Numerical Analysis of L-shaped Retaining Wall with Compressible Expanded Polystrene Under Static and Dynamic Condition

Mrs. Pooja Y E[1], Dr.L.Govindaraju[2], Miss. Poornima D[3], Mrs. Yajnodbhavi H M[4]

[1,3,4]*Assistant Professor, Department of civil Engineering, PESITM, Shivamogga, Karnataka, India*
[2]*Associate Professor, Department of civil Engineering, UVCE, Banglore, Karnataka, India*

Abstract - *A numerical model of L-shaped retaining wall is developed using the finite element Plaxis programme to study the effect of Expanded Polystrene(EPS) on the displacement of L-shaped retaining wall due to lateral earth pressure under static and dynamic loading condition. From the analysis it is observed that the greater lateral earth pressure can be reduced when Retaining wall is provided with EPS.*

***Key Words*: Numerical model, Plaxis program, Retaining Wall, Expanded polystrene(EPS), Lateral Earth Pressure.**

1. INTRODUCTION

Earth retaining structures constitute an important component of many civil engineering works. These structures may be of a number of types (e.g. reinforced concrete retaining walls -gravity or cantilevered, bridge abutments or basement walls) and they are designed to safely resist the lateral pressures exerted by earth masses.

In earthquake prone areas an earth retaining structure must be designed to be able to withstand the seismic earth pressures in addition to the static ones. The provisions of current seismic codes for estimating the earth thrust due to the design earthquake are based mainly on the Mononobe-Okabe method and their use results in a significant increase of earth pressures under strong earthquake motions [4]. Poor design in such cases may lead into serious damage or even collapse of the retaining structure, with catastrophic consequences to important infrastructure works. On the other hand, the appropriate design against the increased lateral -static plus dynamic loading results in a significant increase in the construction cost. Despite the fact that the validity of current seismic code provisions and the applicability of assumptions made by analytical solutions to practical retaining walls has recently been questioned the design and dimensioning of such walls is still, and probably will continue to be for some time in the future, based on the existing codes.

Furthermore, recent research results from large scale shake table tests have shown that for high ground accelerations, significant earth pressure thrusts are measured on the retaining structures [5]. For these reasons, a method for the seismic earth pressure reduction (or isolation) would be particularly welcome by the civil engineering profession and construction industry for both new and existing structures.

1.1 L-shaped Retaining Wall

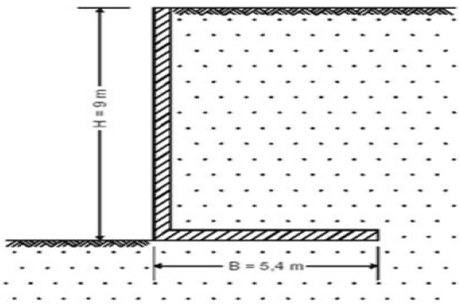

Fig -1: L-shaped Retaining Wall

L-shaped walls are simple to construct and thus often used as earth retainment constructions. Since the usual approaches of the design for overall stability (e.g. bearing capacity, sliding) are believed to be reliable and sufficiently accurate, questions remain concerning the magnitude of the earth pressure acting on the vertical stem of the wall.

For the overall stability design a substitute retaining wall is usually considered. This consists of the wall itself and the soil behind the stem and above the wall base. The wall cross section resists against driving static and dynamic forces by means of its own weight and of the weight of the soil resting on the foundation slab. Standard self-supporting L shape retaining wall provides a cost effective solution where no footings or other supporting structure is required.

1.2 Expanded polystyrene (EPS)

Block or planar rigid cellular foamed polymeric material used in geotechnical engineering applications.

Fig -2: Expanded Polystyrene

Expanded polystyrene (EPS) geofoam has been used as a geotechnical material since the 1960s. EPS geofoam is approximately 1% the weight of soil and less than 10% the weight of other lightweight fill alternatives. As a lightweight fill, EPS geofoam reduces the loads imposed on adjacent and underlying soils and structures. EPS geofoam is not a general soil fill replacement material but is intended to solve engineering challenges. The use of EPS typically translates into benefits to construction schedules and lowers the overall cost of construction because it is easy to handle during construction, often without the need for special equipment, and is unaffected by occurring weather conditions. In addition, EPS geofoam can be easily cut and shaped on a project site, which further reduces jobsite challenges. EPS geofoam is available in numerous material types that can be chosen by the designer for a specific application. Its service life is comparable to other construction materials and it will retain its physical properties under engineered conditions of use.

