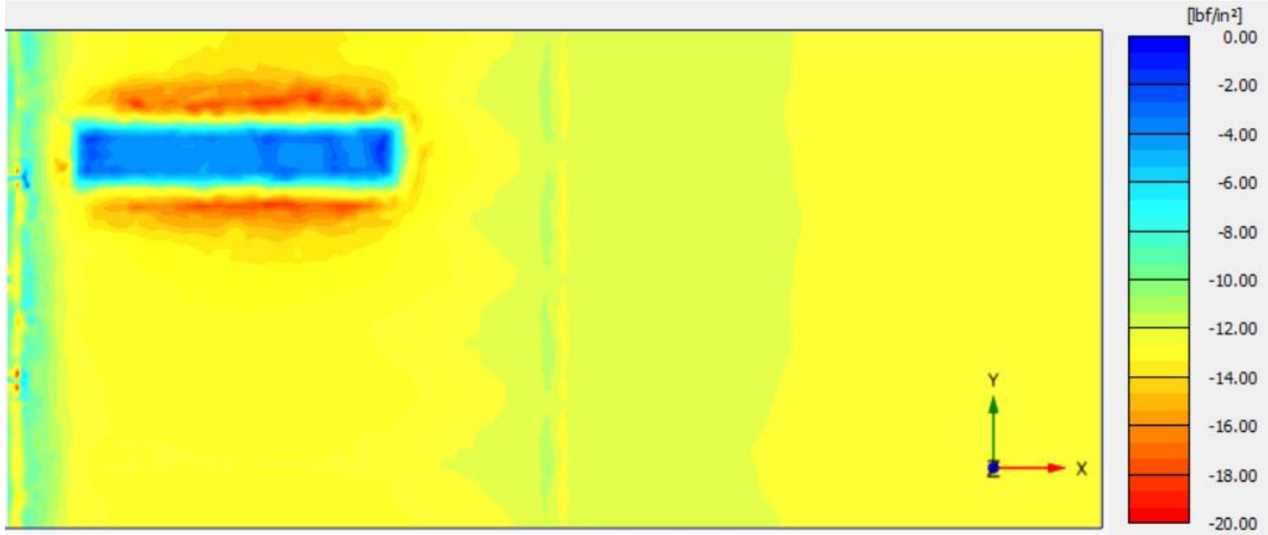




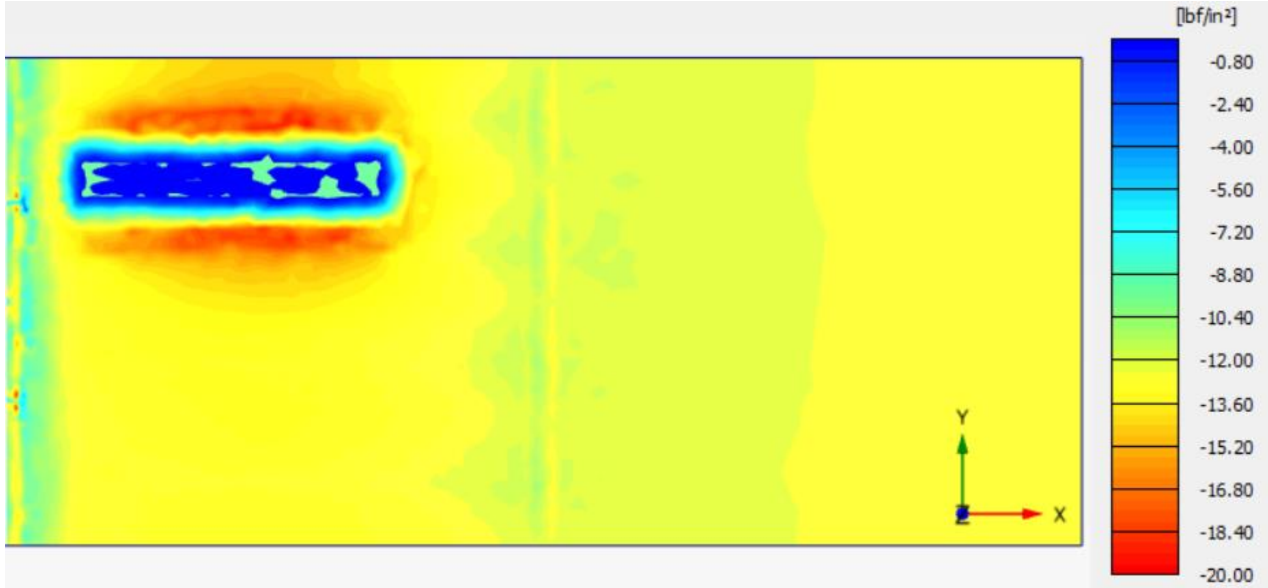


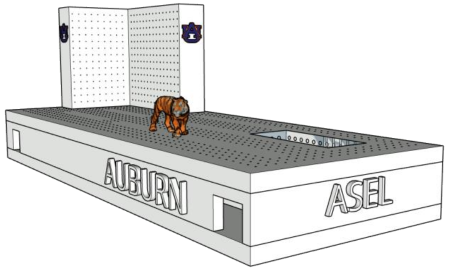
