Georgia Tech School of Civil and Environmental Engineering
College of Engineering

Particle-scale Evaluation of Aggregate-Geogrid Behavior under Cyclic Wheel Loading

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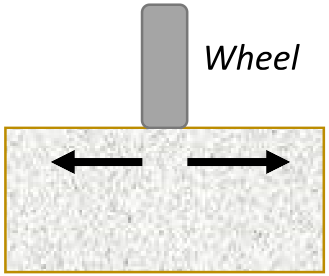
Outline

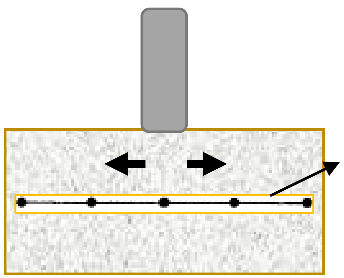
- Introduction
- Bench-scale Pavement Testing
- Experimental Study I
- Experimental Study II
- Future Work and Conclusions

Introduction: Motivation and Background

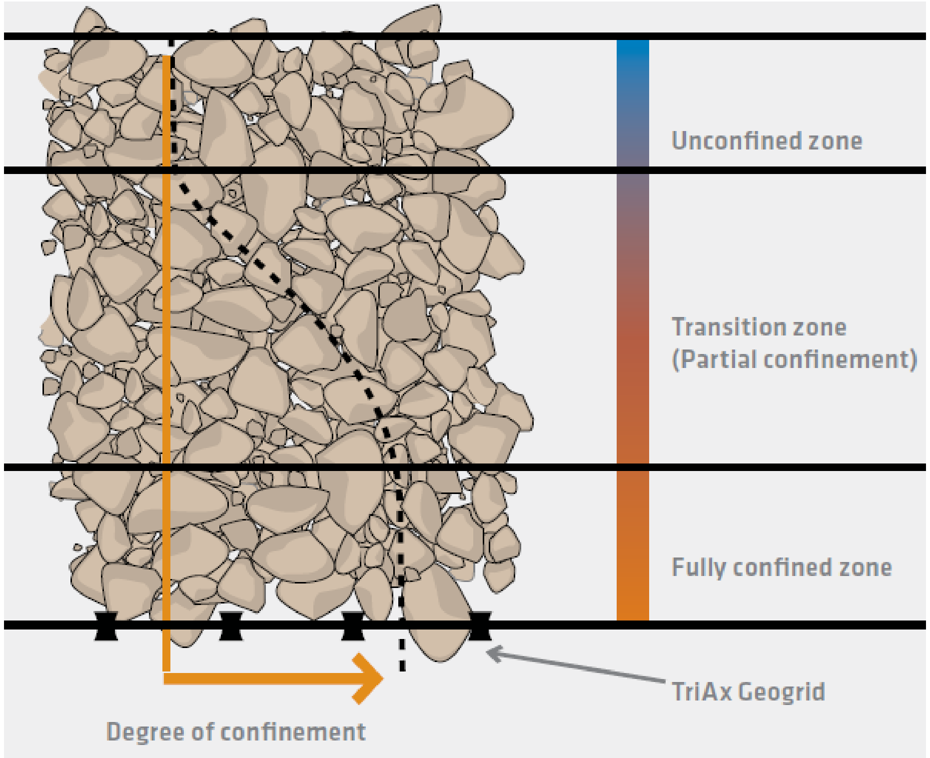
Understanding fundamental aggregate-geogrid interaction



Lateral spreading of particles



Reduced spreading by interlocking with geogrid

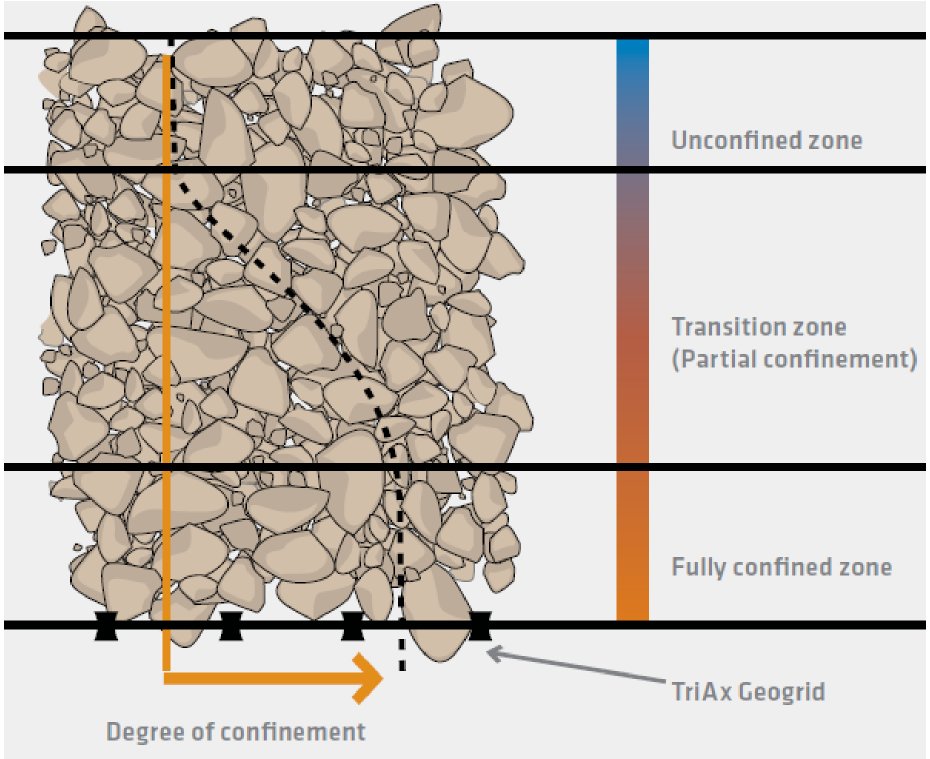


Confinement induced by aggregate-geogrid interlocking

(Tensar Subgrade Stabilization Manual)

Introduction: Motivation and Background

- How do we maximize interlocking?
  - Grid location
  - Aggregate-Geogrid Compatibility
  - Aggregate properties
- How do we measure it?

