UF Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

POWERING THE NEW ENGINEER TO TRANSFORM THE FUTURE

DEPARTMENT OF CIVIL AND
COASTAL ENGINEERING

Performance Testing of GRS Test Piers Constructed with Florida Aggregates – Axial Load Deformation Relationships (BDV31 977-131)

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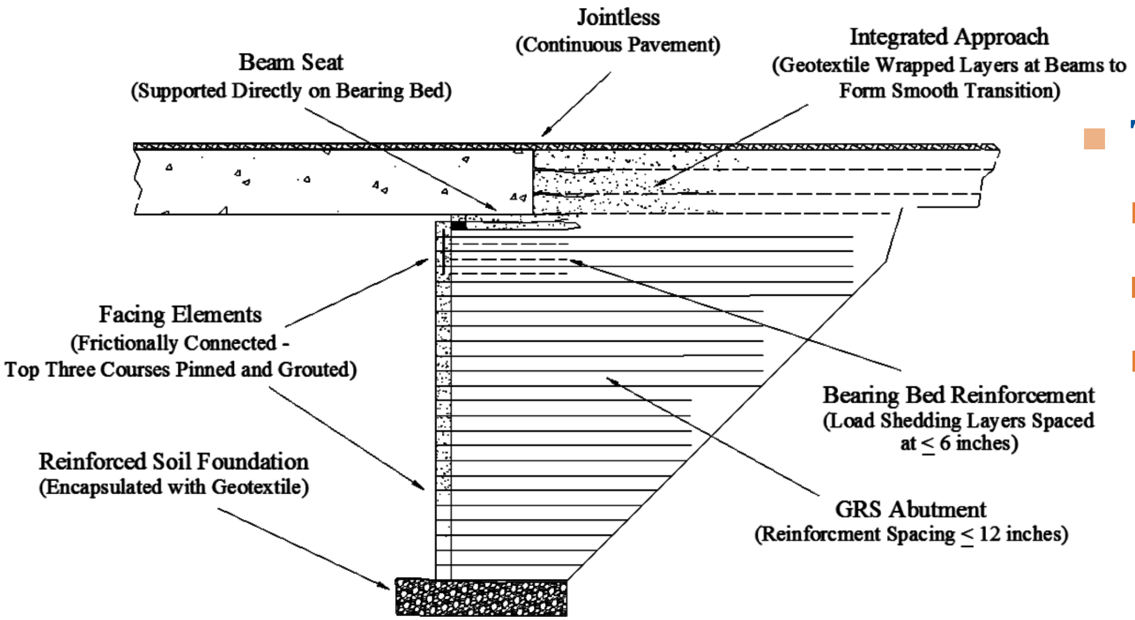
Presentation Outline

- Introduction
- Research Motivation
- Project Objectives and Tasks
- Project Tasks 1, 2, and 3
- Project Timeline

Introduction: What is GRS-IBS?

- Consists of compacted fill and closely spaced (≤ 12 inches) geosynthetics reinforcement
- Stability and load carrying capacity
  - Close vertical reinforcement spacing & composite nature of geosynthetics and GRS backfill (typically aggregate) in distributing loads



Typical GRS-IBS cross section (Adams and Nicks, 2018)

- Typical GRS-IBS consist of:
  - Reinforced soil foundation (RSF)
  - GRS abutment
  - Integrated approach

Introduction: Why consider the GRS-IBS?

- Advantages
  - Lower cost & accelerated bridge construction
  - Smooth transition eliminating the “bump at bridge” problem
  - Flexible design
  - Nearly all-weather construction
  - Lower failure rates than MSE walls and earth retaining walls
- Limitations
  - Simple-span bridge with span length less than 140 ft and abutment height less than 30 ft
  - Service limit pressure up to 4000 lb/ft^2
- More than 300 bridges have been constructed with GRS-IBS in the USA

Research Motivation

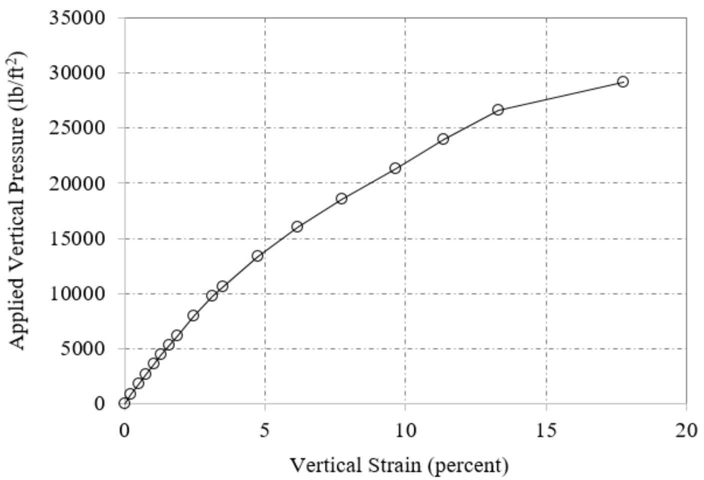
- Performance of GRS piers (experimental proxy for GRS-IBS) that utilize materials in Florida has not been evaluated
- GRS composite behavior depends on:
  - Reinforcement strength & spacing, aggregate size, friction angle, facing elements
- Identify axial loads at limiting service vertical and horizontal strains ($\varepsilon_v = 1\%$ and $\varepsilon_H = 2\%$, respectively), as recommended by FHWA

Project Objectives and Tasks

- Objectives
  - Measure axial-load deformation behavior of GRS piers through full scale fully instrumented tests to identify their performance when constructed with aggregates used in Florida and typical reinforcement types at different vertical spacing
- Tasks
  - Task-1: Review previous studies on GRS, design methods, material, and construction practices-COMPLETED
  - Task-2: Design experimental plan for performance tests-COMPLETED
  - Task-3: Performance tests – Axial load-deformation tests on GRS piers
  - Task-4: Compare performance test results with previous results and predictions and make recommendations for GRS design in Florida
  - Task-5 and 6:Final reports and closeout teleconference

Task-1: Design Methods and Construction Practices

- FDOT requires LRFD design of GRS-IBS according to "***Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide***" FHWA-HRT-11-026, except as otherwise shown in the *FDOT Structures Design Guidelines.*
- Ultimate Capacity, Deformation and Reinforcement Strength
  - Empirical Method*
    - Performance tests
  - Analytical Method*
    - FHWA & NCHRP eqs.
- Materials
  - Backfill: granular materials
    - $d_{max} = 2\ inches, \Phi_{min} = 42°$
  - Reinforcement: biaxial geogrid or woven geotextile
    - $T_{f,min} = 4800\ lb/ft$



Stress-strain curve for GRS composite (Adams and Nicks, 2018)

* Methods presented in GRIP 2020 presentation

Task-2: Design Experimental Plan for Performance Tests

- Performance tests will utilize reaction frame and hydraulic load application apparatus
- Each pier will be externally and internally instrumented
  - Vertical and horizontal movement measured with linear potentiometers
  - Applied load measured with load cell
  - Geosynthetic tensile strains measured with bonded strain gages
  - Vertical and horizontal earth pressures measured with pressure cells
- Instruments will be read with multi-channel data acquisition system and data backed up with external hard drive

