Numerical Analysis of Geogrid CFG Pile Supported Embankment on Soft Soil.

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Abstract. This paper presents an optimum design and analysis of CFG pile supported embankment for the national highway in India. Cement- flash and gravel piles are new approach of ground improvement column technology for the India. These techniques were used in china many project as highway & railway embankment for ground improvement. A couple two different dimension embankments 2D FEM model are used in this paper over the expansive soil near Surat city Gujrat. Present study does with this observation by employing CFG Pile support embankment composite foundation and screening its reflection through 2D FEM analyses. Present study on CFG pile variable length which affect the slenderness ratio, material properties (Grade) as well as Effects of area replacement ratio. The Slenderness ratios of pile, thickness of sand layer on the proportion of loads are shared by CFG piles and its settlement response of composite foundation on different levels of vertical load by highway embankment. Results showed the thickness of sand mattress on CFG pile was transmission load effectively as significant thickness of it. CFG pile was efficiently in improving the bearing capacity and reducing vertical settlement of expansive soft soil. Other way results shows that incremental lengths of CFG pile reducing the settlements of composite foundation and increment in Diameter of CFG pile effectively improved in bearing capacity of Composite Foundation. CFG pile material friction angle are improve the bearing capacity of Foundation system.

Keywords: CFG (cement, fly ash, Gravel) Pile, 2D FEM, slenderness ratio, Area replacement ratio.

1 Introduction

Soils and piles bearing capability can be absolutely developed in composite foundation, which had higher social and economic advantages. CFG pile supported Embankment was used as composite foundation with and without reinforcing support in china engineering Practice. Recent trend in soil improvement are with low strength flexible pile composite foundation which are significantly increasing foundation soft soil strength and decreasing foundation settlement. CFG pile is semi rigid pile as nature which is high strength column technology. It could be fully utilization soil bearing capacity and decreased the settlement in additional reduced the blurred effect of the soils and the piles interaction. The application of CFG pile in consolidating soft soil foundation is gradually applied in soft soil treatment.

This paper is based on the numerical analysis of Highway embankment near the Surat city. This numerical model were simulated the consolidation behaviors by a couple of hydraulic and mechanical model. In order to parametric study of CFG pile influence with length, which effect on Maximum bending moment of the performance of CFG pile supported embankment with and without reinforcement.

The near Surat region soils are expansive during the construction of highway important element is subgrade. The soil distribution of a highway subgrade engineering were difficult, mainly composed of artificial filler, newly sedimentary cohesive soil, silt soil and quaternary deposition of cohesive soil, sandy soil and cohesive soil. The bearing capacity characteristic value was only 100 kPa. Natural subgrade bearing capacity characteristic value was less than the subgrade bearing capacity characteristic value (design value), so natural subgrade cannot be the bearing stratum. The new approach of Cement fly-ash grave (CFG) pile was adopted in to improve the bearing capacity. Bearing capacity characteristic value was required to 200 kPa after the foundation treatment. In developing the proposed theoretical method, the following simplifications are used for embankment design

1) The embankment fill is homogeneous, isotropic.
2) There is only one layer of geosynthetic is considering.
3) The soft soil and the embankment fill deform only vertically, and no relative displacement and slippage between geosynthetic and subsoil.
4) The height of embankment fill is larger than 0.5 times pile spacing.

Literature Survey

The performance of an embankment constructed on a cement deep mixing-formed column–slab system improved soft clay deposit was analyzed using field measurements and finite element simulation results[1] CFG Pile contributed to less than 21% of the total settlement.[2] CFG (Cement Fly-ash Gravel) pile is consisted with macadam, gravel, sand, fly ash mixed with cement and water. In sand, silt, clay and muddy soil and miscellaneous fill foundation, there have been many applications of CFG technology.[3] Geosynthetic-reinforced piled embankments have been increasingly used to stabilize embankments over soft soils. The presence of the reinforcement reduces the stresses transferred to the soft foundation and improves the efficiency of the transference of loads to the piles[4] The laboratory results in the form of vertical load intensity-settlement behavior were com- pared with that obtained from FEM software,[5]

2. A CFG Pile Supported Embankment Model

The finite difference software Plaxis 2D was adopted for this numerical analysis. The cross section of the numerical model for this case study is presented in Fig. ure 1 and which shows the cross-sectional of the CFG Pile Supported highway embankment, which is 1.8-m high with an 8-m wide crest and 1(V): 2(H) side slopes. The elastic modulus and shear strength of the embankment fill were determined from laboratory tests. The CGF Pile under the highway embankment has been installed in a square pattern at a spacing of 1.3 m using a pile installation Method. The water–cement ratio of the mix design and the cement content were 0.59 and 324 kg/m^3 of soil, respectively. All this standard data have been used for CFG pile for design Optimization C- 20.

