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Numerical Analysis of Geocell-Reinforced Foundations under Varying Soil Conditions

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A B S T R A C T

Soil behavior plays a critical role in the stability and performance of civil engineering infrastructures, often requiring reinforcement to enhance tensile strength and resistance to various load conditions. Geosynthetic materials, particularly geocells, have emerged as efficient reinforcement systems that significantly improve the mechanical behavior of soil. The purpose of this study is to evaluate the influence of soil strength parameters on the performance of geocell-reinforced foundations. A three-dimensional numerical model was developed using ABAQUS to simulate the mechanical response of a geocell-reinforced soil foundation. The model was validated against benchmark experimental and numerical data reported in previous studies to ensure reliability. The research employed a parametric analysis approach, varying key soil parameters, including the modulus of elasticity, internal friction angle, and specific gravity, to assess their effects on bearing capacity and settlement behavior. The results revealed that soils with higher modulus of elasticity, greater internal friction angle, and higher specific gravity demonstrated improved load-bearing performance and reduced settlement. Among these factors, the internal friction angle exerted the most pronounced impact, leading to substantial improvements in bearing pressure when the soil was reinforced with geocells. These findings highlight the importance of optimizing soil strength parameters in the design of geocell-reinforced foundations and provide a validated numerical framework for predicting their behavior under diverse loading conditions.

1. Introduction

Geotechnical engineering, a major branch of civil engineering, focuses on developing advanced and sustainable techniques to improve the strength, stability, and overall performance of soil in construction projects. Since soil forms the primary foundation for most civil infrastructure, its mechanical properties directly influence structural reliability. However, natural soils often lack sufficient tensile strength and stiffness to withstand applied loads, particularly when subjected to tensile or shear stresses. This inherent weakness has encouraged researchers and engineers to develop soil reinforcement strategies aimed at enhancing bearing capacity and reducing deformation under service conditions. Among the various reinforcement methods, geosynthetic materials have gained increasing attention for their versatility, cost-effectiveness, and environmental adaptability. Geosynthetics encompass a broad range of products, including geotextiles, geogrids, geomembranes, and geocells, that interact with soil to enhance its structural performance. Among these, geocells, also known as cellular confinement systems, have emerged as a superior form of reinforcement due to their unique three-dimensional honeycomb structure. When filled with soil or aggregate, geocells confine the infill material laterally, substantially improving load distribution and restricting vertical displacement.

The primary reason for the widespread adoption of geocells lies in their confinement mechanism, which significantly enhances the composite action between the geocell and the surrounding soil. This interaction leads to notable improvements in stiffness,

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bearing capacity, and load transfer efficiency. Compared to unreinforced soil, geocell-reinforced soil exhibits reduced settlement and deformation, making it suitable for numerous civil engineering applications such as foundation beds, slope stabilization, road pavements, retaining walls, and erosion control. Fig. 1 illustrates the typical structure and mechanism of geocell reinforcement.

Fig. 1. Geocell reinforcement.

Several researchers have investigated the mechanical behavior of geocell-reinforced soils under various loading conditions. Sitharam and Hegde [1] demonstrated that geocell inclusion redistributes applied loads over a wider area, thereby reducing vertical stresses near the surface. Their study emphasized that geocell layers promote lateral load distribution, resulting in shallower stress transmission zones. Further research indicated that geocell reinforcement can significantly reduce fatigue failure and rutting in pavement structures [2]. Similarly, Banerjee et al. [3] observed that the inclusion of geocells reduces rut depth and local stress concentration, with performance strongly influenced by the height and geometry of the geocell layer. As shown in Fig. 2, geocells provide lateral confinement to soil via their three-dimensional structure. Vertical confinement is achieved through friction between the infill and cell walls, and the geocell-reinforced base acts as a mattress to restrict upward soil movement outside the area [4].

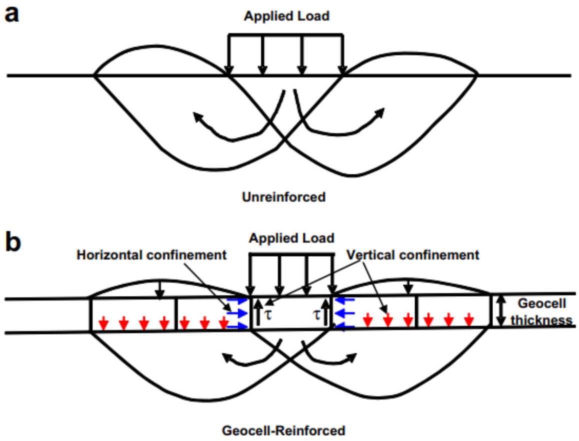

Fig. 2. Effect of geocell on stress distribution [4].

