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Research Article

Optimization of Circular Footing Size by Sand Substitution and Geogrid Reinforcement

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ABSTRACT

Introduction: The performance of circular footing in cohesive soil can be significantly enhanced through soil improvement and proper optimization of footing design.
Objectives: The study investigated the optimization of footing diameter and enhancement of cohesive soil by replacement of soil with sand at varying depths and incorporating geo-grids at various spacings.
Methods: Finite element modeling was used to model the footing to stimulate the behavior of the footing in improved soil.

Results: The study investigated how the bearing capacity, settlement, and general stability of the footing were affected by different sand replenishment percentages, depth, and geogrid spacing. According to the results, replacing sand and placing geogrids strategically both significantly improve the soil's ability to support loads and lessen footing settling. Additionally, geogrid spacing optimization offers a cost-effective design option that strikes a compromise between performance and cost. Through economical soil improvement techniques,

Conclusions: The research's conclusions provide useful information for designing foundations on soft soil, resulting in improved load distribution and decreased settlement.

Keywords: Settlements; Bearing capacity; Geo-grids; Cohesive soil; Circular footing.

INTRODUCTION

Many ground improvement techniques were used for infra structure development where poor soil conditions exists. From all those ground improvement techniques employing geo-grid reinforcement layers was one of the cost-effective methods. (V & T, 2019) (Bestun J Shwan, 2012) The reinforcement

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element minimizes the shearing or excessive deformation failure (Patel, 2019). When a shallow foundation is built on loose soil, it can lead to several structural dysfunctions because the underlying soil's mechanical qualities are inadequate. To overcome the soil's inability to withstand shear and tension stresses and enable safe and sustainable building, the concept of reinforced soil utilizing geogrids was introduced. Large foundation settlements can result from these shortcomings in soil materials; therefore, it was anticipated that applying geogrid materials would reduce the deficiencies in soil materials and, as a result, raise the carrying capacity of foundations (Ehsan Momeni, 2021). Combining geo-grids with dense sand can be a more cost-effective way to improve ground conditions than densifying sand itself. The geo-grid sheet need to be submerged in dense sand at right depth in order offer enough friction resistance on both its top and bottom surfaces (Pragyan Paramita Das, 2022). Several geogrid-reinforcement approaches have become more popular in recent years because to their shown efficacy, ease of installation, and affordability when compared to other upgrading methods. For instance, the heavy construction sector has long acknowledged mechanically stabilized earth (MSE) technology as a reliable method for constructing dams over difficult soil, steep slopes, and retaining walls (Mohamed G. Arab, 2017). A study was conducted to examine the effects of the bearing capacity scale on sandy soil for a circular foundation reinforced with geo grid. Using 3D axisymmetric finite element models, they conducted numerical analyses. They concluded that the carrying capability of As the foundation's diameter grows, the amount of reinforced and unreinforced soil decreases (Danny Useche-InfanteORCID Icon, 2019). In this research an attempt was made analyse the performance of circular footing placed on granular fill overlaying on cohesive soil reinforced with geo-grids. Optimizing geogrid spacing aids in producing a well-balanced design that blends affordability and performance. The study demonstrates how to construct foundations on soft soil to optimize load distribution and decrease settlement by utilizing affordable soil enhancement techniques. The assessment was carried out in PLAXIS-2D.

OBJECTIVES

To optimize the footing diameter while ensuring adequate bearing capacity and settlement performance, using reinforced sand beds.

METHODS

Properties of the materials used in the study:

Table1.Properties of cohesive soil Used in the Study (Hussam Aldeen, 2022)

Property	Value
Specific gravity, G	2.65
Plasticity Index %	15
Maximum dry unit weight(kN/m²)	18.7
Optimum moisture content %	14.8
Cohesion (kN/m²)	21.87

Table2.Properties of granular material used In the Study (Ashraf, 2018)

Property	Value
Coefficient of Curvature, C_C	0.960
Coefficient of uniformity, C_u	1.790
Specific gravity, G	2.670
Maximum dry unit weight (kN/m²)	17.20
Minimum dry unit weight (kN/m²)	15.10
Frictional angle, Ø	35.920˚
e	0.770

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Table 3.Properties of footing used in the study

Footing Material	Concrete
Young's modulus [E_{ref}]	2.480E+07 kN/m^2
Poisson ratio [v(nu)]	0.15
EA – Axial Stiffness (kN/m)	17.52E+0^6
EI – Bending Stiffness (kN.m^2 /m)	182 x10^3
Own Weight (kN/m/m)	23.57

