Detail Study On The Load Carrying Capacity Of Shallow Foundation Resting Over Geogrid Reinforced Sand

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Abstract - Several works have been done relating to the estimate of the ultimate bearing capacities of shallow foundations, supported by geogrid reinforced sand. Few experimental studies have been made on the evaluation of bearing capacity of shallow foundations on geogrid-reinforced sand under eccentric load. These studies relate to strip and a square foundation is yet to be done. The purpose of this thesis is to conduct few model tests in the laboratory by using square surface foundation over the reinforced sand bed. The model footing used for the model tests in the laboratory is of size 10cm x 10cm. The average relative density maintained during the entire tests is69%. The reinforcing material used in the experiment is SS 20 in 2, 3 and 4 number of layers. The load eccentricity is varied from 0 to 0.15B with an increment of 0.05B. The vertical distance of first geogrid layer from base, distance between the consecutive geogrid layers, and width of the geogrid has been kept constant. For each set up load intensity and corresponding settlements are observed which are plotted to get load-settlement curves for each set up. The load-settlement curve for each test is plotted to determine the ultimate bearing capacity. Parametric studies have been made to evaluate the influence of load eccentricity on bearing capacity of the foundation.The ultimate bearing capacity of eccentrically loaded square footings can be computed by knowing the ultimate bearing capacity of square footing under central load and a reduction factor(RkR) for reinforced condition. The reduction factor is developed based on the results of laboratory model tests on geogrid reinforced soil.The existing data base of Patra et al. (2006) is used for predicting bearing capacity of strip footings over geogrid reinforced soil under eccentric load.

I.INTRODUCTION

Foundation is an integral part of a structure whether it may be a building, bridge and dam etc.The function of the foundation is to receive the load from the superstructure and transmit it to the Underlying soil or rock. Soil is used as a construction material for various civil engineering structures. Structure on a ground with adequate bearing capacity is one of the basic requirements for the stability of a structure. Most of the studies for bearing capacity calculation are based on the foundation under vertical and central load. However in some cases due to bending moments and horizontal thrusts transferred from the superstructure, structures like retaining walls, abutments, waterfront structures, industrial machines and portal framed buildings are often subjected to eccentric load. This may be due to (a) moments with or without axial forces (b) the oblique loading and (c) their location near the property line etc. When the load is transferred at the base of the footing, movement of the soil particles in the horizontal and vertical direction occurs. For the footings under eccentric loading, the two edges settle by different amounts, causing the footing tilt. The amount of tilt and the pressure at the base depend upon the value of eccentricity width ratio (e/B). When this ratio is more than 1/6, the contact pressure will be tensile at the edge away from the load. However, since the soil is poor in tension, such situation cannot develop; hence, the footing loses contact with the soil and tilting of the footing occurs. Due to eccentric loading, the footing tilts and the pressure below the footing does not remain uniform. The tilt of footing increases with an increase in the eccentricity and the bearing capacity reduces. Many times reinforcing materials like geogrid, geotextile, geonet etc. are inserted into the granular materials to improve the bearing capacity of poor sub-soil. Over the last two decades the use of geogrids for soil reinforcement has increased greatly because geogrids are dimensionally stable and combine feature such as high tensile modulus (low strain at high load), open geogrid structure, positive shear connection characteristics, light weight, and long service life. Geogrids are made of high-modulus polymer materials, such as polypropylene and polyethylene, and are prepared by tensile drawing. Nelton Ltd. of the United Kingdom was the first producer of geogrids in 1982. The major function of geogrid is soil reinforcement interaction. There are two types of geogrid i.e. uniaxial and biaxial depending on the nature of manufacturing.

A number of laboratory test results and a few field test results have been published that relate to the ultimate and allowable bearing capacity of shallow foundations supported by multi-layered geogrid reinforced sand and clay. The techniques of ground improvement by providing reinforcement were also in practice in olden days. Babylonians built ziggurats more than three thousand years ago using the principles of soil reinforcement. A part of the Great Wall of China is also an example of reinforced soil. Basic principles underlying reinforced soil was not completely investigated till Henry Vidal of France (1966) who introduced the reinforcing mechanism.