The mechanical advantages of geocell systems have been validated through numerous experimental and numerical studies. For example, Pokharel et al. [4] investigated how geocell shape, height, and infill properties influence the load-bearing behavior of single geocell-reinforced foundations. Their findings confirmed that the inclusion of geocells enhances soil confinement, leading to higher bearing capacities. Dash et al. [5, 6] conducted large-scale experiments on sand beds reinforced with geocell mattresses, revealing that reinforcement could increase the bearing capacity of sand up to eightfold. Likewise, Sireesh et al. [7] analyzed the effect of a geocell–sand mattress placed over a clay layer with voids, showing that settlement decreased markedly while bearing capacity improved.

To gain a deeper understanding of the complex behavior of geocell-reinforced foundations, advanced numerical techniques such as the Finite Element Method (FEM) and Finite Difference Method (FDM) have been employed. Hegde and Sitharam [8] and Mehdipour et al. [9] developed finite element models that represented geocell layers as equivalent stiffened soil zones, simplifying the confinement effect into an “equivalent modulus” framework. While these models improved computational efficiency, they lacked the precision required to capture the actual 3D mechanics and interface friction between the soil and the geocell walls. To address this limitation, Hegde and Sitharam [8] proposed a more realistic multi-cell numerical model incorporating the true curvature and shape of the geocell walls.

Recent developments in constitutive soil modeling have further expanded numerical capabilities. Heidarzadeh [10] evaluated the modified Cam-Clay constitutive model in FLAC and demonstrated how refined plasticity formulations can improve the representation of soil behavior under stress paths relevant to geocell–soil systems. The generalized plasticity constitutive model proposed by Heidarzadeh and Oliaei [11] and the extended constitutive framework developed by Heidarzadeh et al. [12] highlight the importance of accurate soil characterization for reliable simulation outcomes. Additionally, Heidarzadeh and Kamgar [13] emphasized the necessity of incorporating steady-state concepts into numerical predictions of soil deformation, reinforcing the need for advanced constitutive models when analyzing soil–reinforcement interaction.

Further contributions from other researchers have expanded the modeling capabilities for geocell-reinforced systems. Hegde et al. [14] compared the performance of PLAXIS and ABAQUS in simulating reinforced foundations, concluding that FLAC3D provides superior element formulations for large-deformation analysis. Oliaei and Kouzegaran [15, 16] applied FLAC3D to evaluate geocell effects in both foundations and road base layers, confirming substantial improvements in stiffness and load distribution. Song et al. [17] studied geocell-reinforced retaining walls and demonstrated that reinforcement enhances base stiffness and durability while allowing thinner base layers. Ari and Misir [18] performed a comparative numerical investigation on shell foundations supported by geocell-reinforced soil, reporting a 70% reduction in settlement. Additionally, Juneja and Sharma [19] examined geometric parameters to determine optimal design configurations, concluding that a geocell layer height of 1.5B located at 0.1B depth yields optimal results. Evirgen et al. [20] combined numerical and experimental analyses using PLAXIS to confirm that geocells enhance both load-carrying capacity and deformation resistance of base layers.

Although extensive research has been conducted on geocell reinforcement, predicting the precise behavior of geocell-reinforced foundations remains a major challenge. The inherent three-dimensional geometry of the geocell, complex soil–structure interactions, and variability in soil properties all contribute to modeling difficulties. Simplified analytical and empirical methods often fail to represent these interactions with sufficient fidelity, underscoring the need for more robust, physics-based numerical models.

In the present study, a three-dimensional numerical model of a geocell-reinforced foundation bed was developed using ABAQUS software to provide a realistic representation of soil–geocell interaction. The model was validated against the benchmark results reported by Hegde and Sitharam [8] to ensure computational accuracy and physical reliability. The study focuses on assessing the influence of three key soil strength parameters, modulus of elasticity, internal friction angle, and unit weight, on the performance of geocell-reinforced foundations. By comparing the relative impact of these parameters, this work aims to identify the most critical soil characteristics affecting bearing capacity and settlement behavior.

The findings of this research provide valuable insights into the interaction mechanisms between geocell reinforcement and soil properties, contributing to improved design approaches for reinforced foundations. Moreover, the validated numerical framework developed herein serves as a reliable tool for predicting the performance of geocell-reinforced systems under varying soil and loading conditions, thereby advancing both theoretical understanding and practical applications in geotechnical engineering.

2. Numerical analysis

A three-dimensional numerical model was developed using the ABAQUS finite element software to evaluate the performance of geocell-reinforced foundations and to study the influence of various soil parameters on their bearing capacity. The research design involved two primary stages: validation of the numerical model and subsequent parametric analysis. To ensure the model's reliability, a reference study conducted by Hegde and Sitharam [8] was first replicated. Once the simulation results showed satisfactory agreement with their findings, the model was modified to investigate the effects of key parameters on the behavior of the reinforced foundation.

