Scientific Journal Impact Factor (SJIF): 1.711

e-ISSN: 2349-9745
p-ISSN: 2393-8161

International Journal of Modern Trends in Engineering and Research
www.ijmter.com

IMPROVED FOUNDATION SYSTEM ON MARINE CLAY USING GEOFOAM

Daigavane P.B.[1], Jain K.[2],
[1] Associate Professor, Dept. of Civil Engineering, Govt. College of Engg & Research, Avasari (Pune),
[2] Research Scholar, Dept. of Civil Engineering, Govt. College of Engg Amravati,

Abstract- It is becoming a great challenge for the civil engineers to design suitable foundation for the structures on marine clay. The paper presents an innovative design for construction of foundation on marine clay soils. In this process geofoam, Expanded Polystyrene (EPS) is placed below foundation. Geofoam properties like lightweight, high strength give best option as fill for poor quality of soil. The various combinations of sizes and density of geofoam under footing, for reduction of settlement are studied. A numerical finite element analysis program, PLAXIS, was used to simulate the problem. The decrease in settlement under the footing and the increase in bearing stresses were compared to those without EPS. Load settlement relationship was studied. Results concluded that use of Geofoam (EPS) decreases the settlement and increases the footing load. EPS thickness appeared to be an important factor in improving footing behavior on marine clay, compared with density of geofoam (EPS)

Keywords- Marine Clay; Geofoam; Expanded Polystyrene; EPS; PLAXIS

I. INTRODUCTION

Marine clay is a type of clay found in coastal regions around the world. Marine clay has the potential to destroy foundations in only a few years. Clay particles can self-assemble into various configurations, each with totally different properties. It is becoming a great challenge for the civil engineers to design suitable foundation for the structures in these regions. These problems posed by marine clay can be handled by various ground improvement techniques.

In present study the Geofoam, Expanded Polystyrene (EPS), as a lightweight material, was use as replacement material of marine clay underlain a footing/foundation in order to decrease the settlement and to increase the footing stress as the geofoam layer redistribute the footing stress over the marine clay layer

Comprehensive finite-element analysis, for different thicknesses of Geofoam EPS and a constant footing dimensions where the footing underlay foam are represented in the mesh are adopted here using the nonlinear elasto-plastic finite element program PLAXIS. The program is plane strain, Finite Element Program for soil modeling. The soil is modeled using 6 noded triangular elements. The soil model is Mohr-Columb method with nonlinear failure envelope

The analytical models showed that EPS decreases the settlement under the footing as a replacement layer for marine clay which allows the designer to increase the stress load. Also the results showed that the EPS layer thickness compared to footing thickness has great effect on analysis

II. MATERIALS AND METHODS

A. Marine Clay Soil

Marine clay soil was collected and laboratory tests were carried out, and has been widely used both in fundamental studies of soil behavior and in analytical model. The physical properties of marine clay were determined. It has a liquid limit (WL) of 78.0 %, plastic limit (WP) of 34 %, plasticity index (PI) of 44 %, dry density (γd) of 9.30kN/m3, wet density (γ) =15.12kN/m3, and specific gravity (Gs) of 2.6. Young's Modulus (E) of 2.52E+03kN/m2.
Detail of soil properties used for modeling as per table 1.

B. Footing Properties and Dimensions

Square footing of 2.0m x 2.0m is use for modeling with fixed thickness 145mm. Density of Concrete is 24.0kN/m3 and Modulus Elasticity is 2.0E+07kN/m2

Table 1, Soil properties for Plaxis

Material Model	Mohr-Coulomb
Density (Unsat) (kN/m3)	12.12
Density (Sat) (kN/m3)	15.12
Young's modulus (kN/m2)	2.52E+03
Poisson's ratio	0.45
Cohesion (kN/m2)	5.1
Friction Angle, (Deg)	4.66

C. Geofoam (EPS) Properties and Dimension

Expanded Polystyrene, EPS, geofoam is a super-lightweight, closed cell, rigid, plastic foam. Its unit weight puts it in a separate category compared to other types of engineering lightweight materials. Its density is about a hundredth of that of soil. It has good thermal insulation properties with stiffness and compression strength comparable to medium clay. Material prices vary depending on the density of EPS as well as the job size and location. EPS density appears to be the main parameter that correlates with most of its mechanical properties. Compression strength, shear strength, tension strength, flexural strength, stiffness, creep behaviour and other mechanical properties depend on the density. Non – mechanical properties like insulation coefficients are also density dependent. EPS densities for practical civil engineering applications range between 0.15kN/m3 to 0.30 kN/m3