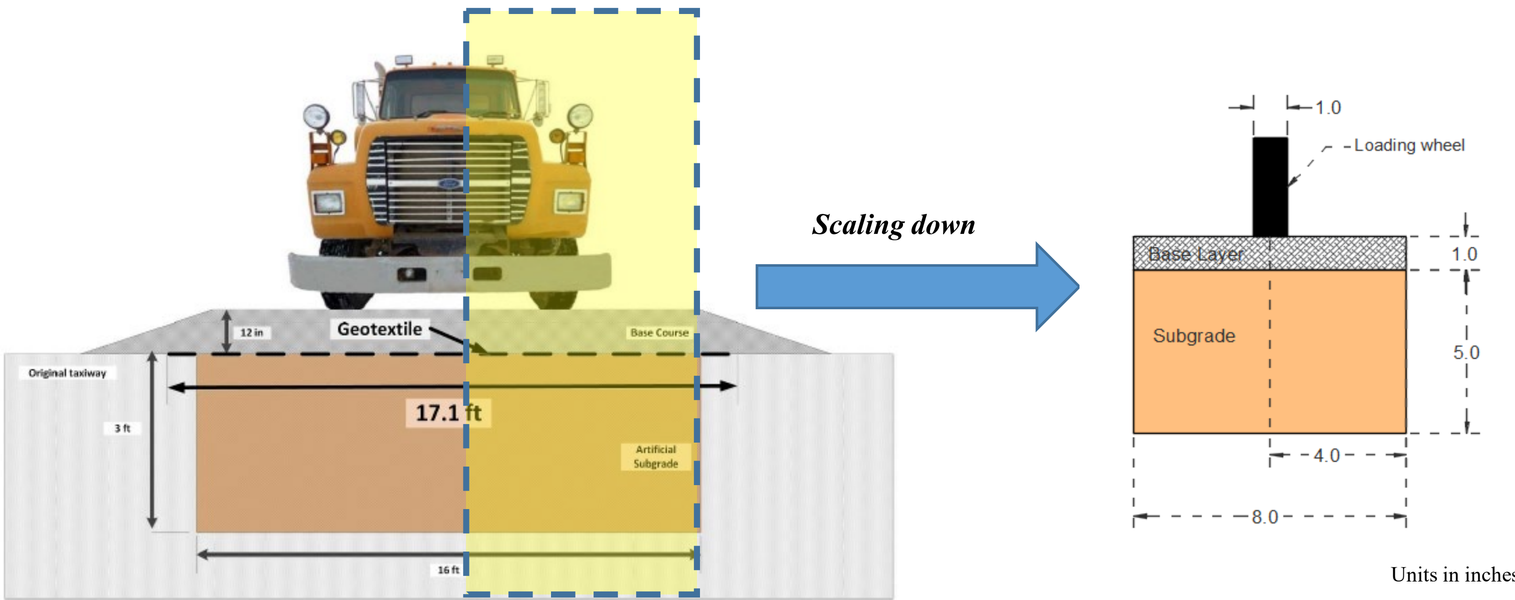


Confinement induced by aggregate-geogrid interlocking

(Tensar Subgrade Stabilization Manual)

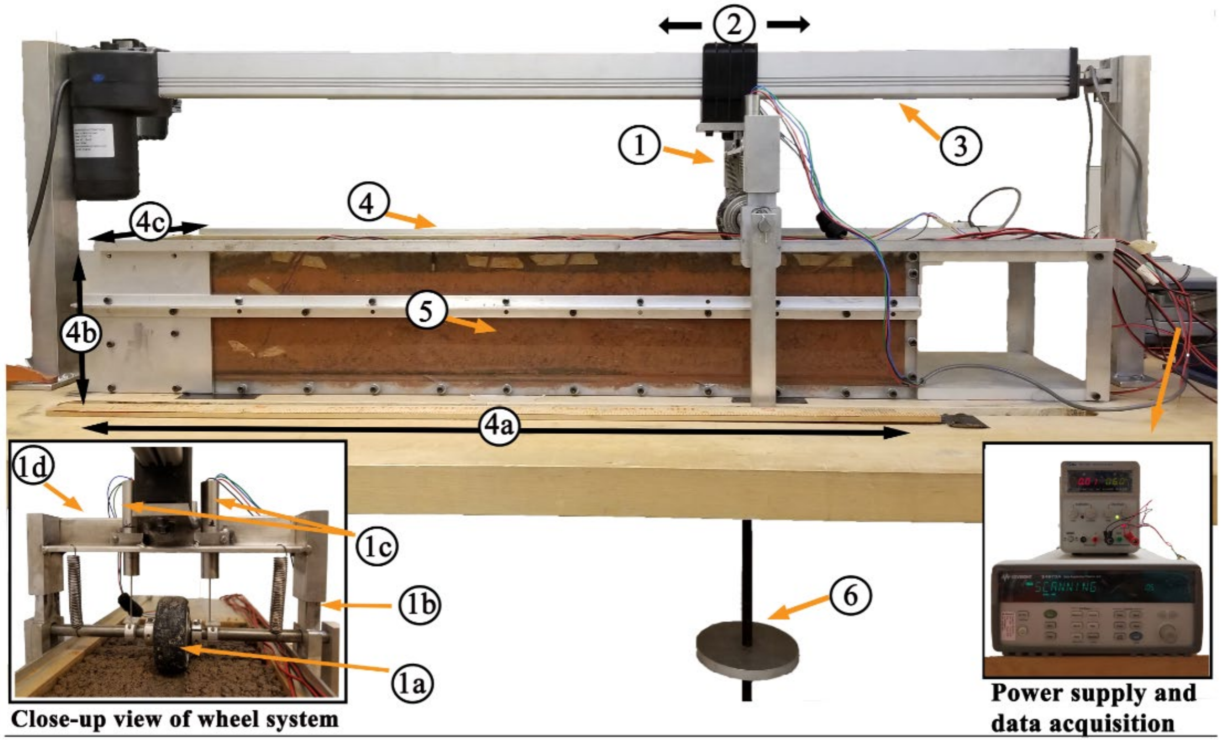
Introduction: Motivation and Background

Schematic showing cross-sections of full-scale and bench-scale specimens



(after Cuelho et al., 2014)

