Numerical Analysis of Strip Footing Resting on Slopes

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Abstract

Foundations are sometimes located either on a slope surface or near to the crown of a slope. These cases arise due to the limitation of available space or according to architectural needs. Cost saving might result if shallow foundations could be used instead of deep foundations to support such structures or if the allowable bearing capacity can be increased using an appropriate soil improvement technique. From an economical point of view, it is more advantageous, in case of bridges, to locate the footings near to the edge of the slope and to make the slope as steep as possible. But in such cases, the ultimate bearing capacity shall be reduced as the footing is more adjacent to a slope crest. This phenomenon is clarified by the theoretical methods used for predicting the bearing capacity of shallow foundation located in or on the top surface of a slope.

In many of the aforementioned structural cases, it might not be possible to use the shallow foundation system, and accordingly, using an expensive foundation system becomes the only suitable solution. For these reasons, over years the subject of improving the load bearing capacity of foundations on slopes and stabilizing the earth slopes have become among the most important areas of geotechnical researches and it has attracted a great deal of attention. In fact, both the stability of a slope and the bearing capacity of the adjacent soil can be increased in different ways, such as modifying the slope surface geometry, using soil reinforcement, or installing continuous or discrete retaining structures such as retaining walls or piles.

In The Present Study Performance of footing resting on slopes which is having homogeneous soil profiles and layered soil profile will be investigated and The dynamic behaviour of model footings are studied during earthquake. In the proposed work numerical studies are planned based on finite element method using software Plaxis version 8.2.

Plaxis version 8” is a finite element software program developed in the Netherlands for two and three-dimensional analysis of geo-structures and geotechnical engineering problems. It includes from the most basic to the most advanced constitutive models for the simulation of the linear or non-linear, time-dependent and anisotropic behavior of soil and/or rock. Plaxis is also equipped with features to deal with various aspects of complex structures and study the soil-structure interaction effect. In addition to static loads, the dynamic module of Plaxis also provides a powerful tool for modeling the dynamic response of a soil structure during an earthquake

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Keywords:

shallow, bearing capacity, retaining, soil-structure,

Introduction

Bearing capacity is the capacity of soil to support the loads applied to the ground. The value of average contact pressure between the soil and the foundation which will produce shear failure in the soil.The ultimate bearing capacity is the minimum gross pressure intensity at the base of the foundation at which soil fails in shear.The vertical downward movement of the base of a structure is called settlement and its effect up on the structure depends on its magnitude, its magnitude, the length of the time over which it takes place and the nature of the structure itself.

Suppose a number of columns in a row are to be supported on a soil of such low bearing strength, that separate bases if provided would overlap a practical solution would be to provide a column footing to support all the columns of the row. Such a footing is called a "STRIP FOOTING". Strip foundations are used to construct medium weight structures when the soil condition is relatively bad. When footing resting near slopes the bearing capacity of soil is significantly decreased. The potential failure of the slope itself significantly increased depending on the location of the footing with respect to the slope. So, it is necessary to stabilized the slope. Foundations are sometimes located either on a slope surface or near to the crown of a slope.

These cases arise due to the limitation of available space or according to architectural needs. Cost saving might result if shallow foundations could be used instead of deep foundations to support such structures or if the allowable bearing capacity can be increased using an appropriate soil improvement technique. From an economical point of view, it is more advantageous, in case of bridges, to locate the footings near to the edge of the slope and to make the slope as steep as possible. But in such cases, the ultimate bearing capacity shall be reduced as the footing is more adjacent to a slope crest. This phenomenon is clarified by the theoretical methods used for predicting the bearing capacity of shallow foundation located in or on the top surface of a slope.

In many situations where shallow footings are constructed on sloping surfaces or adjacent to a slope crest such as footings for bridge abutments on sloping embankments. When a footing is located on a sloping ground, not only the bearing capacity of the soil may be significantly reduced, but also the potential failure of the slope itself significantly increased depending on the location of the footing with respect to the slope. Therefore, over years, the subject of stabilizing earth slope has become one of the most interesting areas for scientific research and attracted a great deal of attention. Typical examples include modifying the slope surface geometry, chemical grouting, using soil reinforcement, or installing continuous or discrete retaining structures such as diaphragm walls, sheet pile walls or piles.