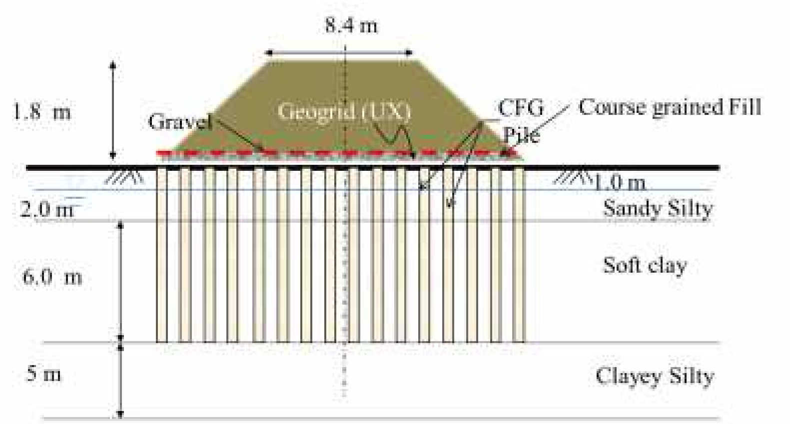

Fig. 1**.** Cross section of Highway embankment

The calculation model was shown as Fig.2.Mesh partition adopted 15 nodes triangular element, and the program automatically subdivided mesh. Especially the mesh of reinforcement area and cushion area was dandified. At the same time, pile was simplified to sheet pile form on the basis of equivalent principle of axial stiffness, in which the pile had a diameter of 0.3m. The physical and mechanical parameters of reinforcement area and substratum and cushion and CFG pile were shown as table 1. The following presumptions were adopted when it was calculated:

(a)The pile is linear elastic material, meeting with generalized Hooke's law;
(b)Soil transition zone and cushion were elastic-plastic materials, adopting Mohr – Coulomb constitutive model.

Table: 1 Properties of embankment fill. Gravel and Pile used in FE analysis

Material	Unit Weight (kN/m^3)	Friction Angle (degree)	Cohesion (kPa)	Young's Modulus E (MPa)	Passion's ratio ν
Embankment fill	18.60	33.8	11.5	20	0.3
Gravel	20	36	60	70	0.3
CFG Pile	24	-	-	20000	0.2

Table – 2 Soft foundation soil properties used in FE Analysis

Layers	Thickness	Degree (φ)	Cohesive C' (KPa)	γ (kN/m3)	γ_{sat} (kN/m3)	K_x, K_y (m/day)	E	ν
Sandy silt	2 m	30.6	4	17	19	6.91E-05	2.0E4	0.35
Soft Clay	6 m	27	13	16	17	8.3E-08	2.0E4	0.3
Clayey silt	5 m	34	0	17	20	8.9E-06	2.0E4	0.27

3. Effect of the thickness change on cushion on settlement

The height of embankment was 1.8 m. The computing result was shown as Fig.2. It can be seen from Fig.2 that the settlement was larger as the cushion is not set up, which was contributed to the Significant stress concentration in the pile under the load for no cushion. Therefore, the pile bore most or the entire load as the load was applied, which caused greater settlement than that of the cushion being set up. The settlement reached 5.0cm in the above example; when the cushion was set up, the settlement rate got slow, which implied that the soil between piles began to bear the part of load. As the thickness of the cushion varied from 0 to 30cm, the extent to decrease of settlement was the largest; while the thickness of the cushion exceeded 30cm, the extent to decrease of settlement got very little; whereas the thickness of the cushion was larger than 50cm, the increase of thickness had almost no effect on the settlement of subgrade. In view of the reliable technique and the sound economy, the reasonable thickness of cushion was from 30cm to 60cm. The cushion of certain thickness was set up to ensure that pile and soil bear load in common and fully plays the role of soil between piles, which resulted in the improvement of bearing capacity for compound foundation.

