FLAC3D modeling of geocell reinforced foundation beds

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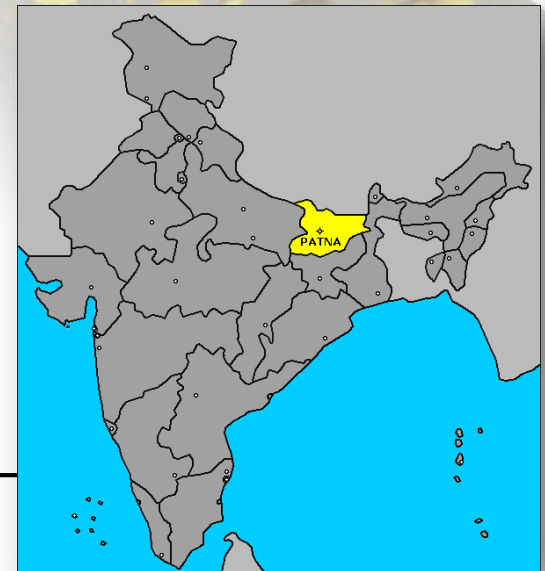Indian Institute of Technology Patna

*Best Wishes from IIT Patna !!*

Outline

- Introduction to geocells

- Issues with geocell modelling

- Geocell subjected to static loading

- Geocell subjected to dynamic loading

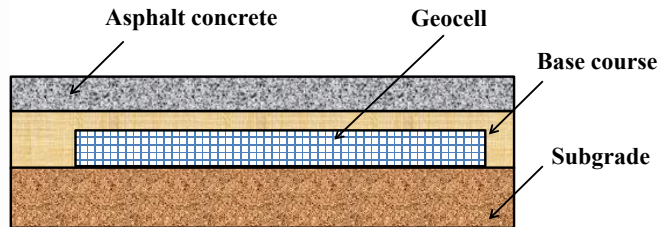- Results and discussions

- Summary

Geocells

- Geocells are three-dimensional expandable panels, made from high-density polymeric material

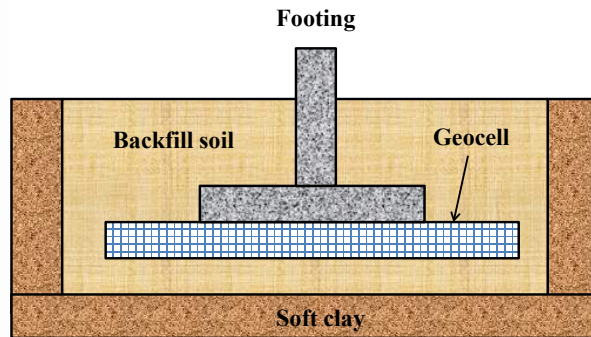- These are being widely used in geotechnical engineering as soil reinforcement
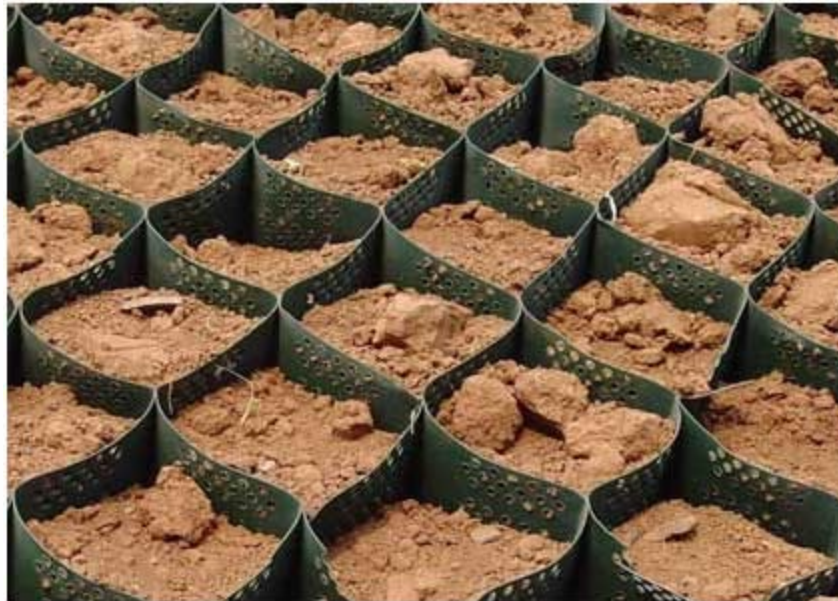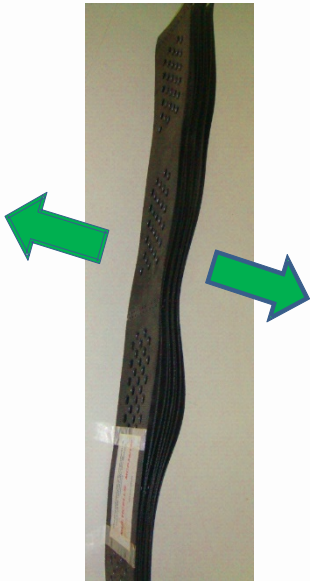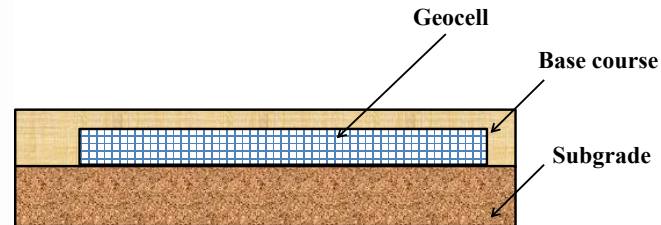
Geocell applications
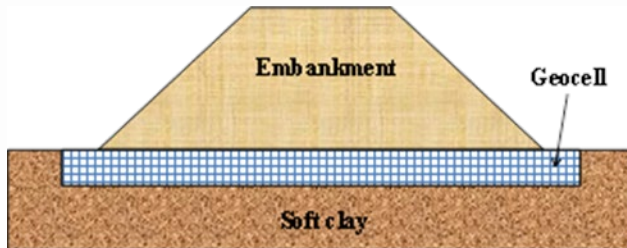
a) Embankments

(b) Paved road

(c) Foundation

(d) Unpaved road
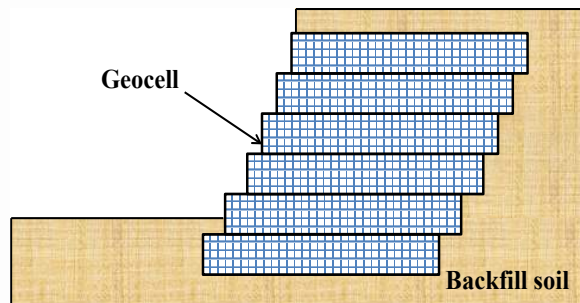
(e) Earth retaining wall
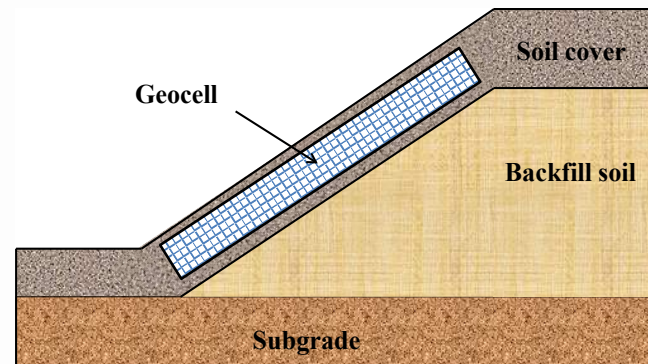
(f) Slope erosion control

Geocell modelling

- Modelling the actual curvature of geocell pockets.

- Geocell & Infill materials are modelled separately
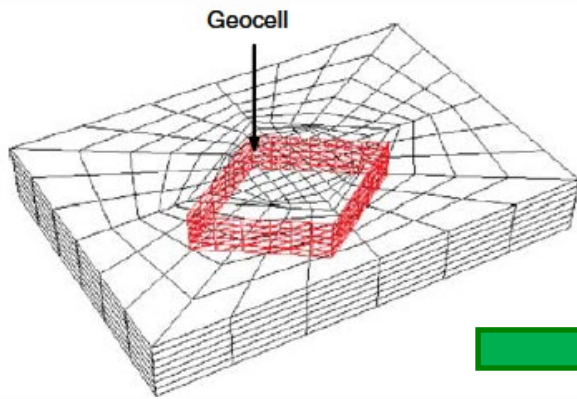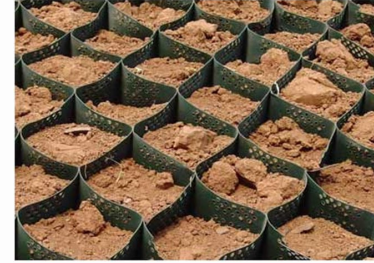
Square shaped single pocket (Han et al. 2008)