Task-2: Design Experimental Plan for Performance Tests

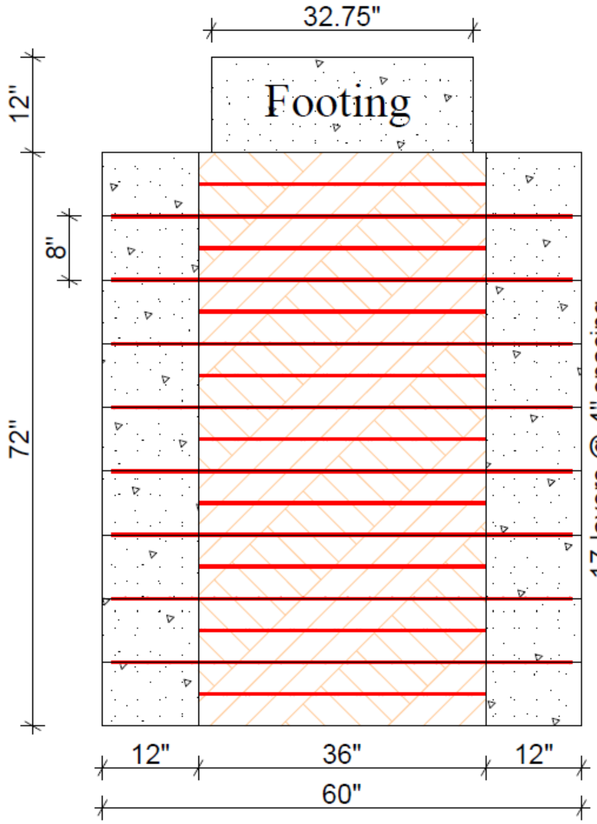
- 8 Piers to be tested

Test No.	Backfill	Reinforcement	T_f (lb/ft)	S_v (inch)	B (ft)	H/B	Ultimate Load (kips)	
							FHWA Equation	2D Numerical Analysis
1	#57 stone	Biaxial woven geotextile [A]	4,800x4,800	8	3	2	287.649	521.327
2	#57 stone	Woven geotextile [B]	7,200x5,760	8	3	2	428.555	749.077
3	#57 stone	Biaxial woven geotextile [C]	4,800x4,800	8	3	2	287.649	521.327
4	TBD	TBD	4,800x4,800	4	3	2	658.396	900.68
5	GAB	Biaxial woven geotextile [A]	4,800x4,800	8	3	2	309.74	612.64
6	GAB	Woven geotextile [B]	7,200x5,760	8	3	2	458.97	853.22
7	GAB	Biaxial woven geotextile [C]	4,800x4,800	8	3	2	309.74	612.64
8	TBD	TBD		8	3	2		

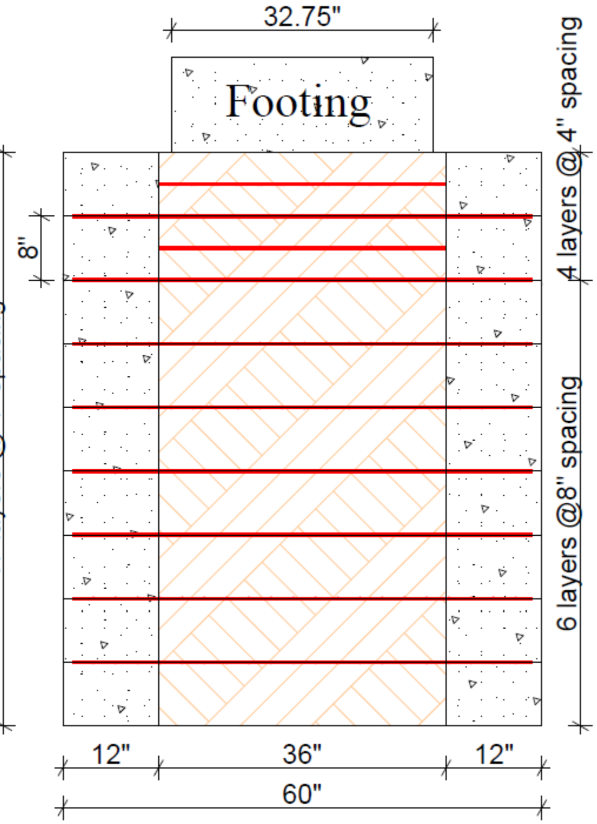
[A] Tencate Mirafi HP570, [B] Tencate Mirafi HP770, [C] Hanes Geo TerraTex HPG 57, TBD = To Be Decided based on results of each test series

