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IMPROVEMENT OF SOIL BEARING CAPACITY USING GEOSYNTHETICS

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ABSTRACT

Soil alone is able to carry only compressive and shear forces. However, through the use of geosynthetics as reinforcing elements, soil structures can be built to carry tensile forces.

When designing structures that will impose a significant load over a large area, such as buildings, tanks, walls, slopes or embankments, geotechnical engineers must address the following situations, especially when dealing with weak foundation soils: bearing capacity failures, intolerable total and differential settlements, large lateral pressures and movement, and slope instability. The construction of reinforced soil foundations to support a footing has considerable potential as a cost-effective alternative to conventional methods of foundation support. With this technique, more than one layer of geosynthetic reinforcement is placed within layers of engineering fill material under the footing to create a composite material with improved performance characteristics. Here an attempt is made to present an overview of the effect of geosynthetic reinforcing material on the performance of soil.

***Key Words:* BCR, Geosynthetics, Geogrids, Soil Reinforcement.**

I INTRODUCTION

In general soil possesses low tensile strength. The use of reinforcement materials in the soil can be determined as a process for improving the soil engineering characteristics. Reinforcement of the soil is specified as a method for improving the mechanical properties. The main objective of strengthening the soil mass is to increase the bearing capacity, to improve stability and to decrease settlements and lateral deformations. During the past four decades, innovative methods of improving soil properties have been extended to solve soil problems. These methods are generally regarded as the most economical ways to improve the conditions of undesirable sites compared to traditional construction methods. For example, use of rope fibers, metal strips, tire shreds, metal bars and geotextiles have proved that they improve soil properties such as shear, compression, hydraulic conductivity and density. For soil reinforcement use of stone columns, soil nailing, micro piles and reinforced soil.

Also rising land costs and decreasing availability of areas for urban infill have established the situation that previously undeveloped areas are now being considered for the siting of new facilities. However, these undeveloped areas often possess weak underlying foundation materials – a situation that presents interesting design challenges for geotechnical engineers. To avoid the high cost of deep foundations, modification of the foundation soil or the addition of a structural fill is essential. One of the best methods to overcome soil problems is the use of synthetic materials, called as the geosynthetics. This paper presents an overview of the effect of geosynthetic reinforcing material on the BCR values of soil. Geosynthetics have transformed many features of the geotechnical engineering process, and some of the applications have replaced building materials entirely conventional. The use of geosynthetic in many cases can significantly improve performance, increase safety, and reduce costs compared to a conventional design. These synthetic materials are made up of synthetic polymers like: high density polyethylene (HDPE), low density polyethylene (LDPE), polypropylene (PP), etc.

A geosynthetic is defined as "a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure or system" (ASTM D 4439-11, 2011). The main objective for use of a geosynthetic is to improve hydraulic, mechanical and physical characteristics of soils. The main areas of influence of geosynthetics are transportation, geotechnical, environmental, hydraulics, soil-rock-water or groundwater activities, etc.

1.1. Basic Functions of Geosynthetic Material

The basic functions of geosynthetic materials can be listed as below but they vary according to type of geosynthetic material:

1. Separation
2. Reinforcement
3. Filtration
4. Drainage
5. Containment (liquid or gas)

1.2. Types of Geosynthetic material

There are various types of geosynthetic material available and are in use for various purposes currently:

1.Geotextile	2.Geogrid
3.Geocell	4.Geofoam
5.Geonet	6.Geomembrane
7.Geopipes	8.Geosynthetic clay liners
9.Geocomposites	

Geotextile: Geotextile is one form of geosynthetic. The use of geotextiles during the past two decades has been extensive. These are textiles in the traditional concept, but consist of synthetic fibres' instead natural ones such as silk, wool, or cotton. This environmental degradation is not a problem. This synthetic fibre is made into flexible, non-woven or is matted together in random or porous fabric by the standard weaving machine, manner. Some of them are also knit. As reported by Koerner (1990), the application areas for geotextile include separation, reinforcement, filtration, drainage.

Geogrid: Geogrid is usually made from polymer materials, such as polypropylene, polyethylene or polyester. 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, raised the possibility that such materials could be used in the reinforcement of soils for walls, steep slopes, roadway bases and foundation soils.

Geocell: Geocell is honeycomb three-dimensional cell structures that provided containment of compacted fill soils. Decreased the lateral movement of the soil particles and form a mat or rigid for the distribution of loads applied to a wider area slab movement. Geocells are used in the construction of canals, embankments, retaining walls, railways and roads.

