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Reduction of Lateral Earth Pressure on Piled Retaining wall Using Geofoam Inclusion

S. A. Belsare[1], Dr. A. I. Dhatrak[2], Prof. S. W. Thakare[3]

[1]*P.G. Student, Department of Civil Engineering, Government College of Engineering, Amravati, India,*
[2]*Dean of Academics, Department of Civil Engineering, Government College of Engineering, Amravati, India,*
[3]*Associate Professor, Department of Civil Engineering, Government College of Engineering, Amravati, India,*

Abstract*— A pile retaining wall structures are to support deep excavation, cuts in slopes and sliding slopes. The piled wall has other applications in addition to support the excavation, such as use as part of the permanent work or foundation. Especially in urban areas, it can be used to reduce the need for a separate foundation by carrying all or portion of the superstructure loads. Geofoam has been used as a geotechnical highly compressible and lightweight alternative material. The weight is less than 1% of natural soils. Several infrastructure projects require the use of large retaining walls with free heights. The classical backfill behind such walls typically consists of heavy compacted soils, which add more loads and lead to increased wall dimensions. In the present study the geofoam compressible inclusion in reducing static earth pressure on piled retaining wall is studied using finite element code PLAXIS 2D. The magnitude and distribution of earth pressure on piled retaining wall with and without geofoam is evaluated. The results indicate that the lateral earth pressure on piled retaining wall can be reduced by using geofoam inclusion. The optimum size and density of geofoam have been determined for piled retaining wall.

Keywords— ***piled retaining wall, optimum size of geofoam, density of geofoam, lateral earth pressure, PLAXIS 2D***

I. INTRODUCTION

For designing and restraining soil to unnatural slopes retaining wall are used. Retaining structures are necessary for various projects such as railways, bridges, highways, and underground structure and to support soil on one of its sides. Retaining structure should be able to withstand pressure due to movement of vehicular traffic, manmade and natural dynamic events and loads from foundations of adjacent building on their backfill. For construction of embankments or foundation walls excavation is always needed, which can disturbs the stability of the soil, so a structure should withstand lateral earth pressures. Retaining walls are helpful for providing safety to many major geotechnical structures that is why geotechnical engineers have more concern about the safety of retaining structure. Pile retaining wall are frequently used when limited space is an issue, or when the soil relatively soft. Although the walls are narrower than other choices, they are inserted much deeper into the soil to allow them to withstand the heavy loads.
The retaining structure become too costly if lateral earth pressure acting on the retaining wall is more. It is very essential to reduce lateral earth pressure for reducing sectional dimensions of earth retaining structure and the cost of project. There are many techniques available to reduce the earth pressure, such as use of tyre chips, Glass fibres, hay, card. Geofoam is a lower-cost alternative to use EPS blocks on projects, where only a modest reduction in lateral earth pressures is desired or cost effective.

II. LITERATURE REVIEW

The reduction of lateral earth pressure on retaining wall had been studied. Experimental and numerical study performed by various authors is briefly explained as follows.

Ozgur L. Ertugrul[1] (2011) had conducted experimental study on reduction of lateral earth forces acting on rigid retaining walls by EPS geofoam inclusions. For rigid non-yielding retaining wall EPS geofoam panels of three different thicknesses (characterized by a t/H ratio of 0.07, 0.14, and 0.28, in which t = geofoam thickness and H = wall height) were installed behind retaining wall. When the no buffer case compared with an inclusion of t/h = 0.14, It was found that the reduction exceeded 50% in the lateral pressure.

Azzam[2] (2015) had conducted numerical analysis on reduce lateral earth pressure on rigid walls using EPS Geofoam in PLAXIS 2D software. The analysis was initially carried out without geofoam inclusion then analysis carried out after adding geofoam inclusion with different thicknesses ranging from 5 cm to 50 cm. Then horizontal earth pressure on the rigid wall was determined. It was found that the reduction in lateral earth pressure can be reduced to more than 50 %.

