International Journal of Engineering Research
Volume No.5 Issue: Special 3, pp: 669-672
ISSN:2319-6890 (online),2347-5013(print)
27-28 Feb. 2016

Analysis of Embankment on Soft Soil improved with Stone Columns

Hans Raj, Associate Professor V. A. Sawant
Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee, India
Email: vhansraj16@gmail.com, sawntfce@iitr.ac.in

Abstract- Construction of embankment on soft soil is one of the biggest challenges faced by geotechnical engineers. Soft soil is being one of the most erratic soils with very low bearing capacity and high compressibility. Attempts have been made to study the phenomenon of soil structure interaction for embankment built on soft soil improved with stone columns through full scale models, laboratory models and various numerical simulations. However, full scale model studies may prove to be uneconomical in most cases of embankment construction except in case of highly funded projects. Hence experiments and numerical simulations using appropriate numerical method (FEM/FDM) is generally deployed to study such complex interaction behaviour. In the present study, it is aimed to carry out a detailed parametric study to critically examine the effects of various key parameters of soft soil and stone column considering linear behaviour.

Keywords Stone column, Finite difference Method, Pasternak shear layer, Spring-dashpot system

1. Introduction

When embankments have to be constructed on weak and compressible ground, columns of strong material like driven piles, vibro concrete columns, stone columns, and deep-mixed columns, can be installed in the soft ground to provide adequately support to the load. Often, a load transfer platform consisting of layers of compacted coarse-grained soil and geosynthetic reinforcement is used to help transfer loads from the overlying embankment, traffic, and/or structure to the columns. Advantages of column supported embankments include rapid construction, small deformations, and low impact on adjacent facilities, which could otherwise experience undesirable deformations due to the new embankment load. Potential disadvantages of column supported embankments include relatively high initial cost and uncertainties about design procedures. The columns are selected to be stiffer and stronger than the existing soil, and if properly designed, they can prevent excessive movement of the embankment. If accelerated construction is necessary, or if adjacent existing facilities need to be protected, then column-supported embankments may be an appropriate solution. The column-supported embankment technology has potential application at many soft-ground sites, including coastal areas where existing embankments are being widened and new embankments are being constructed. The cost of column-supported embankments depends on several design features, including the type, length, diameter, spacing, and arrangement of columns.

2. Statement of Problem

Figure 1 shows an embankment resting on the stone column improved soft soil. This system has four components as embankment, granular layer, soft soil and stone column. H_e is the height of embankment, H is the thickness of granular layer (0.3 to 1.0 m), D is the diameter of stone column (0.6 to 1.0 m) and s is the centre to centre spacing between stone columns (1.5 to 3.5 m). The spacing to diameter ratio (s/D) is kept 2 to 6.The system is idealized by a spring-dashpot model as shown in Figure 2. The soft soil is modelled by spring-dashpot system. The stone columns are idealized by layers of stiffer Winkler springs. The granular layer and embankment have been idealized by the Pasternak shear layer.A 2-D plane-strain condition has been considered for the domain. Stone columns and the surrounding soil are assumed to be settled vertically only. Soil arching effect is ignored as the thickness of the granular layer is assumed to be small. The immediate settlement of the soil has been ignored, as it has been assumed that immediate settlement is very small in comparison with the subsequent primary consolidation settlement of the soft soil. It has been further assumed that at the initial stage of loading (at t = 0) excess pore pressures in the surrounding soil carry all the contact stress at the interface of granular layer and saturated soft soil. The undrained elastic modulus of the saturated soil is theoretically infinite under a condition with full confinement. Material properties of the various parameters considered in the present study are reported in Table 1.

Table 1 Properties of structure

Symbol	Values	Unit
q_o	0 to 150	kN/m^2
H_e	5.0	m
A	7.0	m
γ	18.0	kN/m^3
H	0.5	m
G_o	652.4	kN/m^2
H_s	8.0	m
k_{so}	10000.0	kN/m^2
U	10 to 100	%
D	1.0	m
k_{co}	100000 to 500000	kN/m^2

3. Method of Solution

The governing differential equation within the soft soil and

ISSN:2319-6890)(online),2347-5013(print)
27-28 Feb. 2016

the stone column region can be expressed as equation (1) and (2) respectively.

$$q = \frac{k_{s0} w}{U\left(1 + k_{s0} w / q_u\right)} - GH \frac{\partial^2 w}{\partial x^2} \qquad (1)$$

$$q = k_{c0} w - \frac{\partial^2 w}{\partial x^2} \qquad (2)$$

A finite difference method has been employed to solve the governing differential equations. In the equation, the derivative has been expressed by a central difference scheme. The length L is divided into n number of elements with (n+1) number of node points (i=1 to n); thus, the mesh size (Δx) can be expressed as, $\Delta x = L/n$. Expressing the governing differential equation in a finite difference form, for an interior node (i, j) (where i and j are the indices for space and time, respectively). The solution of this problem has been found considering linear behaviour. For linear solution ,τ_u and q_u are assumed as ∞ which makes *G as* G_o and the governing equation becomes as

$$q = k\, w - G_0 H \frac{\partial^2 w}{\partial x^2} \qquad (3)$$

where $q = k_{s0}/U$ in soft soil region

and $k = k_{co}$ in stone column region.

