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Reduction of Lateral Earth Pressure on Cantilever Retaining Wall Using Geofoam Material

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ABSTRACT

Expanded polystyrene molded beads (EPS), often known as Geofoam, have been used as a geotechnical alternative material in a variety of applications across the globe. It has been used for backfilling retaining walls and embankments with both vertical and sloped sides, as well as for retaining walls and embankments with vertical sides. Geofoam material has many advantages such as, compressibility, light weight, low density, a high strength-to-weight ratio, very little or no lateral expansion under compression load, and cost effective. The efficiency of EPS geofoam compressible inclusions in lowering lateral earth pressures acting on retaining walls is discussed in this work. The effect of geofoam (as a backfill) height, length, and density in reduction of internal actions imposed on retaining walls with different types of soil (clay and coarse sand) has theoretically investigated by FEM PLAXIS program version 8.6. The results have given reasonable reduction of earth pressure comparing with full scale cantilever retaining wall.

Keywords: Retaining structures; Geofoam; Finite element method; Lateral forces

1-INTRODUCTION

Earth retaining structures are the stabilizing structures that are the common part of many civil infrastructure projects that are designed and constructed to withstand lateral pressure of soil which occurs from the instability of earth natural slopes[1]. These soil slopes happen at the construction phases of these projects such as bridges, highways, railways and other civil engineering projects. It plays an important economical role in total project cost. Design of retaining walls requires resistance of the lateral earth pressure and withstand bearing pressure under the wall. One of causes of increasing wall dimensions and instability is good soil backfill (expensive material), and consequently increases the lateral earth pressure. Replacing standard soil backfills behind walls (unit

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weight approximately 1.9 ton/m^3) with lightweight fill material such as expanded polystyrene (EPS) or Geofoam (unit weight ranging from 10 to 40 kg/m^3) is helping to solve the problem, [2]. In this hypothesis instead of traditional fill material, cheap lightweight fill material employed such as expanded polystyrene (EPS) in block form, or Geofoam. In comparison to traditional backfill material, geofoam has a lower density [3] . This decreases the wall's vertical and lateral strains, while the material's durability makes it perfect for fill applications. Geofoam has been widely utilized on a lot of significant projects with great success. such as Central Artery Project in Boston, Yamagata Expressway, Japan with vertical side walls [4], etc.

The goal of this research is to evaluate a numerical analysis conducted using the PLAXIS finite element tool in order to build a link between the thickness of geofoam and the expected straining action due to lateral earth pressure decrease.

2. Numerical model

2.1Finite element program

The finite element plain strain geotechnical program Plaxis 2D v.8.6 professional package [5]was used in this research study.

2.2 Real wall dimensions

The concrete cantilever wall with real dimensions is shown in fig. (1).

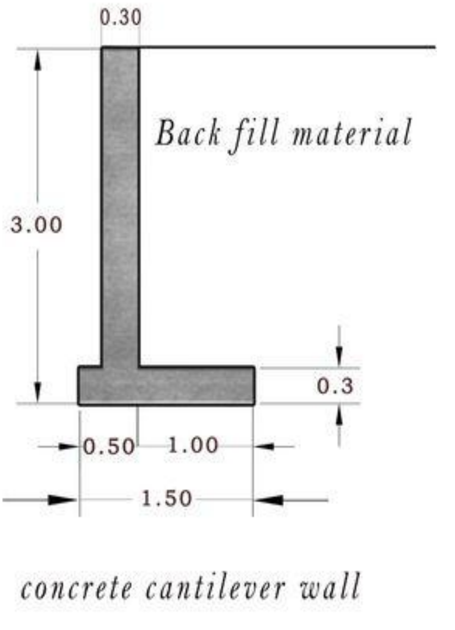

Fig.1. Wall dimension.

2.3 Materials

EPS Geofoam is an ultra-low-density material. Most of the properties of EPS geofoam may be measured by its density[3]. Compression, shear and shear strength as well as other mechanical characteristics such as flexural rigidity and stiffness all rely on the density of the material. An EPS geofoam block's production costs are directly related to its density.

2.3.1 Compression inclusion function

Compression inclusion is a material that compress in one direction, more than other materials that it is either in contact with or adjacent to it[6]. EPS geofoam is one of the inclusion materials which results in a lot of benefits. It will deform more readily than the other system components under an applied stress or displacement[2]. Commonly, if load induced to retaining wall is significantly lower with presence of inclusion, this will lead to effectively less cost in designing the wall to endure loads. The properties of the geofoam materials and soil type used in this research are shown in table (1).