2.1. Validation model

Hegde and Sitharam [8] conducted numerical simulations by modeling the true three-dimensional honeycomb geometry of geocells using the FLAC3D software. In their study, a test tank was prepared with dimensions of 900 mm in length and width and 600 mm in height, as illustrated in Fig. 3. The foundation soil consisted of poorly graded sand (SP), whose physical and mechanical properties are presented in Table 1. The geocell layer was fabricated from polyethylene with cell dimensions of 250 × 210 mm and a strip thickness of 1.5 mm. Loading was applied to the reinforced soil through a square steel plate representing the foundation footing.

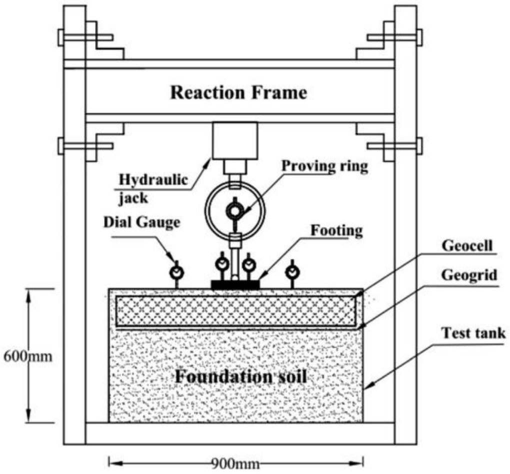

Fig. 3. Schematic view of the test setup [8].

Table 1. Properties of soil and geocell.

Parameter	Value	Parameter	Value
Sand		Geocell	
Elastic modulus (MPa)	15	Elastic modulus (MPa)	275
Poisson's ratio	0.3	Poisson's ratio	0.45
Cohesion (kPa)	0	Unit weight (kN/m^3)	9.5
Friction angle (deg.)	36		
Unit weight (kN/m^3)	20		

The researchers performed both two-dimensional and three-dimensional numerical analyses using FLAC. The two-dimensional analysis utilized the equivalent composite approach, which simplifies the reinforced zone but introduces certain uncertainties. In contrast, the three-dimensional model represented only a quarter of the test tank by applying symmetry conditions to reduce computational cost. The modeled domain measured 0.45 × 0.45 × 0.6 m, and the corresponding reinforced foundation configuration is presented in Fig. 4.

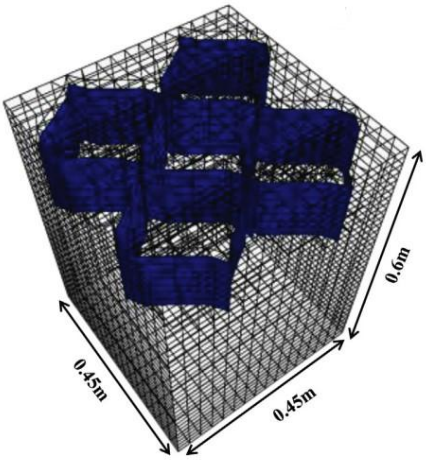

Fig. 4. FLAC 3D model for geocell reinforced foundation [8].

In the present study, a comparable three-dimensional model was constructed in ABAQUS to validate and extend the earlier findings. The geometric dimensions and material parameters from the reference study were adopted, with the geocell reinforcement placed at the top of the soil layer. The soil was modeled using the Mohr-Coulomb yield criterion to capture the nonlinear behavior under loading, whereas the geocell layer was represented by a linear elastic material model.

The simulation procedure consisted of two main steps. In the first step, a gravity load was applied to establish the initial in-situ stress conditions. In the second step, a vertical displacement of 50 mm was applied over a loading area measuring 100 × 100 mm, located at the corner of the model. The boundary conditions are explicitly defined as follows:

- Bottom boundary: Fully fixed (U1 = U2 = U3 = 0).
- Two lateral faces: Restrained against horizontal movement (U1 = 0 or U2 = 0), while allowing vertical displacement.
- Two perpendicular faces: Symmetry applied to simulate one-quarter of the full domain.
- Symmetry justification: Stress contours confirmed that deformation patterns remained symmetric.

The geometry and boundary setup of the model are depicted in Fig. 5.

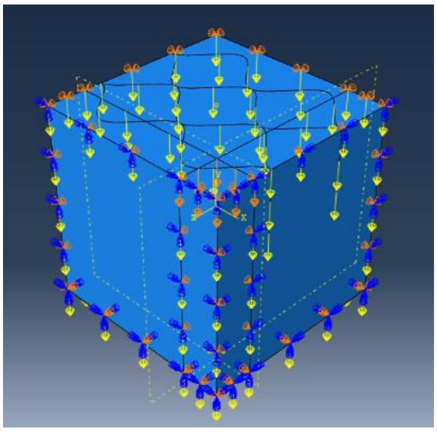

Fig. 5. Model with loading and boundary conditions.

