Laboratory Evaluation of Bearing Capacity of Footing on Clayey Bed Overlaid with Geocell Sand Mattress

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Abstract. The non-availability and scarcity of suitable construction soils at several worksites has led to the increased usage of soils with inadequate engineering properties. With regard to this reason there is a dire necessity for in-situ modification of foundation soils to improve their engineering properties and to obtain adequate bearing capacity. Despite several existing methods of soil improvement techniques, the soil reinforcement is considered to be prominent methods of ground improvement techniques. These days three dimensional method and technique of soil confinement using geocells is gaining reputation for enhancement of bearing capacity of such soils. In the present investigation, the laboratory experimentation was planned and performed various tests to explore the prospective advantages of embedding geocell reinforced sand mattress laid on soil subgrade (clayey soil). Test parameters that varied during the testing included are thickness of plain sand layer and height (clear distance) of geocell sand mattress laid above the clay bed. The experimental results have shown that a considerable enhancement in load carrying capacity. It could be achieved by the spreading of geocell reinforced sand mattress above the clayey bed. Further, it is noted from the test results that, almost 5–fold improvement in bearing capacity is attained by providing geocell reinforced sand mattress embedded in sand layer of thickness equal to twice the dimensions of the footing i.e., 2B (B is the width of footing).

1. Introduction

During the year 1970, the concept of cohesionless soil reinforcement with all-round confinement was introduced. This development was taken the shape at its place when the U.S Army's needed to stabilize sand strata near beaches for pavements [6, 13]. These days the geocell reinforcing system has been gaining popularity for the reinforcing the mass of soil (in layers) in building of the highways. Further type of engineering relevance of this technique have also been proposed for enhancement of the load carrying capacity of soil for various applications such as under foundations, slopes, channel linings, erosion and bank protection. During the last few of years the geocell reinforcing systems have been used in the construction and laying of flexible type of huge structures. Geocells are being utilized for providing facings of soil retaining wall structures with geosynthetic reinforcement that havelower to moderate slopes[1,2]. It is observed from the previous studies that the technique of usage geocell in soil reinforcement is upcoming technique. It could be one of the promising sustainable techniques for ground modification. Geocell is manufactured by polymeric materials. In general, it has a 3-
dimensional with honeycomb-like cell structure interconnected at joints forming into junctions. Coming to mechanism of reinforcement in the geocells, the soil mass is confined (all-round confinement) within its pocket-like cell structure[3,4]. In lot of cases, there is a chance of lateral spreading of soil mass in case of the planar reinforcements wherein the Geocell facilitates confinement thus reduces spreading of the in-filled soil in lateral direction. This phenomenon of confinement and holding soil in these pockets tend to enhance overall stability of the reinforced soil bed for foundations[5]. Almost unyielding property of the Geocell mattress facilitates the axial loads transferring on to the foundation to spread and evenly distribute over a greatly larger area. On the whole aspect of increase in load bearing capacity is achieved. In this way, the geocell layer supports and improved the capacity to carry load of the underlying weak soil could be attained[6]. Owing to an increased practice and usage of geocell reinforcement technique in the construction industry, there exists a wider scope for further study to clearly examine the behaviour of composite matter in much better way [7,8].

A group of researchers [9,10] have proposed various design methods and procedures for construction using geocell mattresses to hold up the foundations for embankments that are laid over soft soils. The authors have described the importance of a latest type of geocell mattress reinforcement for various types of foundations prepared from polymer geogrid which would efficiently sustain embankment over soft ground. The authors have also explained the construction method using this type of geocell mattress. Other researchers [11] investigated load carrying capacity and efficiency of strip footings located over geocell reinforced sand. In this investigation, various tests on geocell patterns, formations, structural performance and density of soil (sand) were planned and carried out. These loading tests were conducted using geocell reinforcement. Various studies were performed on round shaped footings which were supported by geocell reinforced sand that overlaid on clayey layer (bed) [12,13]. Several model tests were conducted by these researchers and have conducted the laboratory to study on the efficiency of geocell reinforcement embedded in the coarse grained soil fills overlaid on soft clays (beds). On these test beds a monotonic loading was applied using a rigid circular foundation. By providing this geocell reinforcement, a 7-fold increment in bearing capacity is observed.