Task-2: Design Experimental Plan for Performance Tests

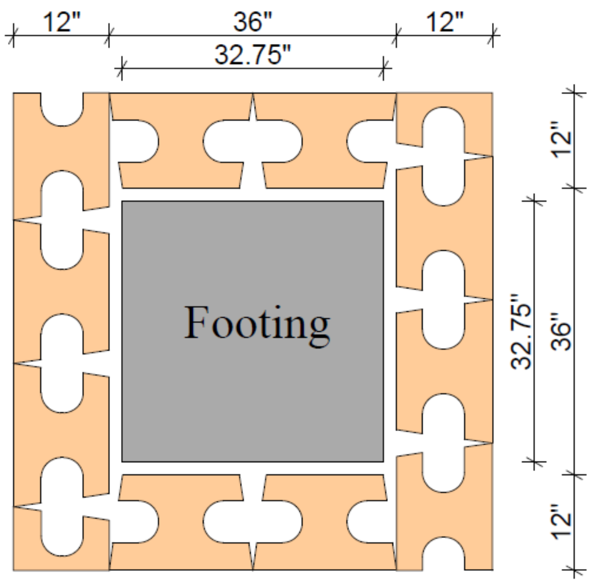
- Layout of the Piers



4 inches reinforcement vertical spacing



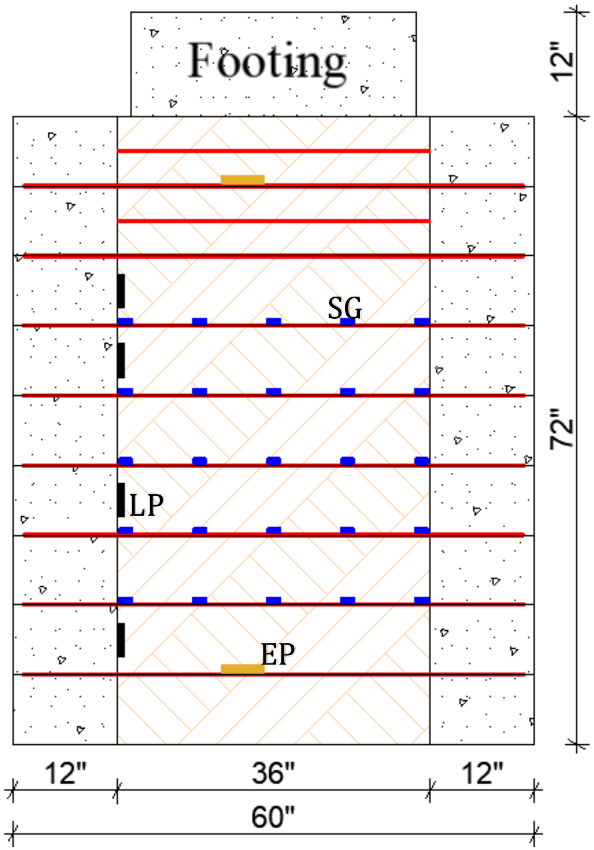
8 inches reinforcement vertical spacing



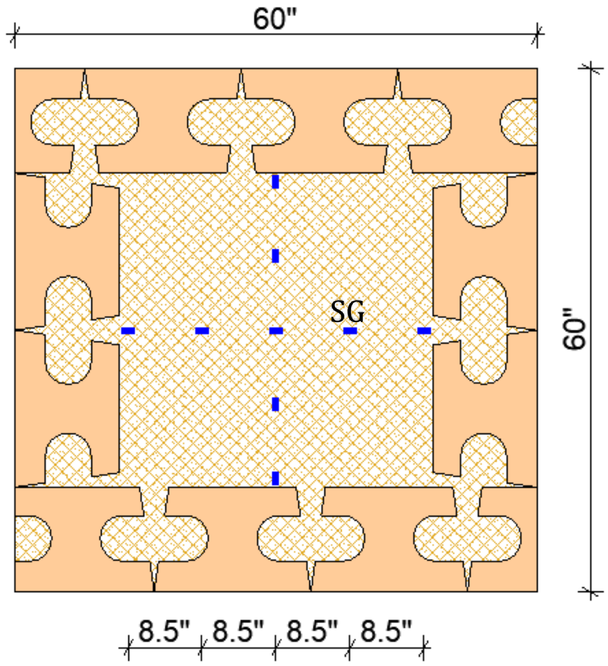
Plan view

Task-2: Design Experimental Plan for Performance Tests

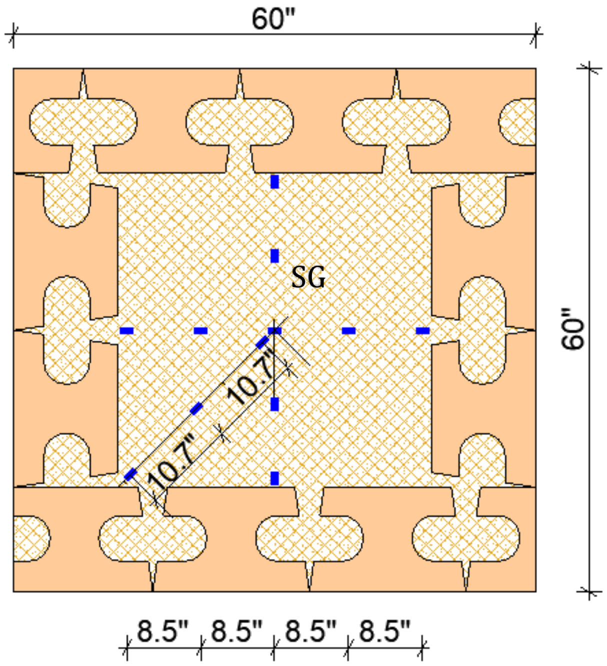
- Strain gage layout



Profile view, 8-inch spacing Pier



a) Top and bottom layers



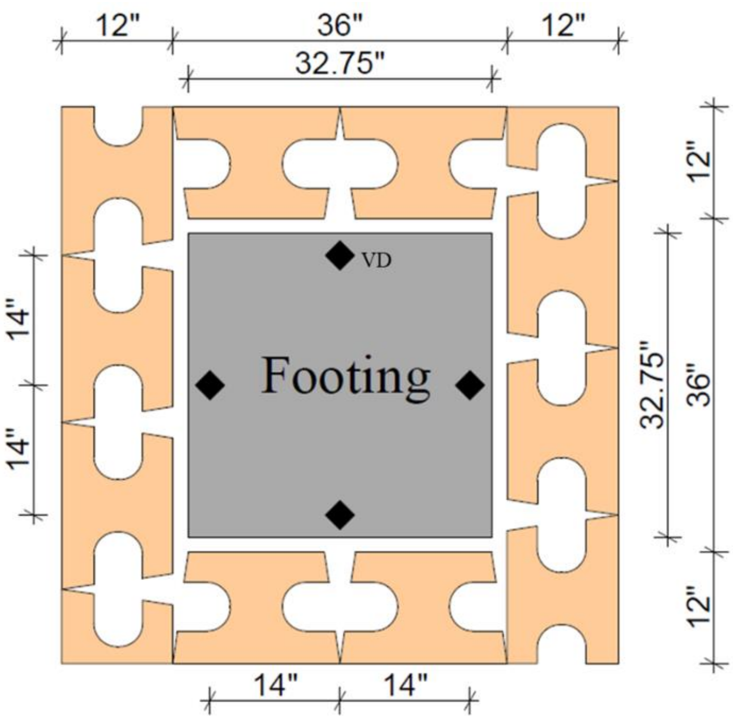
(b) Middle layer

Plan view

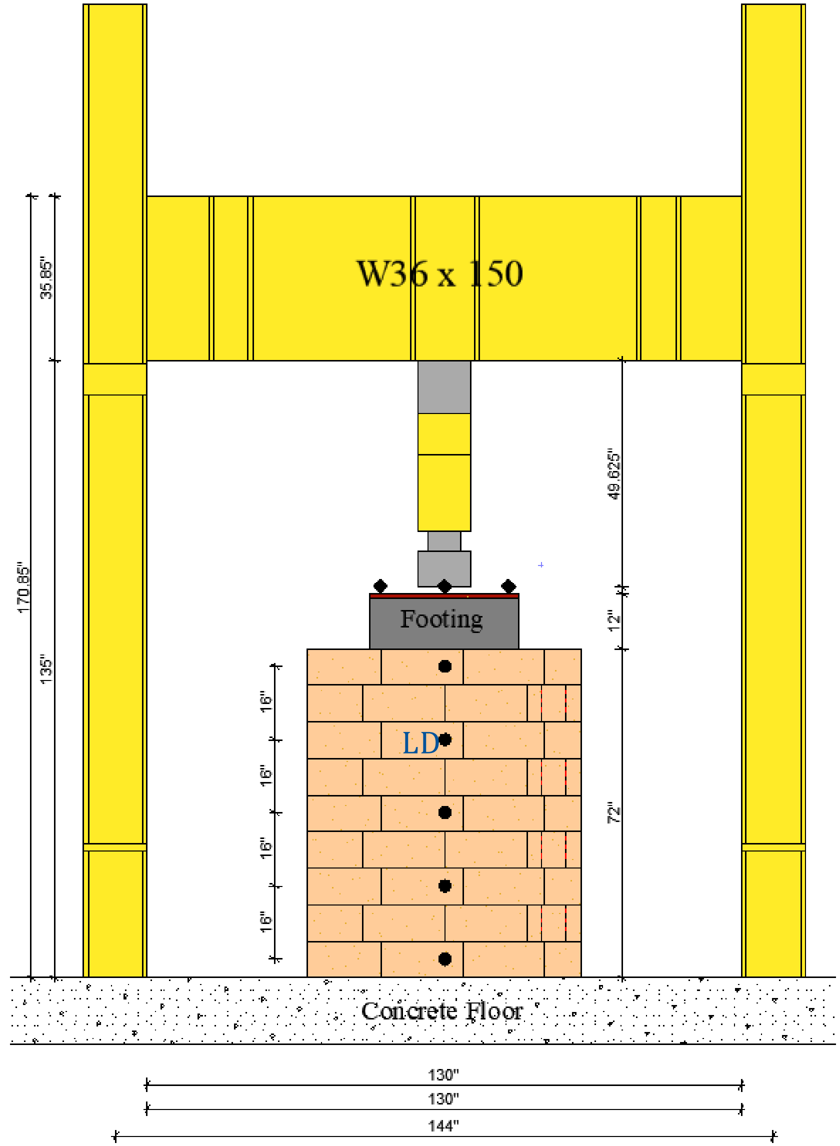
SG: Strain Gauge; **EP**: Earth pressure cells (Vertical); **LP**: Earth pressure cell (Horizontal)