The element type of soil was C3D8R (8-node linear brick, reduced integration, hourglass control) and for geocell M3D4R membrane elements (consistent with geocell behavior).Mesh convergence achieved when further refinement caused < 2% change in bearing capacity. The interaction between the geocell and the surrounding soil was modeled using the Embedded Region constraint. The geocell acted as the embedded region and the soil as the host region. This allows full kinematic compatibility without manually defining frictional contacts, consistent with validated geocell modeling literature.

NLGEOM was set to OFF, because settlements were small compared to model dimensions and enabling large deformation did not influence the load–settlement trends.The comparison between the results obtained from the present model and those reported by Hegde et al. is presented in Fig. 6. Minor differences may arise due to numerical differences between FLAC3D and ABAQUS, or parameters not explicitly specified by the original authors. Following successful validation, the model was subsequently modified to analyze the influence of soil properties and geocell characteristics on bearing capacity and settlement behavior.

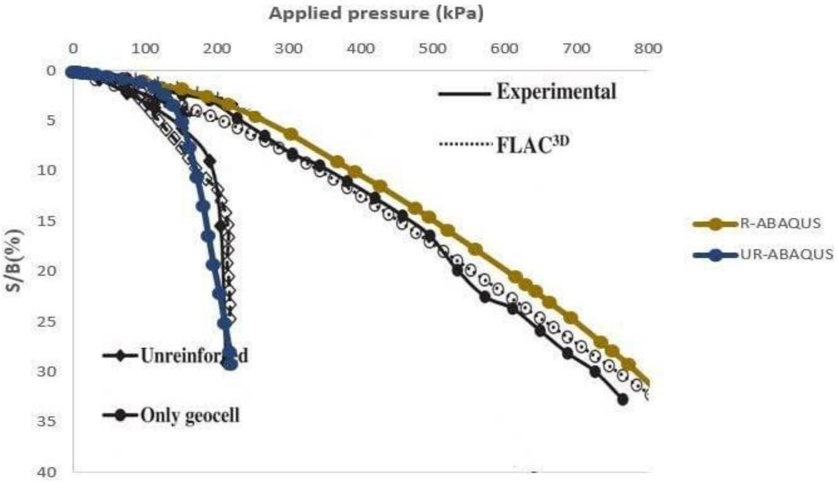

Fig. 6. Comparison of results with the verification article.

2.2. Numerical model

In this section, the details of the developed numerical model are presented. The model dimensions were slightly adjusted to 0.5 × 0.5 × 0.5 m. To examine the influence of soil strength parameters on the performance of geocell-reinforced foundation beds, a total of 48 simulation cases were created with varying soil properties to generate a consistent and comprehensive dataset. The soil parameters were selected based on an extensive review of soil mechanics and geotechnical engineering literature. The soil type used in this study corresponds to medium sand, characterized by a relative density ranging between 35 and 65 percent, as reported in standard references. The main soil properties adopted for the analysis are summarized in Table 2. Four different values were assigned for the elastic modulus and internal friction angle, while two values were used for the unit weight. A cohesion value of 10 kPa was assumed to simplify the numerical modeling process. All other model components and boundary conditions remained consistent with those used in the validation model.

Table 2. Numerical model soil parameters.

Parameter	Value
Elastic modulus (MPa)	30, 35, 40, 45
Poisson's ratio	0.3
Cohesion (kPa)	10
Friction angle (deg.)	30, 33, 36, 39
Unit weight (kN/m^3)	15, 16, 17

3. Results

This study investigates the effect of three soil parameters on the behavior of geocell-reinforced foundation beds. It discusses the effect of reinforcement, examines the impact of each parameter, and compares their relative influence.

3.1. Bearing capacity

Bearing capacity is one of the most critical performance indicators in foundation engineering. In this study, geocell-reinforced foundation beds were analyzed to highlight the effectiveness of this type of reinforcement in improving load-bearing performance. The bearing capacity ratio (BCR) is defined as the ratio between the bearing capacity of the reinforced foundation and that of the unreinforced foundation. The computed values for both reinforced and unreinforced bearing capacities, along with the corresponding BCR values, are presented in Table 3. The soil identification code used in the table consists of four components: "MS" denotes medium-density sand; "U" followed by a number indicates the unit weight in kilonewtons per cubic meter; "E" represents the elastic modulus; and the number following "F" specifies the internal friction angle in degrees.

Table 3. Bearing capacities and BCR.