Other group of researchers [14] has carried experimental work and investigations on embankments using geocell support. Experimentation was carried out by constructing model embankments. Geocell layers were prepared utilizing geogrids that were laid on the top of a soft clay bed. The clay layer (bed) was prepared gently inside a steel test tank. In this study, the influence on the behaviour of the embankment with varied tests parameters such as stiffness (tensile strength) of geocell material, size (shape) of geocell layer (height and length), pattern of formation of geocells, pocket-size of the cell and type of soil mass filled inside the cells were evaluated. Soil is a chief potential construction material that can be used for many purposes [15,16]. Few researchers investigated the load carrying capacity of circular footing under load on geocell–sand mattress overlying clay bed [17]. A series of laboratory model tests were performed to explore the prospective benefits of provision of geocell sand mattress reinforce placed on a clayey subgrade with voids[18].

The various test parameters that adopted in the present experimentation were the thickness of plain sand layer above clay bed, density of sand filled in the geocells height above clay bed and width of geocell mattress. In the present study an attempt is done to determine the properties (physical and engineering) of clay and sand [19]. Further study was made to assess the load carrying capacity and settlement of clayey soil strata laid under geocell reinforced sand mattress[20].

2. Materials Used
The following materials were proposed to be used in the present investigation. Their individual physical and engineering properties are mentioned below.

2.1 Clayey Soil
The soil was collected which is locally available in Warangal City of Telangana State. The soil used in this experimentation was Clay of Medium Plasticity (CI). The soil is so chosen to be considered as a low quality soil (inferior soil). All the properties of this soil have been determined as per procedures
mentioned in Bureau of Indian Standards IS 2720-20 (1992) and were presented in Table 1.

| Property                              | Value |
|---------------------------------------|-------|
| Specific Gravity                      | 2.50  |
| Grain Size Distribution (%)           |       |
| Gravel 0                             |       |
| Sand 45                               |       |
| Silt 23                               |       |
| Clay 37                               |       |
| Atterberg Limits (%)                  |       |
| Liquid Limit ($w_l$)                  | 40    |
| Plastic Limit ($w_p$)                 | 22    |
| Unified Soil Classification           | CL    |
| Optimum Moisture Content (OMC) (%)    | 21    |
| Maximum Dry Density (kN/m$^3$) (%)    | 1.67  |
| Free Swell Index (%)                  | 31    |
| Degree of Expansion                   | Moderate |

2.2 Sand
The category of sand used in the present experimental program was poorly graded sand (SP). The classification was done in accordance with Indian Standards IS: 1498-1970. The properties of the sand were mentioned in Table 2.

| Property                              | Value |
|---------------------------------------|-------|
| Specific Gravity (G)                  | 2.67  |
| Grain Size Distribution (%)           |       |
| Gravel 4                              |       |
| Sand 96                               |       |
| Silt 0                                |       |
| Clay 0                                |       |
| Optimum Moisture Content (OMC) (%)    | 13    |
| (%)                                   | 1.81  |
| Maximum Dry Density (kN/m$^3$)        |       |
| Unified Soil Classification           | SP    |
| Coefficient of Curvature ($C_c$)      | 1     |
| Coefficient of Uniformity ($C_u$)     | 2.58  |
| Coefficient of Permeability (k) (m/s) | $1.85 \times 10^{-3}$ |

2.3 Geocell Mattress
Geocell Mattress was formed and shaped by with a uniaxial geogrid made up of polymers. The opening size (aperture) of the uniaxial geogrid is in rectangular shape with dimensions 0.02m × 0.025m. The geogrid is cut into required dimensions. The connections were made among the longitudinal and diagonal ribs by inserting plastic strips of width 6 mm and thickness of 3 mm. These plastic strips were exactly inserted at junctions through openings (aperture) of the members thus forming three–dimensional cell like structure (Figure 1).
3. Experimental Study

The present laboratory study was intended to evaluate the load carrying capacity of clayey layer (bed) laid under geocell sand mattress. The geocell sand mattress was laid with one and two layers of reinforcement. The test method is explained in following sections.