FLAC3D
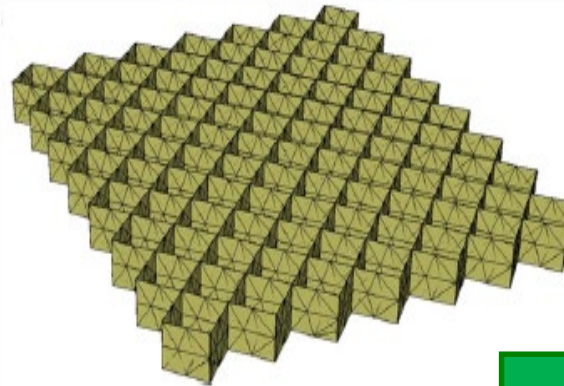
Square shaped multiple cell (Leshchinsky & Ling 2013)

ABAQUS
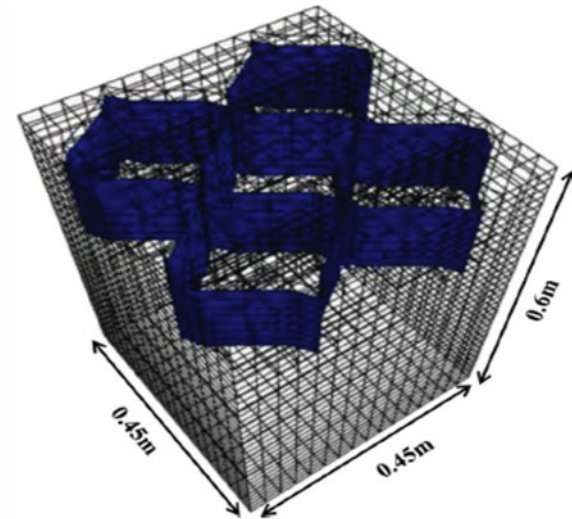
Actual shaped multiple cell (Hegde & Sitharam 2015)

FLAC3D

Geocell behavior under static loading

(Load carrying capacity of geocell reinforced beds)

Experiment setup

Schematic view
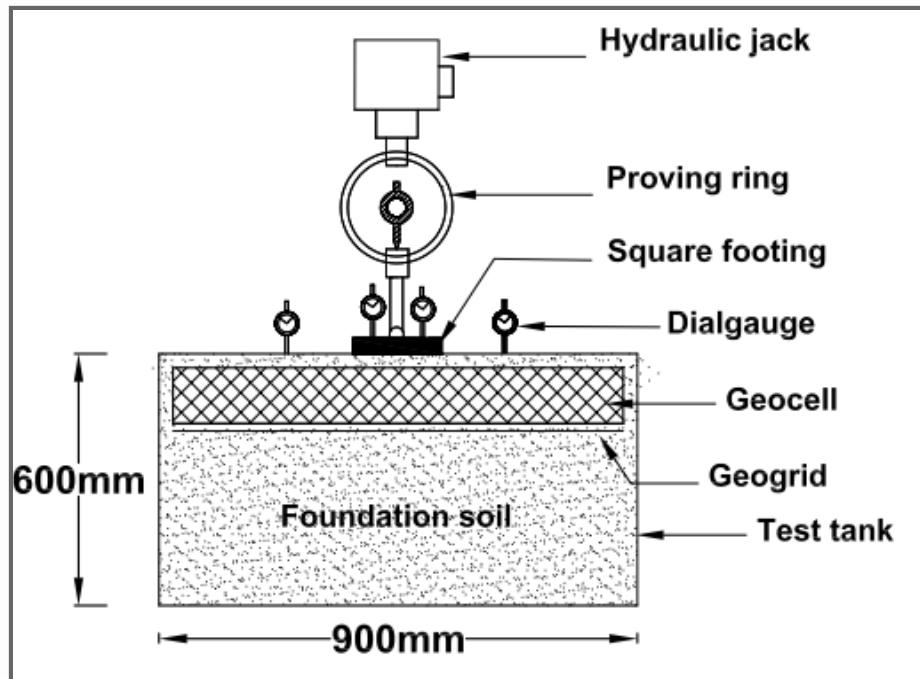
Photographic view

Geocell modelling

- The dimension of the model was kept the same as that of the test bed used in the experiments

- Only a quarter portion of the test bed was modeled using symmetry to reduce the computational effort.

- A photograph of the single cell was taken and it was digitized to obtain the actual curvature of the cell.

- The coordinates were deduced from the curvature and the same were used in the FLAC 3D to model the actual shape of the geocell.

Cases considered

Unreinforced

Footing load

0.6m

0.45m

0.45m

Only geogrid

0.6m

0.45m

0.45m

Only geocell

0.6m

0.45m

0.45m

Geocell+geogrid

0.6m

0.45m

0.45m
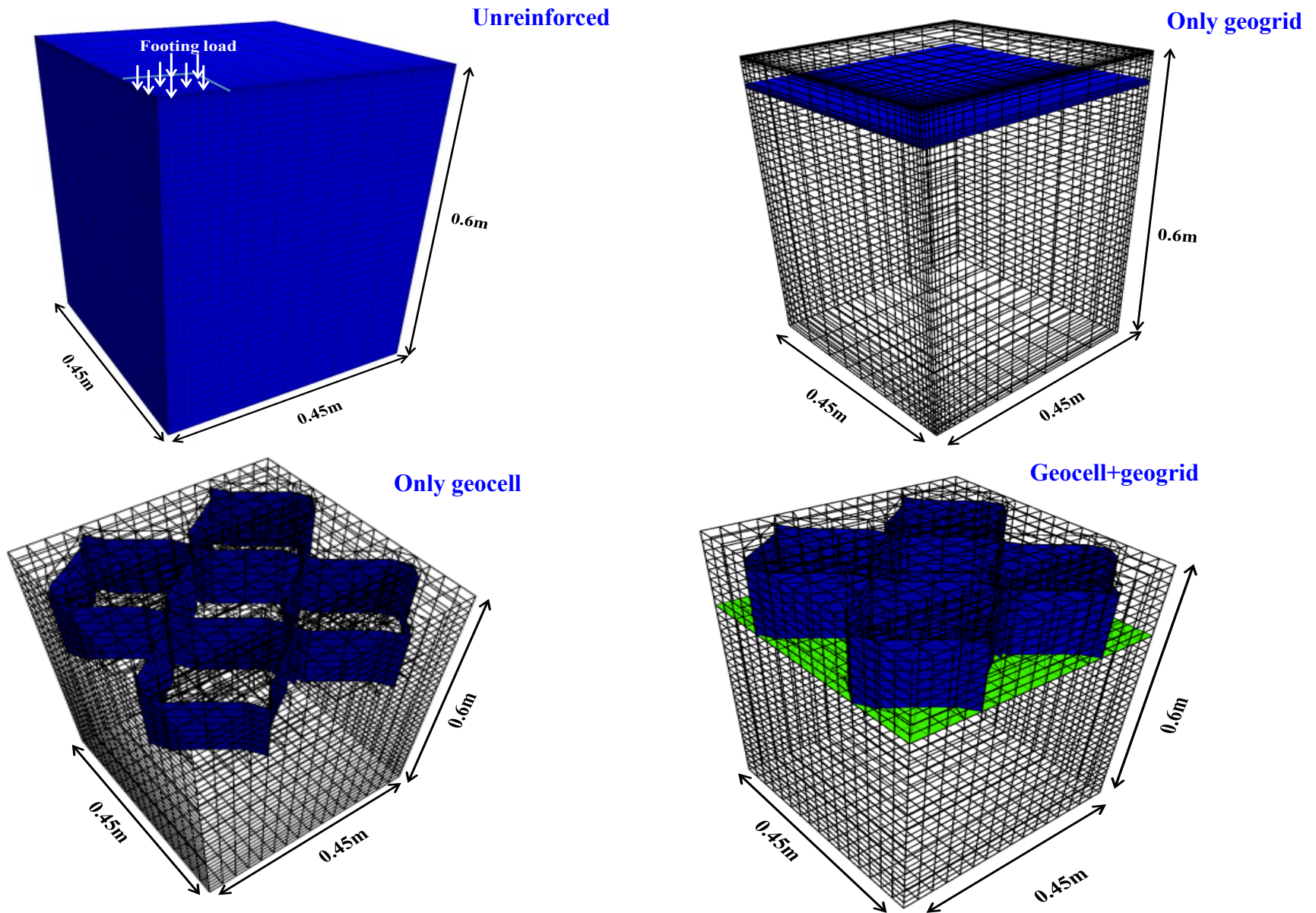
Cam-clay parameters
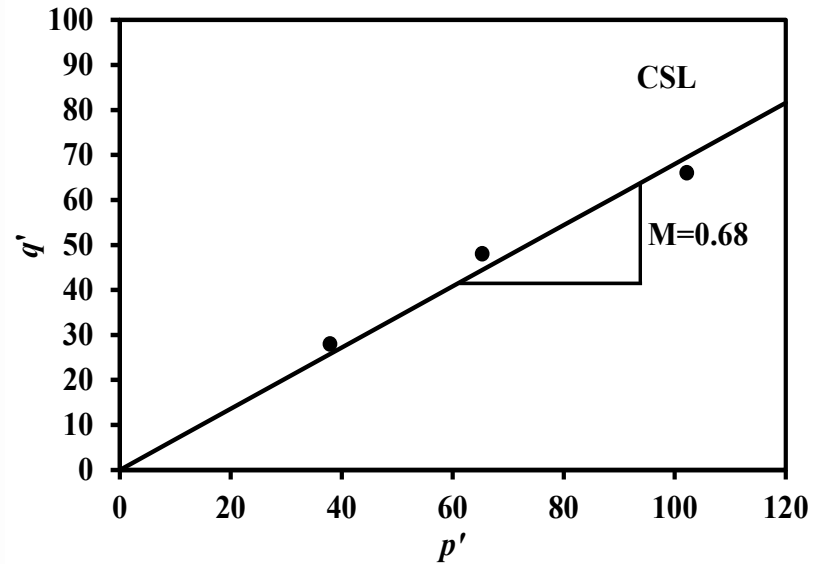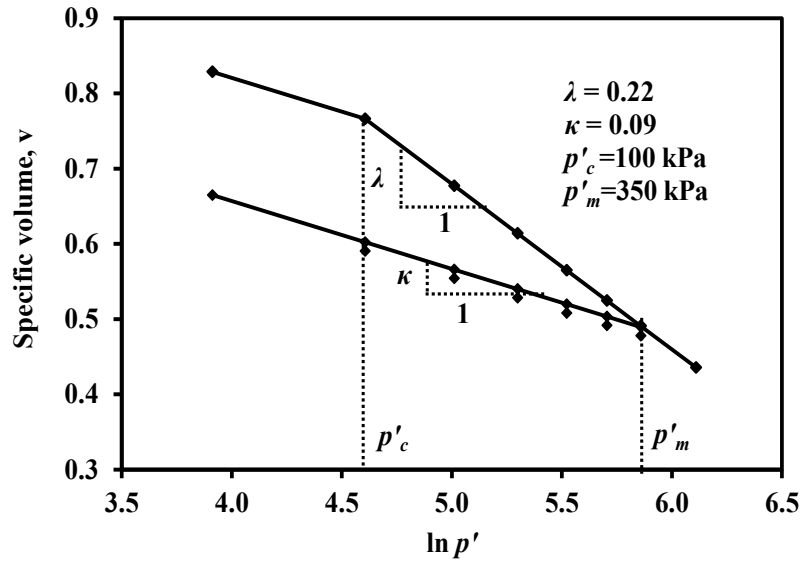
Parameters	Values
Clay	
Shear modulus, G (MPa)	1.36
Friction constant, M	0.68
Slope of NCL, λ	0.22
Slope of swelling line, κ	0.09
Specific volume at reference pressure, ν_λ	1.78
Pre-consolidation pressure, p'_c	100
Unit weight, γ (kN/m^3)	20