BEARING STRESSES

- End of construction



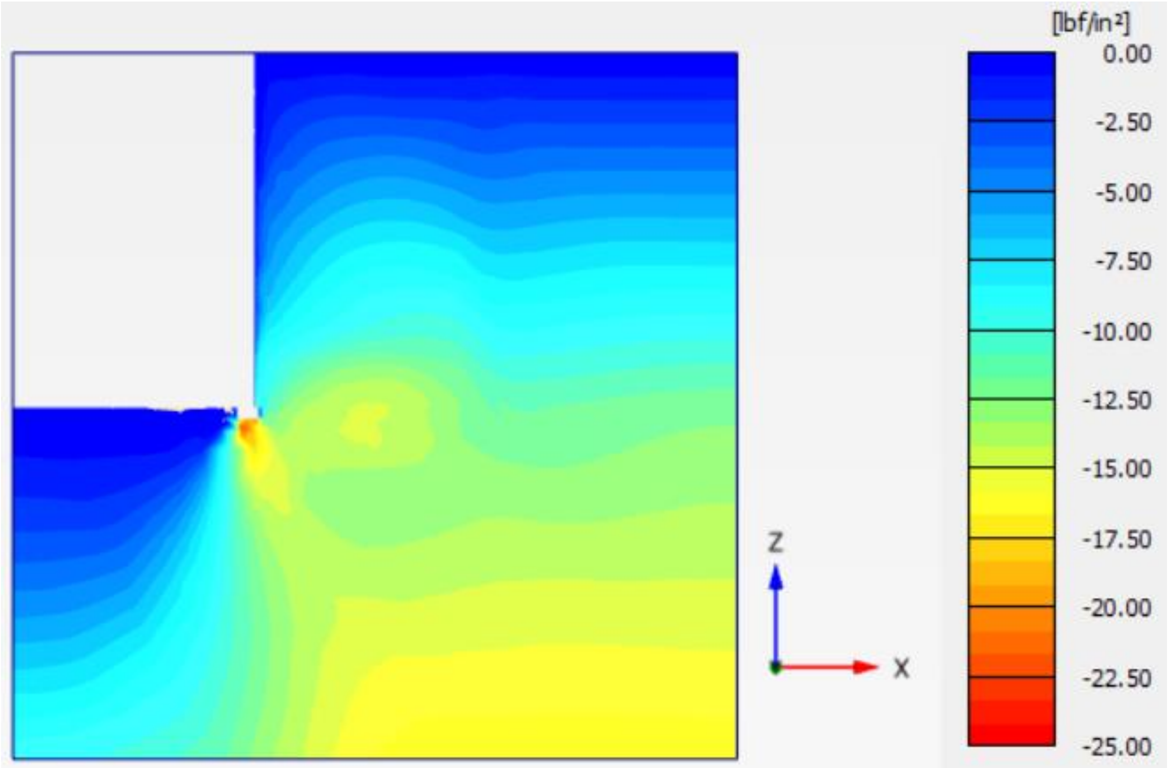
- Deflated bladder