II.GEOGRIDS

A geogrid is geosynthetic material used to reinforce soils and similar materials. Geogrids are commonly used to reinforce retaining walls, as well as subbases or subsoils below roads or structures. Soils pull apart under tension. Compared to soil, geogrids are strong in tension. This fact allows them to transfer forces to a larger area of soil than would otherwise be the case.[2]Geogrids are commonly made of polymer materials, such as polyester, polyvinyl alcohol, polyethylene or polyproylene. They may be woven or knitted from yarns, heat-welded from strips of material, or produced by punching a regular pattern of holes in sheets of material, then stretched into a grid.

The development of methods of preparing relatively rigid polymeric materials by tensile drawing,[3] in a sense "cold working," raised the possibility that such materials could be used in the reinforcement of soils for walls, steep slopes, roadway bases and foundation soils. Used as such, the major function of the resulting geogrids is in the area of reinforcement. This area, as with many other geosynthetics, is very active, with a number of different products, materials, configurations, etc., making up today's geogrid market. The key feature of all geogrids is that the openings between the adjacent sets of longitudinal and transverse ribs, called “apertures,” are large enough to allow for soil strike-through from one side of the geogrid to the other. The ribs of some geogrids are often quite stiff compared to the fibers of geotextiles. As discussed later, not only is rib strength important, but junction strength is also important. The reason for this is that in anchorage situations the soil strike-through within the apertures bears against the transverse ribs, which transmits the load to the longitudinal ribs via the junctions. The junctions are, of course, where the longitudinal and transverse ribs meet and are connected. They are sometimes called “nodes”.

Currently there are three categories of geogrids. The first, and original, geogrids (called unitized or homogeneous types, or more commonly referred to as 'punched and drawn geogrids') were invented by Dr Frank Brian Mercer[4] in the United Kingdom at Netlon, Ltd., and were brought in 1982 to North America by the Tensar Corporation. A conference in 1984 was helpful in bringing geogrids to the engineering design community.[5] A similar type of drawn geogrid which originated in Italy by Tenax is also available, as are products by new manufacturers in Asia.

The second category of geogrids are more flexible, textile-like geogrids using bundles of polyethylene-coated polyester fibres as the reinforcing component. They were first developed by ICI Linear Composites LTD in the United Kingdom around 1980. This led to the development of polyester yarn geogrids made on textile weaving machinery. In this process hundreds of continuous fibers are gathered together to form yarns which are woven into longitudinal and transverse ribs with large open spaces between. The cross-overs are joined by knitting or intertwining before the entire unit is protected by a subsequent coating.Bitumen, latex, or PVC are the usual coating materials. Geosynthetics within this group are manufactured by many companies having various trademarked products. There are possibly as many as 25 companies manufacturing coated yarn-type polyester geogrids on a worldwide basis.

The third category of geogrids are made by laser or ultrasonically bonding together polyester or polypropylene rods or straps in a gridlike pattern. Two manufacturers currently make such geogrids.

The geogrid sector is extremely active not only in manufacturing new products, but also in providing significant technical information to aid the design engineer.

Main application objects of the materials:

- Reinforcement of highways slopes and higher steepness slopes fixation;
- Bed fixation of the various types of road surfacing;
- Reinforcement of littoral zone of water reservoirs and greek beds;
- Fixation of the railroad cone slopes;
- Support wall construction.
- If necessary, strength factor coefficient can be increased by binding the bands with metal clinches.
- Mesh walls have embossed surface to increase friction with fill materials and perforation to improve draining properties. According to the customer’s request we can produce imperforated geogrids.

Material Major Advantages

Geogrid application is a way of soil reinforcement, on soil surface a plate is created according to the thickness of a corresponding geogrid: 50 mm, 100 mm, 150 mm, 200 mm (this standard range of products is manufactured by “Technostroytex” LLC).

Functioning principle: adhesion of grain material with grid meshes. This jamming causes resistance to horizontal soil displacement. Thus, it mobilizes bearing resistance of soft soils.