Modeling details

Coulomb interface

k_i = interface shear modulus

c_i = interface cohesion

Φ = interface friction angle
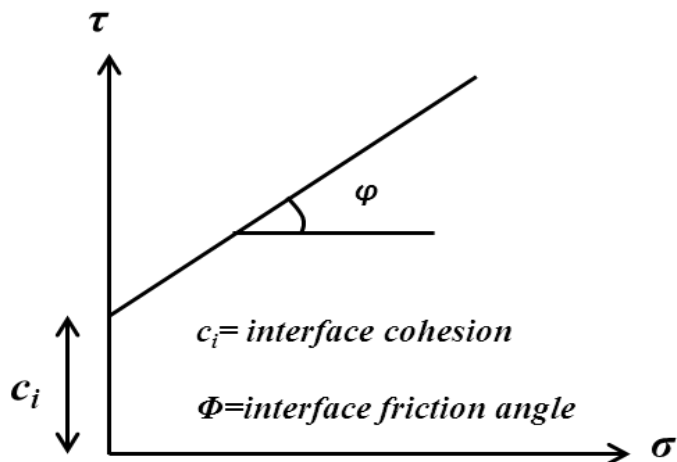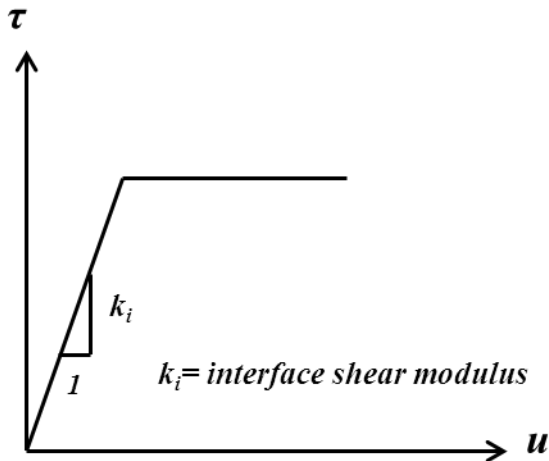
Material Properties

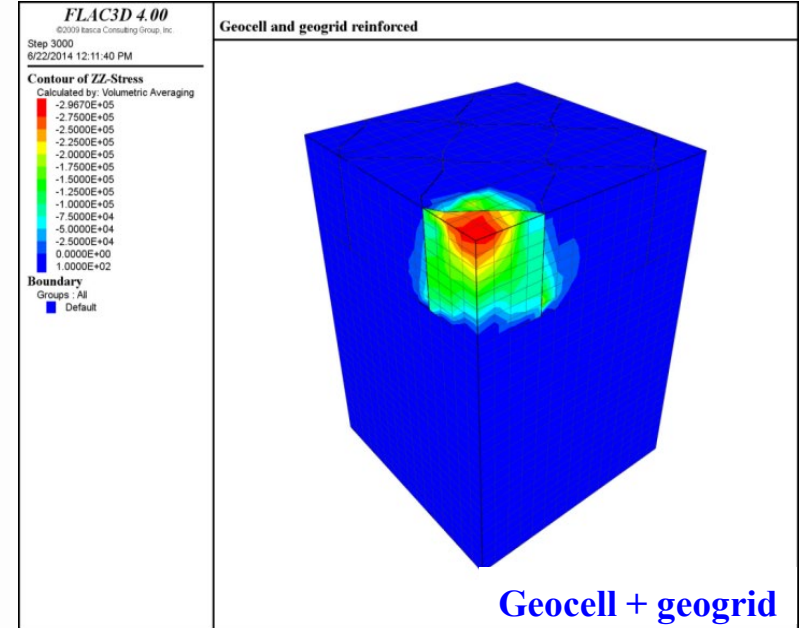| Parameters	Values
Sand	
Shear modulus, G (MPa)	5.77
Bulk modulus, K (MPa)	12.5
Poisson's ratio, μ	0.3
Cohesion, C (kPa)	0
Friction angle, φ (°)	36
Unit weight, γ (kN/m³)	20
Geocells	
Young's modulus, E (MPa)	275
Poisson's ratio, μ	0.45
Interface shear modulus, k_i (MPa/m)	2.36
Interface cohesion, c_i (kPa)	0
Interface friction angle, φ_i (°)	30
Thickness, t_i (mm)	1.5
Geogrids	
Young's modulus, E (MPa)	210
Poisson's ratio, μ	0.33
Interface shear modulus, k_i (MPa/m)	2.36
Interface cohesion, c_i ((kPa)	0
Interface friction angle, φ_i (°)	18
Thickness, t_i (mm)	1.5

Clay bed results

Pressure-settlement response
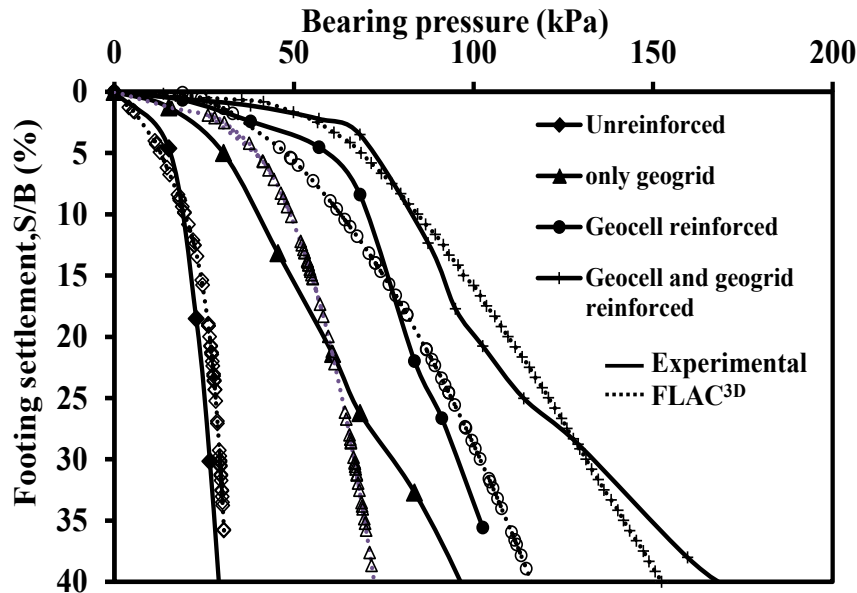
Stress measured in the subgrade

Hegde, A.M. and Sitharam, T.G. (2015). Canadian Geotechnical Journal, 52, 1-12.