W. R. Azzam[3] (2017), had conducted the experiment and numerical analysis on axially loaded - piled retaining wall in sandy soil. It had been found that as the penetration depth ratio increased, the ultimate capacity of the piled wall also increased. An increase in the piled wall penetration depth and pile diameter reduced the horizontal wall movement and increased the axial piled wall capacity. It was found that an increase in penetration depth led to decrease in the horizontal displacement of the piled wall for all sand densities.

P. A. Yadav[4] (2018) had conducted numerical analysis on static and seismic condition with inclusion of geofoam on retaining wall in using Plaxis 2D software. The thickness of geofoam was considered as 0.5 m, 1.0 m, 1.5 m and 2 m. It was found that as thickness of geofoam increased, the reduction in lateral earth pressure increased.

III. METHODOLOGY

The main objective of the research was to investigate the reduction of lateral earth pressure on piled retaining wall using geofoam inclusion in PLAXIS 2D. The various parameters those were considered for analysis are various thickness and density of geofoam. The analyses were carried out for two cases viz., when geofoam upto pile bottom and upto ground level. Fig. 1 shows the Problem Structure for the Present Study.

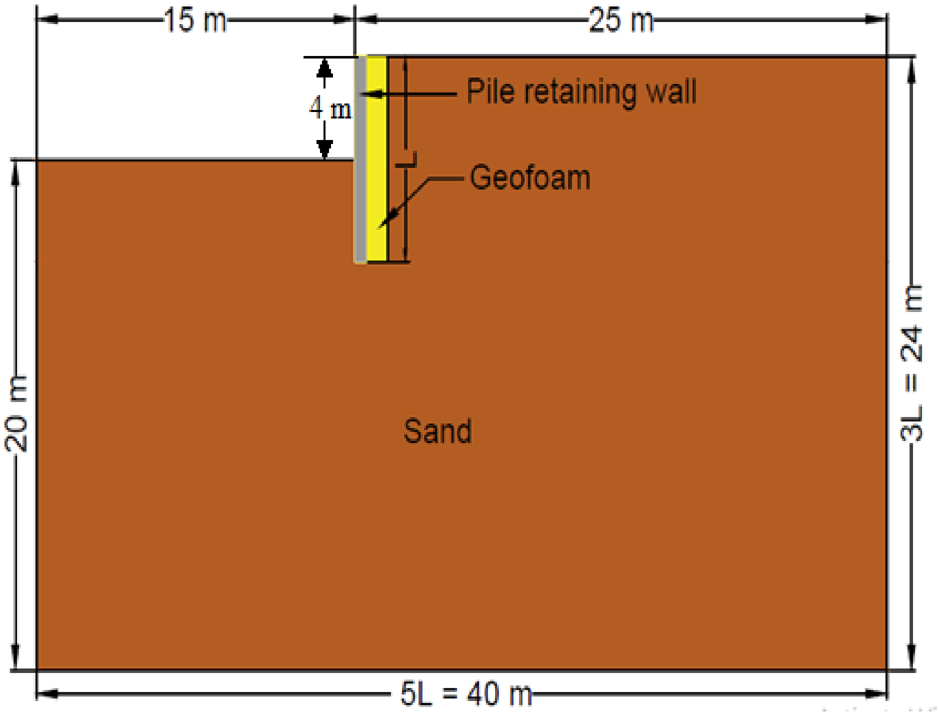

Fig.1: Problem structure for the present study

The material properties selected for the analysis are shown in Table 1 to 3.