In case of building on slope or near its edge like retaining walls, transmission towers and bridge piers. The performance of these structures depends on the stability of slope and the bearing capacity of the soil which is less than the bearing capacity of soil in case of horizontal ground surface. The edge distance and the angle of slope inclination affect the stability of the foundations located at the top of the slope,

Therefore the methods of improving the bearing capacity and stability of foundations on the top of the slope is important.Different soil behaves differently under the action of cyclic loading. one of the main challenges is to predict if or not liquifaction will be triggered at the site. Normally at the site, to what depth it would liquify.If the soil is clay , how would be behave under the action of cyclic loading.It has been observed during the Mexico city earthquake that the earthquake motion was severely amplified by the soil.

Soil by nature is variable and heterogeneous. In general, there are two types of ground response that are damaging to structures. In one, the soil fails typically by liquefaction , such as in the 1995 Kobe earthquake . In the other, the soil amplifies the ground motion. Often laboratoy tests and model tests on earthquake geotechnical engineering problems are carried out on pure sands,or clays or well defined materials.It is very well known from laboratory tests that loose to medium dense sands liquefy under moderate shaking, but how do we assess the liquefaction potential for mixed soils i.e clayey sands or sandy clay.

Litreture Review

Lee and Manjunath (2000) has conducted a series of plane strain model tests carried out on both reinforced and unreinforced sand slopes loaded with a rigid strip footing. The objectives of this study are to (*i*) determine the influence of geosynthetic reinforcement on the bearing-capacity characteristics of the footing on slope, (*ii*) understand the failure mechanism of reinforced slopes, and (*iii*) suggest an optimum geometry of reinforcement placement. The investigations were carried out by varying the edge distance of the footing for three different slope angles and three different types of geosynthetic. It is shown that the load–settlement behaviour and ultimate bearing capacity of the footing can be considerably improved by the inclusion of a reinforcing layer at the appropriate location in the fill slope. The optimum depth of the reinforcement layer, which resulted in maximum bearing capacity ratio (BCR), is found to be 0.5 times the width of the footing. It is also shown that for both reinforced and unreinforced slopes, the bearing capacity decreases with an increase in slope angle and a decrease in edge distance. A numerical study using finite element analyses was carried out to verify the model test results. The agreement between observed and computed results is found to be reasonably good in terms of load–settlement behaviour and optimum geometry of georeinforcement placement.

Radoslaw L .Michalowski (2000) has conducted the stability of slopes subjected to seismic loads entail global equlibrium considerations with seismic influence included as a quasi-static force. Such an analysis does not reflect the earthquake shaking process,and it does not provide any information about permanent displacements that may have occurred as a result of that process.This paper focuses on displacement ca;culations of reinforced slopes.Design of reinforced slopes using the quasi-ststic approach may lead to an unrealistically long reinforcement for large ground accelerations.If slopes are allowed to move by even a small displacement, then the reinforcement length can be reduced significantly.

Mostafa El Sawwaf (2005) has conducted an experimental and numerical study of the behaviour of an eccentrically loaded strip footing resting on geosynthetic reinforced sand is presented. Particular attention was given to simulate footings constructed on unsymmetrical geogrid layers with eccentricity either direction of the footing. Several configurations of geogrid layers with different number, length, layer eccentricity along with the effect of the sand relative density, and the load eccentricity were investigated. A numerical study on a plane strain prototype footing was performed using finite element analysis. Test results indicate that the footing performance could be appreciably improved by the inclusion of layers of geogrid leading to an economic design of the footing. However, the efficiency of the sand-geogrid system is dependent on the load eccentricity ratio and reinforcement parameters. A close agreement between the experimental and numerical trend lines is observed. Based on the numerical and experimental results, critical values of the geogrid parameters for maximum reinforcing effect are established. Based on the laboratory tests and the theoretical analysis, the following main conclusions are drawn;

METHODOLOGY

Numerical analysis is a powerful mathematic tool that enables us to solve complex engineering problems. The finite element method is the most popular and well-established numerical analysis technique. It has been widely used in many civil engineering applications both for research and design of real engineering problems. One such application is the numerical analysis of reinforced soil foundation problem. In the proposed work numerical studies are planned based on finite element method using software Plaxis version 8.2.