Table-2 shows compression strength of geofoam at 1% of strain, i.e. geofoam is in elastic limit. Fig.1 shows stress strain behavior of geofoam. This is useful in final result

Table 2, Mechanical Properties of Geofoam as per ASTM D6817-02. (7)

Type	EPS19	EPS22	EPS29
Density min. (kN/m3)	0.19	0.22	0.29
Compressive Resistance min. at 1% (kPa)	40	50	75
Flexural Strength, min (kPa)	207	276	345

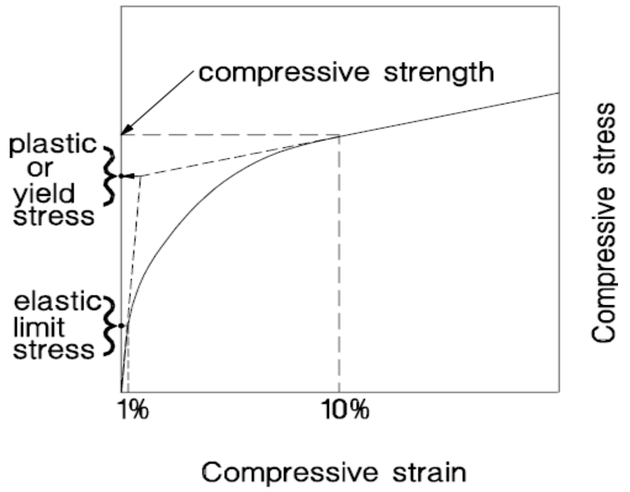

Fig. 1: Stress & strain curves for EPS (5)

The material properties of EPS Geofoam used in the finite element analysis are given in Table 3. The value of Poisson's ratio (υ) of EPS Geofoam is calculated by using Equation 2 given by EDO (1992).

$$\upsilon = 0.0056\,\rho + 0.0024 \qquad (2)$$

Where ρ = Density of EPS Geofoam (kg/m3)

Densities of Geofoam use are 0.20 kN/m3, 0.22 kN/m3 & 0.30 kN/m3. Various ratio of thickness of Geofoam to thickness of footing are 2, 3, 4 & 5. Mohr-Coulomb material model used & Non-porous behaviour used in modelling. Geofoam which have different thicknesses, density and constant footing dimensions

Table 3, Geofoam properties for Plaxis (1)

Density of Geofoam (kN/m3)	0.2	0.22	0.3
Young's Modulus (kN/m2)	4000	5500	7800
Poisson's Ratio	0.12	0.125	0.17
Cohesion (kN/m2)	38.75	41.88	62
Friction Angle (Deg)	2	2	2.5

III. FINITE ELEMENT ANALYSIS

Finite element analysis of grade footing with and without EPS Geofoam under loading condition was carried out using PLAXIS 2D professional finite element software. The nodes on left & right vertical boundary were not allowed to displace horizontally (horizontal fixity) but allowed to undergo vertical displacement whereas all the displacement of the nodes at the bottom surface was arrested (total fixity). A typical geometry model of EPS Geofoam & grade footing under loading condition is shown in Fig. 2. The material EPS Geofoam was modelled as Mohr-Coulomb model with 15 node triangular elements was considered. 100kN/m2 typical loading is applied on footing. Geofoam properties for modelling are as per table 3. Various combinations of sizes and density of geofoam under footing are considered. Various ratios of thicknesses of geofoam to thickness of foundation & density are considered as for analysis these are shown in table 4.