Stress contours

Unreinforced

Only geogrid

Only geocell

Geocell + geogrid

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Pressure bulb

Hegde, A.M. and Sitharam, T.G. (2015). Canadian Geotechnical Journal, 52, 1-12.
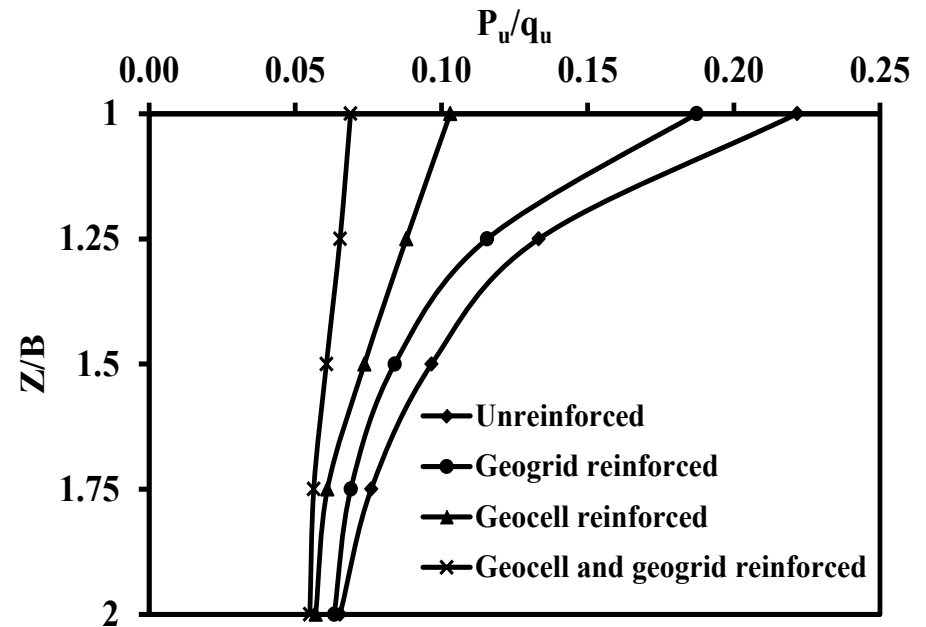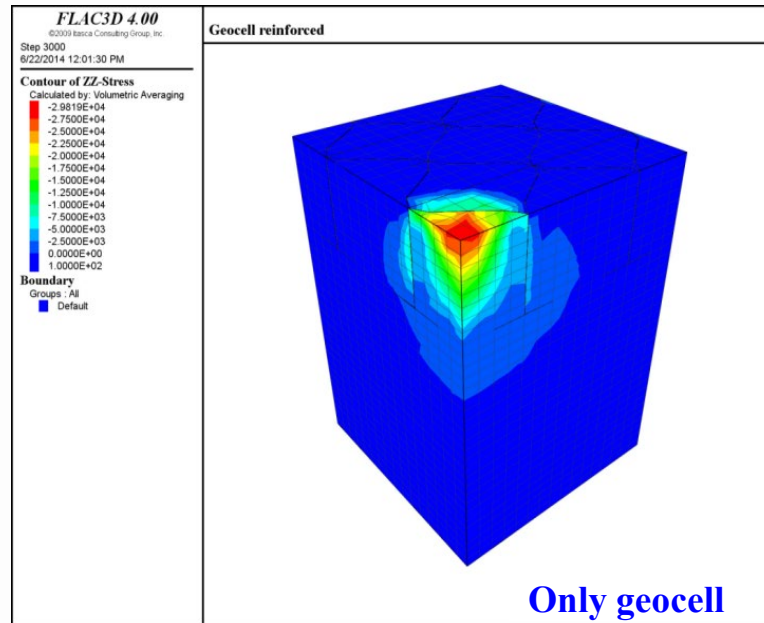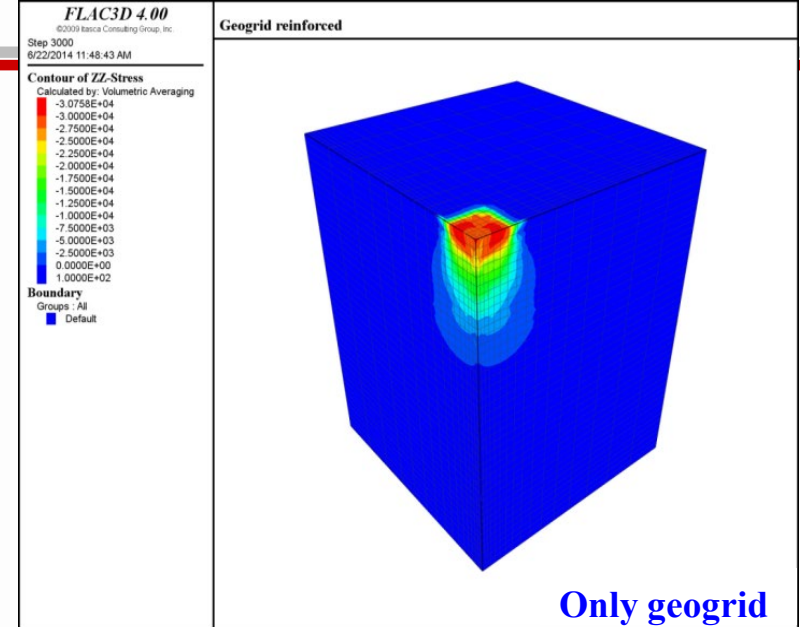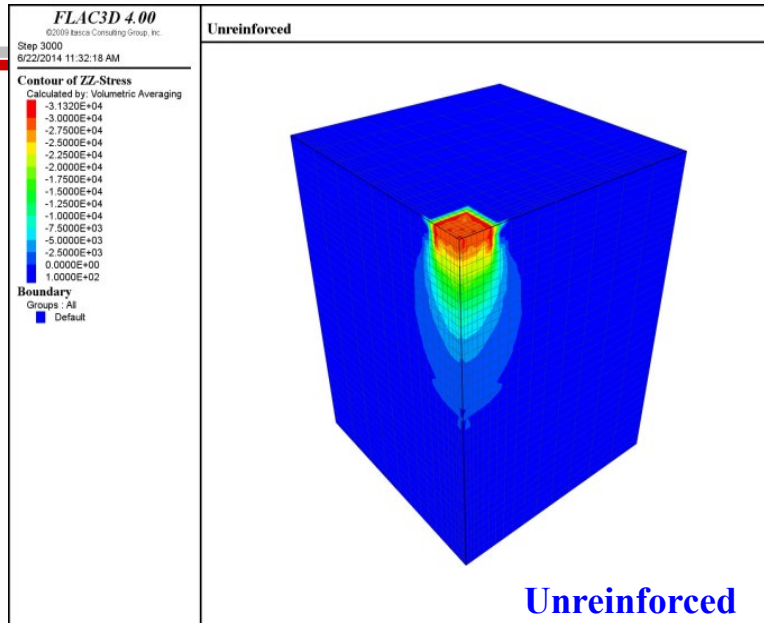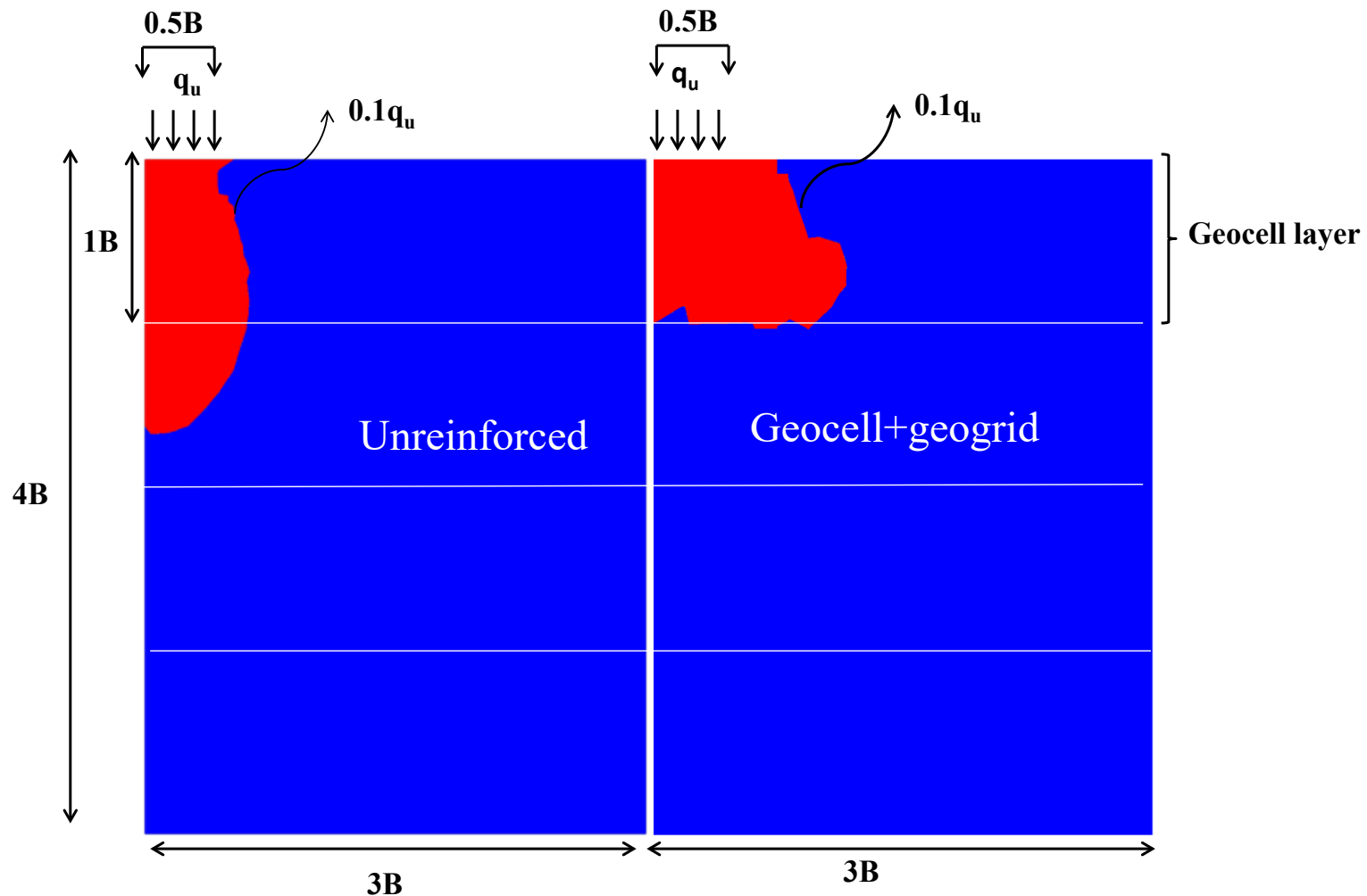
Geocell behavior under dynamic loading (Vibration isolation efficacy of geocell)