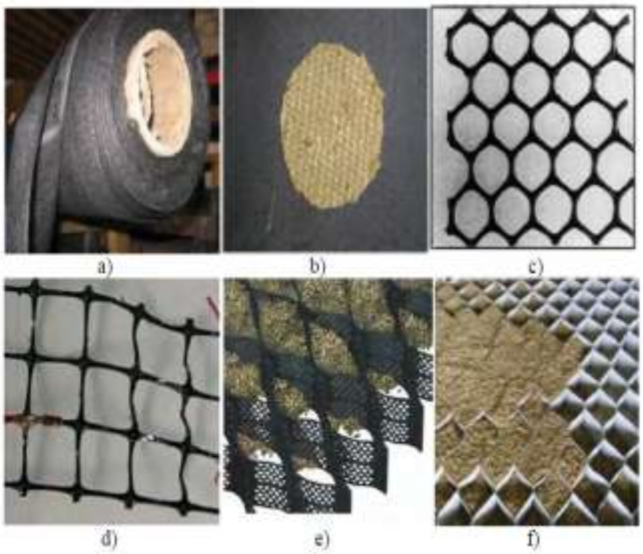

Figure 1: Various Kinds of Geosynthetics

a) Geotextile b) The jute Geotextiles fabric c) Geogrid d) Geogrid e) Perforated geocell f) Geonet

II INTRODUCTION TO GEOGRID REINFORCEMENT

A geogrid can be defined as, "A geosynthetic material consisting of connected parallel sets of intersecting ribs with apertures of sufficient size to allow strike-through surrounding soil, stone or other geotechnical material."

Thus geogrids are matrix like materials with large open spaces called apertures, which are typically 10 to 100mm between ribs that are longitudinal and transverse respectively. The ribs themselves can be manufactured from a different number of different materials and the rib cross over-joining or junction-bonding methods may vary. The primary function of geogrids is clearly reinforcement. The applications where the direction of major stresses are known, as in walls and slopes unidirectional or uni-axial geogrids are used and in those where applied stresses come from random directions as in pavements and foundations bidirectional or biaxial geogrids are used.

2.1. Categories of Geogrid:

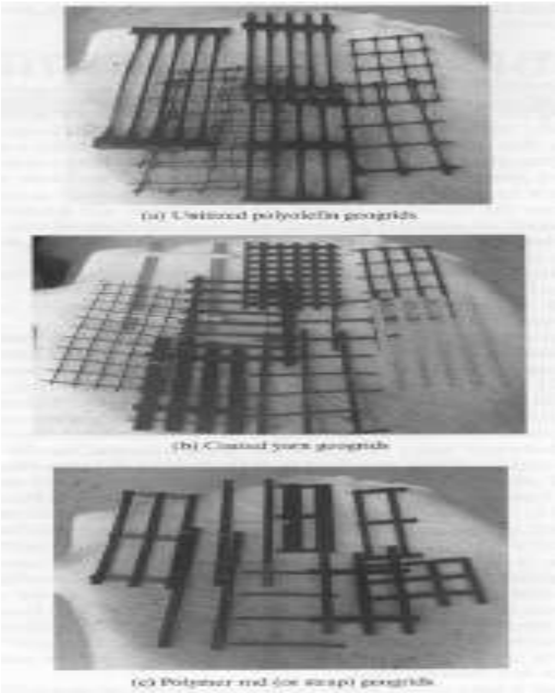

Figure 2: Categories of Geogrids

Figure 2 shows the categories of geogrids that are currently available:

1. Unitized polyolefin
2. Coated yarn
3. Polymer rod or Strap

These categories differ in their testing depending upon the type of manufacture.

Figure 2 (a) shows original type of geogrids, which are characterized as the being unitized insofar as the continuity of the intersecting longitudinal and transverse ribs are concerned. Both unidirectional and bidirectional products are available. Each style begins as a polyolefin polymer sheet which is a thick geomembrane that subsequently has a uniform pattern of holes punched in it. The punched is then sent over and under the number of rollers, each going faster than one before it, thus inducing longitudinal stretching of the sheet. The elongated material between holes becomes the geogrid’s ribs. In the unidirectional deformed products, circular holes punched in high density polyethylene (HDPE) sheet become elongated ellipses with stretched longitudinal ribs in machine direction and un-stretched transverse ribs in cross machine direction. The molecular structure in the longitudinal ribs is highly elongated and the strength, modulus and resistance to creep are increased significantly over the original non-deformed material. A number of different styles with different strength properties are available. In the bidirectional products, squares are punched in a polypropylene (PP) sheet, which is then drawn longitudinally (using rollers) as before, then transversely (using a stretcher), forming near-square or rectangular apertures. This process increases strength in both longitudinal and transverse directions in bidirectional products. Unidirectional products-are for applications in which major principal stress direction is known (such as walls and slopes), and bidirectional products are for applications in which mobilized stresses are essentially random (such as pavements and foundations).