1.3 PLAXIS

Plaxis is a special purpose two-dimensional finite element computer program used to perform deformation and stability analysis for various types of geotechnical applications. Real situations may be modeled either by a plane strain or an axisymmetric model.

"Plaxis version 8.2" is a finite element software program developed in the Netherlands for two and three-dimensional analysis of geo-structures and geotechnical engineering problems. It includes from the most basic to the most advanced constitutive models for the simulation of the linear or non-linear, time-dependent and anisotropic behaviour of soil and/or rock. Plaxis is also equipped with features to deal with various aspects of complex structures and study the soil-structure interaction effect. In addition to static loads, the dynamic module of Plaxis also provides a powerful tool for modeling the dynamic response of a soil structure during an earthquake.

The objectives of proposed studies includes-

To evaluate Lateral earth pressure on L-shaped Retaining wall with EPS under static and dynamic case using Plaxis program.

To evaluate Displacement of L-shaped Retaining wall with EPS both in horizontal and vertical directions under static and dynamic case using Plaxis program.

2. NUMERICAL ANALYSIS

Numerical analysis is carried for L-shaped retaining wall with and without EPS

2.1 Model 1: Analysis of Rigid L-Shaped Retaining Wall

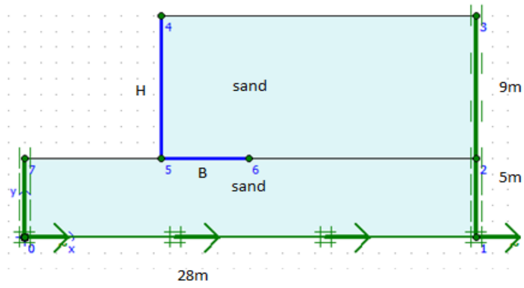

Fig -3: Geometry and Boundary condition.

Height of Retaining of wall(H) = 9m

Width of slab(B) = 5.4m

The geometry of the finite element model was constructed using the graphical procedure of the Plaxis program. At this stage, the geometry of the numerical model, the material properties and the boundary conditions were specified.

The numerical analysis was carried out in plane strain, as presented in Figure 3, the layout of the numerical model extends 28m horizontally and 14m vertically to model the prototype scale of the centrifuge container[1], these boundary limits were assumed to be sufficient to avoid border disturbances. Conditions of plain strain were assumed throughout; the vertical boundaries of the model were pinned in the horizontal direction but free to move vertically, and the horizontal boundary at the base of the model was assumed to be pinned in both vertical and the horizontal directions. Additionally earthquake loads were taken for dynamic analysis.

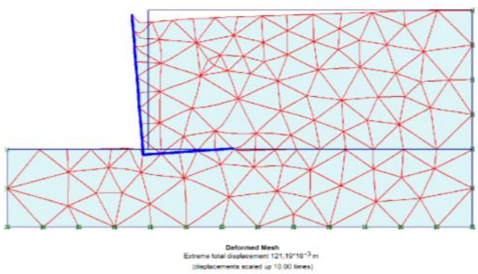

Fig -4: Deformed mesh

Plaxis input programme is used for the generation of the model's finite element mesh. A typical mesh generated is shown in figure 4, the soil model was run with a finite mesh

2.1.1 Wall Modeling

The Retaining wall structure was simulated with one dimensional linear beam element that can resist axial load and bending moments. The stiffness for the wall element is represented by means of the flexural rigidity EI and normal stiffness EA, where A and E are the cross section area and Young's modulus of the reinforced concrete structure wall. The wall modeling parameters are presented in Table 1.

Table -1: Properties of Wall/ Slab [1]

Young's modulus (E)	2.3x10^7 kPa
Axial stiffness (EA)	6.9 x 10^7 kN/m
Flexural regidity (EI)	5.1759 x 10^7 kN/m^2/ m
Equivalent thickness (d_{eq})	3 m
Weight (w)	5 kN/m/m
Poisson's ratio	0.3
Rayleigh α	0.01
Rayliegh β	0.01

2.1.2 Soil Modeling

In the present numerical analysis the soil has been modeled using the hardening soil model, incorporated into the plaxis program, considered in drained conditions. Table 2 gives the properties of sand is used as both backfill material as well as foundation soil.