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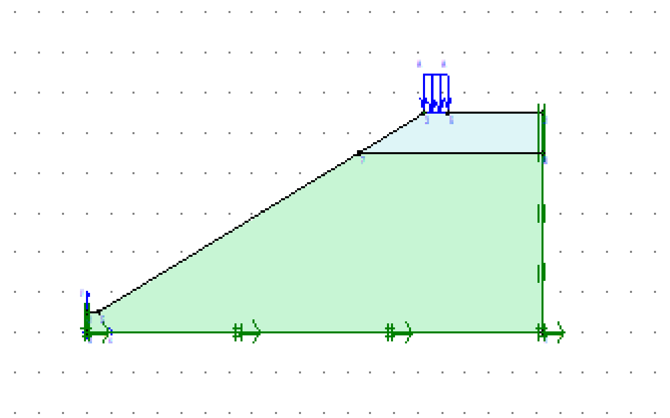
SCOPE AND OBJECTIVE OF THE PRESENT STUDY

Performance of footing resting on slopes which is having homogeneous soil profiles and layered soil profile will be investigated and the dynamic behaviour of model footings are studied during earthquake. Parameters considered in this study are; Variation of slope angle (θ), Variation of footing edge distance from the slope crest (b/B), Variation of thickness of soil (d/B).



b – Footing edge distance from the slope crest
B –footing width
D – Thickness of the soil
θ - angle of internal friction

Results and Discussions for Layered Soil

COMPARISSION OF STATIC AND DYNAMIC ANALYSIS LAYERED SOIL

Footing width=1m

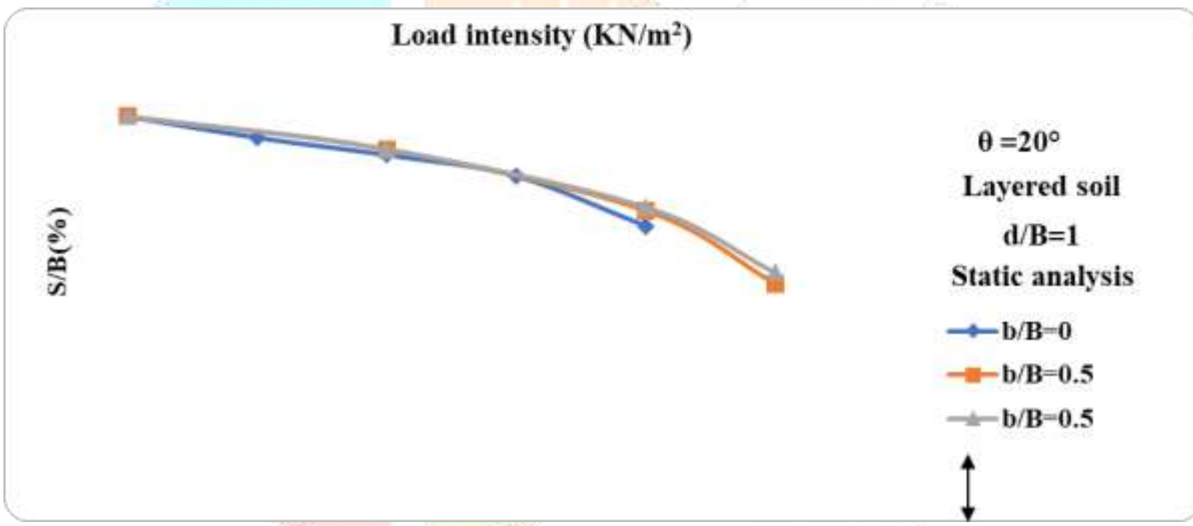


Fig 1: Load intensity v/s Settlement ratio

An intial set of reference tests were performed for a footing resting on a loose sand underlained by a layer of soft clay. The footing placed at a various (b/B) ratio at a depth of 1m with inclination of 20°. It can be observed that increasing the footing edge distance from the slope crest the settlement ratio goes on decreases. From this graph finally concluded that by increasing the footing edge distance the ultimate bearing capacity increases. Footing edge distance of b/B=0.5 is the optimum value for redusing the settlement ratio.