Figure 2 (b) shows variety of coated yarn geogrids. There are more products in this category of geogrids than any other. Most often, the yarns are bundles of high tenacity polyester (PET) filaments. (The side walls of automobiles and truck tires are reinforced with similar filaments-that is the so called tire chords). Fiberglass and polyvinyl alcohol filaments have also been used, but (PET) filaments predominate. The yarn bundles are then woven or knit on conventional textile machinery into the desired grid pattern. Strength can easily be varied using more or fewer filaments per yarn in both directions, giving rise to unidirectional and bidirectional products. Yarn spacing can also be varied. The entanglement of the yarns at their intersections is an important issue and varies from product to product. There is obviously a selvedge on both edges of the manufactured material. As a secondary step, the geogrids are coated, usually by spraying and then dipping in bitumen, latex or polyvinyl chloride (PVC). The purpose of the coating is to maintain geometric stability of the product and to protect the filaments from damage during installation and service.

Figure 2 (c) shows geogrids made from high tenacity (PET) or polypropylene (PP) rods or straps. These are similar to packaging and bonding materials used for shipping purposes. Approximately 10mm wide and 1mm thick, they are manufactured by overlapping the longitudinal ribs over and/or under the transverse ribs. The crossover locations, called junctions or nodes, are either ultrasonically or laser bonded to provide junction strength. Different rib layout patterns give rise to different styles of unidirectional and bidirectional products.

2.2. Geogrid Properties and Test Methods

2.2.1. Physical properties:

Many of the physical properties of geogrids including type of structure, rib dimensions, junction type, aperture size and thickness can be measured directly and are relatively straightforward. Other properties that are of interest are mass per unit area, which varies over a tremendous range from 200 to 1000 g/m2, and percent open area, which varies from 40 to 95%. Density or specific gravity of geogrids depends upon the polymer from which it is made and the values are usually less than unity.

2.2.2. Mechanical properties:

Bending stiffness and torsional stiffness are the properties of geogrids as far as constructability is concerned. Bending stiffness can be measured using ASTM D1388, a flexural test for rigidity. Single rib and Junction (node) strength tests are performed to get the mechanical strength of geogrid reinforcement. The initial tendency when assessing a geogrid's tensile strength is to pull a single rib in tension until failure and then to note its behavior. A secondary tendency is to evaluate the in-isolation junction strength by pulling a longitudinal rib away from its transverse rib's junction. It is important to state in-isolation since there is no normal stress on the junction; thus the test will not represent performance conditions. A performance junction test must be done with the entire geogrid structure contained within soil embedment. Direct shear test is performed to know the shear resistance of the reinforcement.

2.2.3. Endurance Properties:

As geogrids are used in critical reinforcement applications, some of which are service lifetimes, it is generally necessary to evaluate selected endurance properties like installation damage, creep, temperature effects, oxidation effects, hydrolysis effects, chemical and radioactive effects, biological effects, stress crack resistance, etc.

2.3. Areas of application of Geogrids:

The primary function of geogrids is invariably reinforcement, based upon which the areas of application are:

1. Paved roads-Base courses
2. Embankments and Slope stabilization
3. Reinforced walls
4. Foundation and Basal reinforcement

III: METHODOLOGY AND INVESTIGATIONS

3.1. Parametric Studies:

Several factors that can affect the efficiency a geogrid reinforced soil foundation (RSF), including:

1. The depth of first layer reinforcement under shallow foundation
2. Spacing between layers of reinforcement
3. Number of reinforcing layers and
4 .Reinforcement width

3.1.1. Effect of the depth of the first layer reinforcement under shallow foundation (u):

The effects of depth of the first reinforcement layer have been studied by many researchers. The depth ratio is defined as the ratio between u and B (u/B). Figure 3 shows variation between BCR and the depth ratio for multi-layer reinforcement [1]. Figure 3 it can be seen, that the inclusion of geogrid reinforcements has increased the amount bearing capacity of soil and the settlement of the footing has decreased. Figure 4 shows the variations of load settlement relationship for different values of the depth of the top layer (u/d). It can be observed that the ultimate bearing capacity of shallow foundation increases with decreasing (u/d) value. [2]

