EXPERIMENTAL STUDIES ON CONSTRUCTION OF EMBANKMENT ON SOFT SOILS USING GEOCELL LAYERS AND STONE COLUMNS

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ABSTRACT: The main objective of paper is to deal with the study of overall application and mechanism of Geo-cell layers and stone columns used in civil engineering projects constructed on soft clay soils, like canals, storage utilities and earthen dams. In construction of civil engineering projects there are basically two standard procedures which should be followed. Initially the structure which is constructed should be safe against any kind of failure and secondly the structure should economical as far as possible. When we construct the structure over loose soils then it becomes cumbersome and tedious process to follow these two basic criteria's .When the conditions of soil is very weak or poor it is associated with deformability and lack of strength for that purpose stone columns and geo cell layers plays an vital role for soil reinforcement. These techniques are efficient methods in-terms of cost effectiveness and due to which it enhance the strength and durability of soft soil. To prevent the lateral displacement and lateral spreading of soil due to load application this paper presents use of 'Geo-cell-stone column composite' to improved performance. In today's world more land gets dominated to industrial development and urban due to that construction sites are difficult to locate which leads to not fulfilled the client desire, to mitigates this kind of problem engineers focuses and finds an alternative solutions, to make it happen to construct the intended structures at stipulated site through ground improvement techniques. In the field of geo-synthetics, geocell reinforcement is latest adaptation. It is 3-D honeycomb cells made from polypropylene interconnected at joints. The working principle of geocells is based on all-round confinement soil within its small pockets.
KEYWORDS: Geo-cell, stone columns, soil reinforcement.

I. INTRODUCTION

Stone column : The improvement in stress bearing capacity of soils may be undertaken by various soil-improvement techniques. The various techniques which are available to increase more and more bearing capacity are, preloading, grouting ,chemical stabilization, compaction, stone columns, geo-grids, densification using vibratory equipment and by using geo-cell layers. Among listed above stone columns extensively improves more performance. Soil reinforcement has been used over the past three decades to enhance stability of loose and weak soils. Using stone columns is environment friendly and cost-effective. The role of stone column in-terms of load transmitting by creating skin friction as well as end bearing resistance has investigated by several researchers, such as Hughes and Withers(1974). Various tests on floating stone column in order to study its effects under drained conditions, and some of them used stone columns without considered group effect lying on hard stratum. Stone columns are constructed to increase the ground improvement ,by involving vertical columns of stone into the soft soil to a depth of atleast 4m below the ground surface.stone column under goes bucking when load is transferred into hard strata, due to buckling effects it reduces tilt,undulations,and uneven ground subsidence from liquefacion, reduces excess pore water pressure and lateral squeezing, through providing additional drainage paths.

Stone columns/granular piles are constructed by the following two methods

- Displacement Method/Vibrofloatation Method/Bored Reammed Method
- Non Displacement Method

Vibrofloatation is also of two types (Wet or Top Feed Method and Dry or Bottom Feed Method)