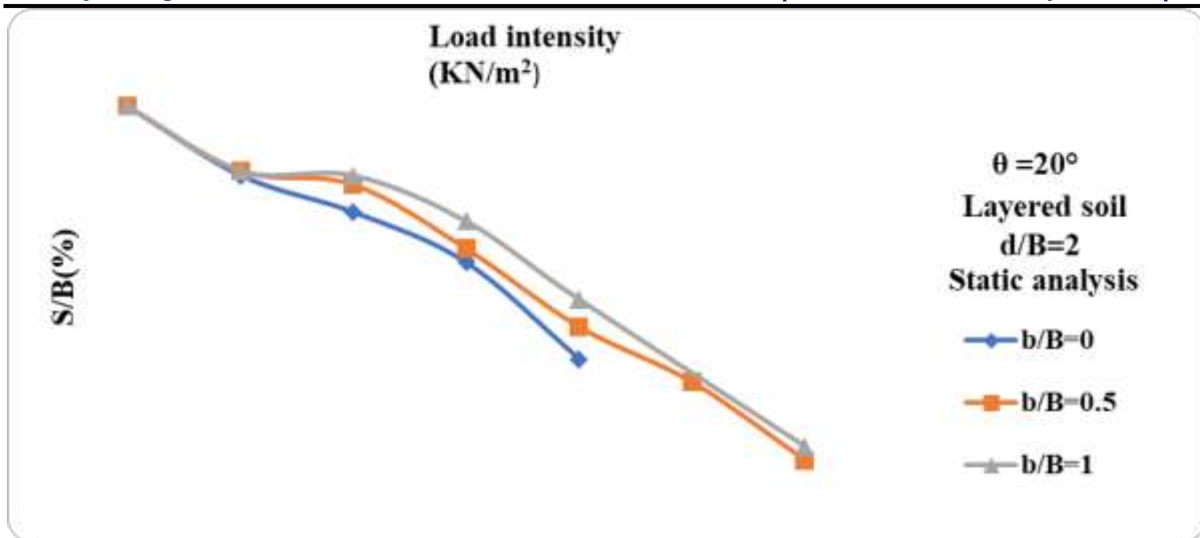


Fig 2: Load intensity v/s Settlement ratio

An intial set of reference tests were performed for a footing resting on a loose sand underlained by a layer of soft clay. The footing placed at a various (b/B) ratios at a depth of 2m with inclination of 20°. It can be observed that increasing the thickness of layer the sellement ratio will be increases. It can be observed that increasing the footing edge distance from the slope crest the settlement ratio goes on decreases. From this graph finally concluded that by increasing the footing edge distance the ultimate bearing capacity increases.