Task-2: Design Experimental Plan for Performance Tests

- Test setup



Plan view of the pier

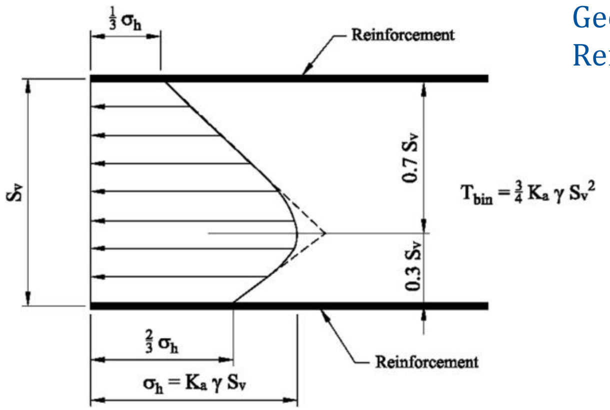


Reaction frame and pier

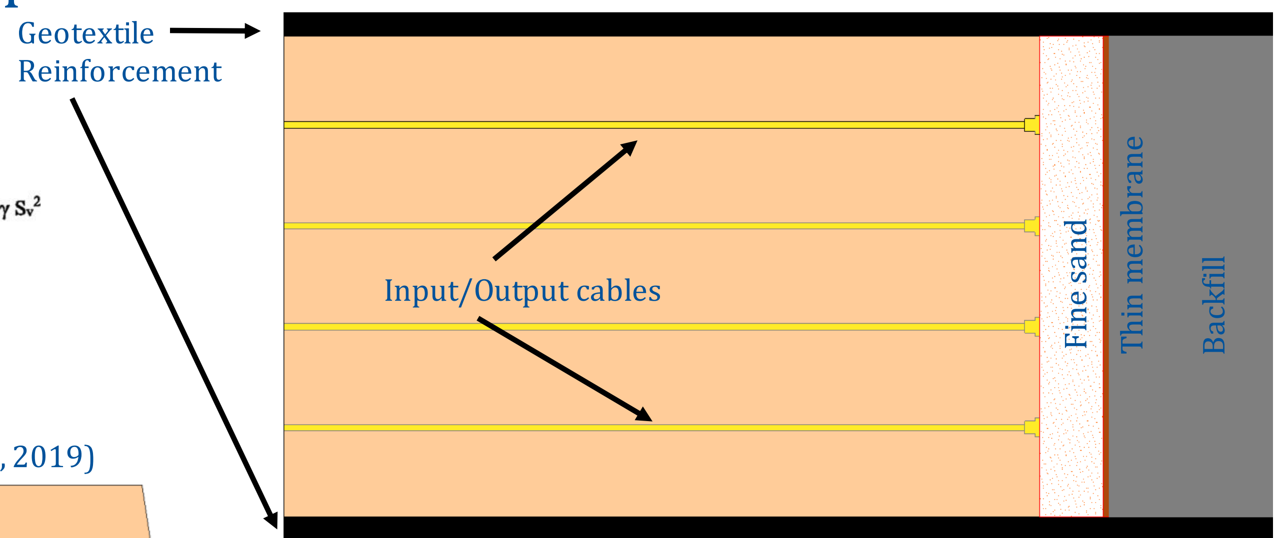
VD & LD: Instruments for measuring vertical and lateral displacement and geotextile strain using string potentiometers

Task-2: Design Experimental Plan for Performance Tests

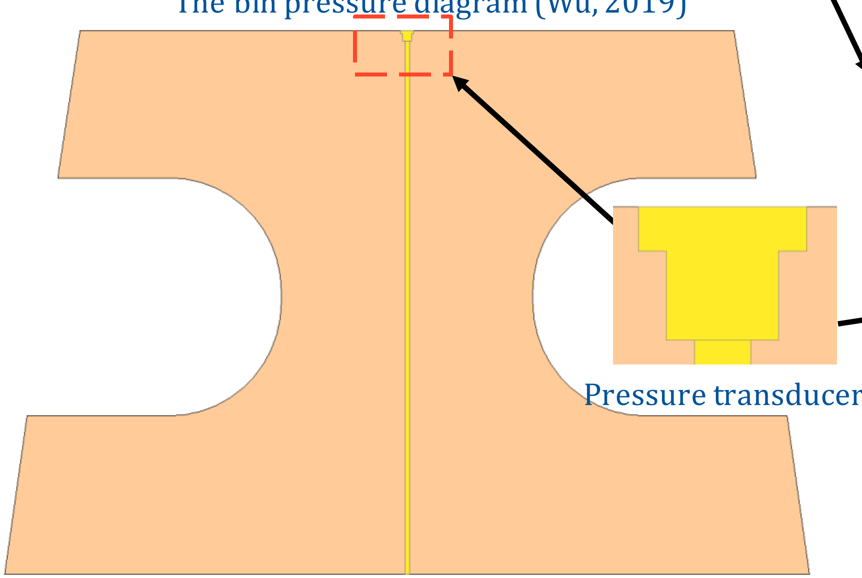
- Measuring earth pressure distribution



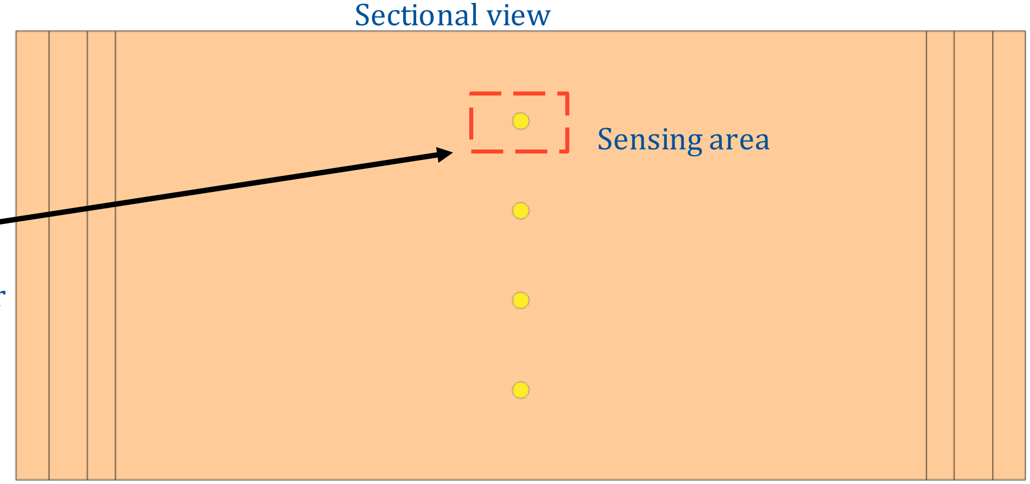
The bin pressure diagram (Wu, 2019)