Table -2: Properties of Sand [1]

Unsaturated unit weight (γ_{unsat})	17 (kN/m^2)
Saturated unit weight (γ_{sat})	20 (kN/m^2)
Permeability in X- direction (k_x)	1 (m/day)
Permeability in Y-direction (k_y)	1 (m/day)
Primary deviatoric loading (e_{50}^{ref})	30000 (kN/m^2)
Primary compression (E_{oed}^{ref})	30000 (kN/m^2)
Elastic (unloading/reloading) (e_{ur}^{ref})	90000 (kN/m^2)
Poisson's ratio (μ)	0.2
Cohesion (C_{ref})	1 (kN/m2)
Friction angle (∅)	32°
Dilatancy angle (ψ)	2°

2.1.3 Dynamic Analysis:

Dynamic analysis carried out after the static analysis taking earthquake input motion. Dynamic analysis is same as static analysis in addition to those earthquake boundary conditions should be considered. Following are the UPLAND earthquake details considered for the analysis.

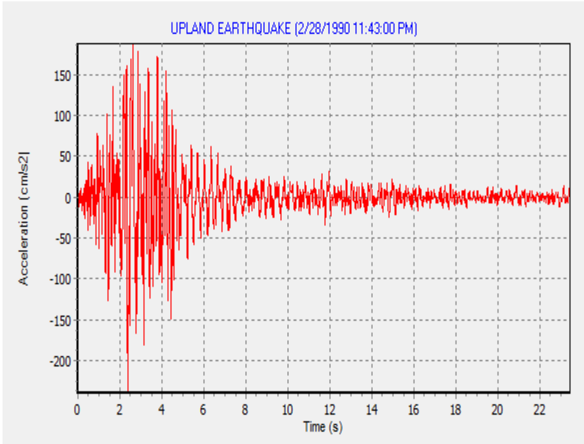

Fig-5: Input accelertation time history of upland earthquake

Upland Earthquake (Southern America,28/2/ 1990)

Peak ground Acceleration : 0.245 g

Duration of Earthquake : 10 sec

Local magnitude : 5.40

Epicentral distance : 5km

2.2 MODEL 2: Analysis of L-Shaped Retaining Wall With Expanded Polystrene

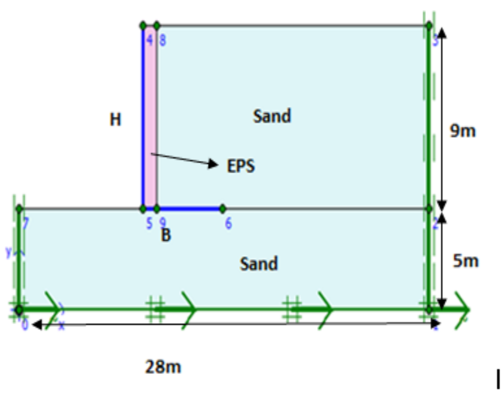

Fig -6: Geometry and Boundary conditions

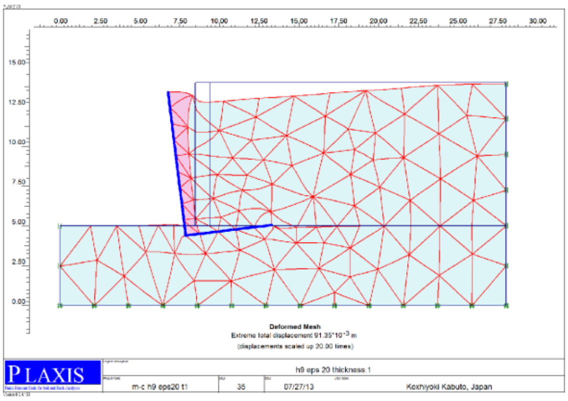

Fig -7: Deformed mesh

Numerical analysis is carried out for this model is same as model 1. Boundary conditions and properties of soil and slab/wall are same as model 1. But in this case EPS 15 is taken for the analysis and their properties are mentioned in the Table 3. Deformation of wall shown in figure 7