TABLE I
PROPERTIES ASSIGNED TO SOIL BED

Parameters	**Notation**	**Value**	**Unit**
Material model	-	Mohr-Coulomb	-
Type of material behavior	-	Drained	-
Unsaturated Unit weight	γ_{unsat}	16.50	kN/m^3
Saturated Unit weight	γ_{sat}	19	kN/m^3
Young's modulus	E'	40000	kN/m^2
Cohesion	c_{ref}	1	kN/m^2
Friction angle	Φ	32	^{0}
Dilatancy angle	ψ	2	^{0}
Poisson's ratio	μ	0.3	-
Interface factor	R_{int}	1	-

TABLE II
PROPERTIES OF GEOFOAM

Parameters	**Notation**	**Value**				**Unit**
Material model	-	Mohr-Coulomb				-
Type of material behaviour	-	Drained				-
Unsaturated Unit weight	γ_{unsat}	0.15	0.20	0.22	0.30	kN/m^3
Saturated Unit weight	γ_{sat}	0.15	0.20	0.22	0.30	kN/m^3
Young's modulus	E'	2400	4000	5000	6000	kN/m^2
Cohesion	c_{ref}	30	36	40	60	kN/m^2
Friction angle	Φ	3	4	4.5	6	0
Poisson's ratio	μ	0.086	0.114	0.170	0.190	-
Interface factor	R_{int}	1	1	1	1	-

TABLE III
PROPERTIES OF PILE RETAINING WALL

Parameters	**Notation**	**Value**	**Unit**
Young's modulus	E	30 x 10^6	kN/m^2
Unit weight	γ	25	kN/m^3
Diameter	D	0.50	m
Area	A	0.39	m^2
Moment of inertia	I	5.33 x 10^{-3}	m^4
Axial stiffness	EA	12 x 10^6	kN/m
Flexural Stiffness	EI	16 x 10^4	kNm^2/m
Poisson's ratio	μ	0.20	-
Weight per area	w	10	kN/m/m

Numerical model of piled retaining wall using geofoam inclusion was developed in PLAXIS 2D as shown in Fig. 2. The dimension of the soil model were; depth = 3L and width = 5L. From the analysis carried out, lateral earth pressure intensity along pile length for each of the case was determined and total earth pressure was calculated. The effect of selected parameter on total earth pressure was studied.

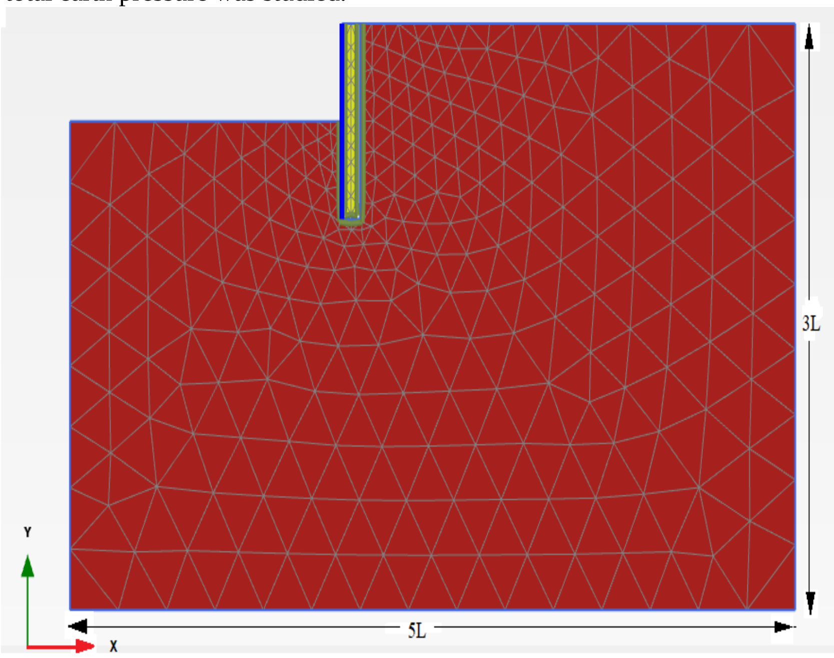

Fig.2: Numerical model developed in PLAXIS 2D

Table 4 and 5 shows the details of constant parameters and varying parameter.