Application Recommendations

Geogrids carry out the function of slopes protection, even of very steep ones, filling it with permeable materials, which increases slopes resistance to erosion. Specific moisture level inside the grid meshes provides vegetation (and esthetic view of earthworks).

Geogrids with gravel chippings for fill material provides horizontal stability of the road surface bed (fixation of gravel chippings under surface to prevent horizontal rupture). Geogrid application allows using gravel chippings of different kinds.

Geogrid application filled with ground material is one of the easy of soil reinforcement. The thickness of such construction may be 50% less than the thickness of standard replacement which allows avoiding costly soil replacement.

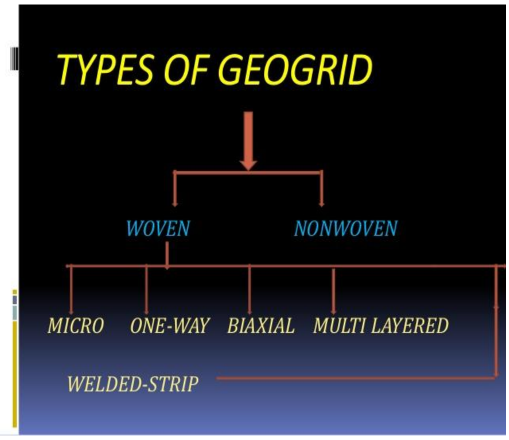
Geogrid protects channel slopes, provides resistance and stability, protecting this object from erosion. Additional advantage is drainage along channels. Geogrid application considerably reduces losses, connected with fall of ground, landslides and deformation of slopes. In case of water streams construction, geogrid application allows planting trees and shrubs along the banks protecting them from ablation. Geogrids are an economical solution for filling water stream base and creates almost an ideal surface for laying down a water resistant layer.

Slopes and subgrades with rails are a serious problem in railroad construction. Under high pressure the layers slide and deform consequently causing rail deformation, which requires closing railroad segments for a long time. Geogrid application allows carrying out comlex repair operations of the necessary road segment in shortest time (which is very essential in transportation).

Geogrid allows assembling within the temperature range from -40°C to +60°C. The material is neutral to aggressive environments and ecologically safe. Laying does not require additional machinery. In fold position geogrid does not take much place.

COMPOSITION OF GEOGRIDS:

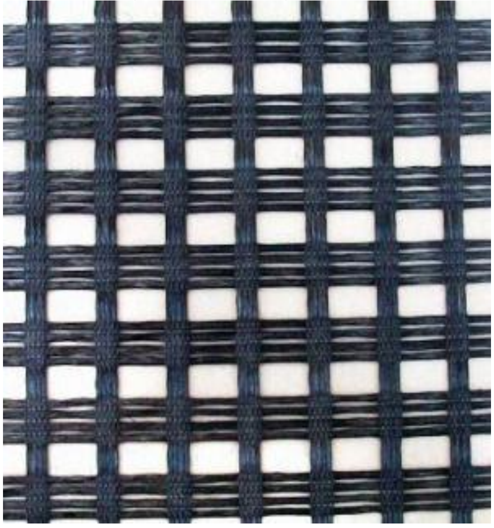
- ➢ POLYSTER
- ➢ POLY VINYL ALCHOHOL
- ➢ PLY VINYL CHLORIDE
- ➢ POLY PROPYLINRE



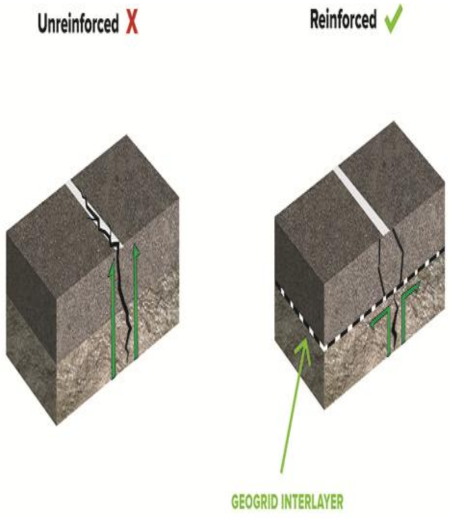
TYPES OF GEOGRIDS:

1) WOVEN AND
   2) NON-WOVEN
      - ➢ MICRO
      - ➢ ONE-WAY
      - ➢ BI AXIAl
      - ➢ MULTI LAYERED

High-Quality-PP-One-Way-Plastic-Geogrid



SBR coated polyester biaxial woven geogrid



III.EXPERIMENTAL WORK AND METHODOLOGY

3.1 Introduction

The experimental program was designed to study the bearing capacity of eccentrically loaded square footing on multi-layered geogrid reinforced sand bed. For this purpose, the laboratory model tests were conducted on square footings in one densities (i.e. dense), load eccentricity e was varied from 0 to $0.15B$ (B = width of strip footing), number of geogrid layer are varied (i.e. N = 2, 3, 4). All tests have been conducted in surface case only. The ultimate bearing capacity was interpreted from each test and analyzed.

3.2 Materials Used in the tests

In this chapter two materials are used (sand and geogrids)

3.2.1 Sand

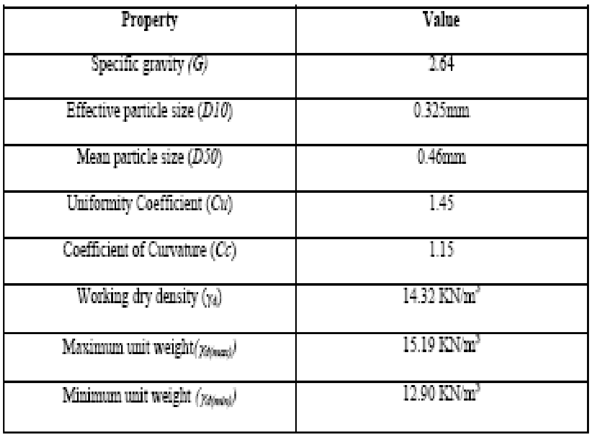
Sample collection

The sand used in the experimental program was collected from the river bed of a nearby Koel river. It is made free from roots; organic matters etc. by washing and cleaning. The above sample was then oven dried and properly sieved by passing through IS 710 micron and retained at IS 300 micron sieves to get the required grading. Dry sand is used as soil medium for the test as it does not include the effect of moisture and hence the apparent cohesion associated with it.

Characteristics of sand

The geotechnical properties of the sand used is given in Table 3.1. The grain size distribution curve is plotted in Figure 3.1. All the tests were conducted in one density (dense) with relative densities of 69%. The average unit weight of relative densities is 14.32kN/m3. The friction angle at relative densities of 69% is 40.80 which are found out from direct shear tests.

Table 3.1. Geotechnical property of sand



Property	Value
Specific gravity *(G)*	2.64
Effective particle size (*D10*)	0.325mm
Mean particle size (*D50*)	0.46mm
Uniformity Coefficient (*Cu*)	1.45
Coefficient of Curvature (*Cc*)	1.15
Working dry density (γ_d)	14.32 KN/m^3
Maximum unit weight($\gamma_{d(max)}$)	15.19 KN/m^3
Minimum unit weight ($\gamma_{d(min)}$)	12.90 KN/m^3

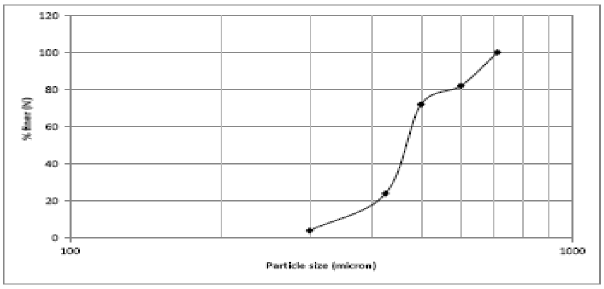
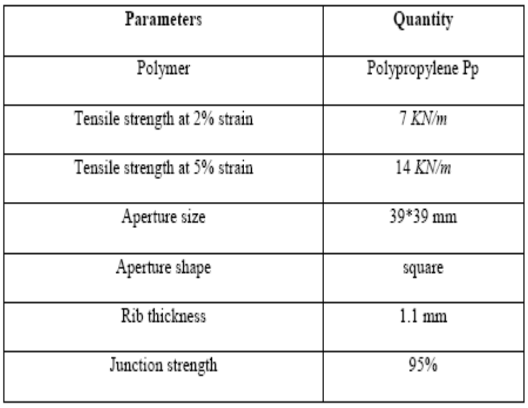