Table 4. Properties of Geosynthetic used In the Study (Ali Abdolhosseinzadeh, 2022)

Property	Value
Geogrid name	CE121
Aperture shape	Oval
Opening size (mm×mm)	6×8
Mesh thickness (mm)	3.3
Tensile strength (kN/m)	45
Axial stiffness (kN/m)	350
Mass per unit area (gr/m^2)	730

Finite element analysis: It is applied in geotechnical engineering to stimulate and analyze soil-structure interactions behavior. FEA predicts the response of soil masses to different loads, including pressure from foundations, retaining walls, or other structures. FEA breaks down the soil in to smaller elements to mimic complex factors such as soil deformation, settlement, shear strength and pore water pressure. This allows engineers to evaluate the stability, safety and performance of foundations, slopes, tunnels, and other geotechnical structures under various conditions, enhancing design accuracy and reliability.

Methodology: The analysis was carried out on circular footing using Finite Element Analysis (FEA) using PLAXIS-2D. To clearly capture the shape of circular footing axisymmetric model was selected, boundaries was set to clearly capture the deformations. A bore-hole was created and all the soil properties were given then a plate was created which resembles the footing and the properties of the footing were given. Line load was given on the plate which resembles the real time loading conditions and mesh was generated. To capture the base line conditions for settlements and bearing capacity analysis was made without any soil improvement techniques.

First sand replacement technique was analyzed and found to be non- economical, then the geo-grids were added which helps to reduce the sand thickness and increase bearing capacity and reduce settlements. In the analysis the footing size was optimized by improving the ground conditions.

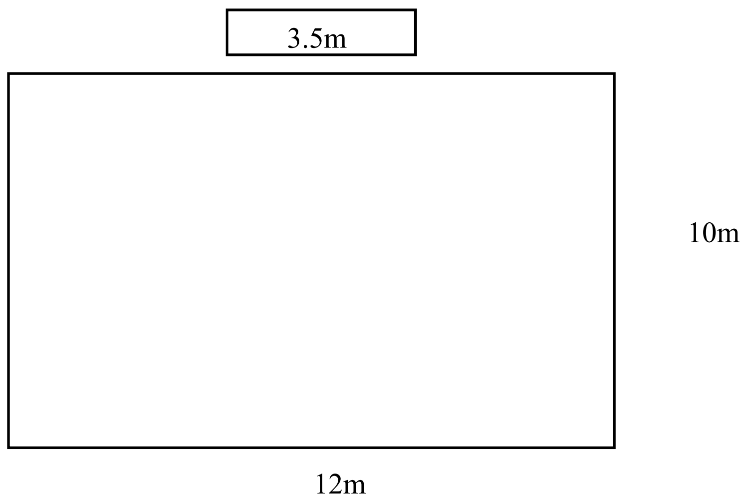

Fig.no.1 Geometry of the model with 3.5m footing resting on cohesive soil.

