

Performance of Stone Column under Circular Storage Tanks

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ABSTRACT: Installation of stone columns to the ground is one of the most effective ground improvement techniques to improve the engineering properties of soft soils. The process involves installation of vertical columns of aggregate into the ground so that the overall stiffness of the ground gets increased. Geosynthetic encased stone columns is the new technique that is used to overcome the limitations of ordinary stone columns. It gives extra confinement to the stone columns especially when the columns are constructed in soft soils. In this paper, finite element analyses were carried out using the software PLAXIS 3D to find the influence of geosynthetic encasement under storage tanks. The study aims to find the effect of encasement on settlement and lateral deformations with respect to encasement stiffness and also discusses the behaviour of stone columns under circular storage tanks.

KEYWORDS: Geosynthetic encasements, Storage tanks, Flexible foundations, PLAXIS 3D, Lateral deformations, Stone columns.

I. INTRODUCTION

Soft clays are known to have high compressibility, low stiffness and low shear strength. Even though there are different ground improvements techniques, stone columns are considered to be the most versatile method. But in case of very soft clay, stone columns exhibit squeezing that results in excessive bulging of stone columns. When structures like storage tanks are to be constructed on such soft soils they may undergo large settlement, both in terms of total settlement and differential settlement. Since stone columns act as reinforcement in soils, it helps restricting the settlement of the ground. The recent development in stone columns is encasing individual stone columns by geosynthetics. Encasing stone columns with geosynthetics prevent excessive bulging and squeezing of stone into the surrounding soft soils and thus impart higher load carrying capacity with less settlement.

Extensive studies were undertaken by many researchers to find the response of soft ground improved with stone columns. Improved performance of geosynthetic encased stone columns (GESC) over ordinary stone columns (OSC) has been again verified by previous researchers by model testing, numerical investigations and by field studies. The potential of encasing columns with geotextiles for improved performance of stone columns initially analysed by Van Impe and Silence [3] and recognised that that encasement can impart with a significant improvement to the ground when compared to the ordinary stone columns. Malarvizhi and Ilamparuthi [8] reported that bearing capacity of encased stone column was 1.5 to 2 times that of ordinary stone columns. But later studies by Murugesan and Rajagopal [6] concluded that encasement beyond depth equal to twice the diameter of the columns does not lead to further improvement in performance. Gniel and Bouazza [9] observed that isolated columns failed by radial expansion beyond the level of encasement where as in partially encased group of column, bulging occurred along the full length of non-encased section. Keykhosropur et.al [10] evaluated the effects of arrangement of encased stone columns in a group of columns and suggested that it may be sufficient to encase only a selected set of columns without losing a substantial percentage of overall performance of ground improvement system.

This paper investigates the behaviour of stone columns reinforced with geosynthetics under storage tanks and also discusses the influence of stiffness of geosynthetic encasement in terms of lateral deformation and vertical settlement.

II. NUMERICAL MODELLING

The influences of stone columns encased with geosynthetics were done by the software called PLAXIS-3D which works on the basis of finite element method. The numerical analysis employed in current analysis was validated by observing the behaviour of single stone column introduced to a soft ground and compared it with the previous research work done by Ambily and Gandhi, S.R., [7]. Fig 1 shows the validation of the model created in PLAXIS 3D. The validation of numerical model was very well converged with literature. The studies were again extended into modelling of storage tanks to find the behaviour of stone columns under flexible foundations. The properties of materials used for the study are given in table.1 Ambily and Gandhi, S.R., [7].

Table.1 Properties of material used for modeling (Ambily and Gandhi, S.R., 2007).