Figure 3.1: Grain-size distribution curve of sand

3.2.2 Geogrid

Biaxial geogrid (SS20) is used for the present tests. Geogrid layers are placed inside the sand layer at desired values of *u/B* and *h/B*. The physical and mechanical properties of the geogrids as listed by the manufacturer are given below-:

Table 3.2: Physical properties of the geogrid:



Parameters	Quantity
Polymer	Polypropylene Pp
Tensile strength at 2% strain	7 *KN/m*
Tensile strength at 5% strain	14 *KN/m*
Aperture size	39*39 mm
Aperture shape	square
Rib thickness	1.1 mm
Junction strength	95%

3.3 Test tank

A test tank of inside dimension 1.0m (length) 0.504m (width) 0.655m (height) is used. The two length sides of the tank were made of 12mm thick high strength fiberglass. The two width sides of tank are made up of mild steel of 8mm thickness. Scales are fitted on the middle of the four internal walls of the box so that it will be easier in maintaining the required density accurately.

All four sides of the tank are braced to avoid bulging during testing. The following considerations are taken into account while deciding the dimension of the tank. As per provision of IS 1888-1962 the width of the test pit should not be less than 5 times the width of the test plate, so that the failure zones are freely developed without any interference from sides. Chumar (1972) has suggested that in case of cohesionless soil the maximum extension of failure zone is 2.5B to the both sides and 3B below the footing. By adopting the above tank size for the model footing (10cm x 10cm), it is ensured that the failure zones are fully and freely developed without any interference from the sides and bottom of the tank.

3.4 Equipments used

- Load transferring shaft
- Model footing
- Proving ring
- Dial gauge

a) Model footing

Model footing used for laboratory tests are made of mild steel plate of sizes *10cm*□*10cm*□*3cm*. One footing is meant for centroidal loading and other three are meant for eccentrical loading, the eccentricity being 0.05B, 0.1B, 0.15B respectively. The bottom of the footing was made rough by applying epoxy glue and then rolling the model footing over sand to give the effect of roughness of actual foundation. Circular depressions accommodating steel balls are made on the footings at proper points so that the loading pattern i.e. centroidal and eccentrical mode can be maintained. The load is transmitted from the loading pad to the footing through the combination of load transferring through spindle and steel ball.

b) Proving ring

Three proving ring are used of 5 KN, 10 KN, 20 KN whose least count are 6.67N, 10.471N, 24.242N respectively.

c) Dial gauge

Two dial gauges of following specifications are used during the tests.

Least count 0.01mm, Range 50 mm. The dial gauges are kept on the top portion of the longitudinal sides of the box because the top portion of the entire box has steel strip welded wide enough to accommodate the magnetic base of the dial gauge. The dial gauge needles are placed over the footing attached with the load transferring column. As the load is applied settlement occurs which is recorded by two dial gauges. The average of the two dial gauge readings is taken as required settlement in mm.

3.5 Sample preparation

First the internal dimensions of the tank are measured accurately and volume for the required thick layer (i.e. 2.5 cm) is calculated. After fixing a density, at which all the tests are to be done by we can calculate the weight of sand needed for that particular thickness of sand layer. Here the density to be maintained is 1.46 gm /cc and the layer of thickness is 2.5 cm. It is found that for maintaining the required density in 2.5 cm layer, required weight is 18.432 kg. The box is filled by sand using sand raining technique. Sand was poured into the test tank in layers of 2.5cm from a fixed height by raining technique to achieve the desired average unit weight of compaction. The height of fall was fixed by making several trials in the test tank prior to the model test to achieve the desired unit weight. For the test without reinforcement footing is placed on the surface. For the application of eccentrically vertical loads to the footing, groove have been made on the top surface of footing at varying distance from the center of the footing as per the required eccentricity to be maintained. For the test with reinforcement the first geogrid layer is placed at a depth of 0.35B from the base of the footing, the other subsequent layer of geogrid being placed at equal spacing of 0.25B. After putting the geogrids, small weight are placed on them to keep the geogrids in position and then the required weight of sand is poured over it using sand raining technique.