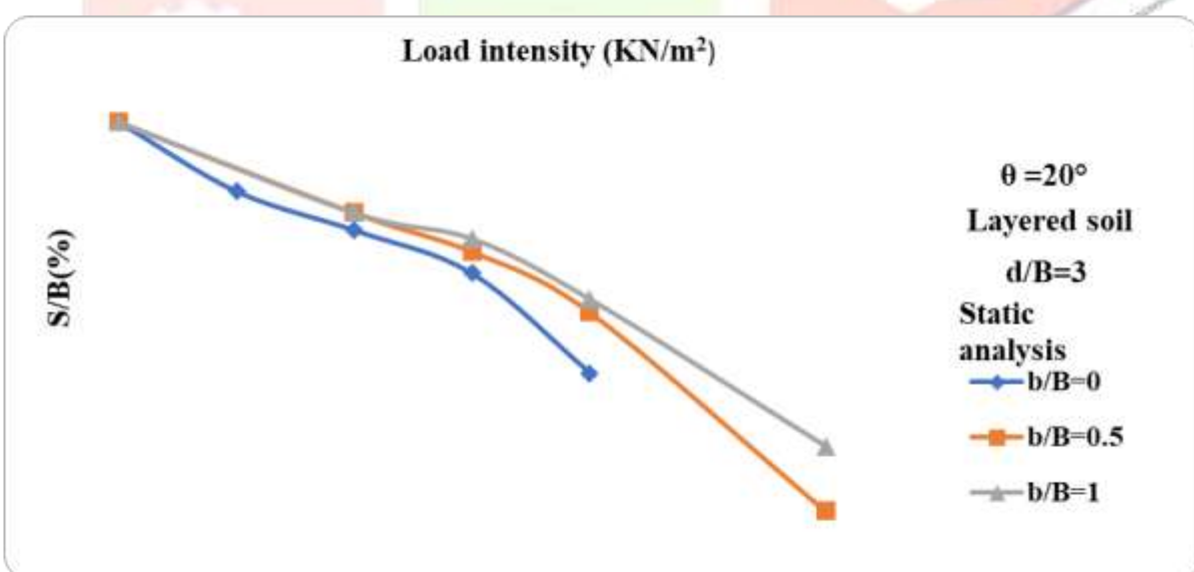


Fig 3: Load intensity v/s Settlement ratio

An intial set of reference tests were performed for a footing resting on a loose sand underlained by a layer of soft clay. The footing placed at a various (b/B) ratios at a depth of 3m with inclination of 20°. It can be observed that increasing the thickness of layer the sellement ratio will be increases. It can be observed that increasing the footing edge distance from the slope crest the settlement ratio goes on decreases. From this graph finally concluded that by increasing the footing edge distance the ultimate bearing capacity increases.

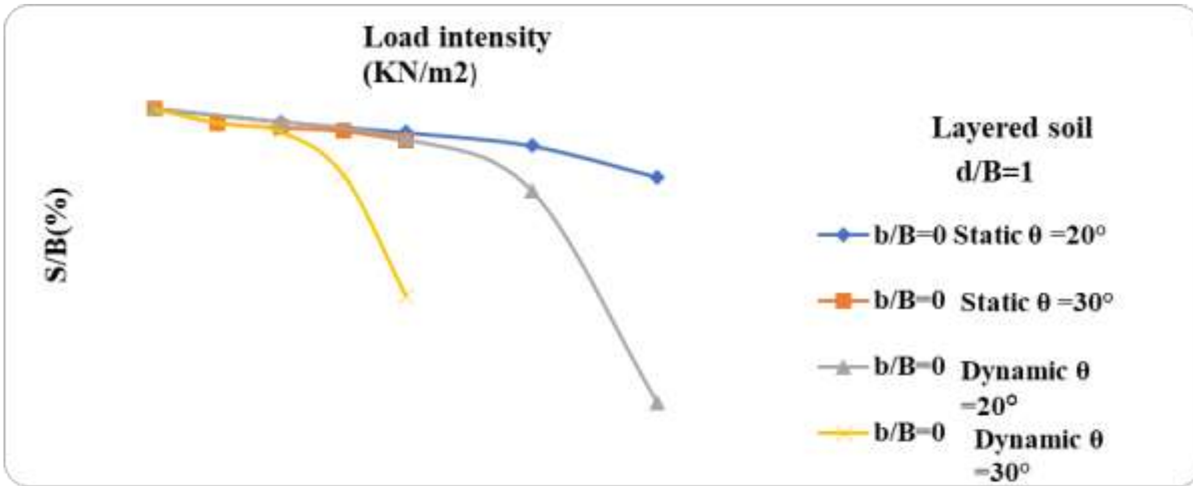


Fig 4: Load intensity v/s Settlement ratio

An intial set of reference tests were performed for a footing resting on a loose sand underlained by a layer of soft clay. The footing distance placed at crest of the slope(b/B=0) at a depth of 1m.In this graph we can see that increasing the slope angle the settlement ratio will be increases for both static and dynamic cases due to its confinement effect decreases, obviously ultimate bearing capacity decreases.