Bench-scale Pavement Testing Setup

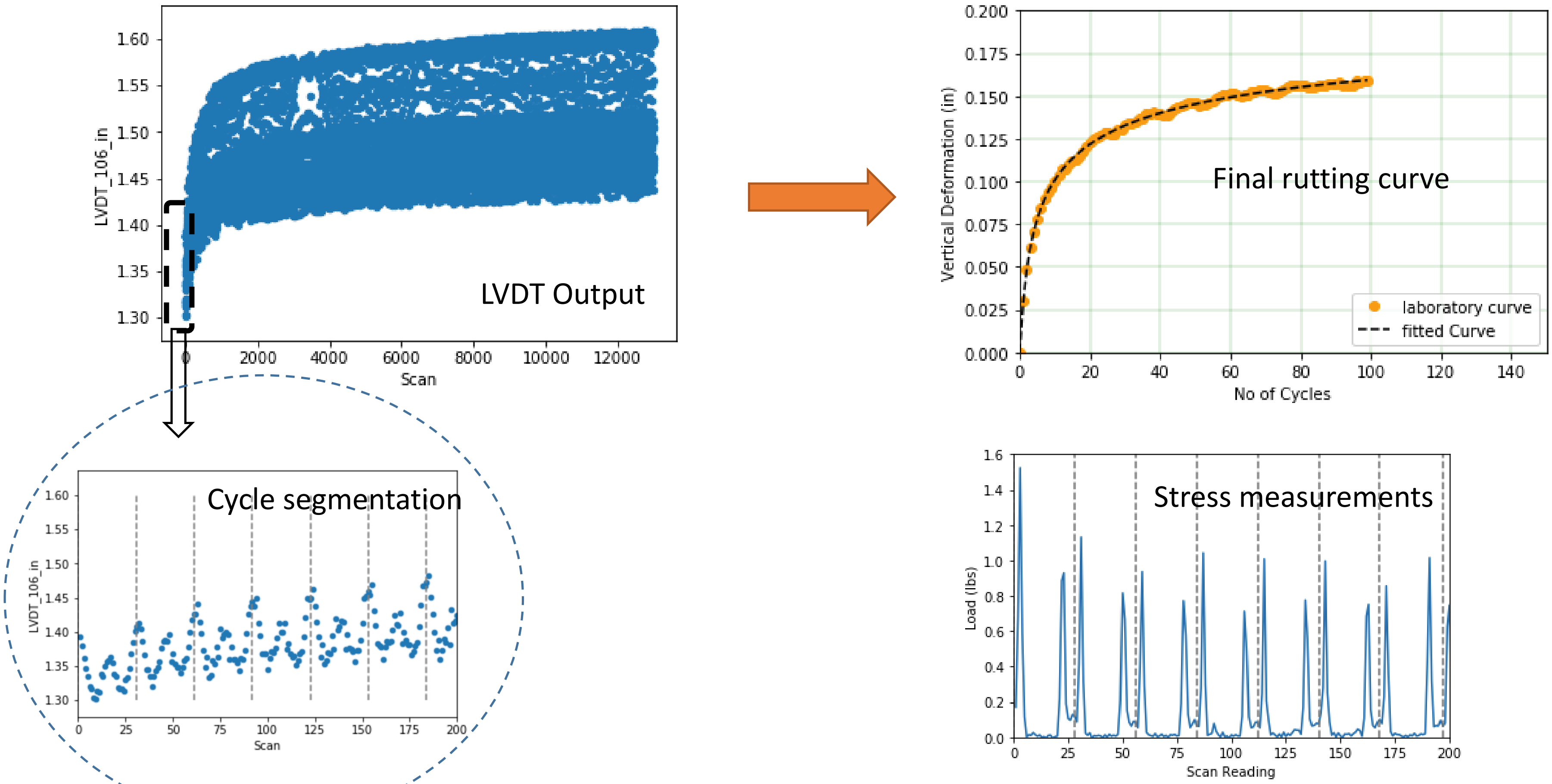


1) Wheel system
   a) Wheel (3 in ∅, 1 in width)
   b) Adjustable yoke
   c) Linear variable displacement transducers
   d) Support frame

2) Direction of wheel motion
3) Micro-conroller driven track actuator
4) Box
   a) 36 in length
   b) 6 in height
   c) 8 in width

5) Transparent lexan wall
6) Suspended loading system

Bench-scale Pavement Testing Setup



Sample plots showing data processing stages

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Experimental Study I

Effect of Aggregate Morphology on Rutting Behavior

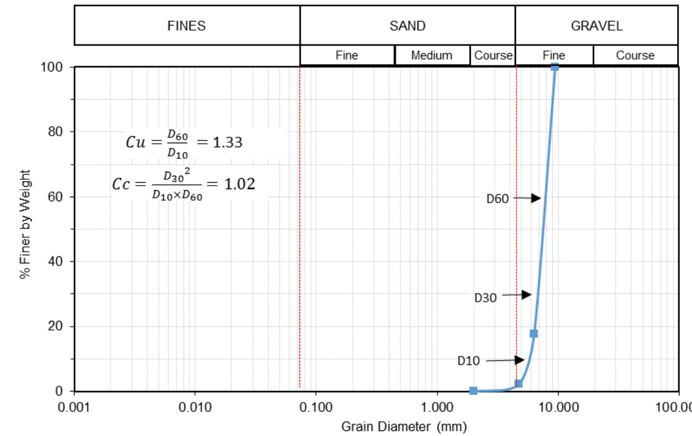
Material Properties

Aggregate Samples

RA Material
Pea Gravel
Sub-rounded and smooth

QA Material
#89 Stone
Angular and rough

Grain Size Distribution



Grain size analysis Chart

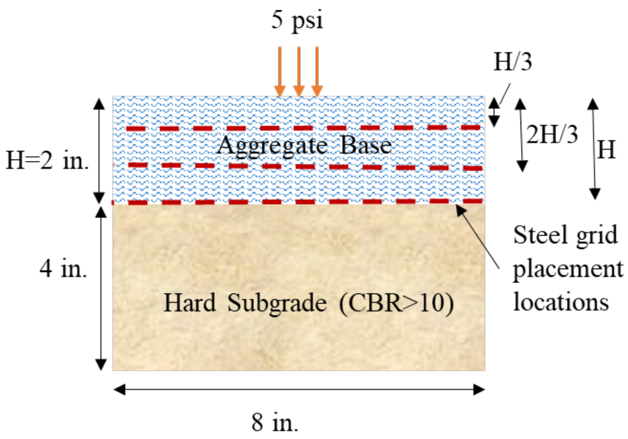
Steel Grids (SG)

Steel Grid	Aperture Size, in. (mm)	Rib Thickness, in. (mm)
SG1	0.25 (6.35)	0.020 (0.50)
SG2	0.50 (12.7)	0.032 (0.815)
SG3	0.75 (19.05)	0.069 (1.76)
SG4	1.00 (25.4)	0.055 (1.4)

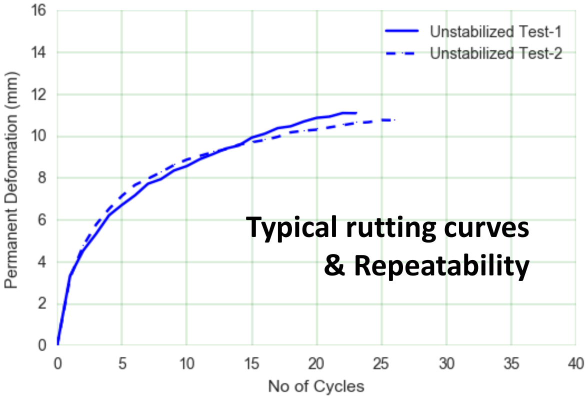
Experimental Program

- Loading stress = 5 psi (35 kPa)
- Loading Duration = 35 cycles
- Testing Program
  - 2 aggregates
  - 4 scenarios of stabilization using each grid