Table (1). Material characteristics included in the FE model[7, 8].

Material	EPS (20)	EPS (30)	EPS (40)	concrete	Sand	clay
Model	Hardening	Hardening	Hardening	Linear elastic	Mohr-Coulomb	Mohr-Coulomb
density (kg/m3)	20	30	40	2400	1700	1600
Cohesion, c (ton/m^2)	3.5	6	7.5	N/A	0.2	3
Friction angle, φ (rad.)	0.523599	0.733038	0.698132	N/A	0.610865	0.174533
Initial stiffness (ton/m^2)	600	900	1.5E+03	2.0E+9	1.3E+03	200
Secant stiffness (ton/m^2)	1.65E+03	2.475E+03	4.125E+03	N/A	N/A	N/A
Poisson's ratio, c	0.1	0.1	0.1	0.15	0.3	0.35

3. Research Program

3.1 Finite element simulation

The dimensions of wall, soil, and geofoam (EPS) in horizontal and vertical installation are shown in figs. (2) and (3).

3.2 Model characteristics

The finite element model of concrete wall, geofoam, and soil in this simulation is shown in fig. (4). It contains Plate element to represent the rough concrete retaining wall. Triangular elements with 15 nodes are used to simulate backfill (sand or clay, and geofoam layers). Two-part interface elements were installed on the contact surface between the Geofoam and the concrete wall, and on the opposite side of the contact surface between the

Geofoam and the coarse sand or clay soil. It is abbreviated as R_{inter}, and it stands for interface reduction factor[9]. Mohr's Column constitutive soil model used to represent traditional backfill sand and clay and Hardening Soil (HS) model used for the geofoam. A Uniform load of 0,1 ton/m2 applied as surcharge load 1 m away from the wall.

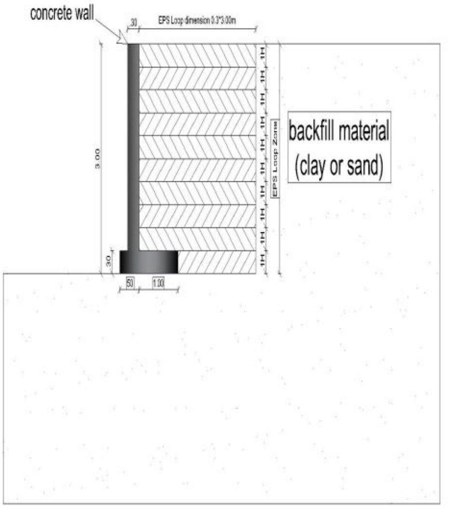

Fig.2. FE simulation with horizontally installation of geofoam.

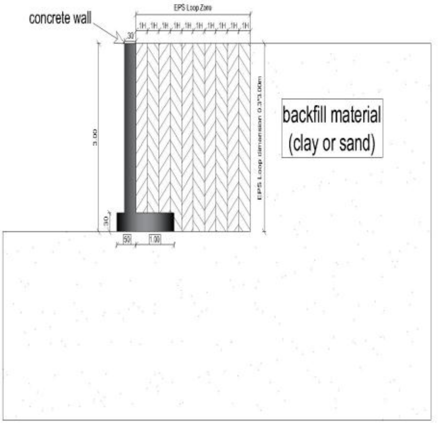

Fig.3. FE simulation with vertically installation of geofoam.

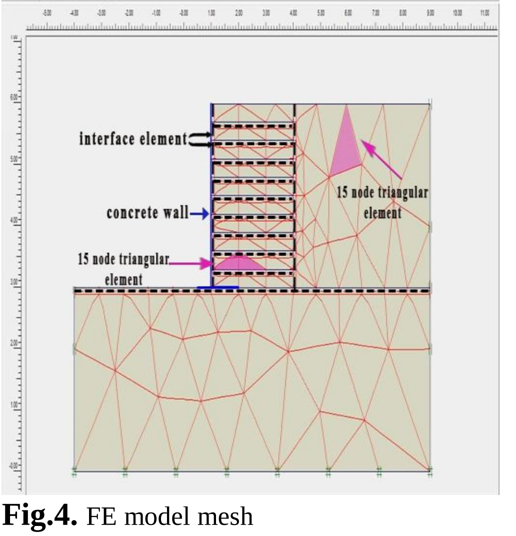

Fig.4. FE model mesh

3.3 Model analysis methods

The model was run many times after adding Geofoam inclusions with varied thicknesses ranging from 0.1H to 1.0H (H stands for the wall's height) in two ways vertically and horizontally. To calculate the percentage reduction in straining force caused to the base of a rigid cantilever wall between the initial case of traditional backfill materials and each loop as shown in Table (2).