Soil Code	qr (kPa)	qu (kPa)	BCR	Soil Code	qr (kPa)	qu (kPa)	BCR	Soil Code	qr (kPa)	qu (kPa)	BCR
MSU15E30F30	1120	495	2.26	MSU16E30F30	1130	505	2.24	MSU17E30F30	1135	510	2.23
MSU15E35F30	1130	500	2.26	MSU16E35F30	1135	510	2.23	MSU17E35F30	1140	520	2.19
MSU15E40F30	1135	510	2.23	MSU16E40F30	1145	520	2.20	MSU17E40F30	1155	525	2.20
MSU15E45F30	1145	520	2.20	MSU16E45F30	1150	525	2.19	MSU17E45F30	1155	535	2.16
MSU15E30F33	1415	690	2.05	MSU16E30F33	1420	695	2.04	MSU17E30F33	1425	705	2.02
MSU15E35F33	1420	700	2.03	MSU16E35F33	1425	705	2.02	MSU17E35F33	1430	715	2.00
MSU15E40F33	1425	705	2.02	MSU16E40F33	1430	710	2.01	MSU17E40F33	1440	720	2.00
MSU15E45F33	1430	710	2.01	MSU16E45F33	1435	720	1.99	MSU17E45F33	1440	730	1.97
MSU15E30F36	1740	985	1.77	MSU16E30F36	1755	995	1.76	MSU17E30F36	1760	1000	1.76
MSU15E35F36	1750	995	1.76	MSU16E35F36	1760	1005	1.75	MSU17E35F36	1765	1010	1.75
MSU15E40F36	1755	1000	1.76	MSU16E40F36	1765	1015	1.74	MSU17E40F36	1770	1020	1.74
MSU15E45F36	1770	1010	1.75	MSU16E45F36	1780	1020	1.75	MSU17E45F36	1785	1030	1.73
MSU15E30F39	2415	1445	1.67	MSU16E30F39	2420	1455	1.66	MSU17E30F39	2425	1460	1.66
MSU15E35F39	2420	1450	1.67	MSU16E35F39	2425	1465	1.66	MSU17E35F39	2430	1470	1.65
MSU15E40F39	2430	1460	1.66	MSU16E40F39	2430	1470	1.65	MSU17E40F39	2435	1475	1.65
MSU15E45F39	2435	1470	1.66	MSU16E45F39	2445	1480	1.65	MSU17E45F39	2455	1490	1.65

To ensure that the observed increases in bearing capacity were associated with realistic load-transfer mechanisms, the vertical stress contours, von Mises stress distribution, and plastic strain zones beneath the footing were examined for representative cases. In both reinforced and unreinforced soils, the stress bulbs developed in patterns consistent with classical bearing capacity theory. The presence of the geocell produced a wider, shallower stress distribution, confirming proper confinement and shear mobilization.

Three groups of soil samples were analyzed, each consisting of 16 variations with different values of unit weight, elastic modulus, and internal friction angle. Within each group, the soil strength increased progressively with the sample number. Consequently, the bearing pressure ratio (BPR) exhibited a gradual decrease, indicating a reduced influence of the geocell reinforcement as the soil became stronger. This trend is illustrated in Fig. 7. The observed improvement due to geocell reinforcement remained consistent across all 48 simulations. Although the magnitude of improvement decreased with increasing soil strength, the qualitative behavior, higher bearing capacity and reduced settlement in reinforced cases, was consistent throughout the entire parameter range.

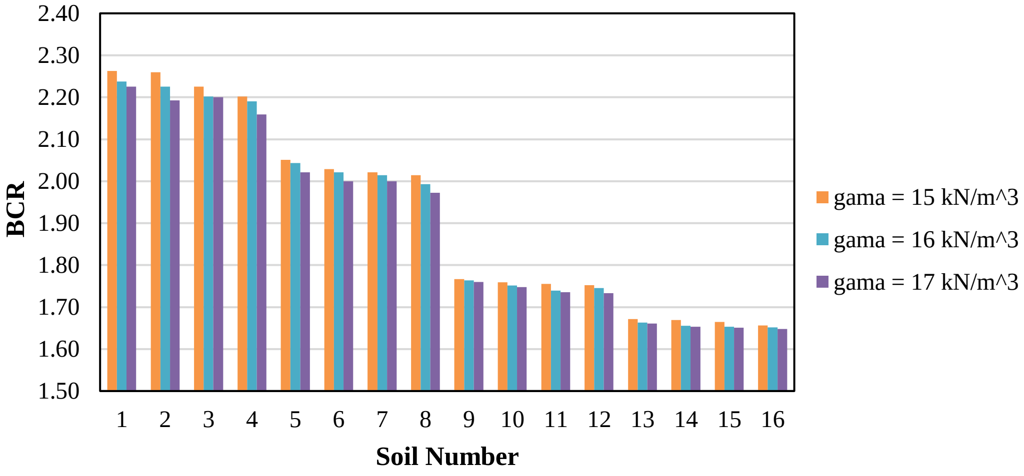

Fig. 7. BCR for different soil samples.