3.6 Test procedure

- After filling the tank surface to a desired height, the filled surface is leveled and the footing is placed on a predetermined alignment such that the load transferred vertically to the footing.
- Then placing the steel ball over the circular groove of the footing, the load transferring shaft is placed over it, through which the load is transferred to the footing vertically.
- Two dial gauges are placed over the footing on the opposite sides of the spindle. Then the initial readings of two dial gauges are noted.
- The load is then applied and the footing is allowed to settle under the applied load. Each load increment is maintained till the footing settlement get stabilized which is measured from the two dial gauge readings.
- The processes of load application is continued till there is failure of foundation soil due to sudden excessive settlement or up to 25mm settlement occur which can be observed in the proving ring of the jack where the load taken by the footing get decreased continuously.
- On completion of the load test, the equipments are removed, tank emptied and the tank again filled for the next set of load test.

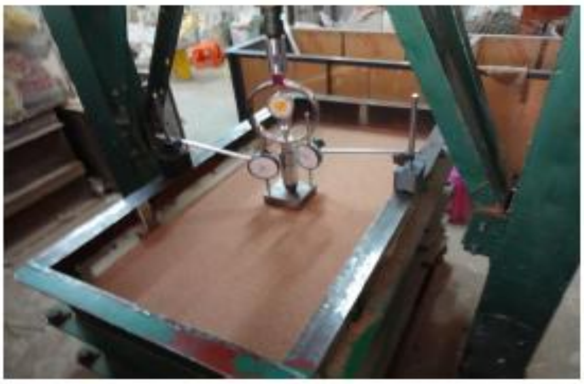


Figure 3.2: Photographic image of sand sample at the start of experiment

Figure 3.3: Placing of geogrid

IV.CONCLUSIONS

The results of laboratory model tests conducted to determine the ultimate bearing capacity of a square footing supported by multi-layered geogrid reinforced sand bed subjected to eccentric load have been reported. Tests have been conducted on dense sand. The load eccentricity ratio *e*/*B* has been varied from 0 to 0.15, and the number of geogrid layers has been varied from 2 to 4.

Based on limited number of experiments conducted in laboratory an empirical equation has been developed for predicting the bearing capacity of square foundation on multi-layered geogrid reinforced sand subjected to eccentric load. In addition to the above, an ANN model has been developed for the case of bearing capacity prediction of eccentrically loaded strip footing on geogrid-reinforced sand taking the database from Patra et al. (2006). The following are the conclusions:

- For similar reinforcement conditions, the ratio of the ultimate bearing capacity of eccentrically loaded foundations to that loaded centrally can be related by a reduction factor. The reduction factor (*RkR*) predicted from the present experiments done in the laboratory is expressed as:0.61 0.89*KR*

- The reduction factor is a function of df / B and e/B.
- At a particular settlement, the bearing capacity will be more in case of reinforced condition than unreinforced case.
- In reinforced soil, the bearing capacity also decreases with increase in eccentricity.
- An ANN model equation has been developed for reduction factor of eccentrically loaded strip footing on geogrid-reinforced sand considering the existing database
- The results for strip footing from ANN model gives better result than the empirical model developed by Patra et al. (2006) for strip footing.

6.2 Scope of future work

The present thesis pertains to the study on the bearing capacity of eccentrically loaded strip footing on dry sand bed. Due to time constraint other aspects related to shallow foundationscould not be studied. The future research work should address the below mentioned points:

- The present work can be extended to foundations on cohesive soil
- Large scale study to be carried out to validate the present developed equation.
- The present work can be extended to eccentrically inclined loaded reinforced soil Condition
- This work can be extended by using different density of sand (i.e. dense sand, medium dense sand)

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