TABLE IV
DETAILS OF CONSTANT PARAMETER

Sr. No.	Parameters	Values
1	Diameter of pile (m)	0.5
2	Length of pile (m)	8

TABLE V
DETAILS OF PARAMETER STUDIED

Sr. No.	Parameter	Range selected
1	Provision of geofoam from top of pile	i) Upto the pile bottom ii) Upto ground level
2	Density of geofoam (kg/m^3)	15, 20, 22, 30
3	Thickness of geofoam (m)	0.5 , 1.0, 1.5, 2.0

IV. PERFORAMANCE ANALYSIS

PLAXIS-2D software, which works on the finite element method approach, was used for analyzing the reduction of lateral earth pressure on piled retaining wall using geofoam inclusion. The length and diameter was constant throughout the analysis. Initially, the analysis was carried out for without geofoam condition and lateral earth pressure on pile retaining wall is determined. Then geofoam was provided upto pile toe and upto ground level. For various thickness and density of geofaom lateral earth pressure on pile retaining wall was performed.

A. Performance of pile retaining wall provided with geofoam upto pile bottom

Initially the analysis was carried out for pile retaining wall by inclusion of geofoam upto the pile bottom. The variation of earth pressure intensity along pile retaining wall with geofoam inclusion for various thicknesses and densities of geofoam are determined and then total earth pressure on piled retaining wall for each thickness and density of geofoam. Total earth pressures on pile retaining wall for various thickness and densities of geofoam are tabulated in Table 6.

TABLE VI
TOTAL EARTH PRESSURES

Sr no.	Thickness of geofoam (m)	Total earth pressure (kN/m)			
		Density of geofoam (kg/m^3)			
		15	20	22	30
1	0	211.45			
2	0.5	126.35	153.07	162.33	173.12
3	1.0	117.79	144.15	153.07	162.47
4	1.5	107.90	121.53	134.01	149.39
5	2.0	98.40	112.57	123.04	137.22

Fig. 3 shows the variation of total pressure acting on pile retaining wall with respect to thickness of geofoam for various densities and the variation of total pressure acting on pile retaining wall with respect to densities of geofoam for various thickness of geofoam is shown in Fig. 4.

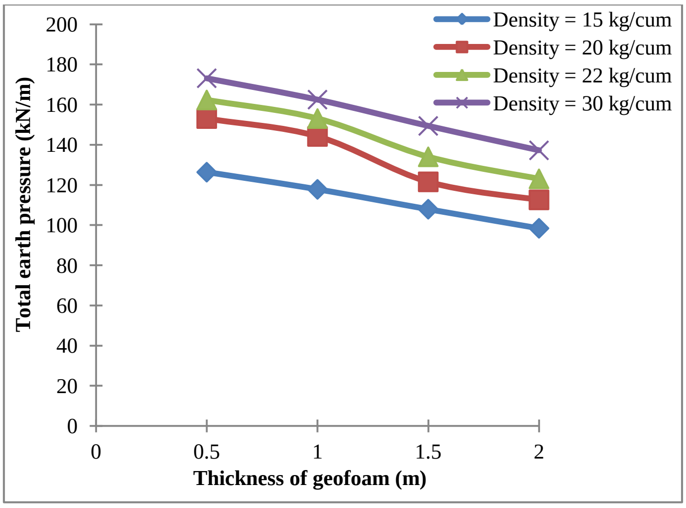

Fig.3: Variation total earth pressure acting on pile retaining wall with respect to thickness of geofoam

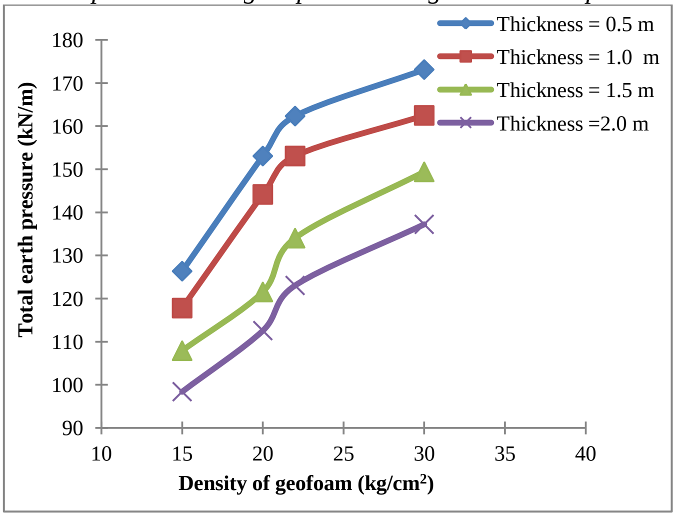

Fig.4: Variation total earth pressure acting on pile retaining wall with respect to densities of geofoam