3.1 Preparation of Clay Beds

The clay soil of a required grade was sieved, which was further dried in oven. The soil is pulverized using a light weight mallet. This sample was weighted and thoroughly mixed with a requisite quantity of water which is equivalent to its optimum moisture content (OMC). After through and uniformly mixing the water the soil was spread uniformly in the test apparatus which was gently compacted in different layers (layer thickness equal to 25mm). The compaction of clay in layers was done till the desired height in the test box apparatus was obtained. In order to acquire required bulk density, each soil layer was measured for its density. The density was measured using core cutter, which was simultaneously filled and compacted using a drop hammer. Each soil layer was compacted up to a height of 250 mm by placing each layer at every 25mm thick. The clayey soil is fully saturated by connecting a water pipe from the water reservoir to the steel tank. The soil is allowed for a mellowing period of 24 hours.

3.2 Testing Procedure

The steel tank was filled up to a predetermined height with clayey soil in layers. The top portion of soil layer was cleaned and leveled to obtain uniform surface. The footing was then placed gently over the soil sample where its alignment is predetermined. The alignment is made such that the loading jack would transfer a uniaxial load coaxially over the footing. An engraved groove with concavity was provided at the center of the plate in order to accommodate arrangement of a ball bearing type, which would aid in transferring vertical load to the footing.

Figure 1. Formation of Geocell Mattress using a uniaxial Geogrid made of Polymers

Figure 2. Schematic diagram showing the laboratory experimental setup
A constant rate of loading was applied to push the footing in the sand as relatively faster rate of loading shall result in undrained sampling in saturated clay bed, resulting worst field conditions. This condition causes zero angle of friction and is mostly observed in transient nature of loading as in the case of highways and railways.

Figure 3. The laboratory experimental setup

The uniaxial load is applied with the help of a pre-calibrated proving ring which was fitted with a ball bearing and jack for loading. The applied load was noted from the proving ring. Two numbers of sensitive dial gauges were arranged on both sides to measure settlements in the footings (depicted in Fig. 1. and Fig. 2) which were arranged on either sides from the central line of the footing. In this study, the amount of settlement of the footing was reported as mean value of the reading taken from these two dial gauges.

3.3 Geocell Reinforced Sand Bed Preparation

The geocell reinforced sand mattress was unfolded and spread evenly on leveled surface of the compacted clayey bed. The geocell layer, which has a continuous 3–dimensional cell like structure was prepared using geogrids of required length and height. The geocell mattress was cut and transversely placed in required directions using dowels at the joint connections. The pins (plastic strips of size 6 mm width and 3mm thickness which are cut from plastic sheets) were used for making of geocell joints in the present study. After keeping the geocell mattress on the top of clay layer, all the geocell three dimensional pockets were filled up with sand, thus forming into Geocell Sand Mattress.

4. Results and discussion

The load carrying capacity (load–settlement responses obtained from the different tests by varying the thickness of plain sand and geocell layer on clay bed. The results obtained from different test conditions are presented in Figures 4 to 6.
It may be noted that the load carrying capacity of the foundation has been improved due to provision of geocell sand mattress in the sand layer overlying clayey layer (bed). The enhancement in load carrying capacity could be by the embedment of geocell sand mattress in sand layer over clayey layer is very much quantified. This is defined as the ratio of load on footing with geocell sand mattress in sand layer overlying clay layer (bed) to the load on footing with clayey layer (bed) alone. Both loads are being considered at equal footing settlement. The bearing capacity of the foundation increased with the increase in thickness of geocell sand mattress.

For a plain sand bed of thickness equivalent to two times width of footing, nearly 3 fold increments in load carrying capacity was obtained. To gain the more benefit, the top of the geocell sand mattress should be placed at a depth of 0.1 times B (B being width of the footing) from the base of the footing. More than 5 times increment in load carrying capacity could be obtained with the provision of geocell sand mattress in the sand layer of thickness 2(B) over the clay bed. A detailed experimentation clearly reveals that in order to gain a maximum beneficial effect the width of geocell must be equal to 4.9 times D. It is evident from the study that by the providing geocell reinforcement within the overlaid sandy soil layer, the load carrying capacity of the foundation bed could be improved.

5. Conclusions

A multi fold enhancement with regard to load carrying capacity is obtained by providing geocell sand mattress as a base reinforcement overlying on the clay bed. Considerable amount of load carrying capacity of the clay layer is obtained by means of spreading geocell sand mattress evenly over width that almost equivalent to the width of the footing. From these laboratory test results obtained during the present investigation, it is observed Geocell Sand Mattress system has significantly shown the better performance than planar type of reinforcement system.

6. References

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