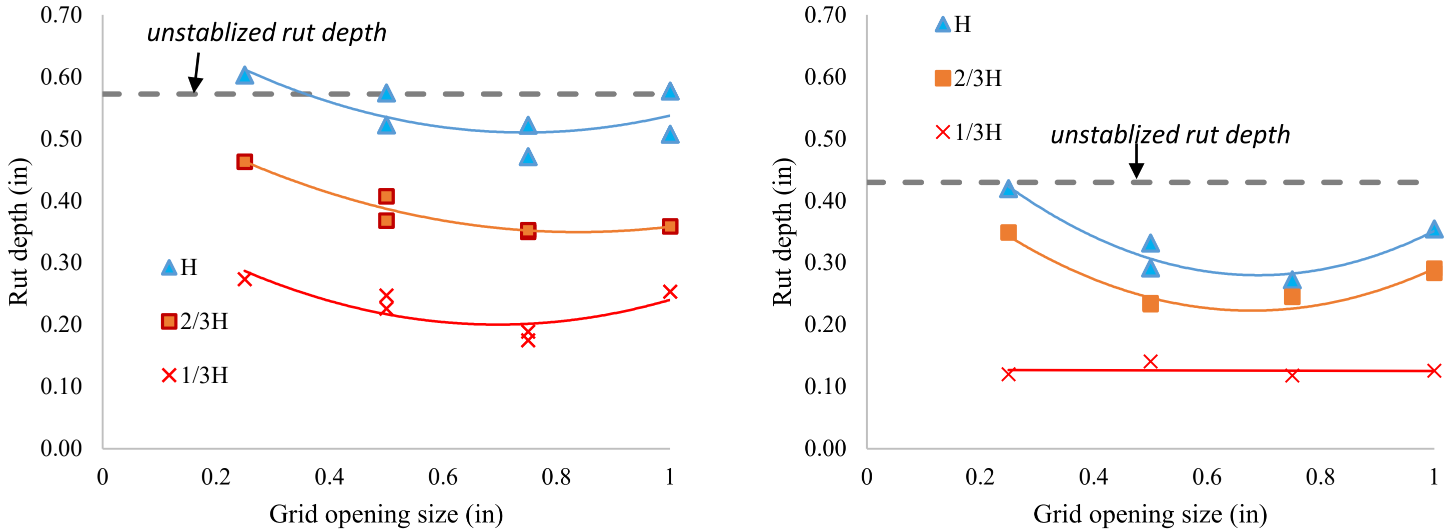
Cross-section of specimen setup



Typical rut formations



Results and Discussion

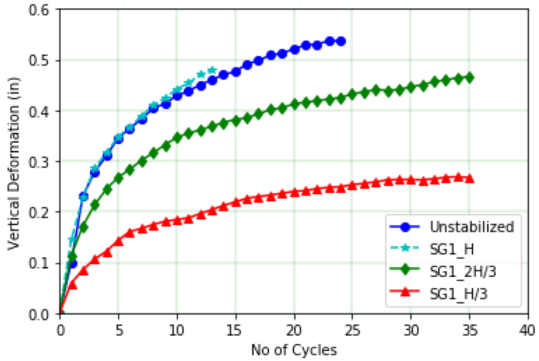


Rutting depth for (a) RA and (b) QA materials and all four grid openings

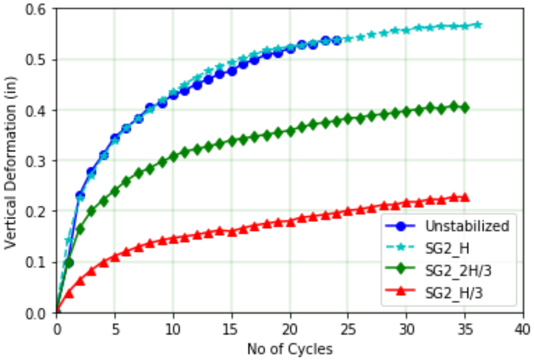
Results and Discussion

RA Aggregate: Rutting behavior for various stabilization scenarios

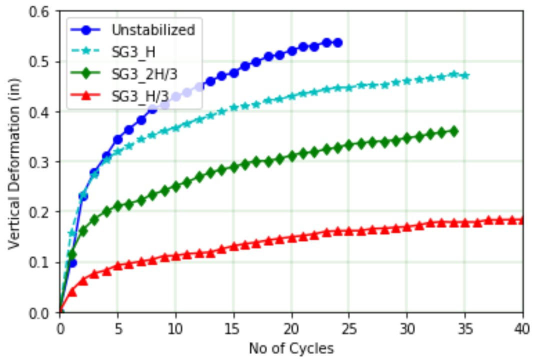
SG1 – ¼ in. opening size



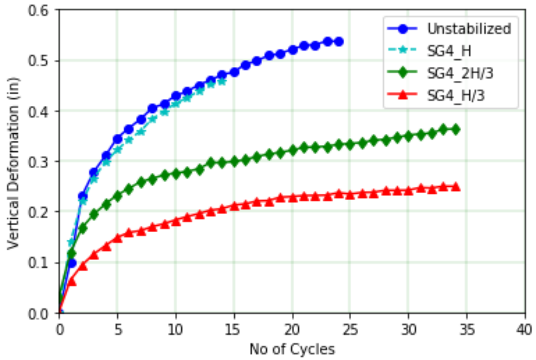
SG2 – ½ in. opening size



SG3 – ¾ in. opening size



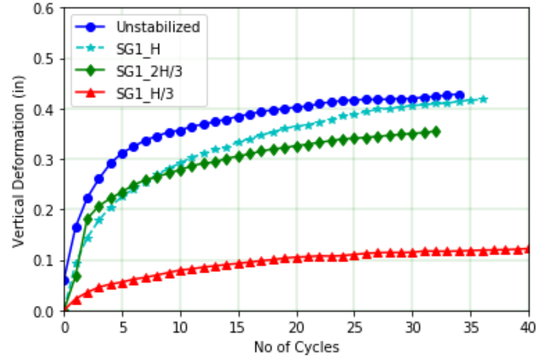
SG4 – 1 in. opening size



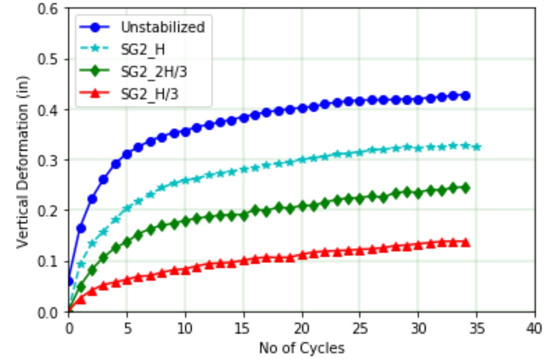
Results and Discussion