Experimental Studies

- Field vibration test performed on unreinforced and geocell reinforced beds was considered for the dynamic case.

Schematic view

Unreinforced condition   Geocell reinforced condition
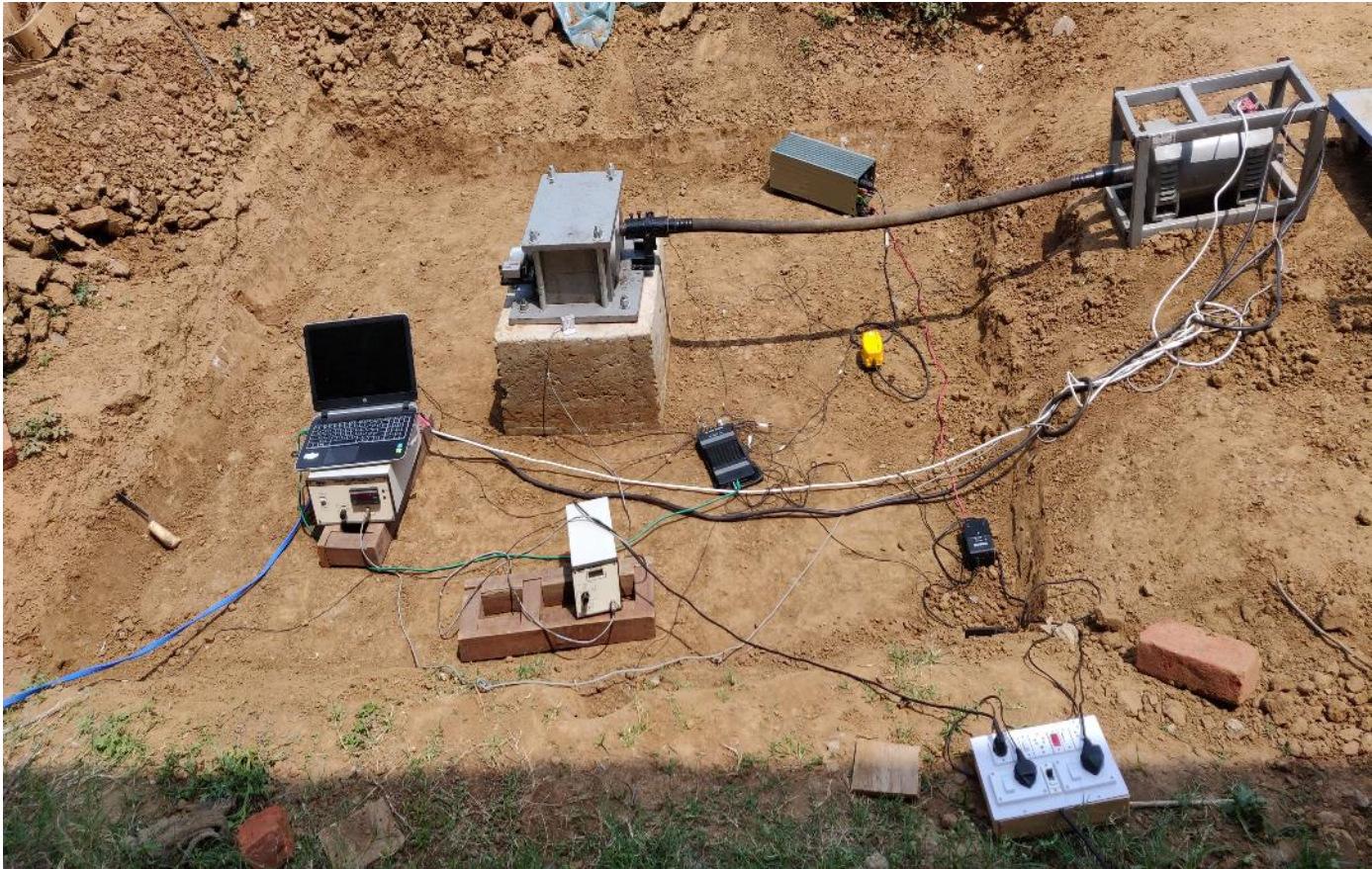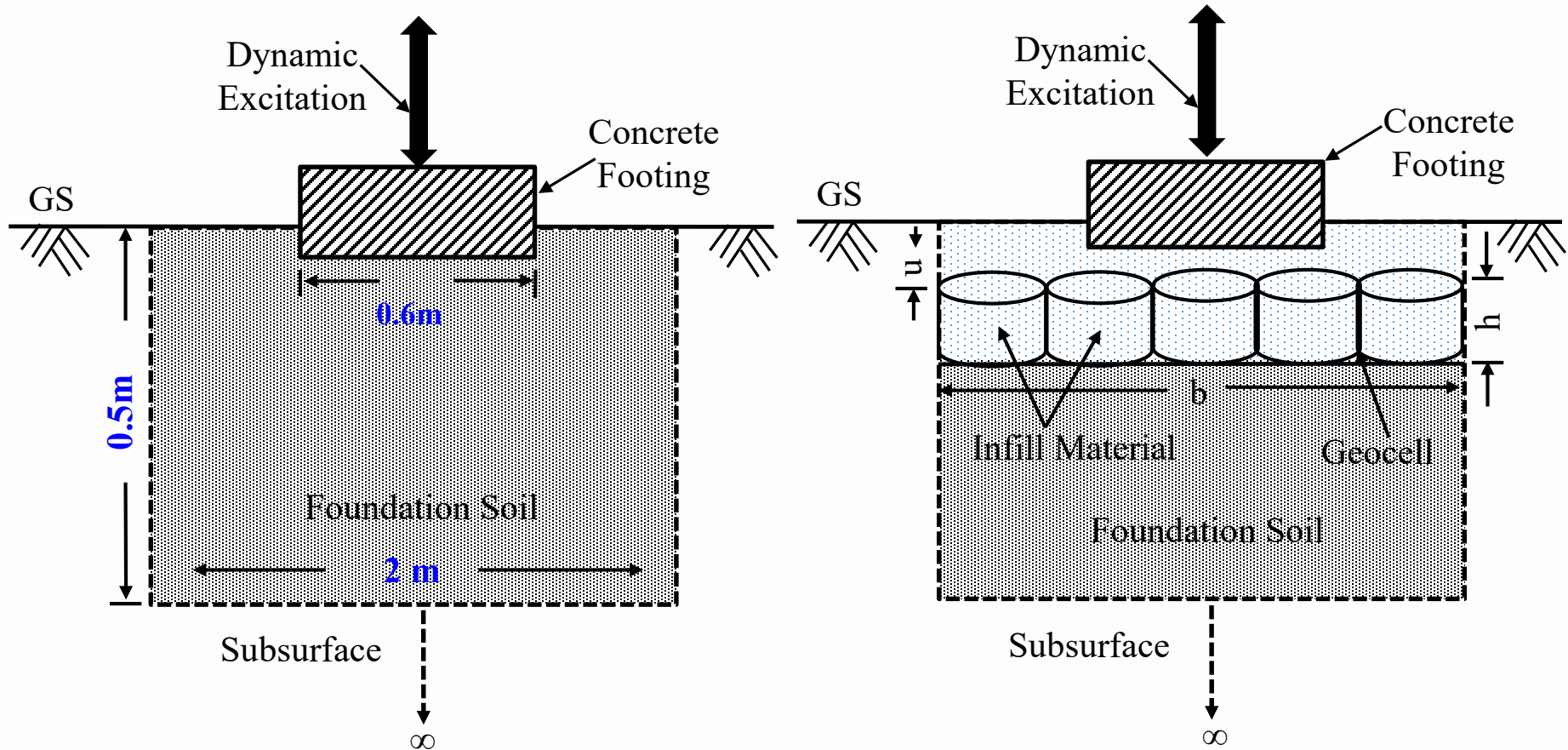
Subsurface parameters

Ground surface

Silty clay
E= 5.1 MPa; ρ = 1.63 g/cc; ν = 0.3; φ = 3°; and C_u = 48 kPa.