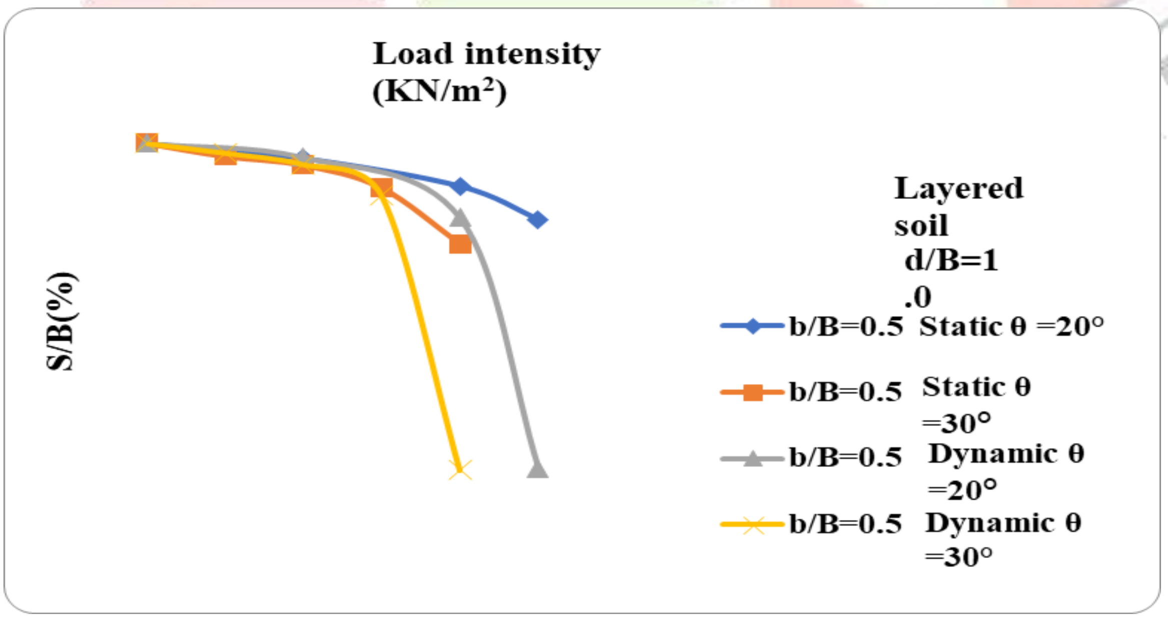


Fig 5: Load intensity v/s Settlement ratio

An intial set of reference tests were performed for a footing resting on a loose sand underlained by a layer of soft clay. The footing distance placed at b/B=0.5 at a depth of 1m. In this graph we can see that footing placed away from the crest of the slope the settlement ratio decreases

CONCLUSIONS

A series of numerical model tests has been carried out to evaluate the settlement and bearing capacity of a strip footing resting on adjacent to the slope crest. Based on the results of the present study the following conclusions can be drawn

1.The settlement ratio of a footing resting on dense sand is less compared to footing resting on loose sand.

2.The settlement ratio of a footing decreases, when footing edge distance increase

3.The settlement ratio of a footing increases by increasing the slope angle s from the slope crest.

4 For dynamic analysis the settlement ratio will be more compared to static analysis due to its vibrations causes more settlement.

5.The settlement ratio of a footing increases by increasing the slope angle due to its confinment effect decreases.

6.The ultimate bearing capacity of a footing resting on a loose sand underlaid by soft clay slope increases with the increase of the footing edge distance from the slope crest.

7.The ultimate bearing capacity of a footing resting on a loose sand under laid by soft clay slope increases with the increase of the footing edge distance from the slope crest.

8.It can be seen that the thickness of soil layer increases the settlement ratio will be increases.

9.It can be seen that footing resting on a losse sand underlaid by dense sand the settlement ratio will be less compared to loose sand underlaid by soft clay. Because its depending on the type of soil and parameters.

10 In layered soil also increasing the footing edge distance the settlement ratio will be decreases and increasing the slope angle the settlement ratio will be increases for both static and dynamic analysis.

11.In Dynamic analysis it can be seen that loose sand get compacted under vibration ultimately cause more settlement.

12 In layered soil settlement ratio is more compared to homogeneous soil because its depending up on the soil properties.

13 settlement ratio is the more in dynamic analysis compared to static analysis, because due to vibration acceleration induced in the soil is more and acceleration travel in different direction.

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