3.2. Effect of soil elastic modulus

The elastic modulus of a material reflects its stiffness and deformation response under applied loads and is a critical parameter in the design and analysis of foundations, slope stability, and retaining structures. It serves as one of the principal input variables in both finite element modeling and the Mohr-Coulomb failure criterion for simulating soil behavior. In this study, four elastic modulus values, 30, 35, 40, and 45 MPa, were selected for the numerical model to evaluate their effect on bearing capacity. The remaining soil parameters for these four cases are listed in Table 4. As illustrated in Fig. 8, an increase in the elastic modulus led to higher bearing pressures in both reinforced and unreinforced models. In the figure, the curves labeled with the letter “R” represent the reinforced versions of the corresponding samples.

Table 4. Soil parameters for samples 1-4.

Unit weight (kN/m^3)	Poisson's ratio	Soil code	Elastic modulus (MPa)
15	0.3	MSU15E30F30	30
Friction angle	**Cohesion (kPa)**	MSU15E35F30	35
30	10	MSU15E40F30	40
		MSU15E45F30	45

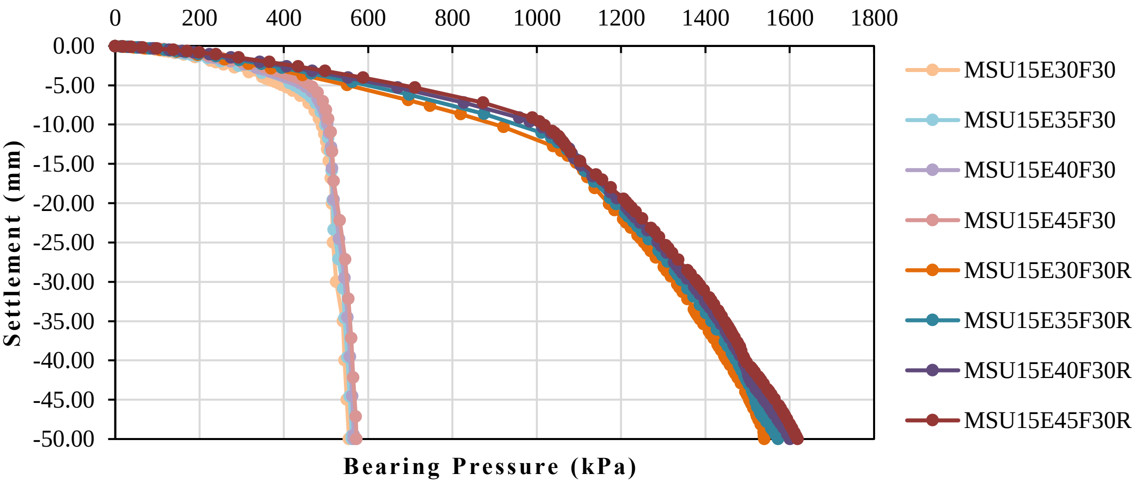

Fig. 8. Effect of soil elastic modulus on settlement.

The moderate influence of elastic modulus on bearing capacity indicates that stiffness governs the deformation response but does not significantly change the failure mechanism. The geocell provides lateral confinement, so increases in E produce diminishing returns once the soil stiffness exceeds the confinement stiffness provided by the geocell layer.

An increase of only 5 MPa in the soil's elastic modulus was found to enhance the bearing capacity of the foundation. On average, this improvement amounted to 0.46 percent in the reinforced samples and 1.03 percent in the unreinforced samples. However, as the internal friction angle of the soil increased, the influence of the elastic modulus on bearing capacity became less significant. Fig. 9 illustrates the average percentage increase in bearing capacity resulting from a 5 MPa increment in the soil's elastic modulus for both reinforced and unreinforced conditions.

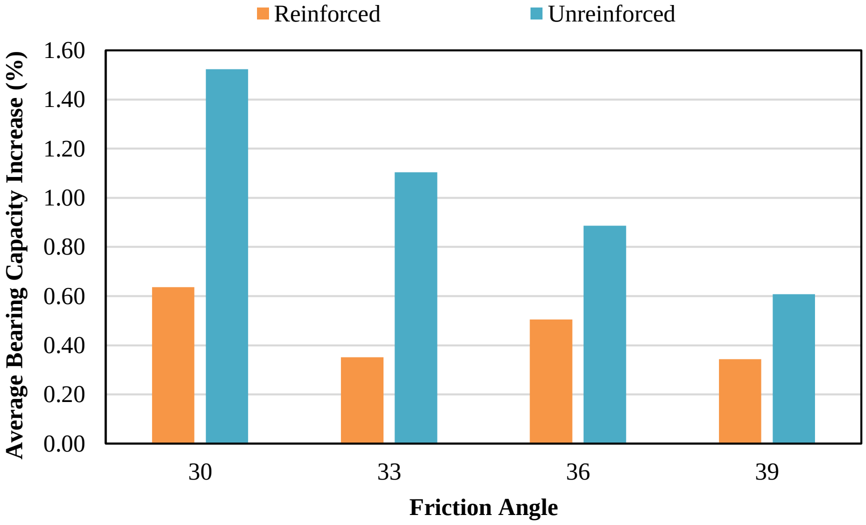

Fig. 9. Effect of elastic modulus on increasing bearing capacity.