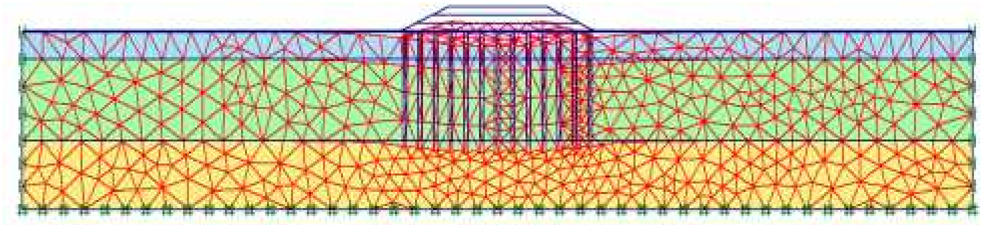

Fig. 2 FEM Modeling with large vertical Displacement

Effect of cushion sand Bed is significant effect of decreasing the settlement effect and arching effect has been created in embankment as shown in Fig. 3. To effect has been nutrised

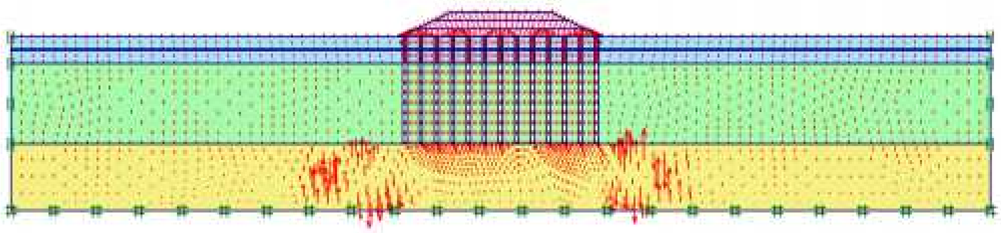

Fig. 3.Out Put Results of CFG Pile embankment

Results

To investigate the influence in view of the thickness of sand cushion are varied in embankment from 0-60 cm in this present study influence of sand cushion thickness 0,0.1,0.3,0.5, and 0.7 m has been considering for evaluating vertical settlement of embankment under static loading. Fig 4 elaborates the relation of influence of sand cushion thickness to vertical settlement it is clearly shows that with increasing the thickness of sand cushion the rate of vertical settlement has been effectively decreasing in respectively.

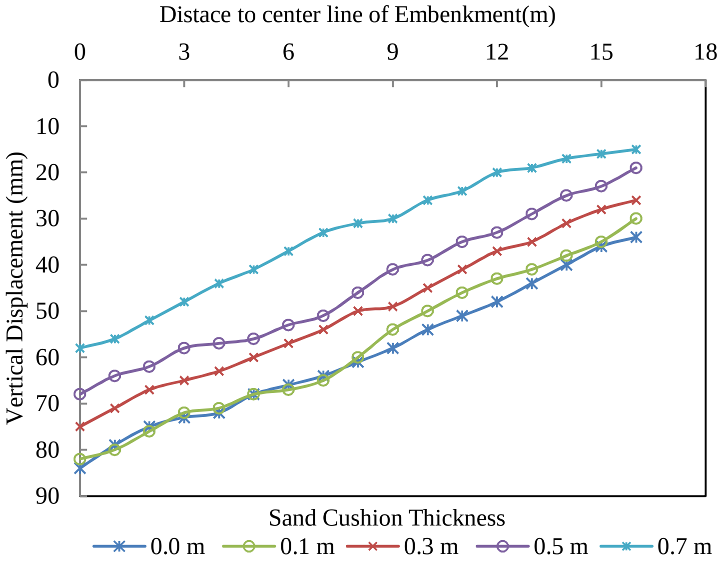

Fig. 4 Influence of the sand cushion in embankment

Fig. 5 illustrates the lateral deformation within clay and the pile group as measured from Plaxis 2D analysis A maximum lateral pile head deflection localized to the center of every pile at considering row in CFG pile supported embankment All piles within the pile group deflected laterally under the influence of the lateral loading from the embankment fill,