Sectional view



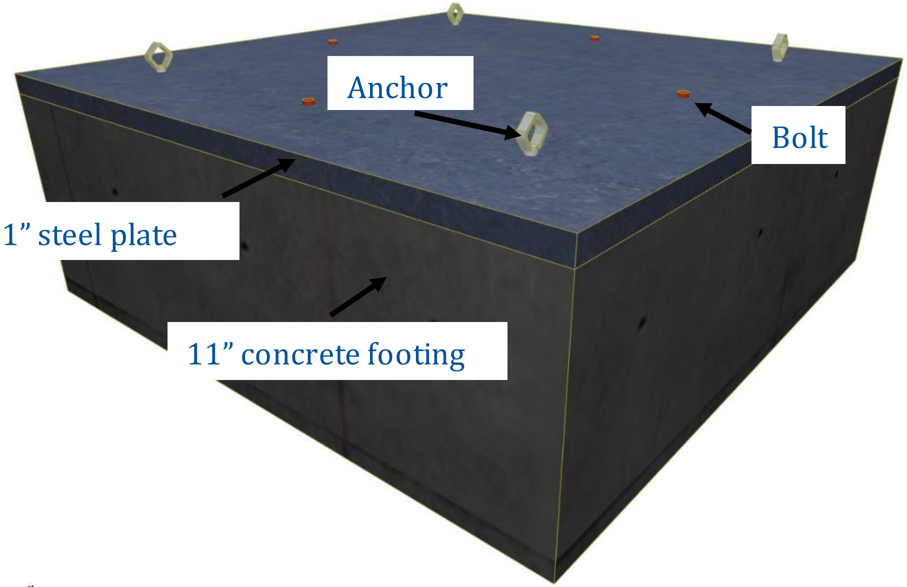
Top view



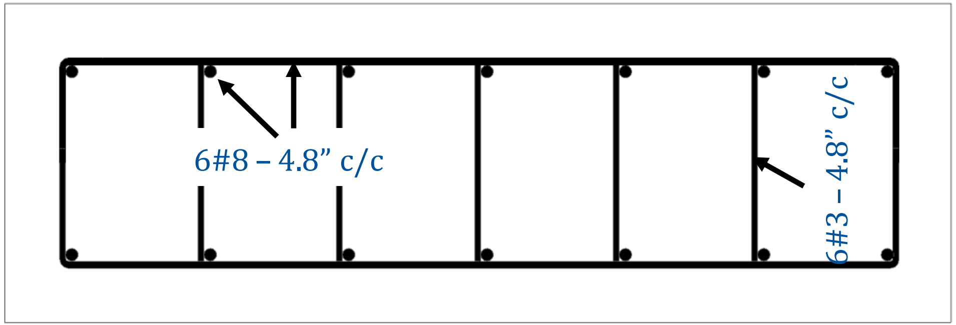
Front view

Task-2: Design Experimental Plan for Performance Tests

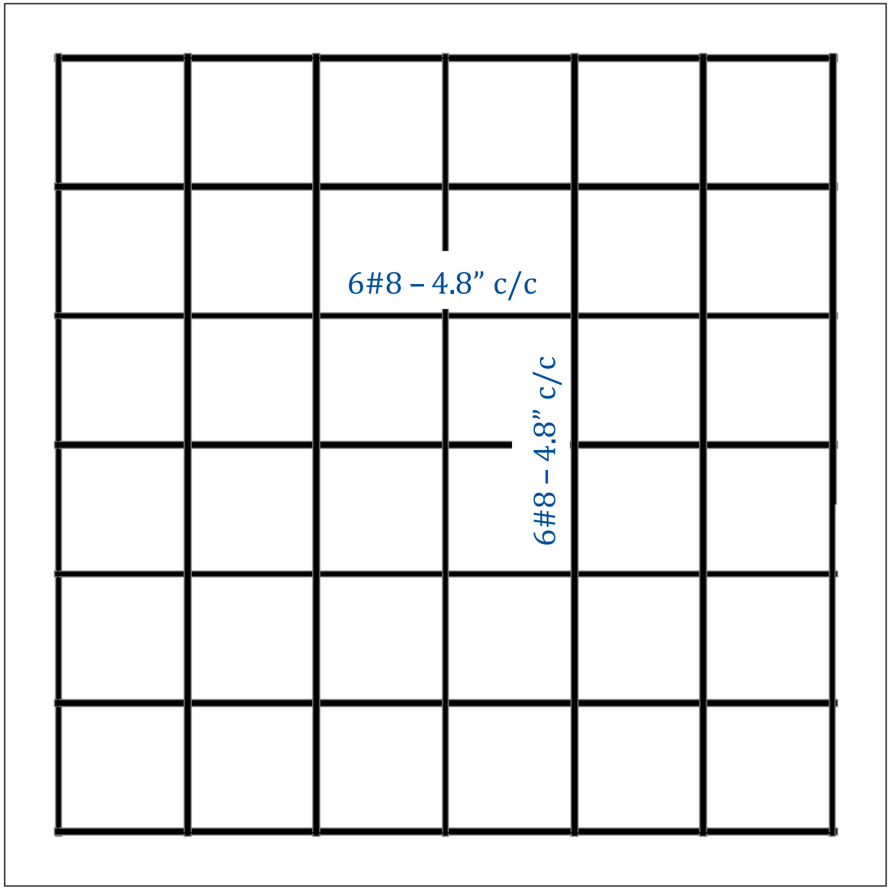
- Footing Design



Isometric view



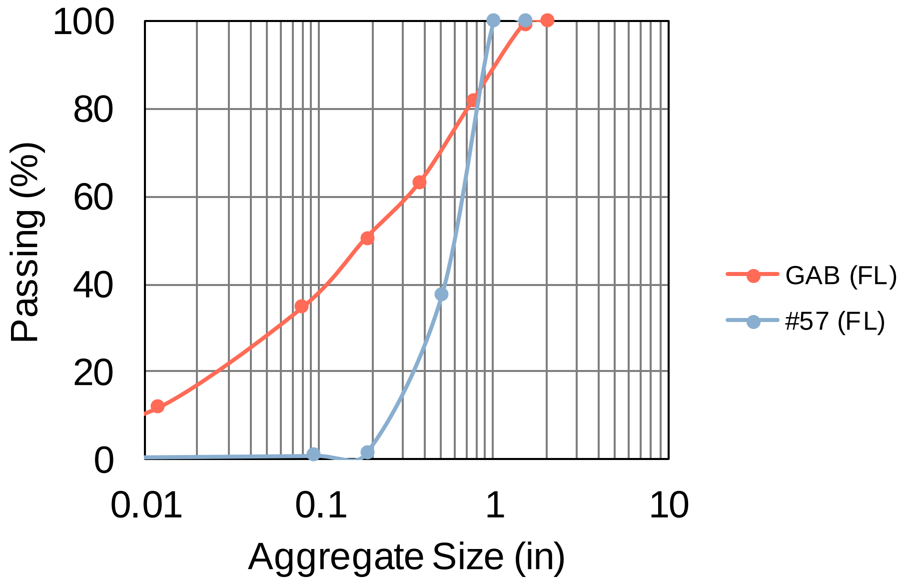
Reinforcement details: Sectional view



Reinforcement details: Layout

Task-3: Axial load-deformation tests on GRS piers

- Material Testing
  - Aggregates
    - Particle size
      - Sieve analysis
    - Density
      - Proctor test
      - Relative Density
    - Shear strength
      - Large scale direct shear test (CD)
      - Triaxial test (CD)



Particle size distribution curves for backfill materials

  - Geosynthetics
    - Tensile strength test (ASTM D 4595 for Geotextiles)

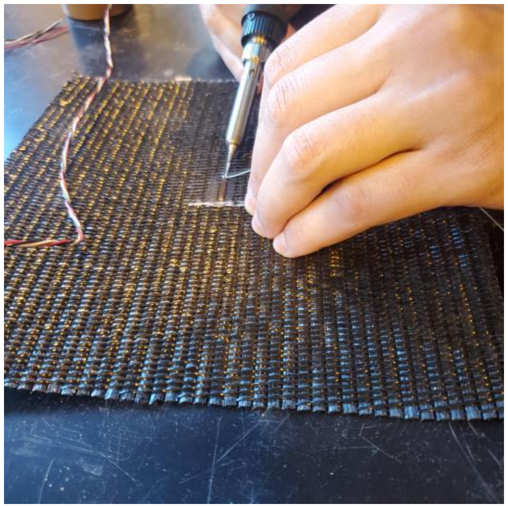
Task-3: Axial load-deformation tests on GRS piers