1.1 m

Loose sand
E = 25.2 MPa; ρ = 1.78 g/cc; ν = 0.3; φ = 30°; and C_u = 1 kPa.

2.35 m

Dense sand
E = 51.0 MPa; ρ = 1.84 g/cc; ν = 0.3; φ = 36°; and C_u = 1 kPa.

6.55 m
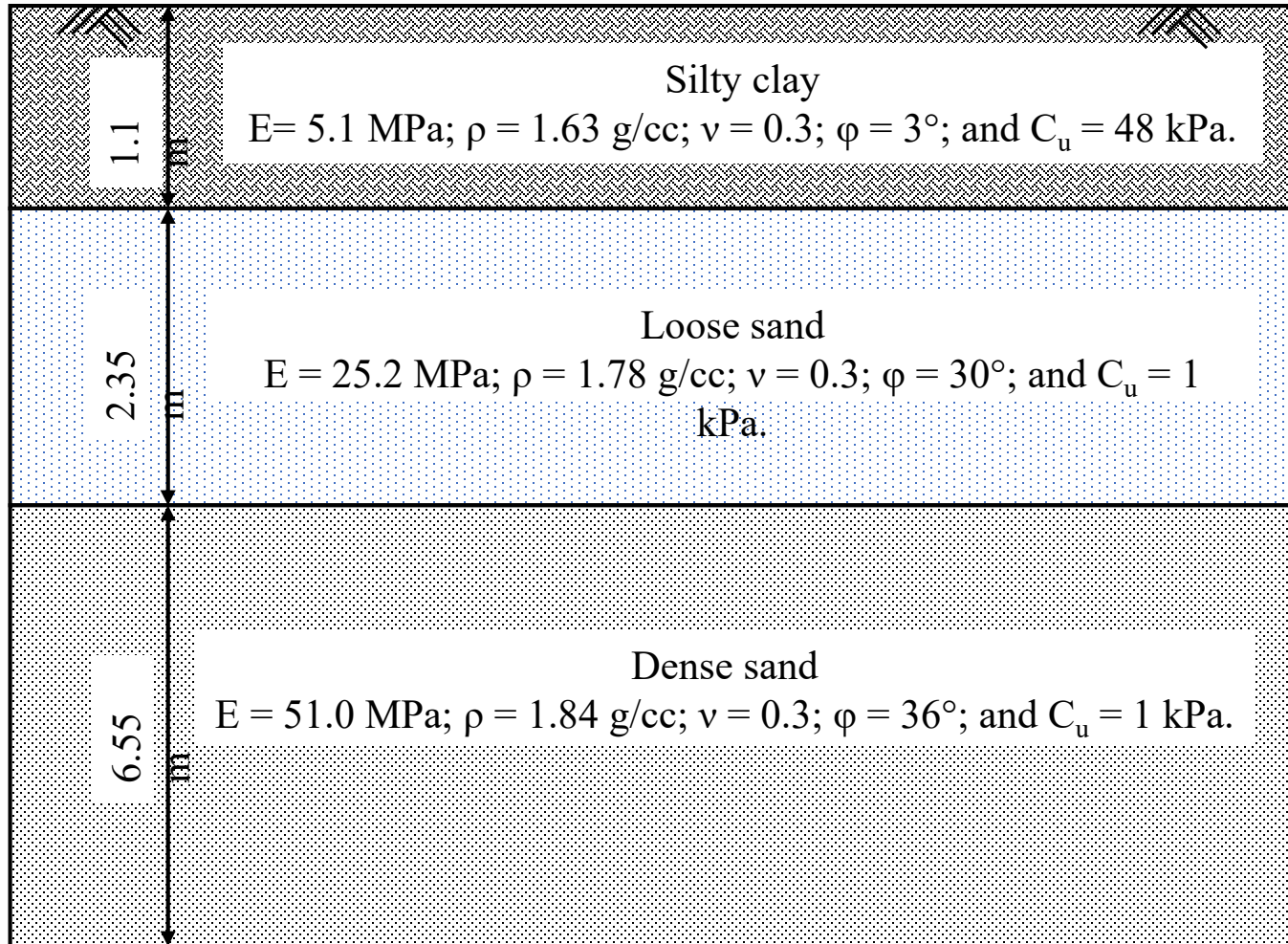
Foundation Bed Parameters

Material	Parameter	Value
Concrete cube foundation	Modulus of elasticity of concrete, E (MPa)	2×10^4
	Unit weight of concrete, γ (kN/m^3)	24
	Poisson's ratio of concrete, ν	0.15
Foundation soil (Silty sand)	Unit weight, γ_d (kN/m^3)	17.45
	Angle of shearing resistance, φ (^{0})	32
	Cohesion, C (kPa)	1
	Young's modulus, E (MPa)	20
	Poisson's ratio, ν	0.3
Reinforcement Properties		
Geocell	Young's modulus, E (MPa)	275
	Poisson's ratio, ν	0.45
	Thickness, t_i (mm)	1.5
	Interface shear modulus, k_i (MPa/m)	2.36
	Interface cohesion, c_i (kPa)	0
	Interface friction angle, ϕ_i (º)	30

Boundary and loading condition

Foundation Bed

Surface footing

10 m

15 m

15 m

f=45Hz

f=25Hz

f=5Hz

f=15Hz

f=35Hz

Dynamic force (kN)

Note:

Lateral restraint

Lateral and vertical restraint

Quiet or Absorbent boundary

5% material damping in foundation soil

Results and Discussion

Ujjawal, K.N., Venkateswarlu, H. and Hegde, A. (2019). Soil Dynamics and Earthquake Engineering. 119, 220-234.

Results and Discussion

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Effect of Height of geocell mattress

H = 0.075 m

H = 0.12 m

H = 0.15 m

H = 0.20 m
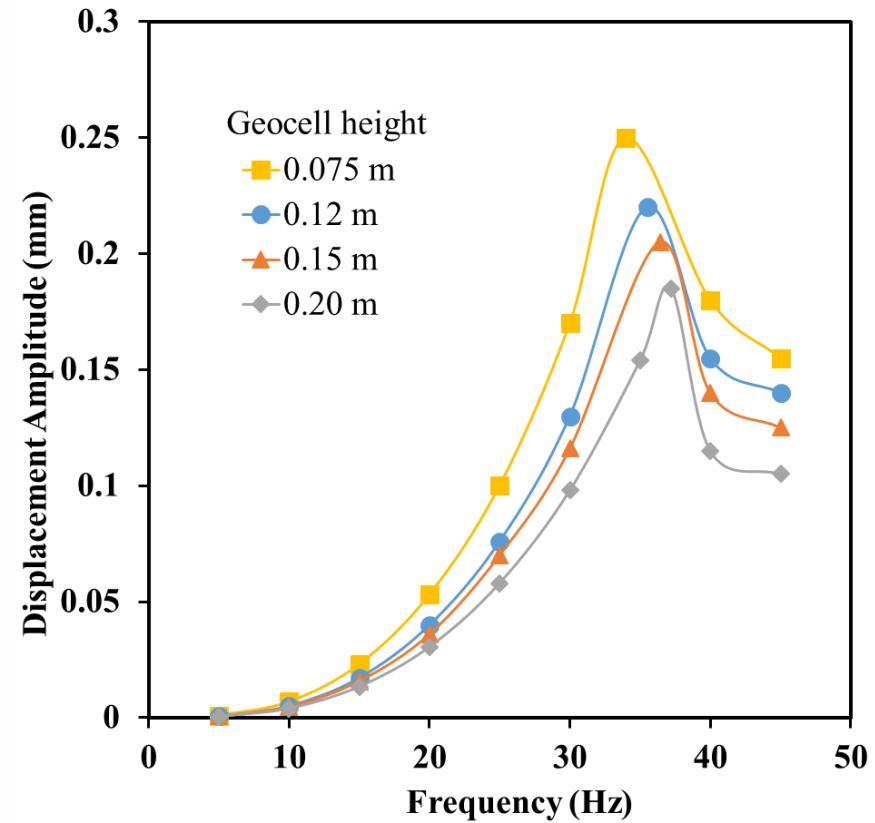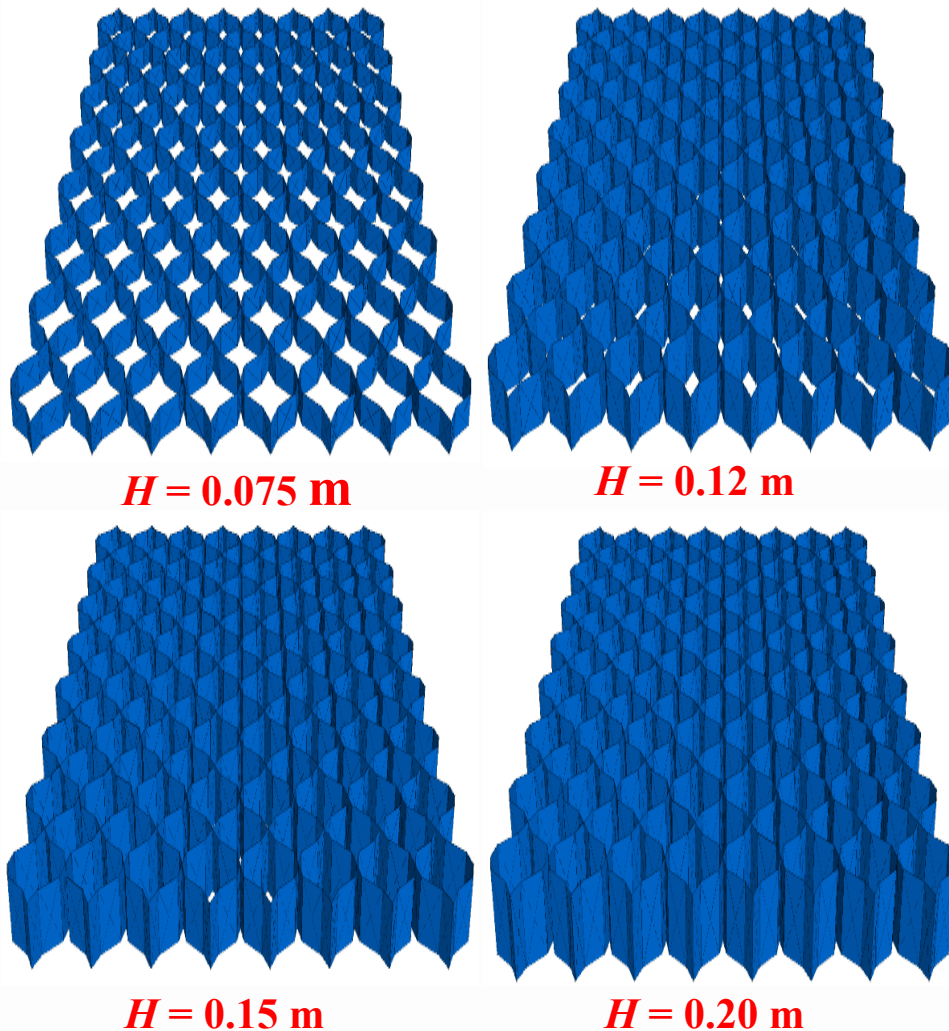
Effect of pocket diameter