QA Aggregate: Rutting behavior for various stabilization scenarios

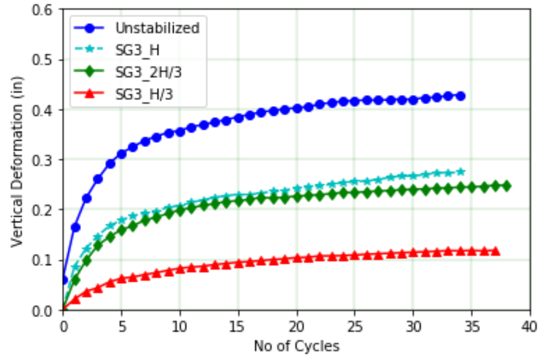
SG1 – ¼ in. opening size



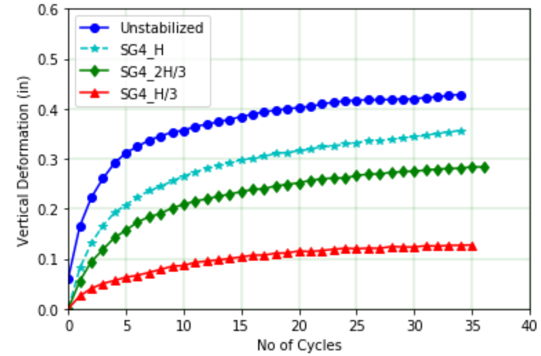
SG2 – ½ in. opening size



SG3 – ¾ in. opening size



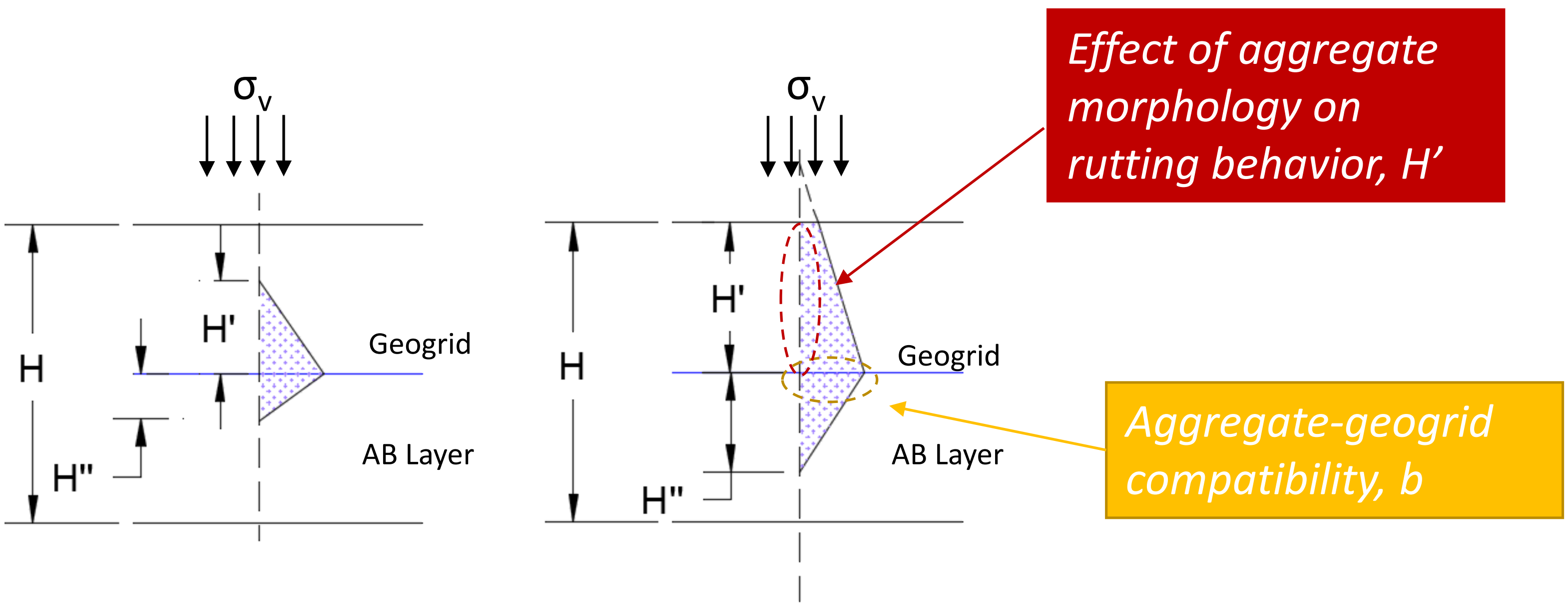
SG4 – 1 in. opening size



Results and Discussion

- *QA showed consistent reduction in rutting while RA only showed change for shallow grid placement*
- *QA is more bilinear than RA*

GG performance ~ f(σ_v, H', b)

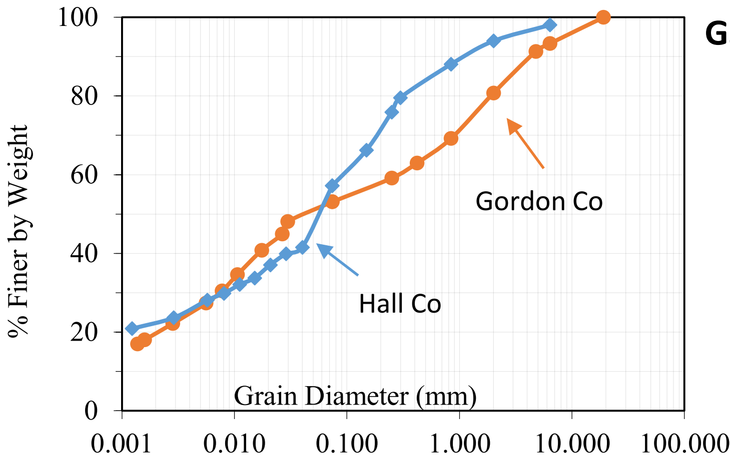


Hypothetical zones of confinement induced by geogrid

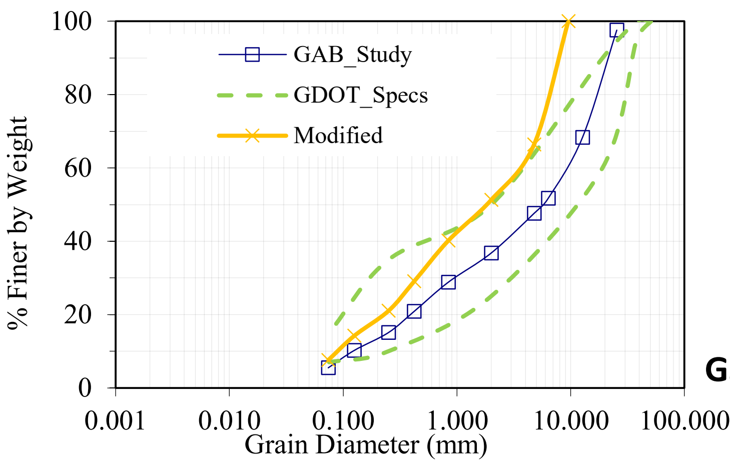
Experimental Study II

Effect of Subgrade Stiffness and Geosynthetic Stabilization on Pavement Performance