- Geotextiles

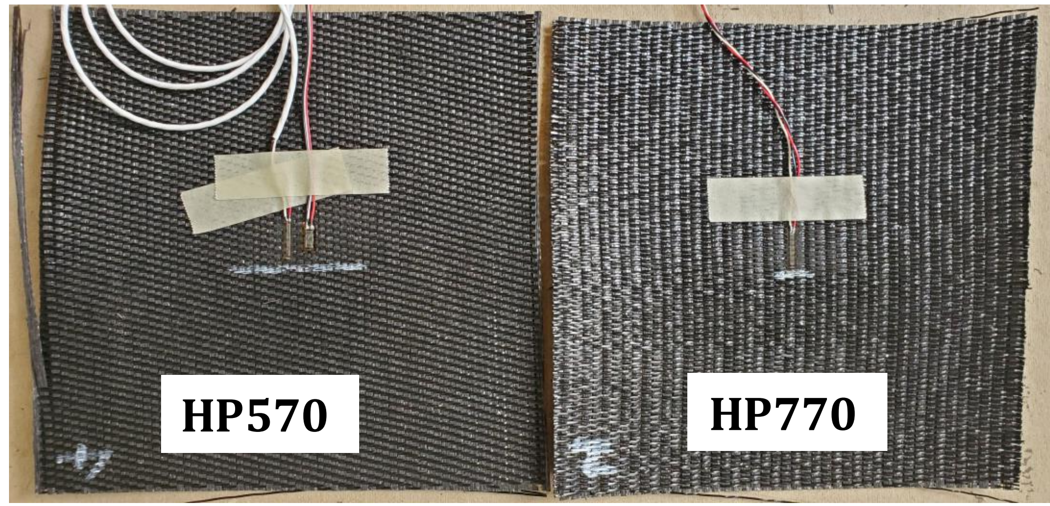
Mechanical Properties	Test Method	Minimum Average Roll Value	
		Machine Direction (MD)	Cross-Machine Direction (CD)
Mirafi HP 570			
Tensile Strength (at ultimate)	ASTM D4595	4,800 lbs/ft	4,800 lbs/ft
Tensile Strength (at 5% strain)	ASTM D4595	2,400 lbs/ft	3,000 lbs/ft
Mirafi HP 770			
Tensile Strength (at ultimate)	ASTM D 4595	7,200 lbs/ft	5,760 lbs/ft
Tensile Strength (at 5% strain)	ASTM D 4595	3,600 lbs/ft	3,600 lbs/ft

Task-3: Axial load-deformation tests on GRS piers

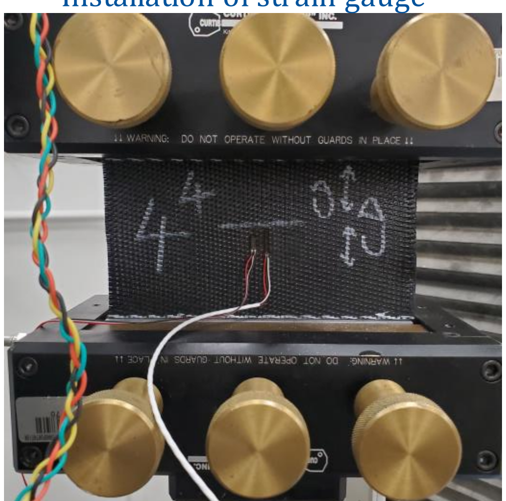
- Installation of strain gauges and testing of geotextile



