A STUDY ON THE BEARING CAPACITY OF SHALLOW FOUNDATIONS ON GEOSYNTHETIC REINFORCED SAND

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Degree of Master of Science

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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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Dr. L.I.N. De Silva

ABSTRACT

A study on the bearing capacity of shallow foundations on geosynthetic reinforced sand

This thesis demonstrate a research study aimed at investigating the significance of bearing capacity improvement of shallow foundation supported on geocell, geogrid and combination of geocell and geogrid reinforced sand. To implement the objective, laboratory model test, numerical study using PLAXIS 3D and theoretical study were performed to investigate the behavior of reinforced soil foundation. Honeycomb shape HDPE geocell and biaxial geogrid were used in laboratory model test.

For geocell, initially single layer geocell was experimented with different cover thickness (geocell placing depth). From the results, suitable cover thickness was found at [depth (U)/width (B)] ratio between 0 and 0.5 for a square pad footing. Numerical modeling of the geocell has been an immense challenge due to their curved shape. The equivalent composite approach (ECA) is widely used to model the geocells. However, the composite method has a number of limitations, including the disregard of the effect of shape. The shape has a major influence in stress distribution. Hence a realistic model approach is essential to simulate the same experimental condition in numerical analysis. In this study, a 3D Auto Cad model was imported to PLAXIS 3D and modeled using geogrid structural element. Then the model was validated using experimental results where the results satisfied each other. According to the numerical analysis, optimum cover thickness for sand was found as 0.1B (width of footing). The static load test showed that with the provision of HDPE geocells, bearing capacity of soil can be improved by a factor up to 2.5 times of unreinforced soil. Further numerical investigations were carried out using double layer geocell for prototype footing to compare the bearing capacity improvement with single layer geocell. The results clearly depict that bearing capacity is improved by a factor of 2.75 and 3.5 times of unreinforced soil when using single layer and double layer geocell respectively. When doubly reinforced geocell was used, footing size is reduced by 40% and cost is reduced by 65%. It is apparent that using double reinforced geocell will lead to cost effective foundation designs. These ultimate bearing capacity results were validated by theoretical approaches. A good matching was found between experimental, numerical and theoretical approach.

For geogrid, laboratory model test and numerical modelling were performed to find the correlation between number of geogrid and bearing capacity, using optimum cover thickness and spacing. The experimental results show that both surface heaving and settlement are reduced with number of geogrid mattress. Moreover it was also observed that bearing capacity of reinforced soil increases with increasing number of reinforcement layers (at same vertical spacing). However, the significance of an additional reinforcement layer decreases with the increase in number of layers, and bearing capacity is improved by a factor of 2.86 times of unreinforced soil when four layer geogrid was used. Further validations were performed using (FHWA/LA.08/424) technical report.

Finally, a combination of geocell and geogrid was used as reinforcement. Two different cases were investigated, namely 'geocell+geogrid' combination and 'geogrid+geocell' combination. Optimum bearing capacity was obtained when geogrid was placed at the base and on the top of geocell in which bearing capacity is improved by a factor of 4.3 and 3.8, times of unreinforced soil respectively. It shows that a layer of planar geogrid placed at the base of the geocell mattress improves the bearing capacity significantly compared with provision of geogrid above the geocell layer.

Based on the overall study, key recommendations are made, which can be made for the improvements of reinforced soil foundation design. The results stated in this study will be useful in construction of building and pavements on the weak soils to significantly improve the bearing capacity of shallow foundation.

Key words: Bearing capacity, shallow foundation, geosynthetic, honeycomb shape geocell, PLAXIS 3D, feasibility study

DEDICATION

To my ever-loving teachers

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Abbreviations	Description	Unit
ϕ	Friction angle	[°]
c	cohesion	[kN/m^2]
δ	Interface friction angle	[°]
k	Coefficient of permeability	[m/day]
γ	Dry unit weight	[kN/m^3]
BCR	Bearing capacity ratio	-
M	Secant modulus of the geocell material	[kN/m]
K_e	Young's modulus parameter of the unreinforced sand	-
n	Modulus exponent of the unreinforced soil	-
K_r	Young's modulus parameter of the geocell-reinforced sand	-
P_a	Atmospheric pressure	[kPa]
D_{10}	Effective particle size	[mm]
D_{50}	Mean particle size	[mm]
C_u	Coefficient of uniformity	-
C_c	Coefficient of curvature	-
G_s	Specific gravity	-
RD	Relative density	[%]
t	Thickness	[mm]
E	Young modulus	[MPa]
k	Interface shear modulus	[MPa/m]
T	Tensile strength	[kN]
J	Tensile modulus	[kN/m]
U	Cover thickness	[mm]
X	Spacing	[mm]
Bx	Width	[mm]
k_o	coefficient of active earth pressure	-
p	surcharge load	[kN/m]

c	cohesion of soil	[kN/m^2]
N_c	bearing capacity factor	-
S_c	loading shape factor related to cohesion	-
N_q	bearing capacity factor	-
S_q	loading shape factor related to surcharge load	-
B	loading width	[m]
N_γ	bearing capacity factor	-
S_γ	loading shape factor related to the soil unit weight	-
h/d	geocell aspect ratio	-
e	stress redistribution parameter	-
d	Geocell pocket size	[mm]
h	Geocell height	[mm]
D_f	embedment depth	[m]
E_s	Elastic modulus of sand	[kN/m^2]
$I_{\varepsilon p}$	strain influence factor	-