Material Properties



GSD for subgrade soils



GSD for GAB

Subgrade and GAB Material Properties

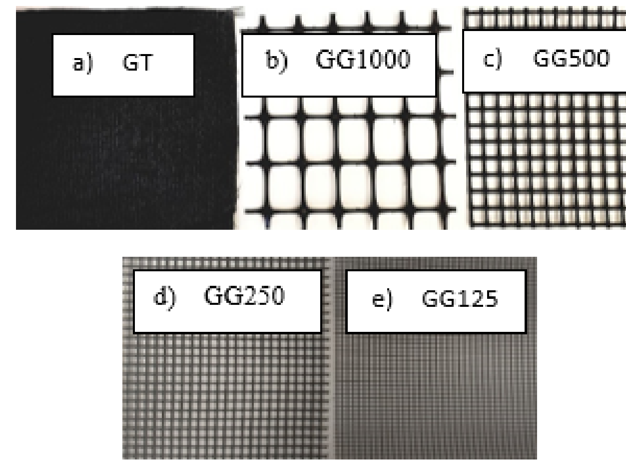
	Gordon Co	Hall Co	GAB
USCS Classification	MH	MH	GW
Percentage fines	53.1	57.2	5.5
Plastic Limit	41.7	37.4	-
Liquid Limit	63.4	57.1	-
Plasticity Index	21.7	19.7	-
Max Dry Density (pcf)	107.0	114.0	133.5
Optimum Water Content	17.5	15.0	7.2

Material Properties

Geosynthetics Material Properties

		GG1000*	GG500	GG250	GG125	GT*
Opening size, inch (mm)		1.0 (25.4)	0.5 (12.7)	(0.25) 6.35	0.125 (3.18)	0.024 (0.6)
Minimum rib thickness, inch (mm)		0.05 (1.27)	0.08 (1.95)	0.05 (1.30)	0.03 (0.74)	-
Tensile Strength @ 2% strain lb/ft (kN/m)	MD	410 (6.0)	292 (4.26)	209 (3.05)	132 (1.93)	-
	XMD	620 (9.0)	347 (5.06)	249 (3.63)	163 (2.38)	-
Tensile Strength @ 5% strain lb/ft (kN/m)	MD	810 (11.8)	402 (5.87)	286 (4.18)	169 (2.46)	1274 (18.6)
	XMD	1340 (19.6)	492 (7.18)	363 (5.3)	206 (3.02)	1439 (21.0)
Ultimate Tensile Strength lb/ft (kN/m)	MD	1310 (19.2)	410 (5.99)	292 (4.26)	169 (2.46)	2640 (38.5)
	XMD	1970 (28.8)	504 (7.36)	405 (5.91)	206 (3.02)	2460 (35.9)

*Provided by manufacturer



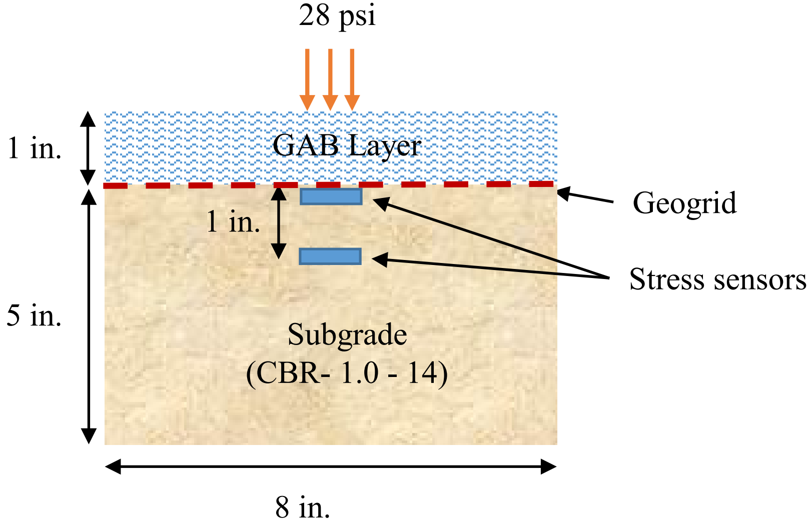
Geosynthetics used in study

Experimental Program

- Loading stress = 28 psi (190 kPa)
- Loading Duration = 250-500 cycles
- Testing Program
  - At least 2 subgrade stiffness conditions
  - 5 scenarios of stabilization using each geosynthetic