3.3. Effect of soil friction angle

The internal friction angle is a key parameter representing the shear strength of soil. Based on the Mohr-Coulomb failure criterion, it defines the soil's resistance to shear deformation and failure. In this study, four friction angle values, 30, 33, 36, and 39 degrees, were assigned to the numerical model to examine their influence on the bearing capacity of the foundation. The remaining soil properties for these cases are provided in Table 5. Fig. 10 presents a comparison of the results for these soil models, illustrating the effect of increasing the friction angle on the foundation's bearing pressure. In the figure, curves labeled with the letter "R" correspond to the reinforced samples.

Table 5. Soil parameters for samples 44, 48, 52, 56.

Unit weight (kN/m^3)	Poisson's ratio	Soil code	Elastic modulus (MPa)
15	0.3	MSU15E30F30	30
Friction angle	**Cohesion (kPa)**	MSU15E30F33	33
30	10	MSU15E30F36	36
		MSU15E30F39	39

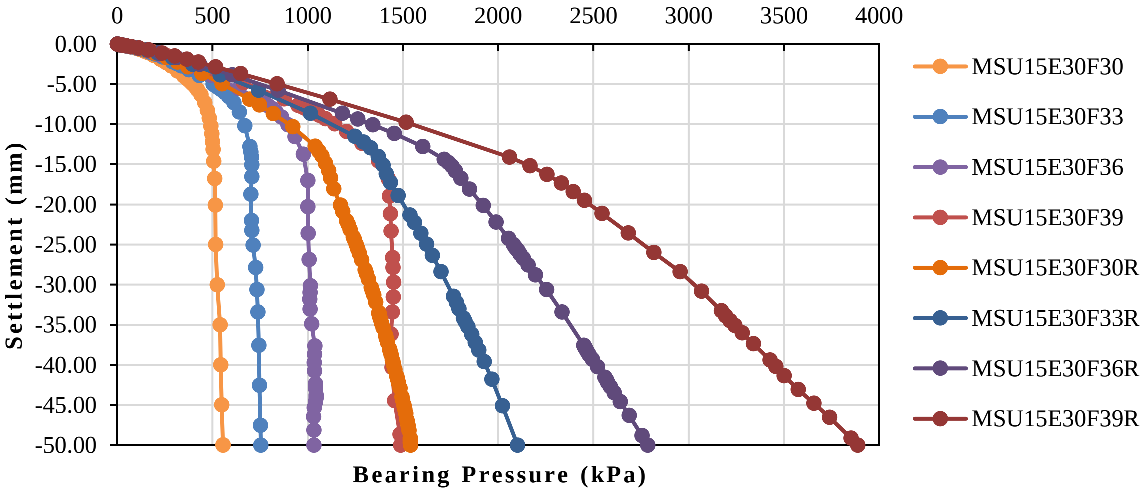

Fig. 10. Effect of friction angle on settlement.

An increase of only three degrees in the soil's friction angle was found to raise the foundation's bearing capacity by as much as 45 percent. For geocell-reinforced foundations, soils with higher elastic modulus exhibited a smaller improvement when the friction angle was increased. Moreover, the higher the initial friction angle of the soil, the greater the relative impact of this three-degree increment, as summarized in Table 6. The strong sensitivity to friction angle highlights that geocell systems perform best when combined with soils capable of mobilizing high shear resistance. In practice, this suggests that selecting granular infill with high φ, or improving in-situ soils through compaction or stabilization, can significantly enhance the performance of geocell-reinforced foundations. In reinforced cases with higher φ, the contribution of the geocell becomes more efficiency-driven rather than capacity-driven, because the soil itself controls the shear failure mechanism.

Table 6. Comparison of change in friction angle.

Angle change	Average bearing capacity increase (%)
30 to 33	31.5
33 to 36	32.8
36 to 39	41.7

3.4. Effect of soil unit weight

The unit weight of soil is a crucial property in geotechnical engineering. It represents the weight of the soil material contained within a given volume. Three different unit weights with values of 15, 16 and 17 were assigned to the soils with different parameters. Fig. 11 shows that raising the soil's unit weight can have a small increase in the bearing capacity of the foundation.

The results highlight that soil friction angle exerts the dominant control on the performance of geocell-reinforced foundations. This suggests that in practice, geocell systems should be optimized primarily through site-specific shear strength improvement and selection of suitable granular infill, while elastic modulus plays a secondary role. The minimal sensitivity to unit weight indicates that for confined and reinforced foundation beds, shear strength parameters (φ, c) dominate load-bearing mechanisms, while density plays only a secondary role. This aligns with the fact that confinement suppresses the effect of self-weight on failure surface formation.