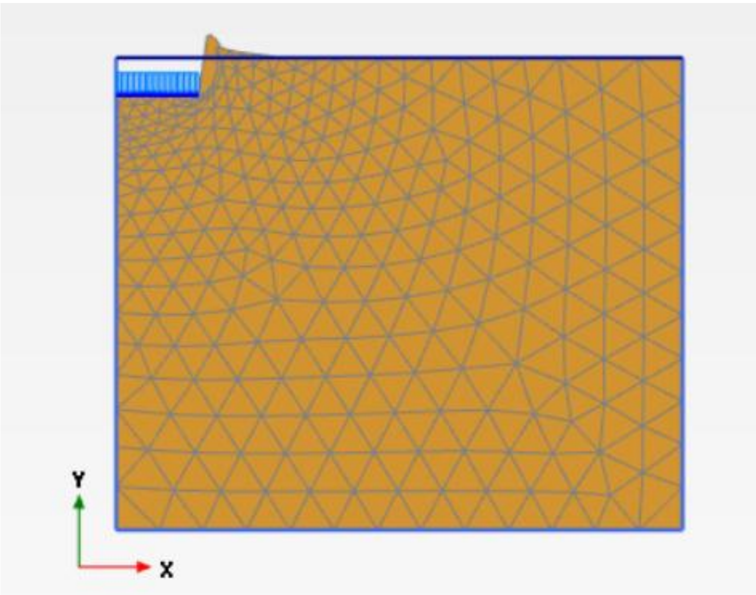

Fig.no2: 3.5m Footing generated in PLAXIS-2D

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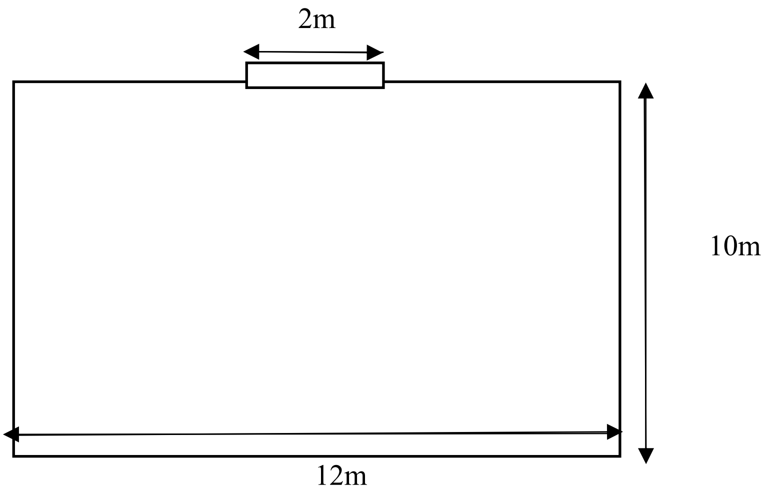

Fig.no.3: Geometry of the model with 2m footing resting on cohesive soil.

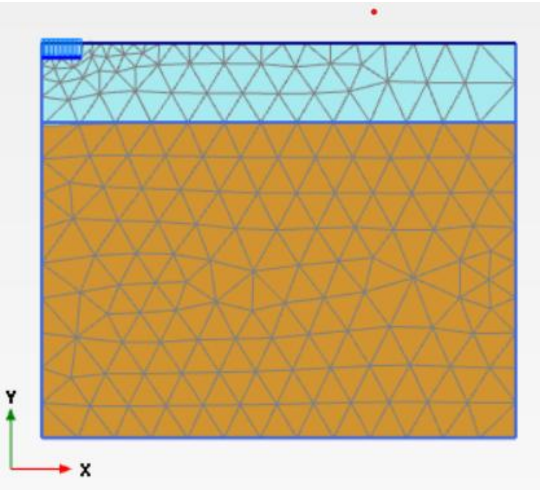

Fig.no4: 2m Footing resting on sand-bed generated in PLAXIS-2D

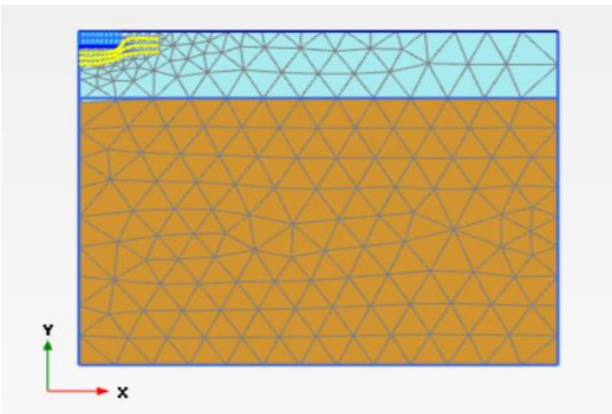

Fig.no5: 2m Footing resting on sand-bed with geogrid reinforcement generated in PLAXIS-2D

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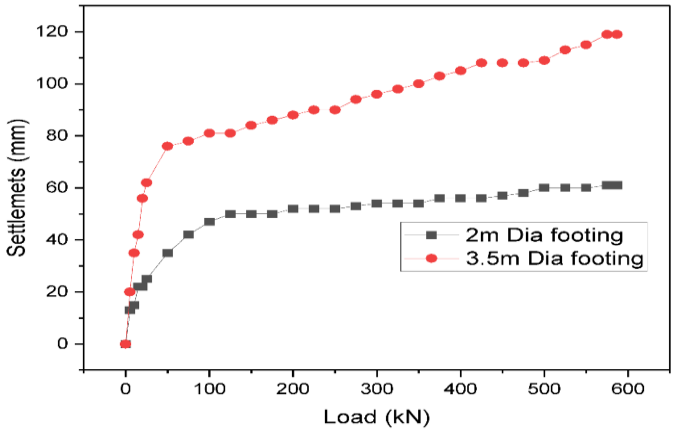
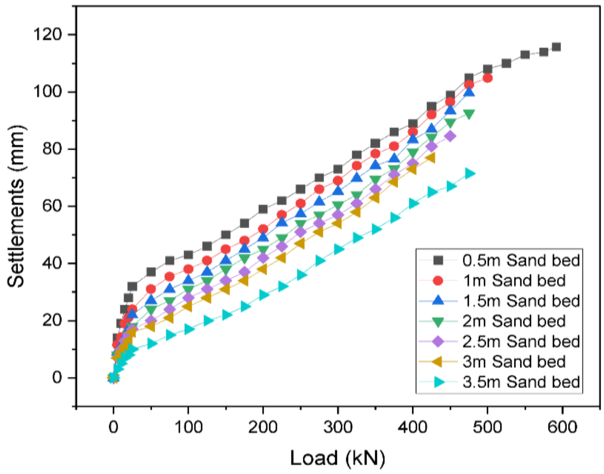
RESULTS