Parameter	Clay	Stones	Sand
Model	Mohr-Coloumb	Mohr-Coloumb	Mohr-Coloumb
Modulus of Elasticity (kPa)	2150	55,000	20,000
Dry density γ_{dry} (kN/m ³)	13.60	16.62	15.5
γ_{sat} (kN/m ³)	18.38	16.62	15.5
Angle of Internal friction ϕ (deg)	0	43	30
Dilatancy angle, Ψ (deg)	0	10	4
Shear strength, C_u (kPa)	7	0	0
Poissons ratio, μ	0.47	0.3	0.3

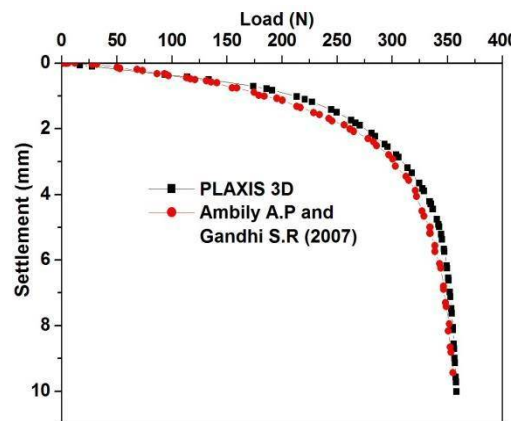


Fig.1 Validation of PLAXIS 3D

In the present study the stone columns with diameter 0.8m were arranged in triangular pattern with equal centre to centre spacing of 2 m in both longitudinal and transverse direction. The stone columns extended up to a depth of 8m, below which a rigid layer was assumed. The flexibility of the foundation was accounted by modelling that foundation as plate element. The whole problem was analysed as axi-symmetric case due to its geometrical symmetry. A well refined mesh was given around stone columns to achieve greater accuracy of predictions. No displacement was allowed at bottom boundary of the mesh and normal displacements on planes of symmetry were also restricted. All materials used in the analysis were idealized using an isotropic linearly elastic perfectly plastic model with a Mohr–Coulomb failure criterion. Geosynthetic was modelled using geogrid element available in PLAXIS 3D, composed of 6 node triangular surface elements having axial stiffness of 2000 kN/m. No interface elements were used between materials in analysis (Murugesan and Rajagopal, 2007). The load coming from the superstructure was given in stages to achieve an ultimate surface load of 200kPa. The model of stone columns under storage tanks were modelled in PLAXIS 3D as shown in Fig 2 (a) and Fig 2(b). The analyses were carried out as drained to capture the response of the ground.

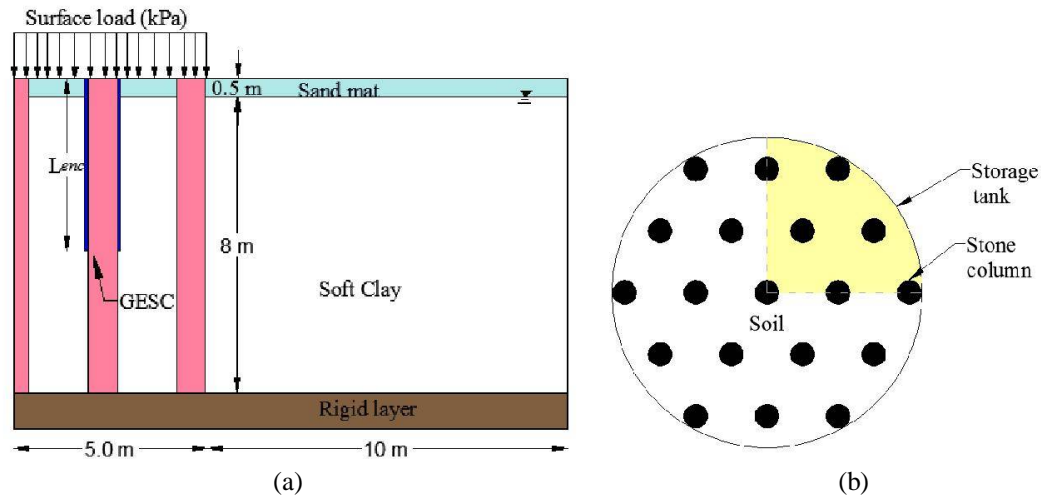


Fig.2 Numerical modelling. (a) Cross section of stone columns under circular tank. (b) Plan of circular tank.