Properties of EPS

Material Model : Mohr's coulomb model

Material Type : Drained

Table -3 Properties of EPS [2]

EPS type	Density kN/m3	Cohesion, C (kPa)	Angle of internal friction, Ø(°)	Modulus of elasticity E(kPa)	Poisson's Ratio μ
EPS15	0.15	33.75	1.5	2400	0.10
EPS20	0.20	38.75	2	4000	0.12
EPS30	0.30	62	2.5	7800	0.17

2.2.1 Effect of Thickness of EPS

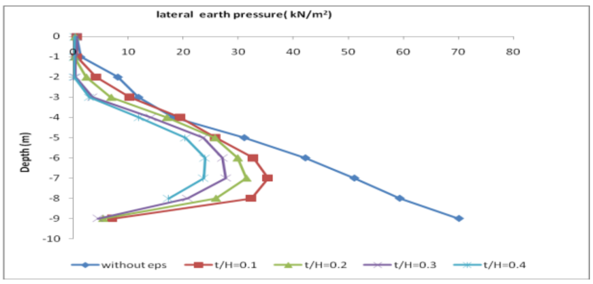

Chart -1: Lateral Earth Pressure for varies EPS thickness (t/H) ratio

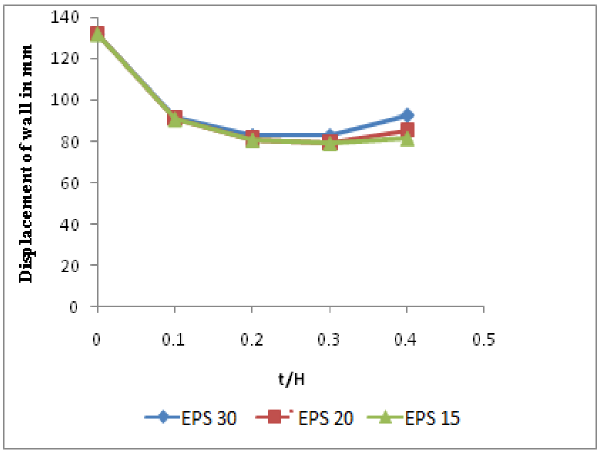

Chart -2: Extreme displacement of wall for different thickness of EPS

Chart 1 shows that increasing the thickness of EPS there will be a greater reduction of lateral earth pressure. From chart 2 it is observed that displacements values decreases upto t/H ratio 0.2 beyond those displacement value increases, since self weight on foundation slab decreases. Hence EPS thickness ratio upto 0.2 is efficient.

2.2.2 Isolation Efficiency of EPS For Varies Densities

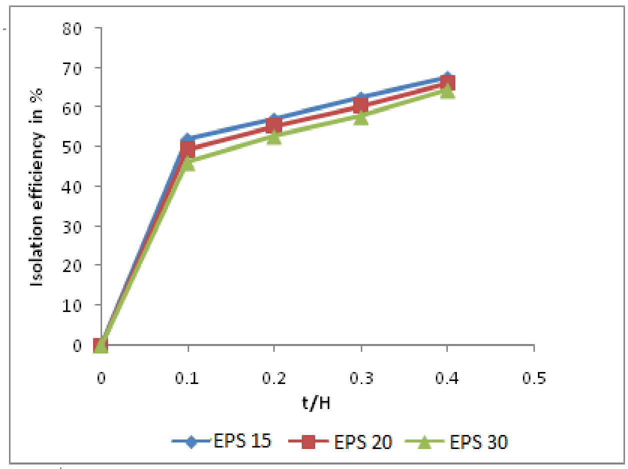

Chart -3 Isolation efficiency of EPS

Ap = (change in wall force b/w rigid and EPS)/(peak wall force without EPS)

Where, Ap = Isolation efficiency

Chart 3 represents the isolation efficiency of EPS. In this study EPS15, EPS20, EPS30 has been used for analysis. The result shows that lower the density of EPS, higher the isolation efficiency.