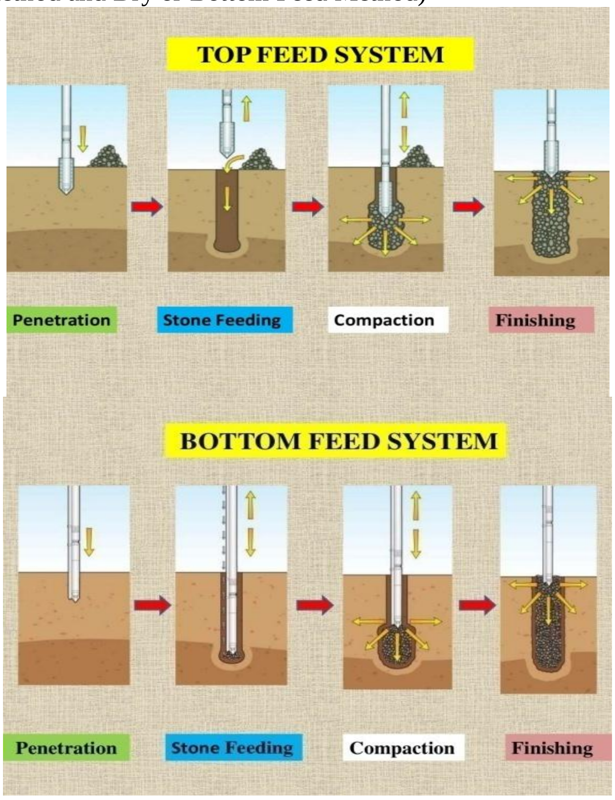

Fig 1 and 2 repreesents Methods of Installation of stone column

Geocells: Geo-cells decreases settlement issues of soft clay soils, comparing to other methods like pre-consolidation using PVD's pre-consolidation, lime treatment, stone columns and geo cell, among all of them geocell layers is more preferred due to its easy installation and better and more economical results. Surface heave is reduced by encasement geo cell mattress. Shanu.et.al(2000) finds out the impact of granular mat for improved ground within the framework of unit cell concept and equal strain theory. Geocell reinforcement increases granular, bed load and reduce settlement issues. Equivalent composite method used by Madhavi Latha et.al(2006) on geocell design to support embankment. Lumped approach was used for single layer as well as multilayer geo-synthetic granular bed (Deb et al;(2008). Arulrajah (2009) has reported the use geo-grid-soil in construction of stone column high-speed railway embankments. Analytical method proposed by Zhang et.al(2010) to calculate bearing capacity of geo-cell reinforced bed of clay which support an embankment, the bearing capacity was increased by membrane effect and vertical stress distribution effect. Most studies considered geo-synthetic material as elastic material.

Fig 3 Close View of Geocell

II. METHODOLOGY

GEOCELLS: Geocells are fabricated at the site by joining various geocell cuts together in a definite pattern and into the required size. Geocells is also called as Cellular Confinement System (CCS)-are mainly used in construction for controlling erosion, soil stabilization, steep slopes, and enhances bearing capacity of earth. The interlocking property of rigid geo-cell mattress changes failure planes by allowing them to pass perpendicularly through them. Geocell reinforcement is latest adaptation, it is 3-D honeycomb cells made from polypropylene interconnected at joints. The honey combed structures are filled by compact non cohesive soils like sand, gravel, rock and concrete. Geocells are typically perforated this property allows drainage from one cell to another. Geocells are constructed through various equipment called pneumatic stone-slingers or sand slingers.

Stone Column Installation

The length of stone column in the model test was 600mm and diameter of 100mm. The ratio diameter to length of stone column is approximately one-sixth scale representation. Method used for construction of stone column was replacement Method, with average size of Crushed aggregates 3.80mm. A thin stainless-steel pipe both sides open of outer diameter of 100mm and 1.5mm thick pushed into clay soil at a depth equal to length of stone column to be formed. Grease was applied on both sides to overcome friction and adhesion during penetration and withdrawn without creating disturbance to adjacent soil. The material which goes inside pipe was scooped gradually by helical auger having 90mm diameter, to reduce suction effect at a time at-least 100 mm height was removed. When target depth is reached checking is done for whether any clay is sticking, if so were cleaned, after that stone chips with measured quantity of 600 g was put at a time per batch and then compacted to height of 50mm with circular steel tamper of weight 900 g with height of fall 300 mm in 30 number of blows.

In stages the pipe was raised minimum of 25 mm penetration, so that no disturbance in surrounding clay occurs. This procedure was repeated till full height of stone column is achieved. After that full area of bed was loaded with initial pressure of 2.5kN/m2 for4hours to achieve bed uniformity. To check stone column is formed stone pieces were removed before load test and powder form ($CaSO_4 \cdot 0.5H_2O$) was mixed with sufficient amount of water to form thick paste and poured into shaft which was formed due to removal of stones chips. Due to its high viscosity of plaster of Paris it cannot goes into the clay and gets solidified and then removed by removing the surrounding soil.