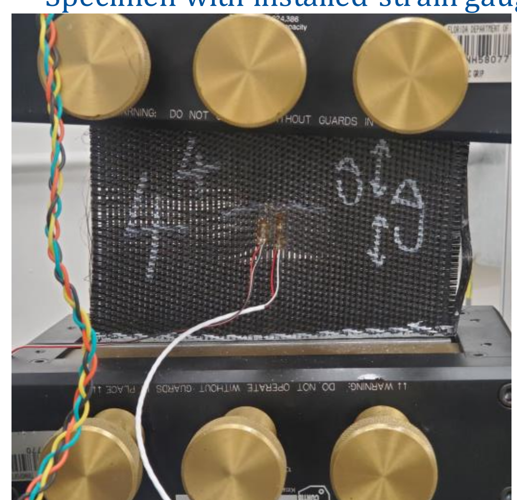
Installation of strain gauge



Specimen with installed strain gauges



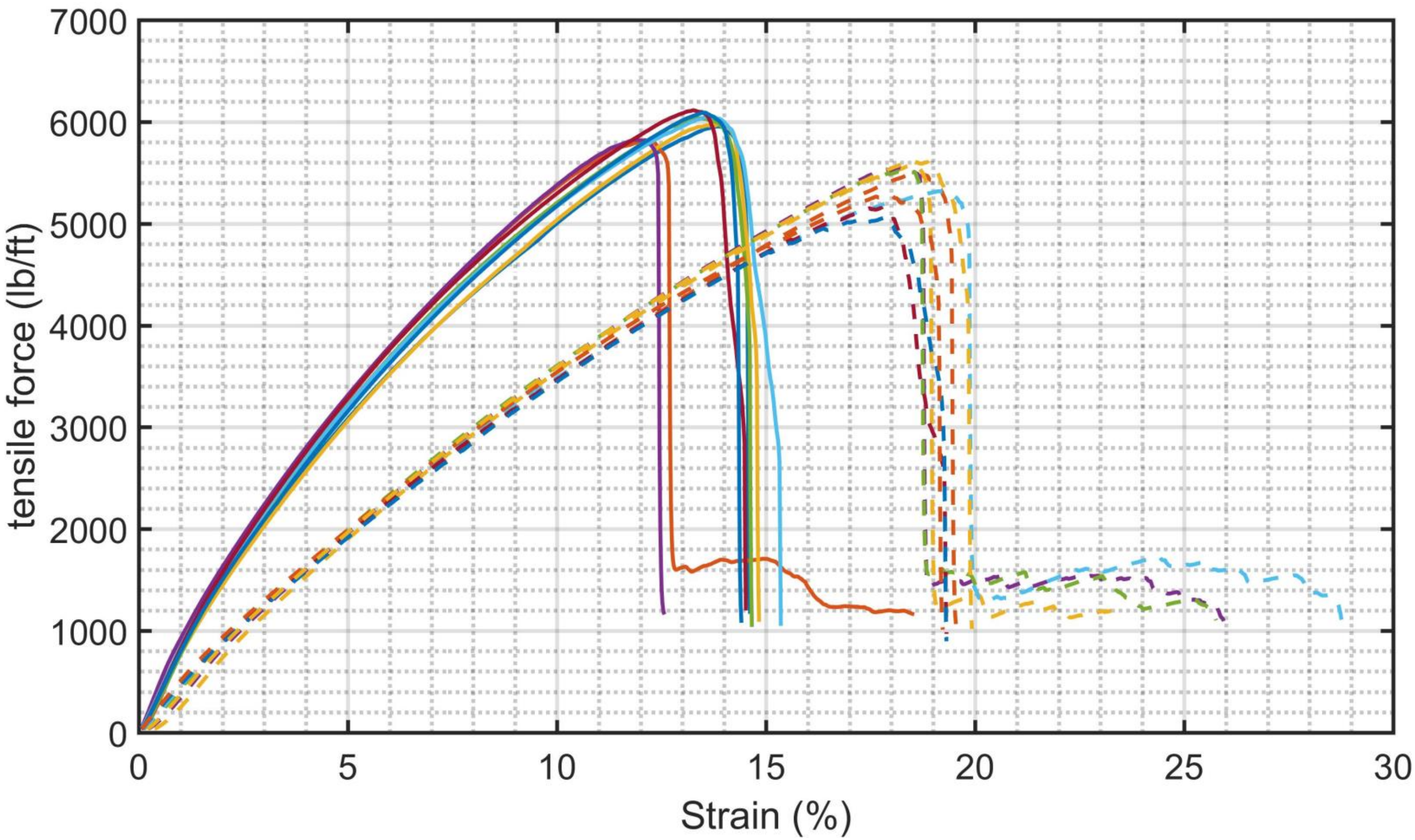
Specimen before failure



Specimen after failure

Task-3: Axial load-deformation tests on GRS piers

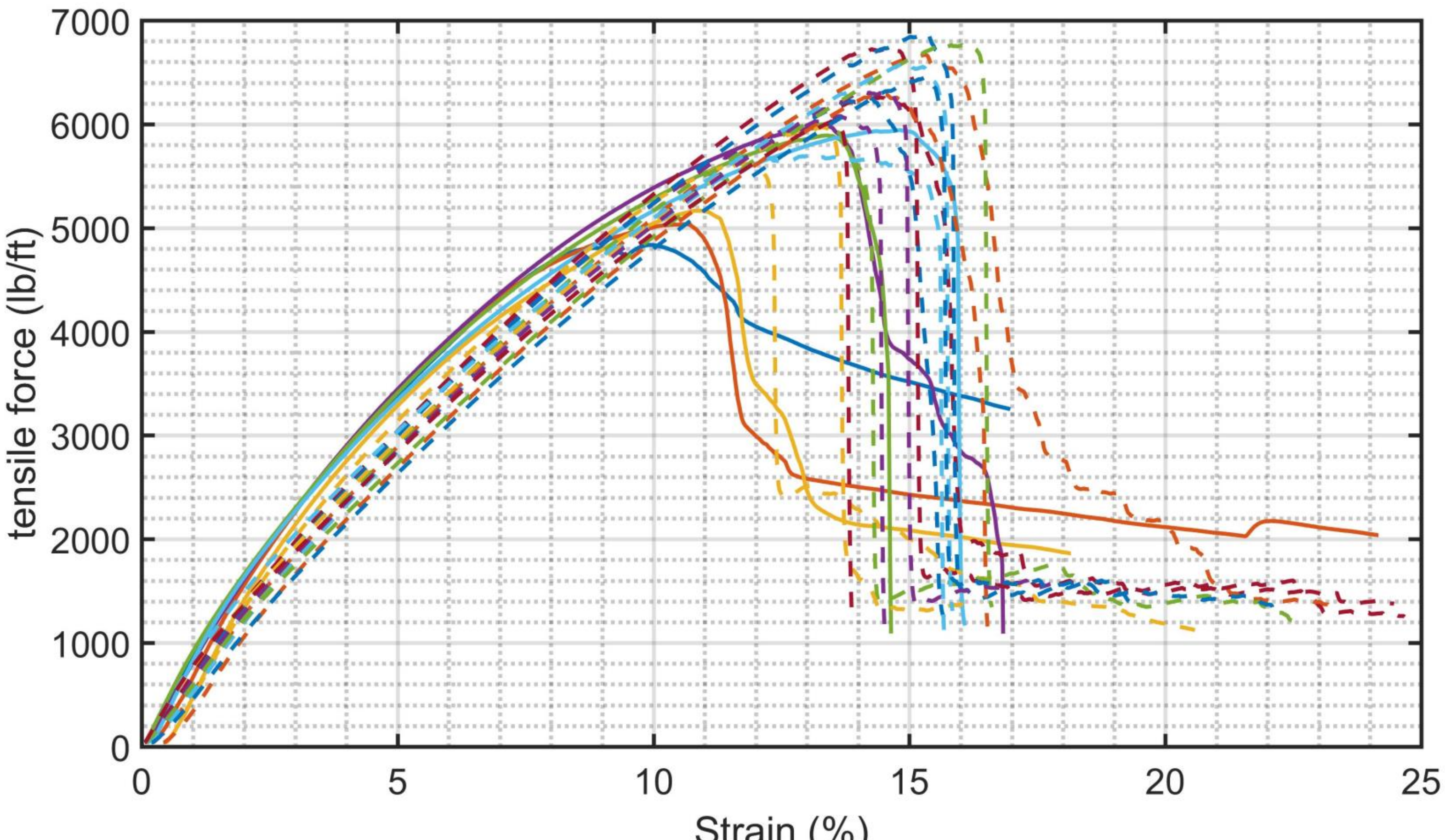
- Geosynthetics tensile test results (ASTM D4595)



A plot of axial-load versus strain for Mirafi HP570. Solid lines-cross-machine direction (CD), dashed lines-machine direction (MD)

Task-3: Axial load-deformation tests on GRS piers

- Geosynthetics tensile test results (ASTM D4595)

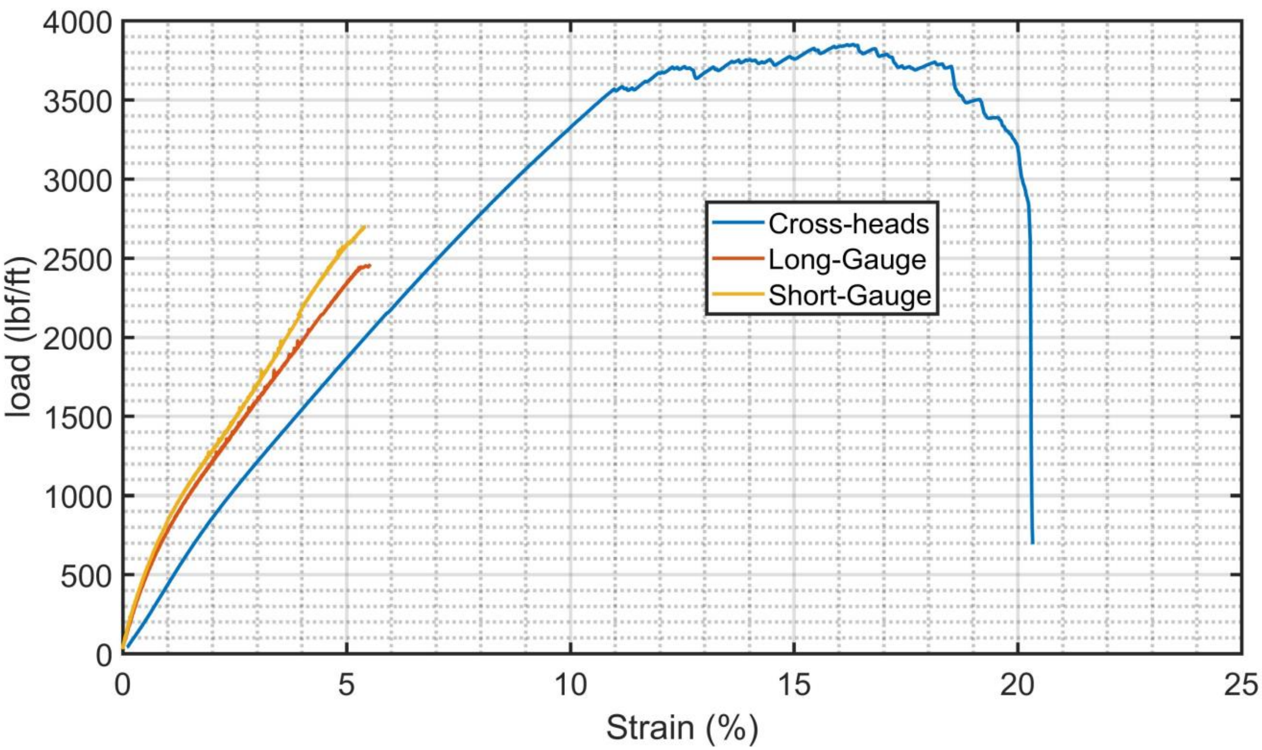


A plot of axial-load versus strain for Mirafi HP770. Solid lines-cross-machine direction(CD), dashed lines-machine direction (MD)