$d_0 = 0.1$ m

$d_0 = 0.2$ m

$d_0 = 0.25$ m

$d_0 = 0.5$ m

Geocell pocket size
- 0.10 m
- 0.20 m
- 0.25 m
- 0.50 m
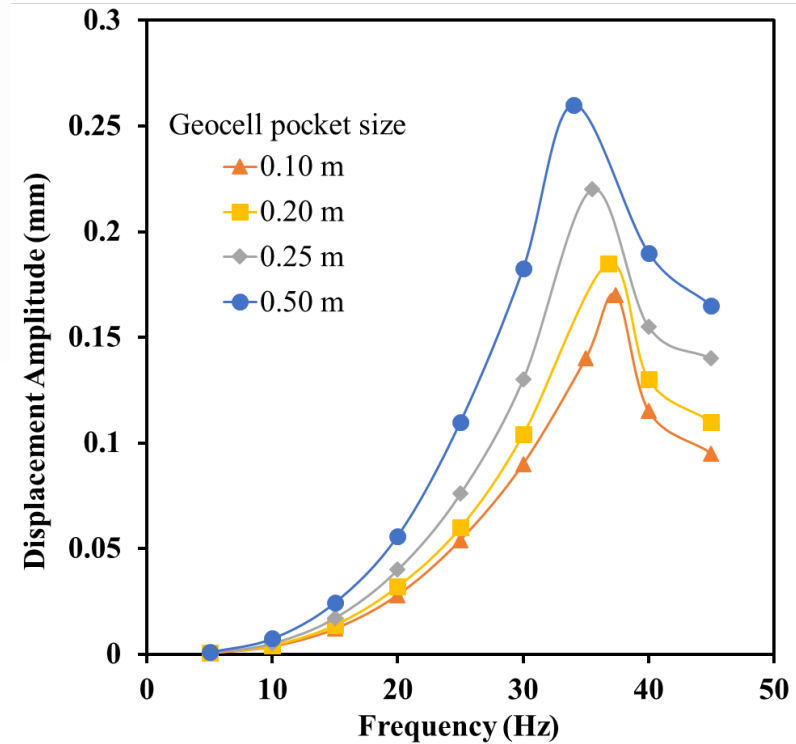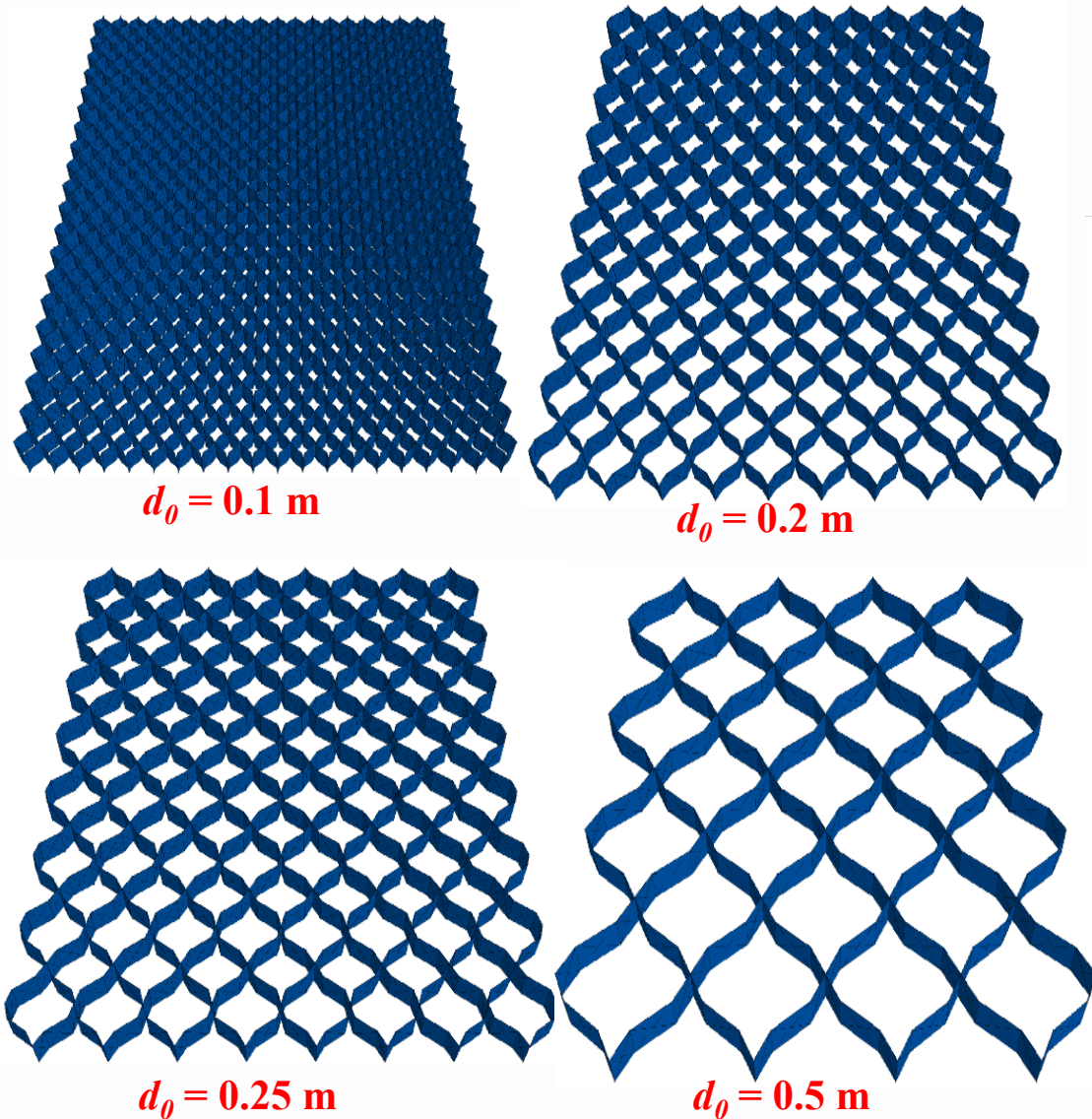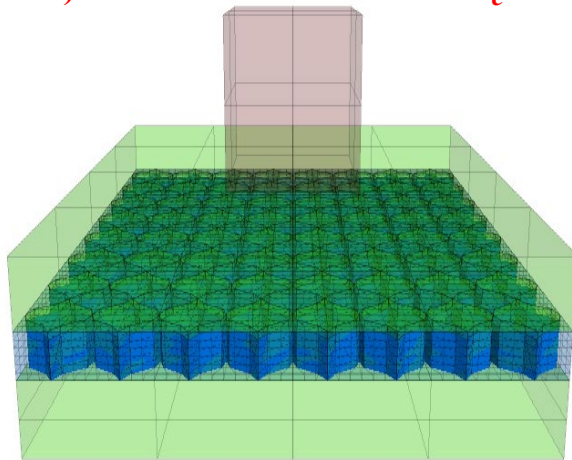
Effect of depth of geocell placement
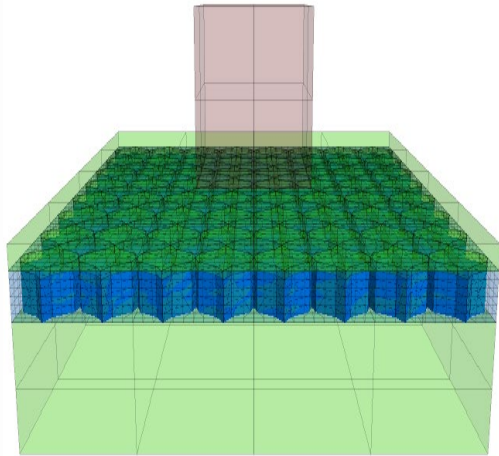
$u_c = 0.1B$
(Optimum)