INSTRUMENTS USED IN PRESENT EXPERIMENT

The load cell of strain gauge type with least count (0.01N) and capacity of 22KN was placed between reaction frame and hydraulic actuator to measured load on footing. The calibrated curve at known calibrated loads was used for the model tests. The Linear Variable Differential Transducer (LVDT) of potentiometer type with least count of 3 microns was used to measure deformation of fill and settlement in footing. Two LVDT's placed over settlement plate in diagonally opposite sides to measure settlements of footing. The displacement transducers and load were connected to an automated control system. The data were recorded through highly precise computerized data acquisition system

III. RESULTS AND DISCUSSION

Different experiment tests was conducted by varying Length of stone column and height of Geocell mattress. The pressure- settlement shown in Fig.4 below indicates the load and stiffness of clay using composite foundation is much higher to that of geocell alone (i.e. Clay + GC). On the other hand, similar behavior is noticed for other cases. This enhancement in performance is mainly due to attribution given by stone column to geocell mattress, primarily, mobilized stiffness and friction. The length of stone column has influenced the overall performance of composite foundation system. In tests length of stone column is varied from (i.e. L =2dSC- 6dSC, where dSC is stone column diameter). And also by varying heights of geocell mattress (i.e. h = 0.60D, 0.95D, 1.20D and 1.50D; where D is footing diameter). The other parameters were kept constant, i.e. stone column spacing, geocell pocket size, infill density, and geocell layer depth as; S = 2dSC, dGC = 0.7D, ID = 80%, u

= 0.2D respectively. The obtained results are discussed and presented in below subsections.

1 Geocell mattress Height (h/D) of0.60

When height of geocell equal to 0.60D,and maximum length of stone column(L=6dSC) is provided , the performance improvement in bearing capacity as compared to unreinforced clay bed was very much increased up to 5.5 times. From total of 5.5, only 1.7 folds occurs through geocell reinforcement the rest of bearing capacity was achieved by stone column alone i.e.3.8 folds, along with settlement reduction in foundation bed close to 100%. While increasing the length from 2 to 6 times diameter, we get predominately sharp enhancement both in terms of percentage reduction in settlement (PRSSCGC) and improvement factor of bearing (IFSCGC).

2 Geocell mattress Height (h/D) of 0.95

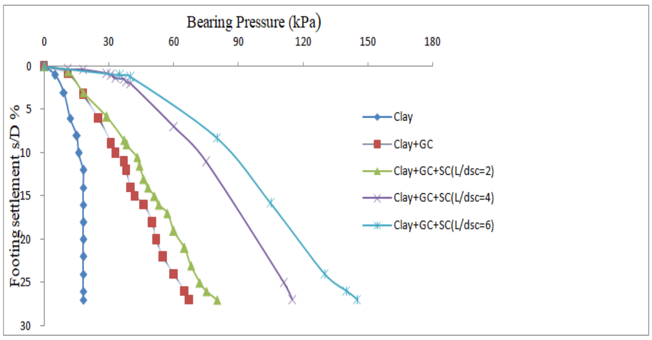

Fig.4 Bearing pressure verses footing settlement at h/D =0.95

From the results and data shown in Fig 4, concluded that with inclusion of geo-cell (h=0.95D) the clay foundation can bear up to78kPa of bearing pressure, and with stone column (L=6dSC) alone it can bear up-to 135kPa. With provision of both can increase bearing capacity more than 6 folds (IFSCGC>6).

3. Geocell mattress Height (h/D) of 1.20

Fig.5 shown that with inclusion of composite reinforcement, keeping length up to 6 times diameter and height of geocell 1.20 times diameter can enhance bearing capacity 9.5 times compared to unreinforced case and percentage reduction in settlement as high as 100%. Due to higher height provided in geocell it can bear higher shear, bending, resistance through anchorage. Maximum amount of load is carried by geocell and relieving stone columns present underneath. This contribution in load stabilizing by stone columns sharply reduce till settlement in footing reaches to about 6%,beyond this limit rate of reduction is relatively less. However, the contribution by geo-cell reinforcement have steadily increased up-to large settlement. This behavior is due to polypropylene material needs large amount of deformations leading to more strength mobilization. However, when rate of deformation is increased, the geocell mobilizes more of its strength, and hold the fill material more, so that it stands against footing and reduces pressure in stone column significantly. Therefore, the contribution by stone columns is marginally towards improvement in the performance.