III. RESULTS AND DISCUSSIONS

III.A Behaviour of stone columns under storage tank

Stone columns in compressive loads fail in three main different modes: bulging [1] and general shear failure [2], punching in short columns and bulging in long columns [5]. Therefore to investigate bulging and settlement characteristics of stone columns beneath the tanks, analysis was carried out. From fig 3 (a) shows that interior stone columns experiences less lateral deformation than exterior stone columns and is mainly due to higher confining pressure. This is in agreement with different previous research works on group of stone columns [7], [10]. Lateral deformation of exterior stone columns is about 8 times more than interior stone columns. Whereas when settlement behavior of stone column under storage tank was considered, settlement of stone columns decreases with radial distance from centre of tank. In other words, centre columns experienced more settlement than columns at edge and is as shown in fig 3 (b).

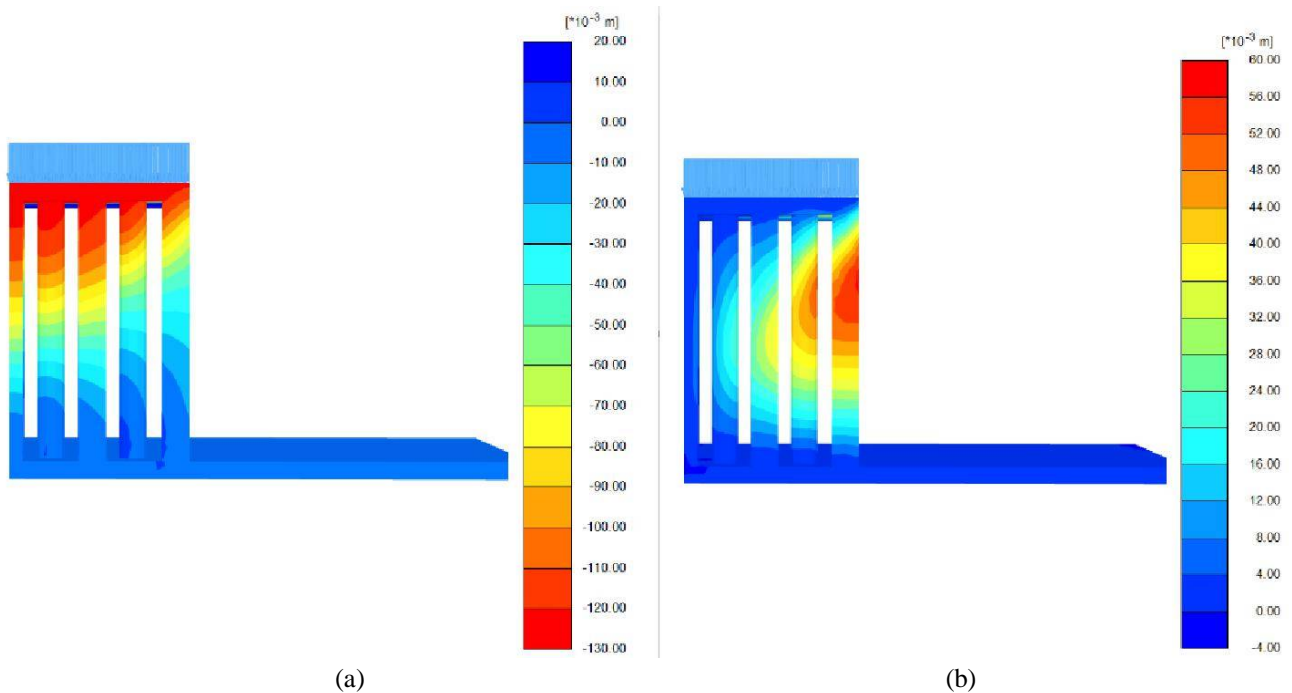


Fig.3: Behavior of different stone columns under storage tank. (a) Vertical settlement of stone column. (b) Lateral deformation of columns under storage tank.