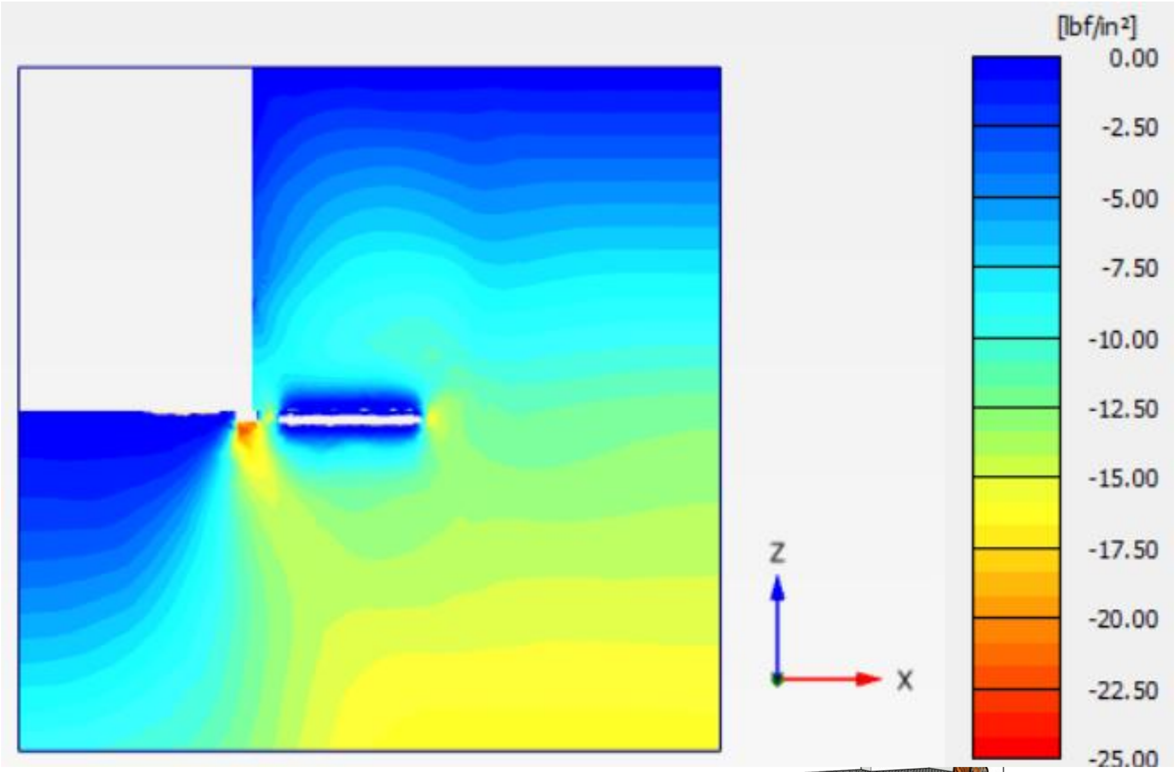




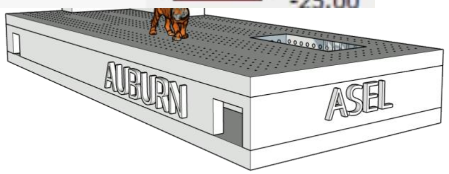
VERTICAL STRESSES (SECTIONS)