Now, governing differential equation may be expressed as

$$q = k\, w_i - G_0 H \frac{w_{i-1} - 2w_i + w_{i+1}}{\Delta x^2} \qquad (4)$$

Let $\varepsilon = G_0 H / \Delta x^2$ (5)

Hence

$$q = -\varepsilon\, w_{i-1} + \left(k + 2\varepsilon\right) w_i - \varepsilon\, w_{i+1} \qquad (6)$$

Boundary Conditions

As the problem is symmetric, only half the system is considered for the analysis. Thus, at the center of the loaded region, due to symmetry, the slope $\frac{\partial w}{\partial x}$ will be zero. The length of the granular layer considered in the analysis is sufficient enough so that at the edge, the slope of the settlement-distance curve is zero. The continuity at the edge of the stone columns is automatically satisfied.

4. Results and Discussions

A computer program based on the above formulation has been developed and solutions are obtained. Parametric studies have been carried out to show the effect of various parameters on the settlement response

Effect of degree of Consolidation on settlement profile is reported in Fig. 3 for the case of embankment without stone column. It is observed that maximum settlement is increasing with degree of consolidation. Effect of stone column stiffness on settlement profile is reported in Fig. 4 for the case of embankment with stone column. It is observed that maximum settlement is increasing with degree of consolidation. Though maximum settlement is not affected much, settlements are reduced at stone column. With increase in stone column stiffness, settlements are reducing as reported in Fig. 5.

Effect of surcharge on settlement profile is reported in Fig. 6 for the case of embankment with stone column. It is observed that maximum settlement is increasing with increase in surcharge. Effect of degree of consolidation on settlement profile is reported in Fig. 7 for the case of embankment with stone column. It is observed that maximum settlement is increasing with degree of consolidation.

Effect of degree of consolidation on maximum settlement is summarized in Fig. 8. As expected, maximum settlement is increasing with increase in degree of consolidation.

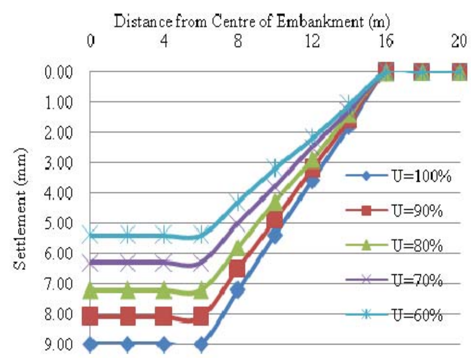

Figure 3 Settlement Profile for Varying Values of Degree of Consolidation (without Stone Column)

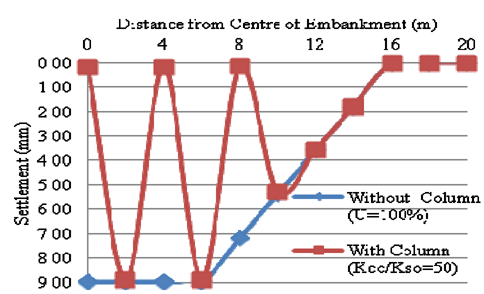

Figure4. Settlement Profile with and without Stone Column

doi : 10.17950/ijer/v5i3/032

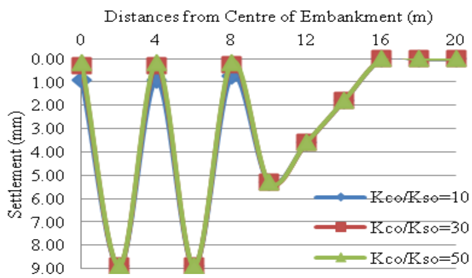

Figure5. Settlement Profile for Varying Values of Initial Modulus of Subgrade Reaction of Stone Column

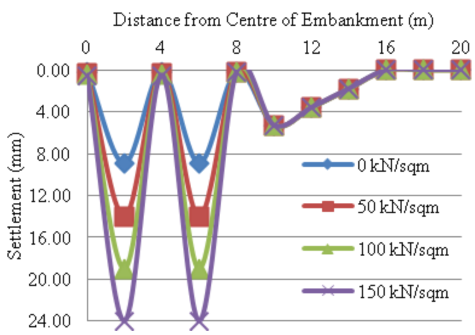

Figure6. Settlement Profile for Varying Values of Surcharge (with Stone Column)

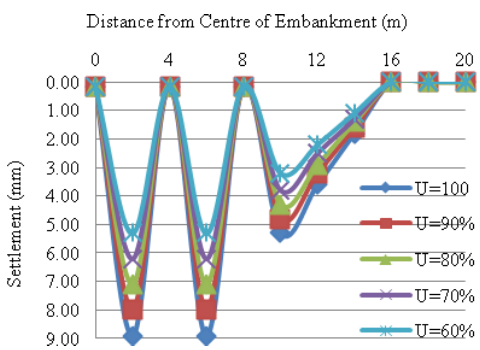

Figure7. Settlement Profile for Varying Values of Degree of Consolidation (with Stone Column)