Task-3: Axial load-deformation tests on GRS piers

- Strain gauge (EP-Type : Vishay Micro-Measurements)

Gauge type	Gauge Length (in)	Grid Width (in)	Resistance (ohms)
EP-08-250BG-120 (Short-Gauge)	0.25	0.125	120
EP-08-500GB-120 (Long-Gauge)	0.50	0.060	120



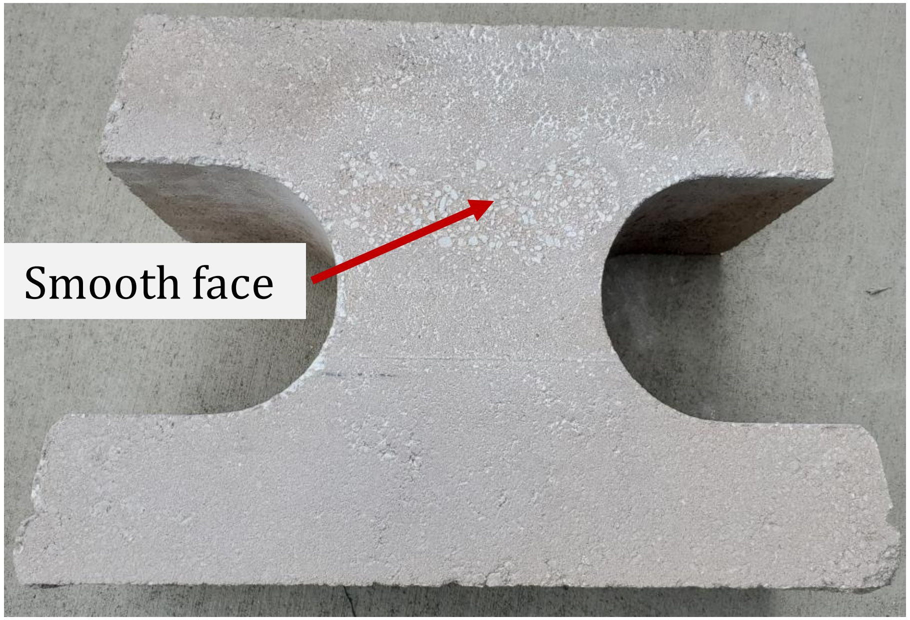
A comparison of strain from cross-head (Instron) and strain-gauges

Task-3: Axial load-deformation tests on GRS piers

- Preparation of blocks

Anchor Vertica straight face blocks

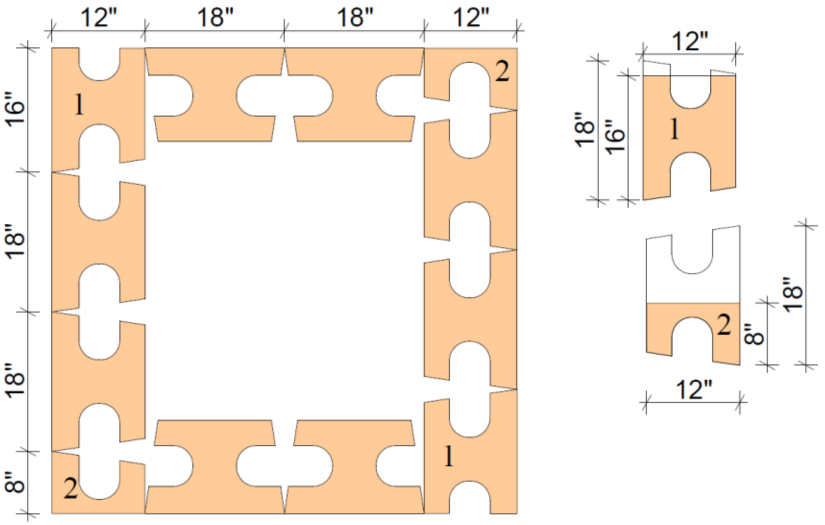
Grinding the lug off the tops of the Vertica straight face block



Block with smooth surface after removal of the lug

Task-3: Axial load-deformation tests on GRS piers

- Preparation of blocks



Details of the corner blocks for cutting

Cutting of blocks (Wet saw)

Vertica straight face blocks after being wet cut

Task-3: Axial load-deformation tests on GRS piers

Construction of Pier

GRS test pier construction. A-D are the first through fourth courses

- A Laying the face blocks
- B Placing and compacting backfill
- C Laying down geosynthetics
- D Repeat A-C until the final height is reached

Task-3: Axial load-deformation tests on GRS piers

- Construction of Pier

GRS test pier constructed to limited height with five courses

Project Timeline

Deliverable # / Description as provided in the scope (included associated task #) Project start date 2/27/2020	Anticipated Date of Completion	Status
Kickoff Teleconference	3/2020	Completed
Deliverable #1/ Task 1- Report on previous studies on GRS piers, design methods, and construction practices	7/1/2020	Completed
Deliverable #2/Task 2 – Report on the design experimental plan for GRS performance tests	10/1/2020	Completed
Deliverable #3a/Task 3 – Report on GRS performance tests (axial load-deformation tests)	4/1/2021	Completed/Active
Deliverable #3b/Task 3 – Report on GRS performance tests (axial load-deformation tests)	10/1/2021	Active
Deliverable #3c/Task 3 – Report on all GRS performance tests (axial load-deformation tests)	12/1/2021	
Deliverable #4/Task 4- Report on comparison of GRS performance test results with published results and predictions based on available design methods	4/1/2022	
Deliverable #5/ Task 5 –Draft final report: a comprehensive description of the work performed and will include a summary of piers tested: including dimensions (H/B), facing elements, geosynthetics, and aggregates as well as all measured results. Also provided will be a comparison of the pier's measured and predicted axial capacities and recommendations on their construction and design with Florida aggregates.	6/1/2022	
Deliverable #6a/Task 6 – PowerPoint presentation- closeout teleconference to review project performance, the deployment plan, and next steps.	8/15/2022	
Deliverable #6b/Task 6 – Final Report to the FDOT	9/1/2022	

References

- FDOT. (2021). Structures Manual: Volume 1 – Structures Design Guidelines.
- Adams, M.T., Nicks, J.E., Stabile, T., Wu, J.T.H., Schlatter, W., and Hartmann, J. (2012). Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide, Report No. *FHWA-HRT-11-026*, Federal Highway Administration, Washington, DC.
- Adams, M., Nicks, J. (2018). Design and Construction Guidelines for Geosynthetic Reinforced Soil Abutments and Integrated Bridge Systems, Report No. FHWA-HRT-17-080. Federal Highway Administration, Washington, DC.
- Wu, J. T. H. (2019). Characteristics of geosynthetic reinforced soil (GRS) walls: an overview of field-scale experiments and analytical studies. Transportation Infrastruct. Geotechnol. 6 (2), 138–163 (2019).

Thank You!