- Phase after deflating bladder

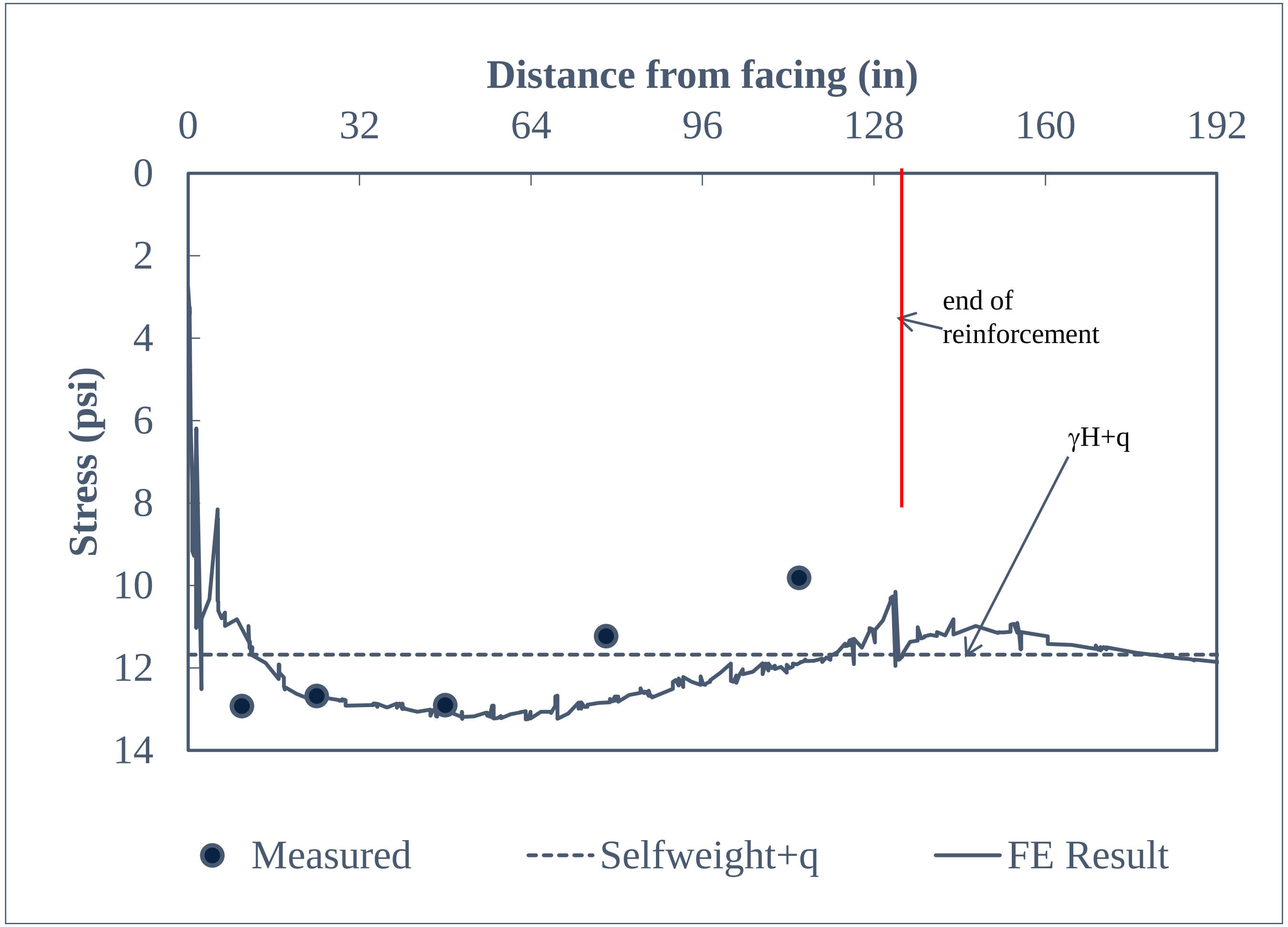


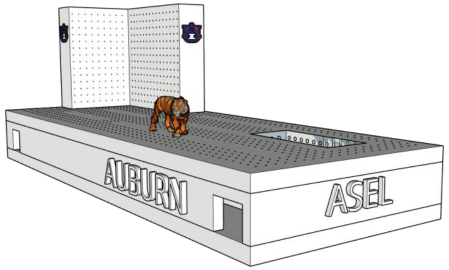


- Line 1
- Line 2



VERTICAL STRESSES (SECTIONS)





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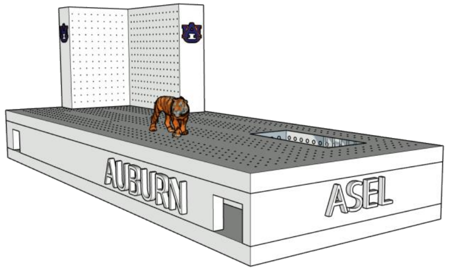
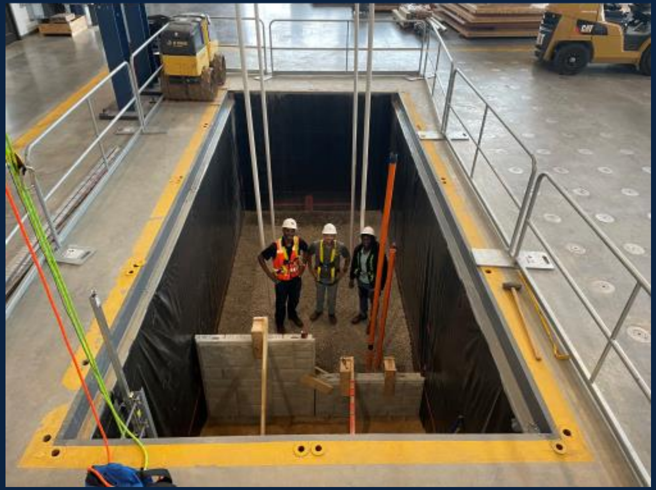
CONCLUSION

- Adopting the vertical stress function from rigid gravity walls for an MSE structure over-estimates the eccentricity and the bearing stress
- Worst case scenario (foundation failure) given by design is L/6 (i.e., a load multiplier of 1.50γH). From measured stresses, it is L/34 (1.06γH) about 10% increase
- Induced differential settlement at foundation doesn't entirely progress to the surface
- All stability assessment are satisfactory even with a poor bearing zone in the foundation
- Eccentricity does not increase with increasing surcharge
- Applied surcharge is not completely transferred to foundation (only 30%)
- FE results also showed stress redistribution
- More FE analysis is ongoing
- Future research will look at bearing capacity factors for MSE walls



ACKNOWLEDGEMENTS



- ALDOT
  - Kaye Davis, Scott George
- AUBURN
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