Initially the footing diameter was 3.5m which gives settlements of 61.25mm which is in permissible limit. These settlements were when there is no improvement in the ground conditions, but building 3.5m footing is not economical. A 2 m footing was an economical option which can carry same amount of load that a 3.5m footing can carry with sand replacement up to a certain depth and placing reinforcement at different depths.



Graph.no.1 Load Vs Settlements graph of 3.5m and 2m footing with out any ground improvement

When the footing size reduced the settlements got increased from 61.25mm to 119mm and the bearing was reduced from 157kN/m² to 115kN/m².



Graph. no.2 Load Vs Settlements for different sand replacement depths.

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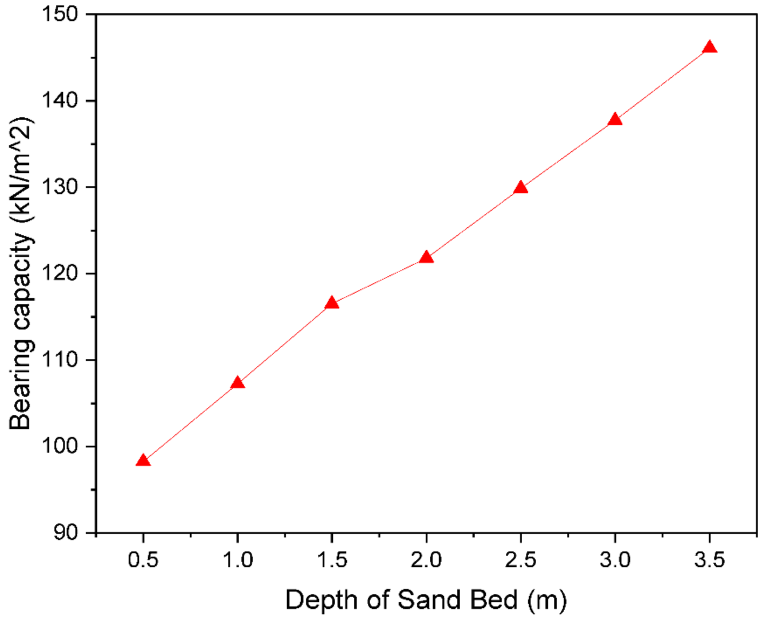
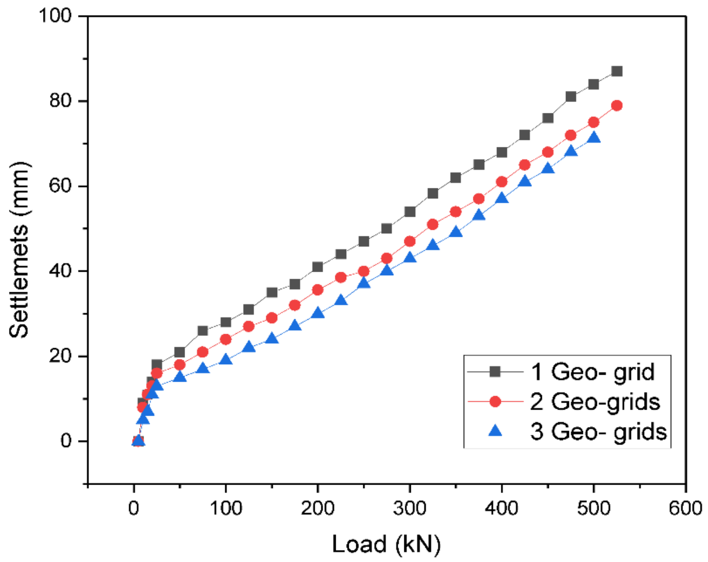


Graph.no.3 Bering capacity Vs Depth of sand-bed.

The sand bed is replaced with different depths and maximum Bering capacity of 146.1 kN/m^2 and permissible settlements of 71.5 occurred when the sand is replaced at 3.5m depth. This was also not economical.