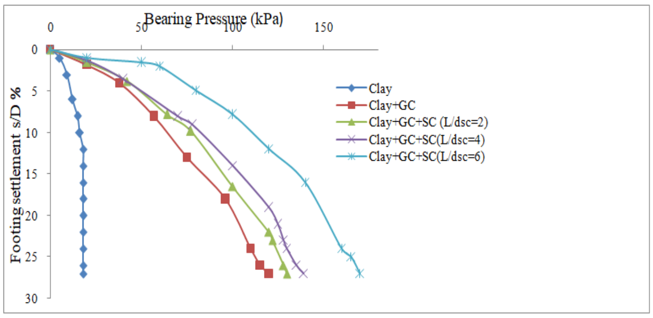

Fig.5 : Bearing capacity verses footing settlement at h/D=1.2

Height of geocell mattress (h/D) of 1.5

The variation of footing settlement verses bearing pressure of composite bed foundation by keeping height equal to 1.5D are presented in Fig.6.It has been observed with geocell mattress alone can bear maximum pressure of about 145kPa while composite reinforcement (GC+SC) can bear 165kPa. The maximum improvement in performance when geocell height is kept(h/D=1.5) and length equal to 6 times diameter bearing capacity can be enhanced 10 folds compared to unreinforced clay bed. Summarizing all the results it has been also concluded that performance improvement significantly increases up to 1.20 beyond there is marginal increase. Hence, we can say optimum height of geocell equal to diameter gives maximum performance.

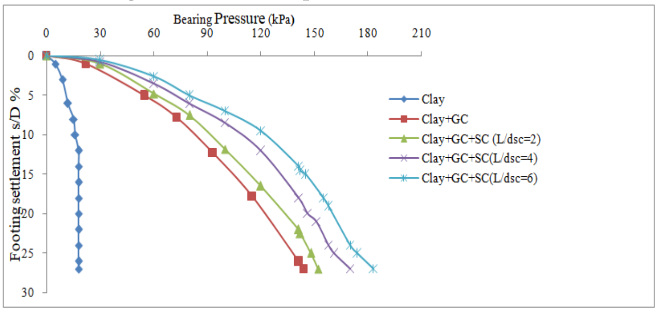

Fig .6 Bearing capacity verses settlement of footing at h/D=1.5

IV. CONCLUSION

Using stone columns with geocell reduces lateral confinement pressure. The further enhancement in bearing capacity occurs with increase in stone column diameter .Due to composite system increase in liquefaction resistance, reduce settlement and sliding, increase shear strength, bearing capacity and rate of consolidation. It has estimated that by reducing the spacing of stone column, bearing capacity is very much increased in the bed of footing. The substantially high bearing pressure is observed, when spacing (S) is reduces from 4dSC to 2dSC, beyond that limit increases less marginally. Hence from design point of view the optimum spacing is taken as 2dSC. When spacing is provided 2dSC at this stage the ring of stone column tries to protect the foundation soil by providing an additional higher confinement and leads to improvement in performance. The settlement comparison of fill surface at S= 3dSC and S = 4dSC the former settles less as compared to later. This attributed that by reducing spacing leads to relatively higher confining effect and inducing additional amount of heaving resulting in reduced the surface settlement. It has been observed with inclusion of stone column pressure increases as high as 3.6times. Beyond settlement of 3%, IFSC increases and becomes directly proportional to increase in settlement. This effect initially is due to stiffening of stone columns..It is observed that stiffness and ultimate capacity both increases as we increase height of geocell mattress. Due to increased height of geocell load gets transmitted and redistribute effectively over wider area. The bearing capacity maximum of ten times increased when geocell height of 1.5D and length of stone column as high as 6 times its diameter. As we reduce the size of pockets bearing capacity is substantially increased and settlement gets reduced, the improvement due to reinforcement with geocell is prefab ally more as we increase density of fill material. The lateral displacement of dense soil is restricted by walls of geocell membrane, leading to more strength mobilization of reinforcement.

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