III. Effect of encasement on performance of stone columns under oil storage tank

In order to find the influence encased stone columns under storage tank, the base model was analyzed using both ordinary stone columns (OSC) and encased stone columns (GESC). From the previous analysis it is clear that central column experienced more settlement, and thus this column was chosen for analysis. Fig 4 (a) represents the settlement of treated soil with OSC and GESC. It is observed that encasing stone columns increases the overall stiffness of column thus reducing the settlement. The settlement reduction is mainly due to the fact that more stresses are transferred to GESC than to OSC under storage tanks. Thus it can be said that use of GESC reduces stress in surrounding soft soil under storage tank by transferring it to geosynthetic encasements. Therefore the encasements are advantageous under storage tanks since the higher stiffness of columns helps to transfer the load to underlying strata.

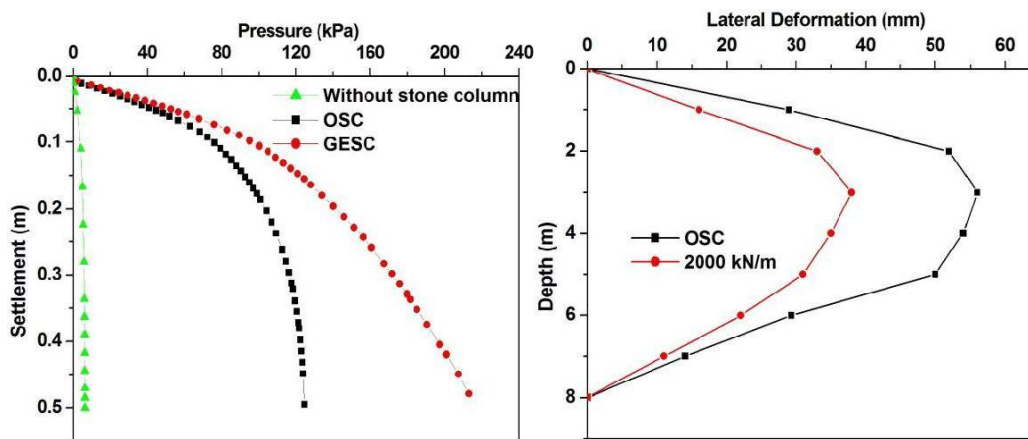


Fig.4: Effect of encasement on performance of stone columns (a) Effect of encasement on vertical settlement (b) Effect of encasement on lateral deformation of stone columns under storage tank

Even though stone columns proves to be a very versatile method among other ground improvement techniques, lack of adequate confining pressure poses many problem in very soft soils. Encasing stone columns with geosynthetic imparts a significant improvement in strength by resisting lateral deformation over OSC [11]. Therefore, to understand the behavior of stone columns under storage tanks, analysis were carried out with and without encasement. For studying the lateral deformation characteristics, exterior central stone column was chosen. Fig 4 (b) shows that use of geosynthetic encasement reduces the lateral deformation and resultant settlement of stone columns with respect to OSC. Therefore, encasing stone columns prevents both lateral deformation of stone columns and also prevents penetration of stone into soft soil and thus imparting high stiffness and load carrying capacity.

IV. CONCLUSIONS

The results of behaviour of circular storage tank constructed on geosynthetic encased stone column installed soft ground were analysed. The following conclusions can be drawn based on the findings from this study.

1. The results of this study confirmed that exterior columns experienced about eight times more lateral deformation than interior columns.
2. On analysing the vertical settlement, central columns experienced more settlement than exterior columns, i.e., settlements reduced with radial distance from centre of circular tanks.
3. With the use of geosynthetics, 40% increase in load carrying capacity was observed in geosynthetic encased stone columns when compared to ordinary stone columns.
4. The lateral deformation of column with depth was reduced up to 33% with the use of geosynthetic encased stone columns when compared to ordinary stone columns.

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