$u_c = 0.2B$

$u_c = 0.3B$

Ujjawal, K.N., Venkateswarlu, H. and Hegde, A. (2019). Soil Dynamics and Earthquake Engineering. 119, 220-234.
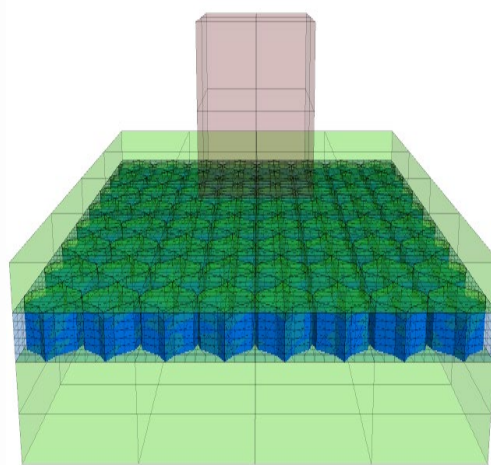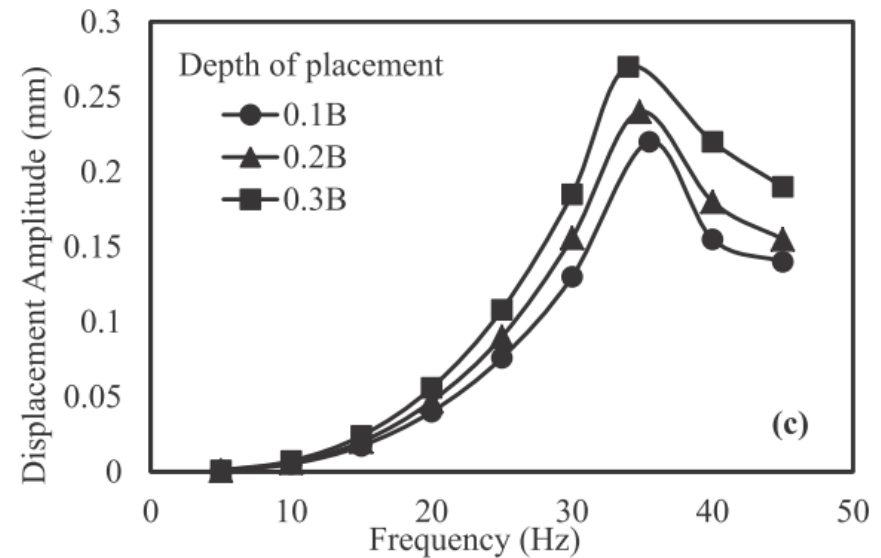
Other parameters
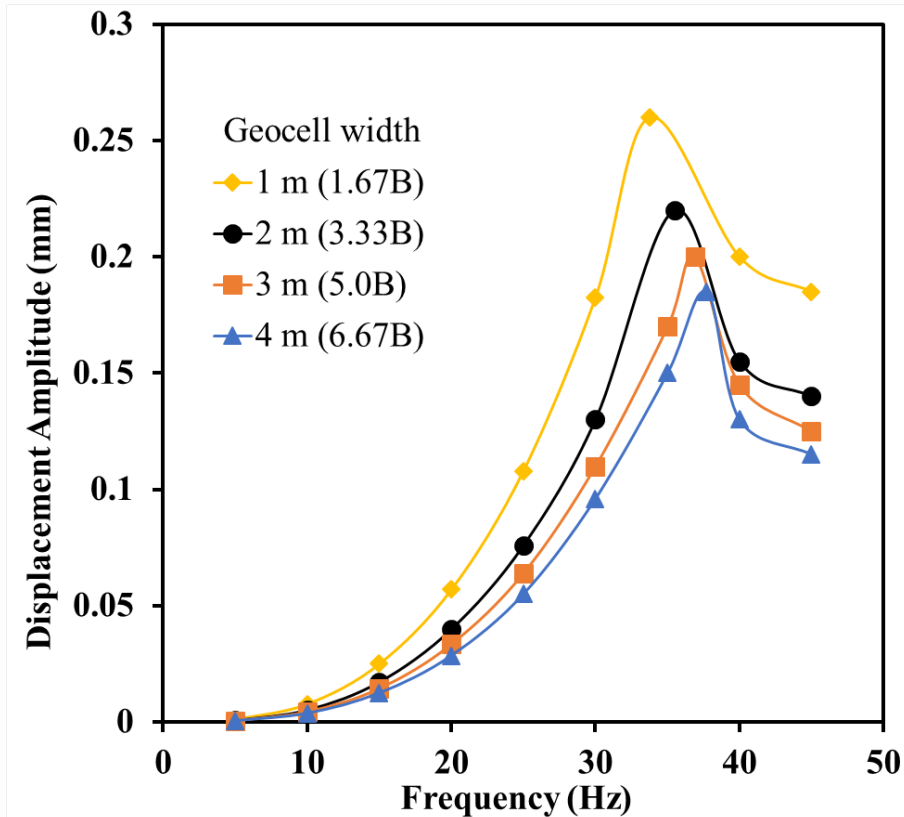
Optimum width of geocell = 5*B*
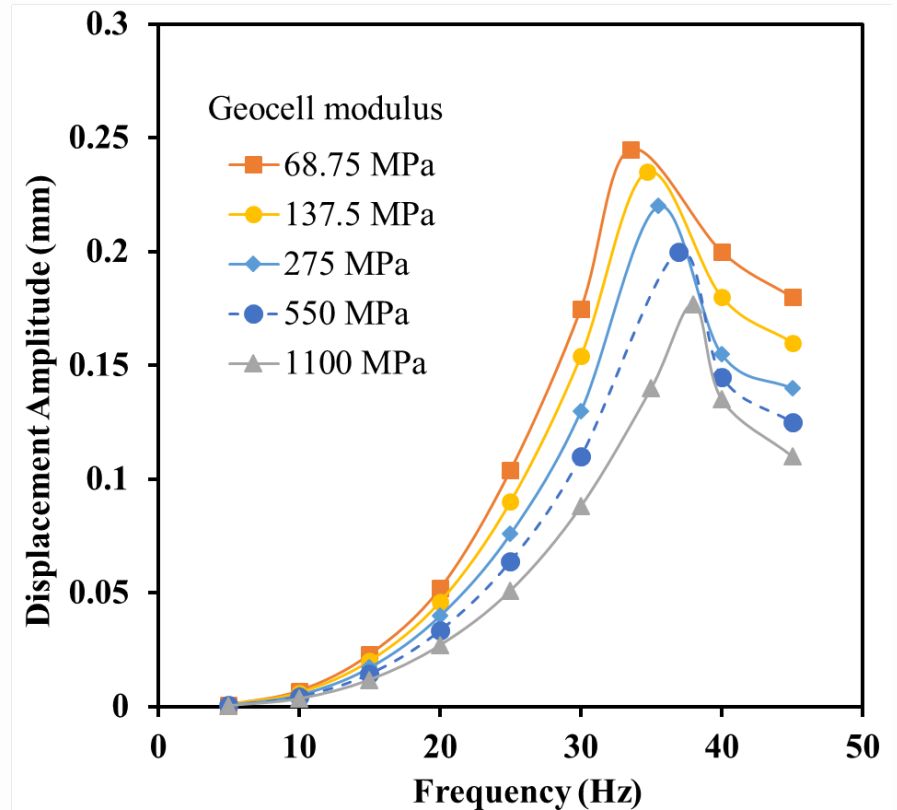

Geocell modulus

Ujjawal, K.N., Venkateswarlu, H. and Hegde, A. (2019). Soil Dynamics and Earthquake Engineering. 119, 220-234.

Summary

• FLAC3D numerical simulations were successfully used for predicting the static and dynamic response of geocell reinforced beds.

• Encouraging agreement was observed between the numerical and experimental results in both the cases.

• In case of the static loading, geocell found to distribute the load in the lateral direction to wider areas.

• In case of the dynamic loading, geocell found to confine the lateral spreading of induced vibration.

Thank You !