4. Conclusions

This study investigated the influence of three key soil strength parameters, elastic modulus, internal friction angle, and unit weight, on the bearing capacity and settlement performance of geocell-reinforced foundation beds. A total of 48 three-dimensional numerical simulations were conducted in ABAQUS, using a validated FE model benchmarked against Hegde and Sitharam [8]. The results lead to the following conclusions:

- Geocell reinforcement significantly enhances bearing capacity, especially in weak soils where the confinement effect compensates for insufficient stiffness. The bearing capacity ratio (BCR) ranged from 1.65 to 2.26, confirming the strong contribution of lateral confinement and improved shear mobilization. As soil strength increased, the relative improvement declined, but reinforcement effectiveness remained consistent across all parameter combinations.

- All three soil parameters, elastic modulus, friction angle, and unit weight, positively contributed to bearing capacity and settlement reduction. However, their influence was not equal. The internal friction angle showed the strongest effect: a 3° increase raised bearing capacity by up to 45%, underscoring the central role of shear resistance in geocell–soil interaction.
- The elastic modulus had a moderate effect on bearing capacity. Increasing E by 5 MPa produced average improvements of 0.46% in reinforced and 1.03% in unreinforced soils. However, as friction angle increased, the influence of elastic modulus diminished, indicating that stiffness affects deformation more than ultimate shear-controlled failure.
- Unit weight had the least influence among the studied parameters. The small improvements observed indicate that in confined reinforced beds, strength parameters (φ, E) play a far more dominant role than density in governing load-carrying behavior.
- Based on the comparative assessment, the internal friction angle is the most influential parameter for enhancing the performance of geocell-reinforced foundations. Higher φ not only raises shear strength but also increases the efficiency of geocell confinement, creating a stiffer composite zone and improved stress redistribution.

Overall, the study confirms that geocell reinforcement provides a highly effective and practical solution for improving the bearing capacity of shallow foundations, particularly in weak or lightly compacted soils.

The validated numerical model offers a reliable framework for predicting the behavior of reinforced foundations under variable soil conditions.

Future work should incorporate more advanced constitutive models (e.g., generalized plasticity or state-dependent formulations), evaluate cyclic or dynamic loading, and consider the explicit influence of geocell geometry and material stiffness to improve field-scale applicability and design optimization.

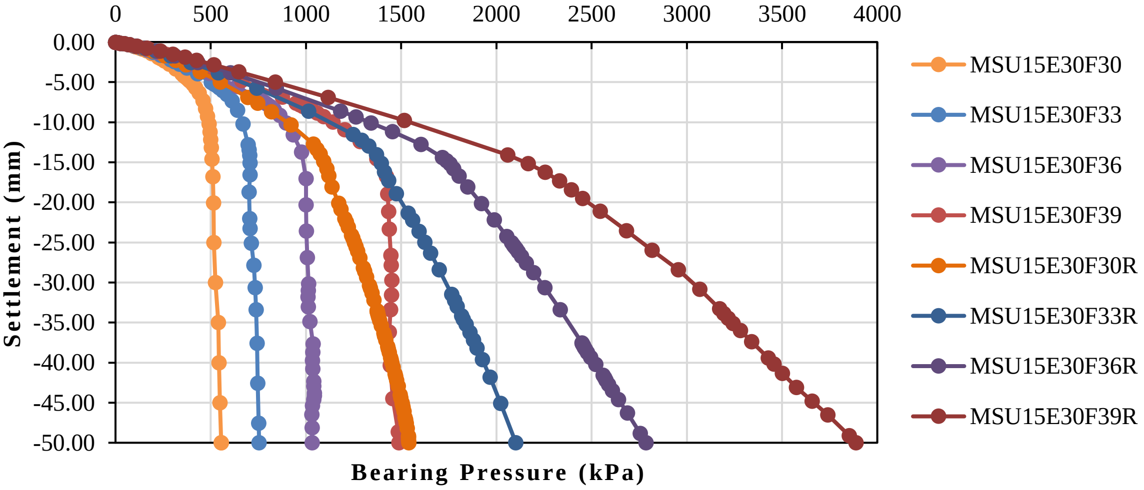

Fig. 11. Effect of unit weight on settlement.

Statements & Declarations

Author contributions

Mohammad Javad Hosseinzadeh: Investigation, Formal analysis, Data curation, Software, Writing - Original Draft.

Mohammad Oliaei: Project administration, Supervision, Resources, Writing - Review & Editing.

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Data availability

The data presented in this study will be available on interested request from the corresponding author.

Declarations

The authors declare no conflict of interest.

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