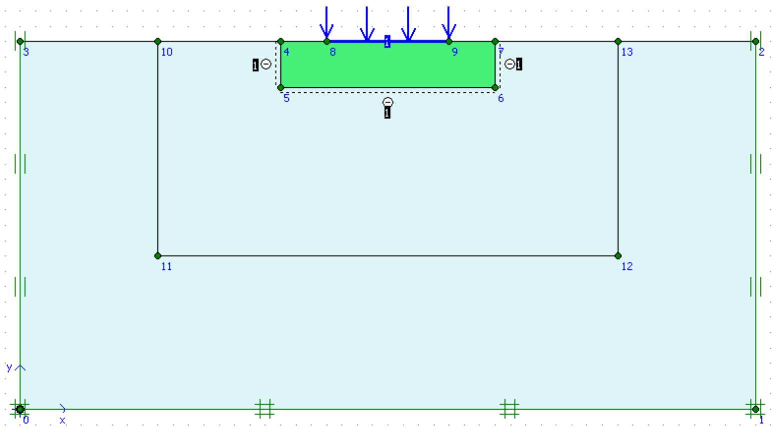

Fig. 2: Typical analytical model of footing on Marine clay with Geofoam (EPS)

Based on table 4, various models was prepared and reviewed.

Table 4 Geofoam (EPS) combination for Plaxis

Case	Density of Geofoam (kN/m3)	Thickness of Geofoam (mm)
Case1	Without Geofoam	-
Case2	0.20, 0.22, 0.30	300
Case3		450
Case4		600
Case5		750

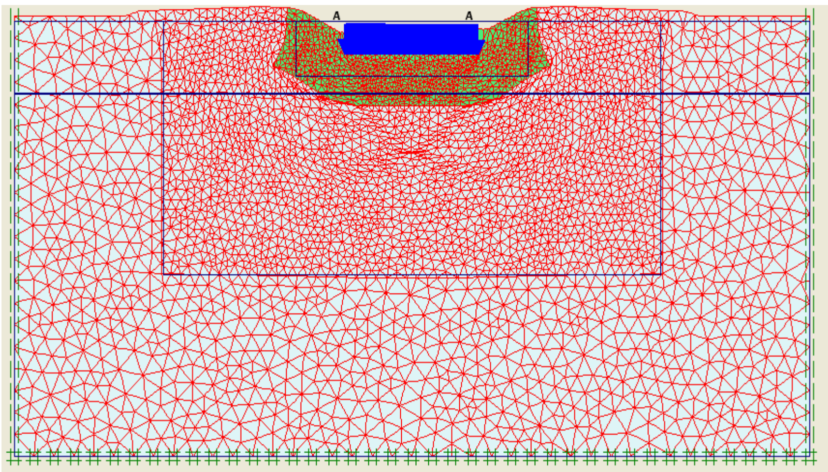

Fig. 3: Typical Deformed shape for Marine clay with Geofoam (EPS)

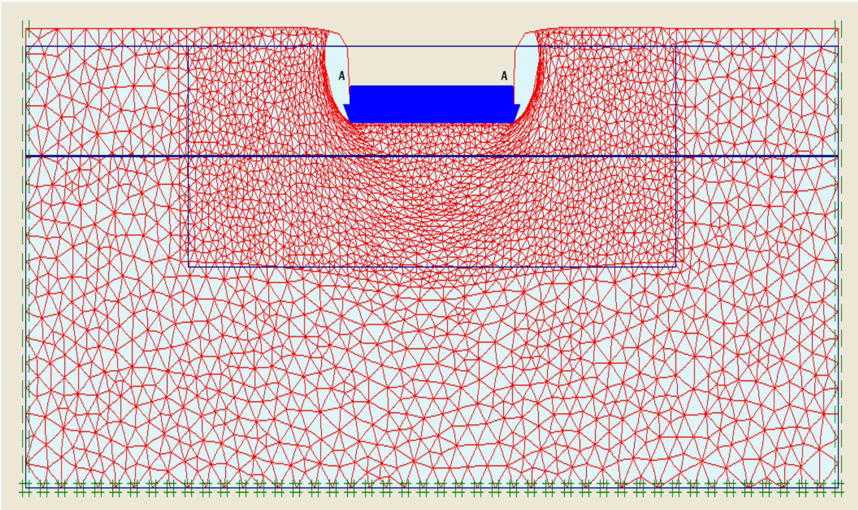

Fig. 4: Typical Deformed shape for Marine clay without Geofoam (EPS)

IV. RESULTS AND DISCUSSIONS

Fig. 5 shows load settlement curve for constant density of geofoam with different thickness of geofoam & footing without geofoam. Load capacity without geofoam is 30kN/m2 and it will increase with addition of geofoam from 30kN/m2 to 54kN/m2.

Fig. 6 shows load settlement curve for various densities of geofoam and constant geofoam thickness. It shows that there is minor change on load capacity.