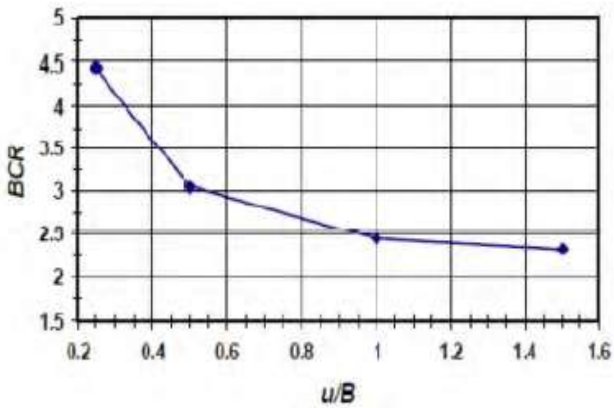

Figure 3: Variation of BCR with depth in multi-layer reinforced sand (Square footing), (N= 5, h/B =0. 25, b/B=5) [1]

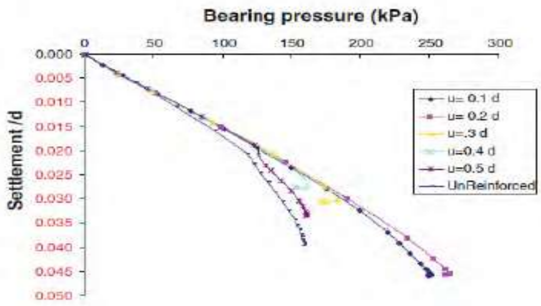

Figure 4: Variation of circular footing settlement as a function of depth to top layer value for case of (x/d) = 0.3 and N = 2 compared to unreinforced sand [2]

3.1.2. Effect of Spacing between layers of reinforcement (h or x):

The previous studies have shown that the optimum value is 0.25B for the vertical spacing of reinforcement layers [1]. The BCR increased with (h/B) or (x/d) up to 0.75B after which it decreases [3]. The effect of the vertical spacing between geogrid layers in figure 5 shows the variation of load settlement for different values of (x/d). Figure 6 presents the results when the value of (u/d) is 0.2, it can be observed that the BCR improved with increasing number of reinforcement layers and by reduction vertical spacing between layers [2].

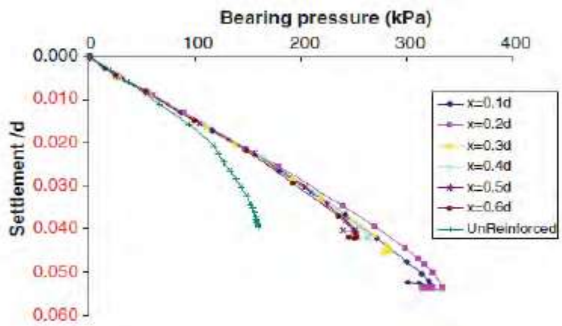

Figure 5: Variation of footing settlement as a function of the layer spacing x/d value in case of (N = 4) and (u/d = 0.2) compared to unreinforced sand [2]

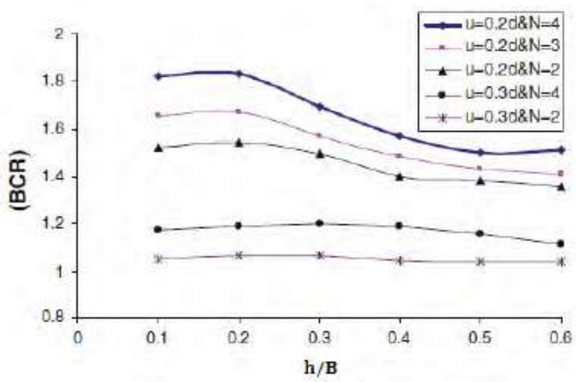

Figure 6: Effect of x/d ratio on bearing capacity ratio as a function of variation of number of layers number and depth to topmost layer [2]