B. Performance of pile retaining wall provided with geofoam upto ground level

Initially the analysis was carried out for pile retaining wall by inclusion of geofoam upto the ground level. The variation of earth pressure intensity along pile retaining wall with geofoam inclusion for various thicknesses and densities of geofoam are determined and then total earth pressure on piled retaining wall for each thickness and density of geofoam. Total earth pressures on pile retaining wall for various thickness and densities of geofoam are tabulated in Table 7.

TABLE VII
TOTAL EARTH PRESSURES

Sr no.	**Thickness of geofoam (m)**	**Total earth pressure (kN/m)**			
		Density of geofoam (kg/m^3)			
		15	**20**	**22**	**30**
1	0	211.45			
2	0.5	170.75	178	180.42	184.46
3	1.0	168.90	175.80	177.58	181.84
4	1.5	162.39	166.61	174.22	178.73
5	2.0	155.82	160.71	163.95	175.73

Fig. 5 shows the variation of total pressure acting on pile retaining wall with respect to thickness of geofoam for various densities and the variation of total pressure acting on pile retaining wall with respect to densities of geofoam for various thickness of geofoam is shown in Fig.6.

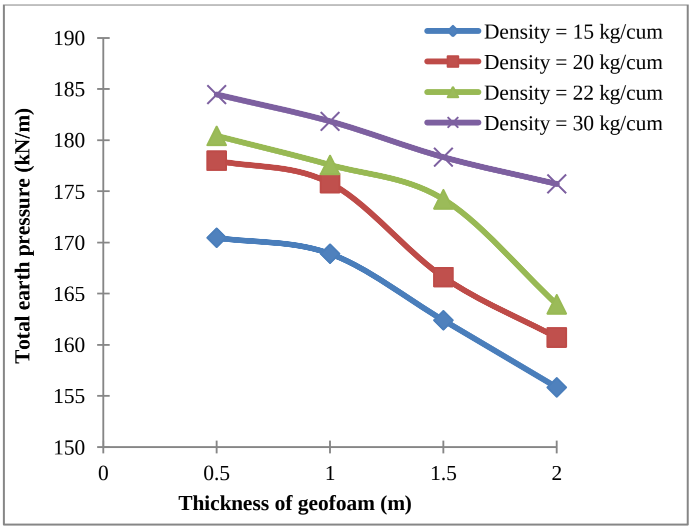

Fig.5: Variation total earth pressure acting on pile retaining wall with respect to thickness of geofoam

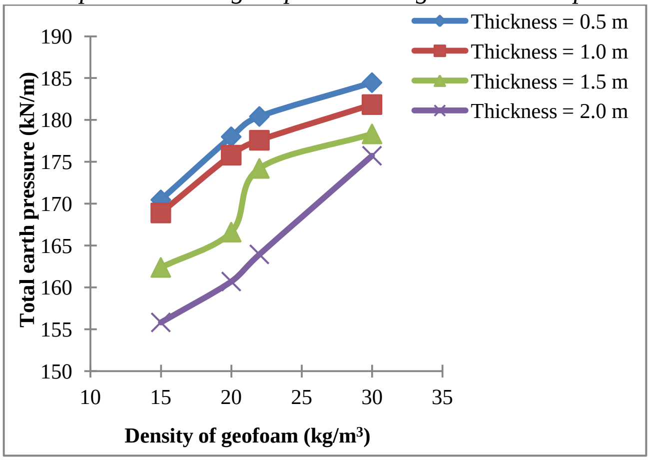

Fig.6: Variation total earth pressure acting on pile retaining wall with respect to densities of geofoam

V. DISCUSSION OF RESULTS

The potential finding from the the present work are discussed in this section. The analyses were performed on piled retaining wall using grofoam upto pile bottom. The percentage reduction of total earth pressure on pile retaining wall for various thickness and densities of geofoam is shown in Fig. 7.