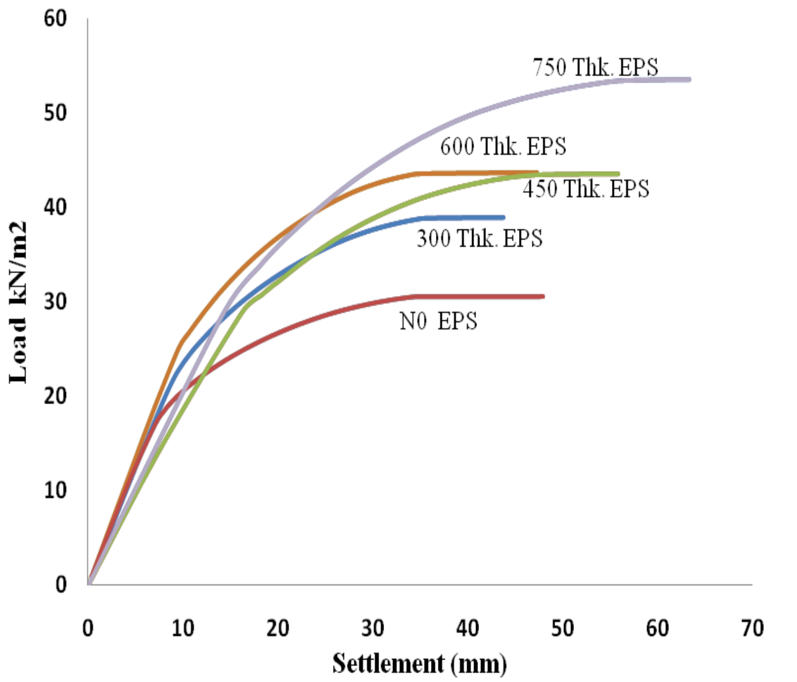

Fig. 5: Typical Load Settlement curves for Marine clay with and without Geofoam (EPS)

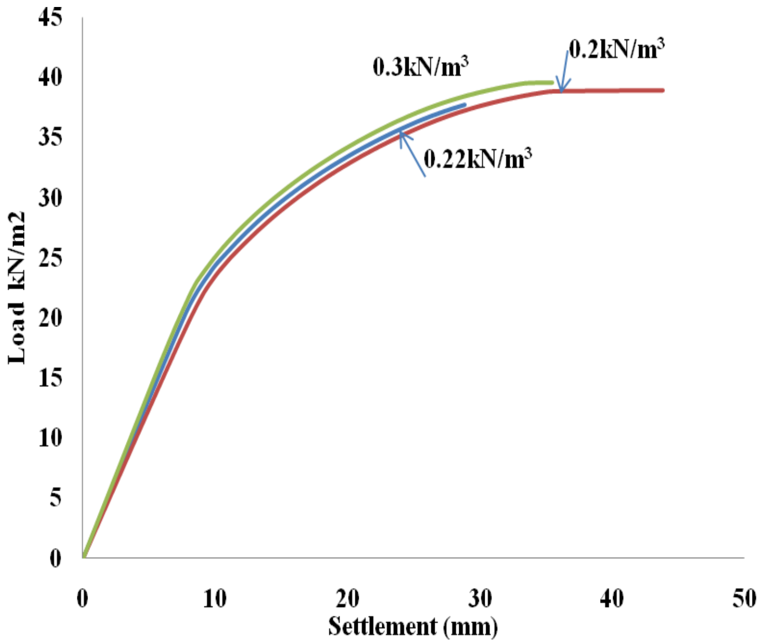

Fig. 6: Typical Load Settlement curves for Marine clay with constant thickness of Geofoam (EPS) & various densities

V. CONCLUSIONS

Finite element simulation has been carried out on footing with expanded polystyrene (EPS) geofoam under uniform loading condition. From the study following conclusions can be drawn

1. Load carrying capacity of system with geofoam is higher than without geofoam
2. There is definite reduction in settlement with use of geofoam
3. Effect of higher density of geofoam is less as compared to thickness of geofoam

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ACKNOWLEDGEMENT

The authors wish to acknowledge, The Director of Technical Education, Mumbai, (M.S.). The Principal Govt. College of Engineering Amravati and Professor S.V. Joshi, Principal, Government College of Engineering & Research Avasari, Pune for their valuable guidance, support and encouragement to write this paper.