3.1.3. Effect of Number of Reinforcement Layer (N):

It has been found that there is improvement in the load bearing capacity of the shallow foundation with an increase in the number of layers, up to 3 layers and a vertical space layer up to 0.25 widths of the footing. Figure 7 shows the variation of (q) with (S/B) for different number of layer geogrid. The analysis showed that the bearing capacity ratio (BCR) value changes more with the number of the reinforcement layers than the other parameters. With increase in the number of reinforcement layers there is increase in the BCR value. Moreover placing of geogrid reinforcement more than the depth of 1.5B cannot significantly increase the bearing capacity. Also it has been reported that increasing the number of reinforcement layers more than a certain amount would not increase the BCR significantly. [1]

The inclusion of geogrid layers causes increase in the load bearing capacity of the model shallow foundation as well as, for the same size footing, the settlement ratio reduced significantly with increasing the number of geogrid layers, but the behavior continued until N = 2. Also for N = 3 there was not the variation in BCR [3]. The Figure 8 clearly has indicated that the BCR much improved with the number of geogrid layers. Although, the rate of bearing capacity ratio (BCR) increased with the increasing number of geogrid layers until N= 3 and then the rate of load improvement becomes much less. As shown in Figure 9 the BCR, increases with increasing number of layers, especially when the amount of (u/d) is relatively small. When the amount of (u/d) greater than 0.2, the bearing capacity shallow foundation a little increase with increasing number of geogrid layers. [2]

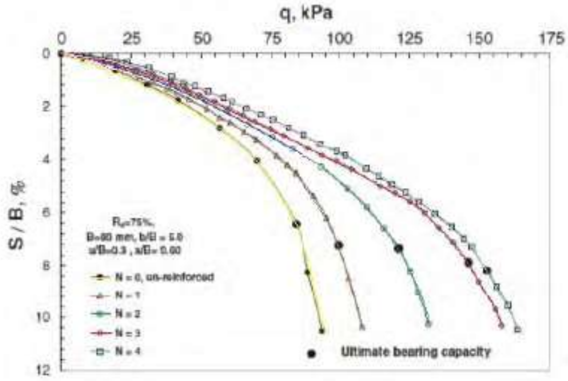

Figure 7: Variation of (q) with (S/B) for different number of layers [5]

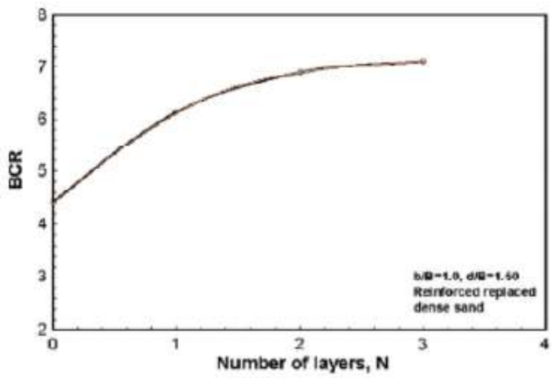

Figure 8: Variations of bearing capacity ratio with number of geogrid layers [5]

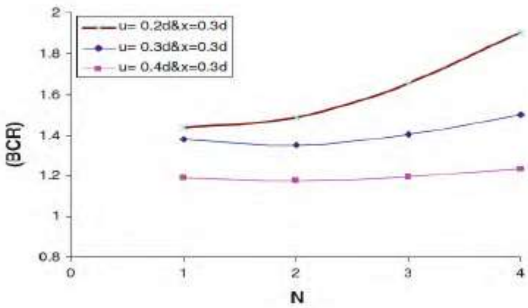

Figure 9: The effect of the number of geogrid layers on bearing capacity ratio a function of number variation of the depth of the topmost layer [2]

3.1.4. Effect of reinforcement width:

Figure 10 shows the variety of bearing capacity ratio (BCR) and (b/B) for circular footings supported on different sand densities. The BCR increased with increasing geogrid layer width. This improvement in the ultimate bearing capacity with an increasing layer width has been significant until an amount of (b/B = 5). Further increase in layer width of geogrid did not show important contributions in increasing the ultimate load of the footing. [5]

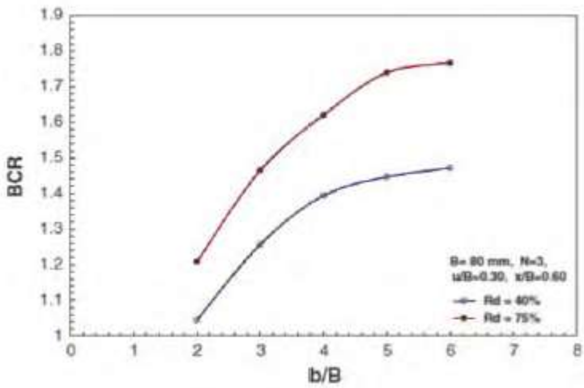

Figure 10: Variations of BCR with b/B [5]