Table (2). Model analysis cases.

Case study	EPS Type	Installation type	EPS thickness behind wall loops (m)										case material
			0.1 h	0.2 h	0.3 h	0.4h	0.5h	0.6h	0.7 h	0.8 h	0.9h	1.0h	
Case I	EPS 20	horizontally	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	clay
	EPS 30		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	
	EPS40		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	
Case II	EPS 20	vertically	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	clay
	EPS 30		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	
	EPS40		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	
Case III	EPS 20	horizontally	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	Coarse sand
	EPS30		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	
	EPS40		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	
Case IV	EPS20	vertically	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	Coarse sand
	EPS30		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	
	EPS40		0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	

4.Results

As a result of this analysis the Models indicated a significant reduction in lateral earth pressure, resulting in a remarkable low straining action and horizontal displacement acting on the wall. The result for all the cases is shown in Table (3).

Table (3). Cases results.

Case study	EPS Type	Installation type	Bending moment (%) reduction at wall base from EPS installation loops									
			0.1 h	0.2 h	0.3 h	0.4h	0.5h	0.6h	0.7 h	0.8 h	0.9h	1.0h
Case I	EPS 20	horizontally	15,49	32,10	46,00	59,50	70,68	77,47	81,86	81,62	84,00	91,77
	EPS 30		17,57	33,78	48,40	61,66	70,44	76,2	82,18	83,70	84,50	88,97
	EPS 40		18,13	33,9	47,68	62,3	71,32	75,0	79,2	80,91	80,0	89,61
Case II	EPS 20	vertically	19,51	43,53	57,02	70,84	81,28	89,71	93,71	93,54	91,40	89,87
	EPS 30		24,49	44,73	58,15	67,63	81,04	88,51	91,88	93,06	91,00	89,63
	EPS 40		27,63	47,79	61,92	71,08	81,84	91,00	95,42	94,96	93,50	90,68
Case III	EPS 20	horizontally	18,14	34,46	48,29	60,09	69,69	77,62	82,76	85,48	86,99	89,41
	EPS 30		17,68	33,56	47,46	59,41	69,00	76,94	82,01	84,73	86,09	89,41
	EPS 40		16,70	32,12	46,25	58,65	68,55	76,26	80,95	83,67	85,26	90,62
Case IV	EPS 20	vertically	14,01	25,48	44,64	60,12	71,59	78,82	83,98	87,37	89,06	89,53
	EPS 30		15,01	27,55	45,26	61,35	72,82	79,90	85,06	87,52	88,91	89,45
	EPS 40		16,32	31,56	49,34	65,66	76,82	84,06	88,99	90,83	90,76	90,22

Results in table (3) show massive reduction in bending moment induced to the rigid wall due to EPS geofoam compressive inclusion presence. Figs from 5 to 8 show selected results of some cases

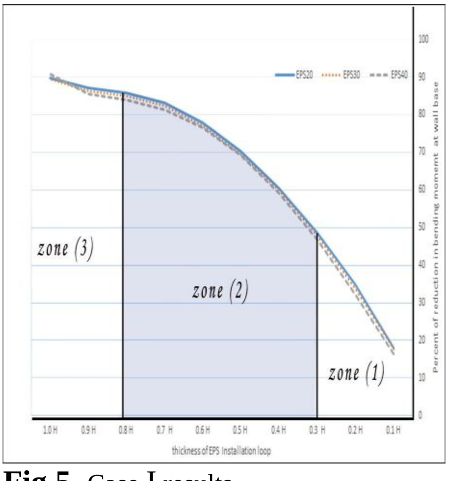

Fig.5. Case I results

Fig. (5) drives a relation between every loop and the amount of reduction in bending moment for case I. Results classified in three zones: Zone 1, an initial linear reduction up to 18% from 0.1 h to 0.3 h loop; Zone 2, or effective zone from loop 0.3 h to 0.7 h loop show magnificent reduction up to 79.2%; and Zone 3, from 0.7 h to 1.0 h loop a small reduction inducted up to 89.6%. Fig. (6) show horizontal displacement at final loop using EPS 20.