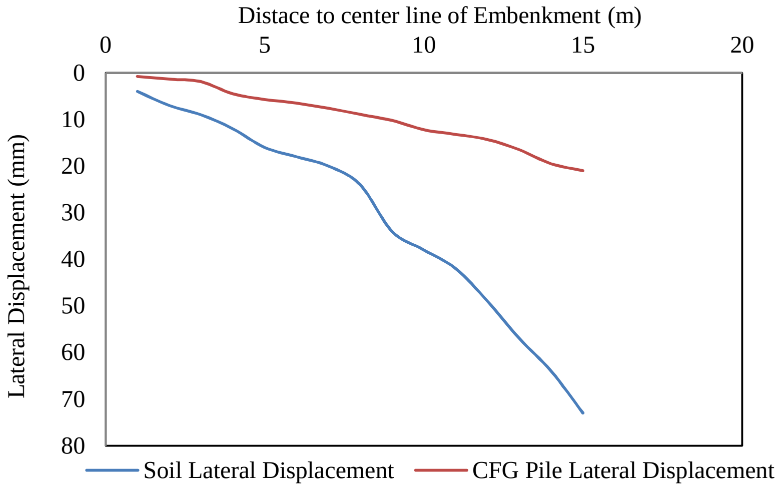

Fig. 5 Comparitive lateral dispalcement of soft soil and CFG pile under static load

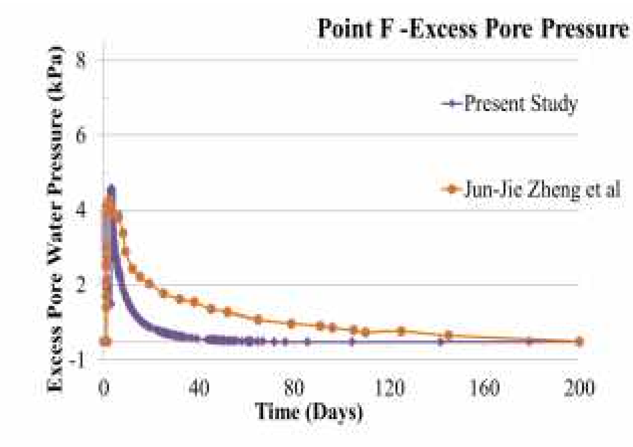

Fig. 6 Pore pressure behaviors with respect to time

The results are shown in Fig 6 which is described the pore water pressure of the embankment at center point of embankment pore water pressure analysis it is maximum during the 15 to 80 days effect. Soil has been consolidated than pore pressure has been decreasing.

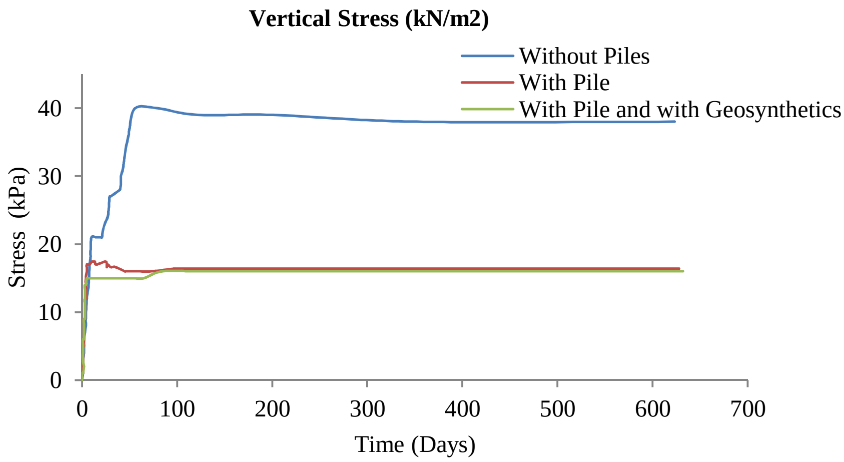

Fig. 7 Stress vs Time acting vertical stress center point of embankment

The Fig. 7 shows the stress at middle point of embankments with pile, without pile and with pile with single layers of geosynthetics obtained by numerical analysis under its embankment load only It is clearly observed that stress maximum in 70 days after construction than after it is became constant. When used CFG pile for ground improvement it has been significant decreeing the stress concentration. While the use one layer of Geosynthetics layer is also decreasing in the stress. The approximately stress concentration have been decreasing 38%.