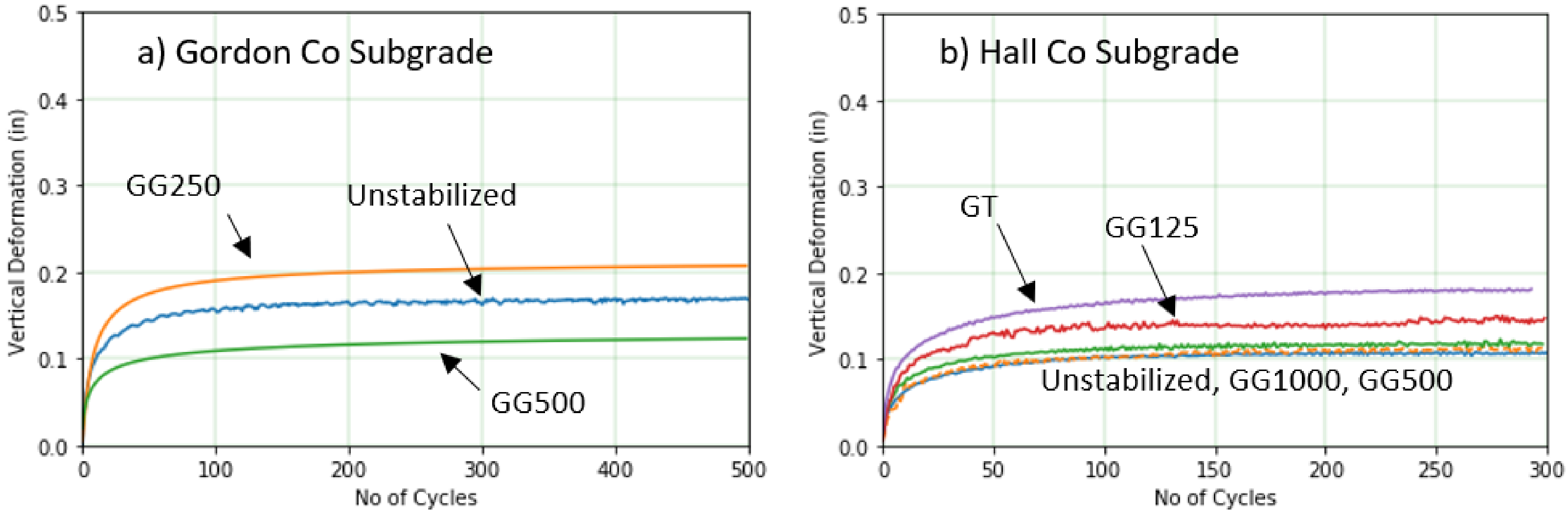
Typical rut formations

Cross-section of specimen setup



Results and Discussion

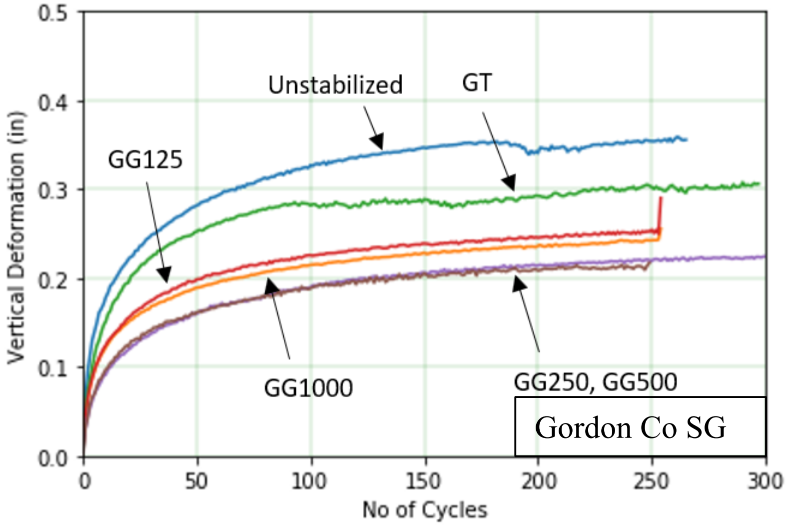
Rutting with Stiff Subgrades at CBR>2.5

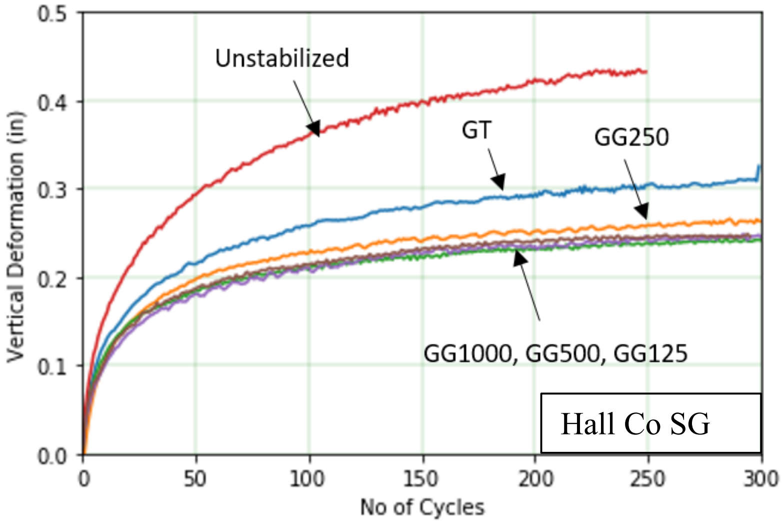


Effect of geosynthetic stabilization on a) Gordon (CBR 5.5) and b) Hall Co (CBR>10) subgrades with CBR>2.5

Results and Discussion

Rutting with Soft Subgrades at CBR<2.5

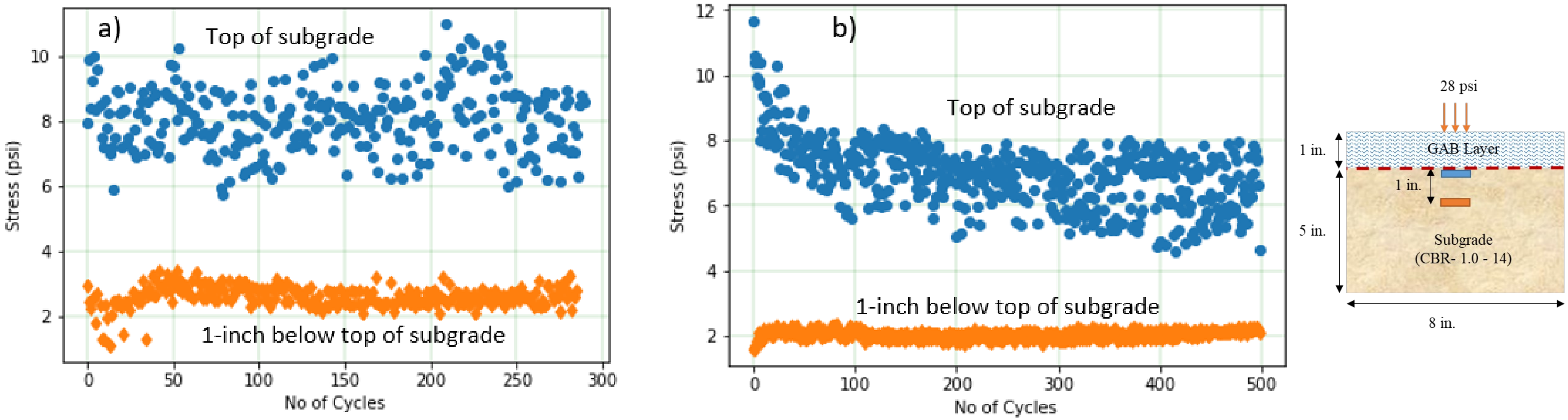




Effect of geosynthetic stabilization on a) Gordon and b) Hall Co subgrades with CBR<2.5