Graph.no.4 Load Vs Settlements by placing geo-grids at different depths

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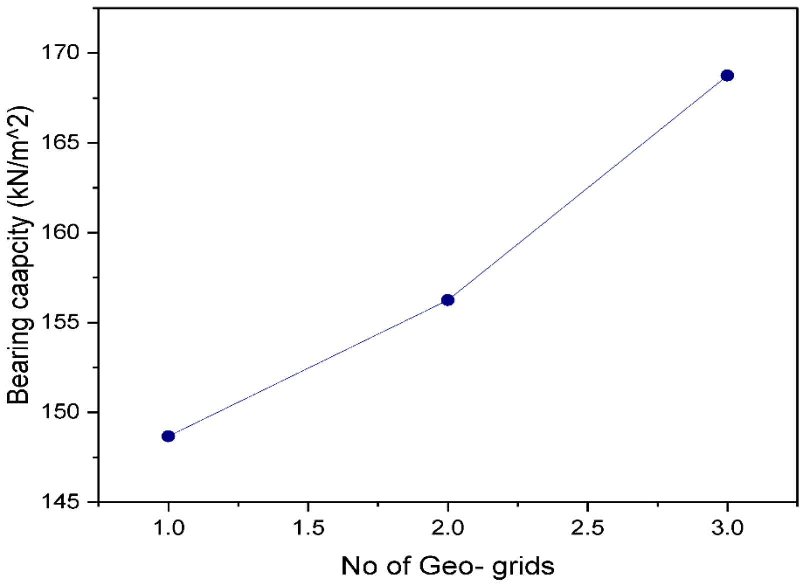

Graph.no.5 No of Geo- grids Vs Bearing capacity

As the sand replacement for 3.5m was not economical and time taking. Geo-grids were used along with the sand replacement which reduced the depth of sand bed. The maximum bearing capacity of 168.75 kN/m². And settlements of 71.24mm were obtained when 3 geo grids of length 6m with spacing of 0.2m were placed.

Footing optimization

Footing Size Reduction: The diameter of the footing was decreased by 1.5 meters, being 42.8% lower than the original diameter, hence demonstrating the success of reinforcement methods in creating a more streamlined footing.

Despite the smaller footing dimensions, geogrid reinforcement over a sand bed gave a stable and structurally sound foundation, which allowed it to carry the loads effectively.

The decrease in foundation size resulted in a more effective foundation system, where materials and resources were used more effectively and still achieved performance standards.

This optimization resulted in cost reduction material- related costs and excavation.

The design efficiency was boosted using sand bed and geo-grid reinforcement, thus reducing the need for wider and more resource-intensive foundations.

The compaction footprint reduced the construction time and resource consumption, shortening the entire project duration and reducing the resource cost, man hours, and excavation. The geo-grid reinforcement and sand bed enhances and sustainability of the foundation by reducing the consumption of material and the environmental impact of the construction.

DISCUSSION

This research seeks to quantitatively analyse the behaviour of soil improvement with a sand bed and geogrid reinforcement under a circular footing. The important parameters affecting soil improvement include sand bed depth, geo-grid length, no of geo-grid layers, spacing between each layer and spacing between footing and first geo-grid.

The 3.5- meter footing produced a settlement of 61.25mm, which was in permissible limit but was not economical due to its larger size. The alternative was to use a 2-meter footing, more economical for carrying the same load. This led, however, to a further increase in settlements increasing from 61.25mm to119mm whilst reducing inherent bearing capacity from 157kN/m² to 115kN/m².

The method increased the bearing capacity to 146.1 kN/m² with settlements of 71.5 mm replacing the sand bed at a depth of 3.5 m. However, this method was not economical due to the depth of sand replacement and the time taken to carry it out.

Geo-grids have decreased bed-sand depth, thus yielding 168.75 kN/m² of bearing capacity and 71.24mm of settlements. The three geo-grids, of 6m long each, spaced at 0.2m throughout, conferred a more economical and efficient method of construction as compared to the replaced deeper sand bed.

The diameter of the footing was reduced by 42.8%, thus showing the effectiveness of the geogrid reinforcement in designing a compact and streamlined foundation. As a result of the reduced size of the footing, the foundation was still able to carry that load, which in fact confirmed that reinforcement could retain the structural integrity and serviceability.

The use of smaller foundation sizes and geogrid reinforcement thus brought down construction time, material consumption, excavation efforts, and therefore savings to this task.

The application of geogrid reinforcement and sand bedding presented an ecologically sustainable solution characterized by the very economical usage of materials along with minimum impact on the environment.

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