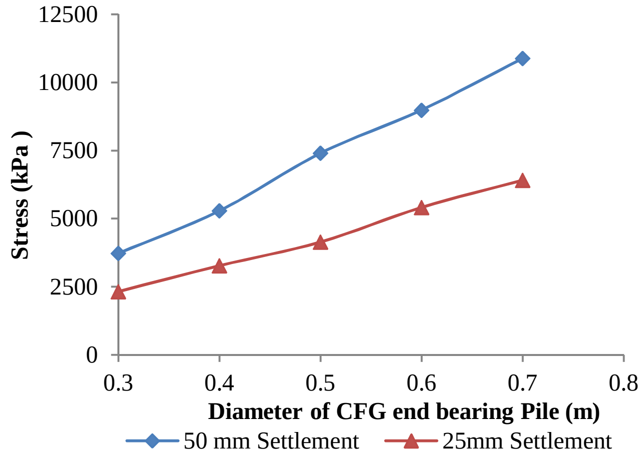

Fig. 8 Influence of Single CFG end bearing pile diameters on stress and vertical settlement

To better understand the behavior of CFG pile, using Plaxis 2D axis symmetrical model analysis for the variation of stress on top of the CFG pile is plotted in Fig. 9 with a various diameters and a constant length 10 m of end bearing CFG piles for a vertical settlement of 25 and 50 mm. in order to increase the diameters of CFG pile with effectively the percentage increase in stress is about 70. The corresponding increase in stress is about 70% at 25 mm settlement have the same percentage it can also be observed that the stress for the smaller diameter column is higher because of higher confining pressures (consequently higher stiffness) developed in the CFG pile.

Conclusion

1. As the soft soil subgrade was treated with CFG pile, the bearing capacity of composite foundation increased substantially, at the same time the settlement of embankment decreased significantly.
2. As per the results the effect of vertical stress obtain is less affected on embankment used with CFG pile.
3. The settlement of subgrade decreased and tended to stabilize as the ratio between length and diameter of pile increased, which also showed there existed in reasonable pile length with the same height of embankment.
4. When the necessity of bearing capacity single pile CFG pile is not high therefore the diameter of CFG pile is usually to select in composite foundation between 300mm and 500mm.
5. In CFG pile supported embankment sand cushion are significant effect to load distribute equally the settlement of subgrade was larger while the cushion in embankment has been not constructed. In case of constructed sand cushion settlement of subgrade have been decreasing as the increasing the thickness of cushion.

References

[1] J. Chai, Y. Lu, and T. Uchikoshi, “Behavior of an Embankment on Column–Slab Improved Clay Deposit,” *Int. J. Geosynth. Gr. Eng.*, vol. 4, no. 4, p. 0, 2018.

[2] G. Zheng, Y. Jiang, J. Han, and Y. F. Liu, “Performance of cement-fly ash-gravel pile-supported high-speed railway embankments over soft marine clay,” *Mar. Georesources Geotechnol.*, vol. 29, no. 2, pp. 145–161, 2011.

[3] Z. Lijie, Q. Wei, S. Shiwei, and L. Haibin, “Researching the Application of CFG Pile Treatment in Soft Foundation of Expressway,” no. Icismme, pp. 432–435, 2015.

[4] E. C. A. Fonseca, E. M. Palmeira, and M. V. Barrantes, “Load and Deformation Mechanisms in Geosynthetic-Reinforced Piled Embankments,” *Int. J. Geosynth. Gr. Eng.*, vol. 4, no. 4, p. 0, 2018.

[5] M. Hasan and N. K. Samadhiya, “Performance of geosynthetic-reinforced granular piles in soft clays: Model tests and numerical analysis,” *Comput. Geotech.*, vol. 87, pp. 178–187, 2017.