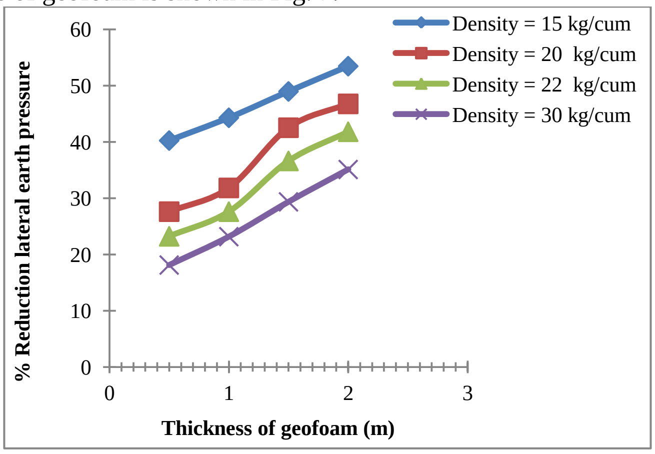

Fig.7: Percentage of reduction in total earth pressure due to geofoam inclusion for various densities and thickness of geofoam (geofoam upto pile toe)

From the analysis it is observed that the percentage reduction in lateral earth pressure is higher (53.46 %) in case of 15 kg/cum density and 2 m thickness of geofoam.

The analysis was performed on piled retaining wall using grofoam upto ground level. The percentage reduction of total earth pressure on pile retaining wall for various thickness and densities of geofoam is shown in Fig. 8

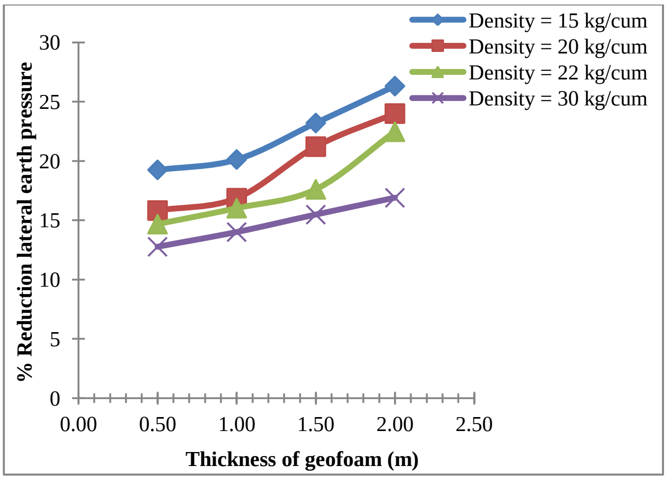

Fig.8: Percentage of reduction in total earth pressure due to geofoam inclusion for various densities and thickness of geofoam (geofoam upto ground level)

It is observed that the percentage reduction in lateral earth pressure is inversely proportional to the density of geofoam. From the analysis it is observed that the percentage reduction in lateral earth pressure is higher (26.31 %) in case of 15 kg/cum density and 2 m thickness of geofoam.

VI. CONCLUSIONS

Based on the results of present study, following broad conclusions are drawn:

1. The percentage reduction in lateral earth pressure is higher when geofoam is provided upto pile toe as compare to geofoam upto ground level.
2. The percentage reduction in of lateral earth pressure is higher for geofoam of 15 Kg/cum density as compared to other densities.
3. As the thickness of geofoam increases the reduction in lateral pressure on retaining wall increases.
4. When the geofoam is provided upto pile toe, reduction in the lateral earth pressure on retaining wall varies from 18.13% to 53.46 %.
5. When the geofoam is provided upto ground level, reduction in the lateral earth pressure on retaining wall varies from 12.76 % to 26.31 %.

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