3.2. Comparison between Numerical test and Experimental test results:

The load and displacement curves for some cases have obtained the experimental test and numerical test are compared in Figure 10 for a circular footing. The values of bearing capacity obtained numerical test were greater than those obtained experimental tests. This can be due to the soil parameters such as friction angle, cohesion and modulus of elasticity have used in the analysis. The changes of bearing capacity ratio (BCR) with (N) obtained experimental test and numerical test are shown in Figure 11 for a circular footing. The agreement between the numerical test and experimental test results, in terms of load and displacement behavior was good. [4]

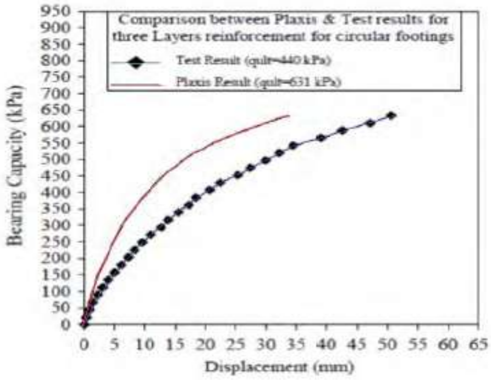

Figure 11: Comparison of load–displacement curves obtained experimentally and numerically for a circular footing [4]

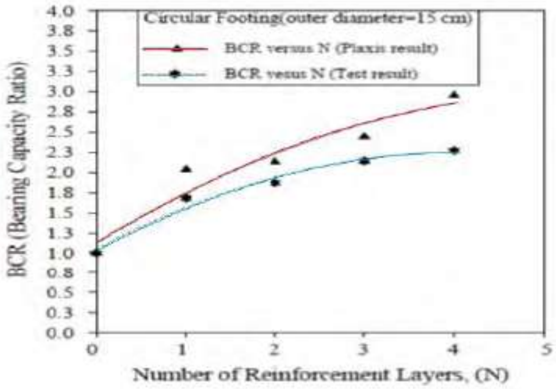

Figure 12: Comparison of variation of BCR with N obtained experimentally and numerically for a circular footing [4]

IV CONCLUSIONS

Experimental study results obtained by previous researchers on reinforced soil with geogrid can be concluded as follows:

1. The presence of geogrid in the soil makes the relationship between the settlement and applied pressure of the reinforced soil almost linear until the reaching to the failure stage.

2. When the circle, square or strip footings are subjected to static load, the improvement in ultimate bearing capacity increases with the increase number of reinforcement layers. 3. The number of layers was not significant difference when the ratio of the depth of the topmost layer to footing dimension was greater than 0.2.

4. With an increase in the number of planar reinforcement layers and the reinforcement width, the bearing capacity of the foundation increases and the shallow foundation settlement decreases.

5. The depth of topmost layer is very effective in the performance of the reinforced system. The influence of geogrid becomes practically negligible when the ratio of depth of the first layer to the footing dimension is equal to 0.5

6. The improvement in bearing capacity shallow foundation increases with decreases of vertical space between geogrid layers when the amount of (u/B) was less than 0.2. In addition, no significant effect of vertical space between geogrid layers is seen when the ratio of depth of the first layer to footing dimension greater than 0.3.

7. The reinforcement's efficiency in reducing the maximum footing settlement reduces as the width of geogrid is increased.

8. The values of bearing capacity obtained from numerical test are greater than those obtained from experimental test. This can be due to the soil parameters such as friction angle, cohesion and modulus of elasticity have used in the analysis.

The main application areas for geogrid include separation, reinforcement, filtration, drainage. Geogrid materials could be used in the reinforcement of soils for walls, steep slopes, roadway bases and foundation soils. Geocells were used in the construction of canals, embankments, retaining walls, railways and roads.

FUTURE SCOPE:

To avoid the high cost of deep foundations and settlements, modification of the weak foundation or the addition of a structural fill is essential. Case histories have found out, there are 1.5% reduced foundation costs for projects involving geosynthetics specifically geogrid. Currently geogrid is proved to be better geosynthetic.

The best suited material amongst variety of geosynthetics should fulfil requirements of-

1. BCR and Permissible settlement for any type of soil.
2. Economy

Experimental and numerical test and studies of case history would help to find the best geosynthetic material.

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