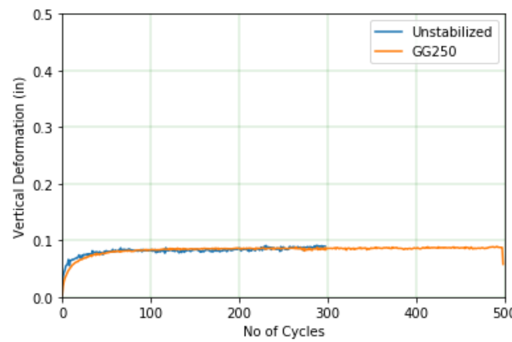
Results and Discussion

Stresses with Stiff Subgrades at CBR>10



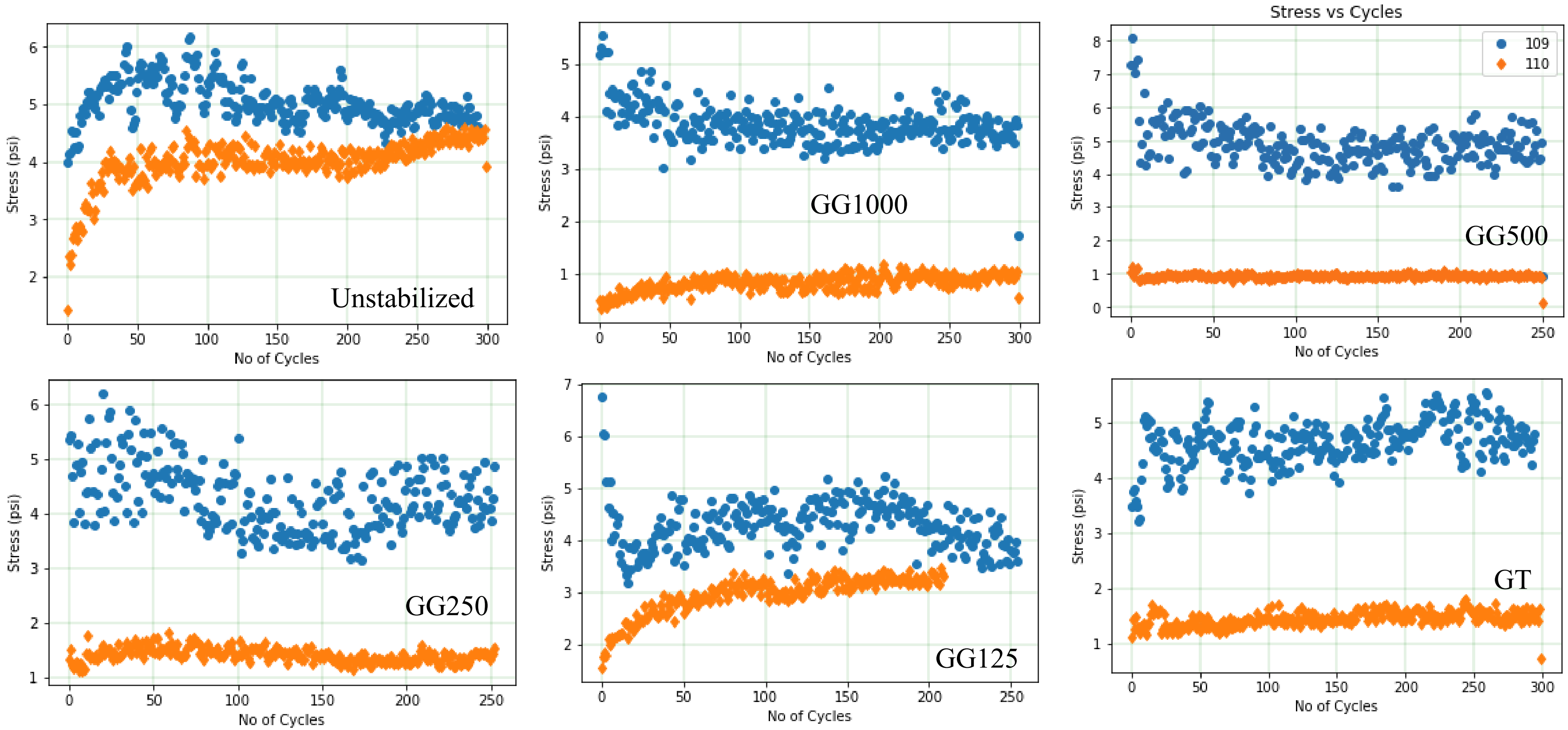
Vertical stresses measured over stiff Gordon (CBR>10) in a) unstabilized b) GG250 stabilized conditions

Corresponding rutting curves



Results and Discussion

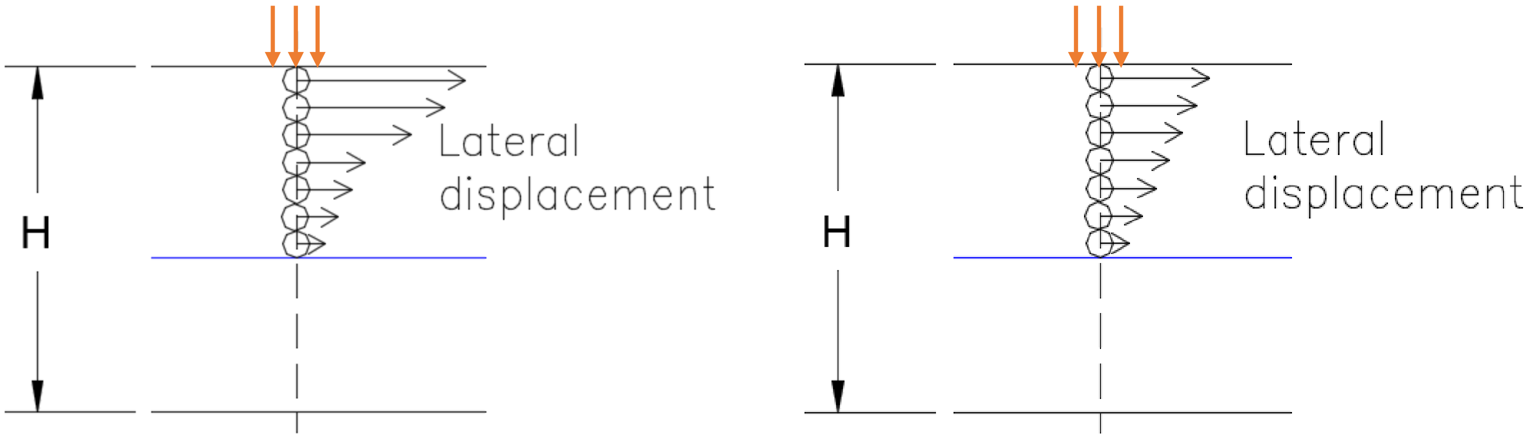
Stresses with Soft Subgrades at CBR<2.5



Vertical stresses measured over soft Gordon (CBR<2.5)

Future Work

- Locate zone of confinement in AB layer surrounding geogrid by tracking particle displacement and horizontal stress
- Can this be a new way to represent performance of geogrid which encapsulates aggregate-aggregate and aggregate-geogrid interaction?



Future Work

- What is stress distribution under geogrid?
  - Is there stabilization period while interlocking is mobilized?
  - Model horizontal stress and displacement as well
  - How are force chains in granular media affected with geogrid introduction?
- Can we predict rutting performance using vertical stress, relative density, and morphological properties of aggregates + geogrid geometry, location using curve fitting parameters ?

$$\epsilon_a = a.e^{-\left(\frac{b}{N^c}\right)}$$

ϵ_a *is axial permanent strain*

N is number of load cycles

a, b and c are fitting parameters

References

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THANK YOU

Questions and Comments?