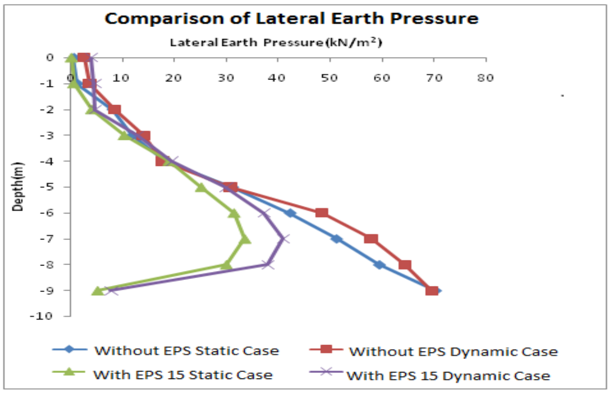

Chart -4: Comparison of Lateral Earth Pressure

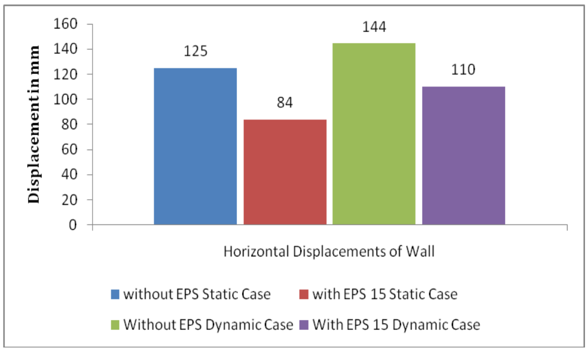

Chart -5: Horizontal Displacement of Wall

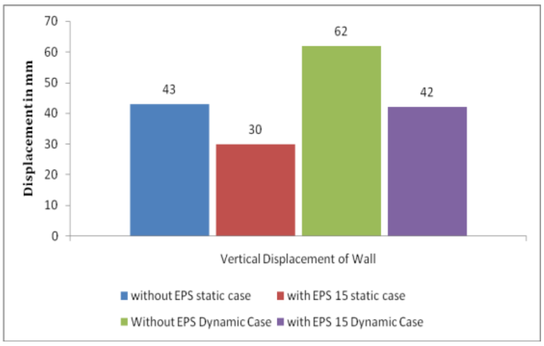

Chart -6: Vertical Displacement of Wall

Chart 4 represents the variation of static and dynamic lateral earth pressure with and without EPS, it shows that by providing EPS greater reduction of lateral earth pressure takes place especially at the base of the wall due to its compressible nature.

Chart 5 and Chart-6 represents the horizontal and vertical displacement of wall respectively. When retaining wall is provided with EPS, it reduces displacement wall both in horizontal and vertical directions under both static and dynamic cases.

3. CONCLUSIONS

When L-shaped Retaining wall is provided with EPS lateral earth pressure on the wall can be reduced effectively, so that the displacement of the wall can also be reduced under both static and dynamic cases.

By increasing the thickness of EPS earth pressure decreases and it is efficient upto t/H ratio 0.2, beyond that wall displacement increases.

Lower the density of EPS, higher the isolation efficiency.

REFERENCES

1. Rouili. A, Djerbib. Y, Touahmia. M , "Numerical modelling of an L-shaped very stiff concrete retaining wall". Journal of Sciences and Technologie B-No 24, Dec. 2005, PP 69-74.

2. Amit Harihar padade and Mandal.J.N, "Behavior of expanded polystyrene (EPS) Geofoam under Triaxial Loading Condition" EJGE, vol.17, 2012, Bund.S

3. Saman Zarnani and Bathurst.R.J, "Numerical parametric study of expanded polystyrene(EPS) geofoam seismic buffers" Canadian Geotechnical Journal, Vol. 46, 2009, pp. 318-338.

4. Towhata, I. Geotechnical Earthquake Engineering, Springer ed, 2008.

5. Wilson, P., and Elgamal, A. "Large-scale passive earth pressure load displacement tests and numerical simulation", ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol. 134, 2010, pp.1634-1643.

6. Yoshimichi Tsukamoto and Kenji Ishihara, "Use of compressible expanded polystrene blocks and geogrids for retaining wall structures"Japanese Geotecnical society vol. 42, 2002, No. 4, 29-41.

7. Seed. H.B, Whitman. R.V, "Design of earth retaining structures for dynamic loads". Proceedings of specialty conference on lateral stresses in the ground and design of earth retaining structures, Ithaca, New York: ASCE, 1970, PP 103-147.