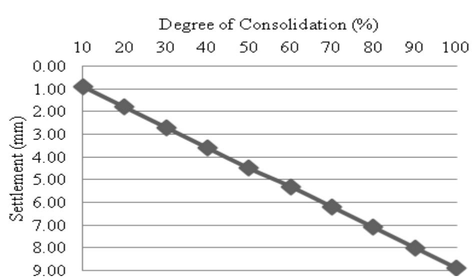

Figure8. Maximum Settlement Profile for Varying Values of Degree of Consolidation (with Stone Column)

5. Conclusion

1. It is observed that maximum settlement is increasing with increase in degree of consolidation.
2. It is observed that settlement is decreasing at stone column region.
3. It is observed that settlement is decreasing with increase in stone column stiffness.
4. It is also observed that maximum settlement is increasing with increase in surcharge.

Acknowledgement

First author wants to keep on record his sincere thanks to Irrigation Department of Uttar Pradesh for kindly sponsoring him to undertake the present study..

REFERENCES

i. *A. P. Ambily, S. R. Gandhi. Behavior of stone columns based on experimental and FEM analysis, Journal of Geotechnical and Geo-environmental Engineering, Vol. 133, No.4, 405-415, 2004.*

ii. *C. Ghosh, M. R. Madhav. Settlement response of a reinforced shallow earth bed, Geotextiles and Geomembranes, Vol. 13, No.10, 643-656, 1994.*

iii. *K. Deb. Modeling of granular bed-stone column-improved soft soil, International journal for numerical and analytical methods in geomechanics, Vol. 32, No.10, 1267-1288, 2008.*

iv. *K. Deb, A. Dhar. Optimum design of stone column-improved soft soil using multiobjective optimization technique, Computers and Geotechnics, vol. 38, No.1, 50-57, 2011.*

v. *K. Deb, A. Dhar. Parameter Estimation for a System of Beams Resting on Stone Column–Reinforced Soft Soil, International Journal of Geomechanics, Vol. 13, No.3, 222-233, 2011.*

vi. *K. Deb, N. K. Samadhiya, J. B. Namdeo. Laboratory model studies on unreinforced and geogrid-reinforced sand bed over stone column-improved soft clay, Geotextiles and Geomembranes, Vol. 29, No.2, 190-196, 2011.*

vii. *M. D. Babu, S. Nayak, R. Shivashankar. A critical review of construction, analysis and behaviour of stone columns, Geotechnical and Geological Engineering, Vol. 31, No.1, 1-22, 2013.*

viii. *P. Maheshwari, S. Khatri. A nonlinear model for footings on granular bed–stone column reinforced earth beds, Applied Mathematical Modelling, Vol. 35, No.6, 2790-2804, 2011.*

ix. *M. Alamgir, N. Miura, H. B. Poorooshasb, M. R. Madhav. Deformation analysis of soft ground reinforced by columnar inclusions. Computers and Geotechnics, Vol. 18, No. 4, 267-290, 1996.*

x. *C. Giannaros, G. Tsiambaos. Stabilization of embankment foundations by using stone columns. Geotechnical & Geological Engineering, Vol. 15, No. 3, 247-258, 1997.*

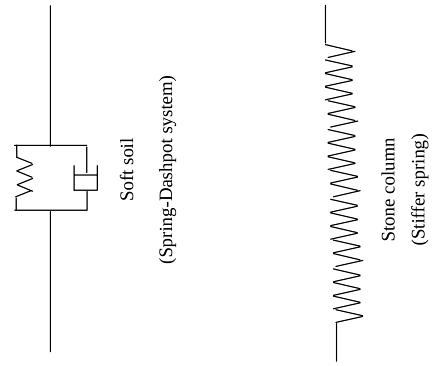

Figure1. Embankment Resting on the Stone Column Improved Soft Soil

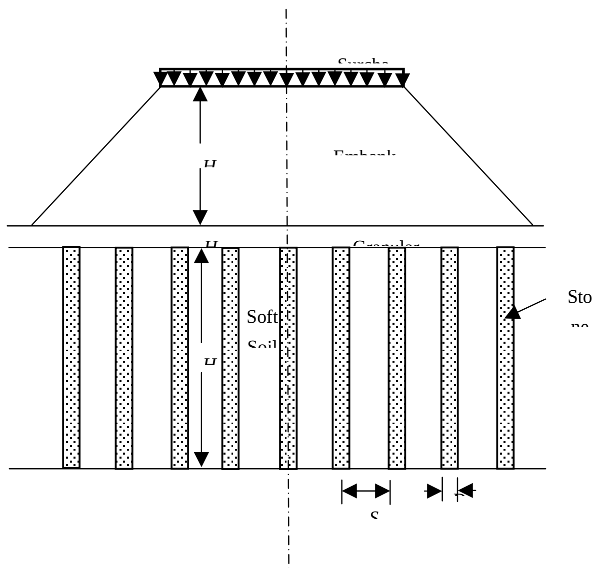

Figure2. Spring -Dashpot Idealization of Soft Soil and Stone Column