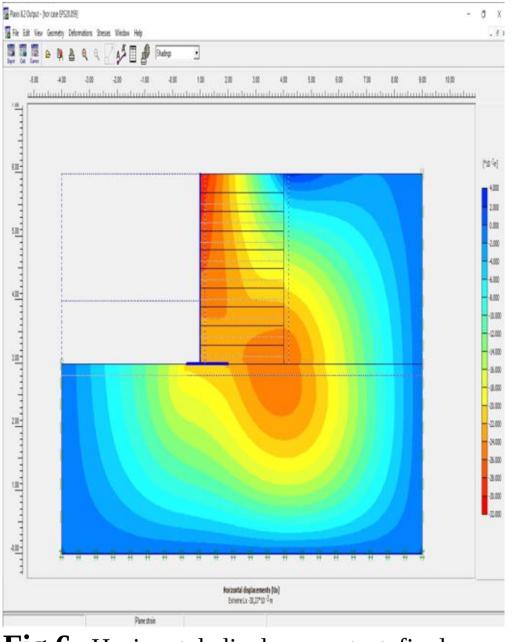

Fig.6. Horizontal displacement at final loop using EPS 20 for case I.

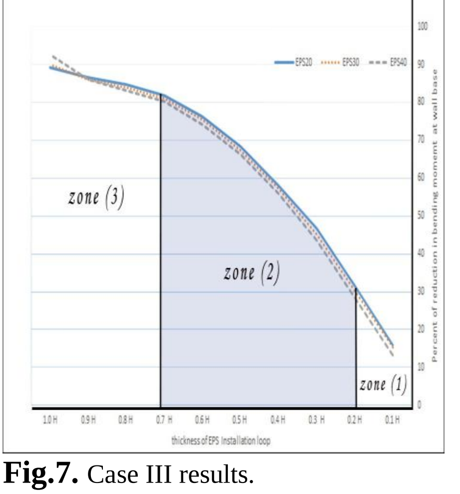

Fig.7. Case III results.

Fig. (7) drives a relation between every loop and the amount of reduction in bending moment for case III in three zones: Zone 1, an initial linear reduction up to 32% from 0.1 h to 0.2 h loop; Zone 2, or effective zone from loop 0.2 h to loop 0.8 h show magnificent reduction up to 85.4%; and Zone 3, from 0.8 h to 1.0 h loop indicate little increase in the reduction up to 90.6%. Fig. (8) show horizontal displacement at final loop using EPS 40

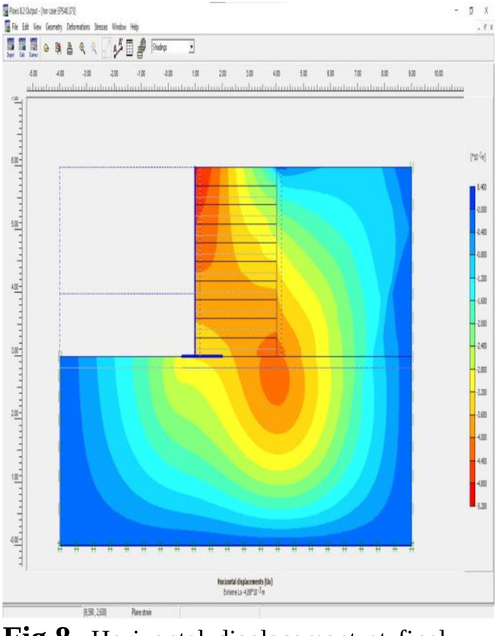

Fig.8. Horizontal displacement at final loop using EPS 40 for case III.

5-SUMMARY AND CONCLUSIONS

The EPS Geofoam compressive inclusion was used as backfill in a numerical simulated cantilever retaining wall. the findings are summarized in the list below.:

- Lateral stresses are greatly decreased depending on the thickness of the EPS Geofoam utilized between rigid walls and soil backfill.
- Vertically installation of geofoam layer in clay and sand cases indicate huge reduction trough loops from 0.2 h to 0.6 h than horizontal ones.
- When the thickness of the geofoam is increased from 0.1H to 0.8H, the percentage of stress reduction grows exponentially up to 90% barely
- Models results show that EPS geofoam can be used in both sand and clay slopes with the restriction of as its low resistance to fire and heat, chemical exposure, and long-term performance. the lack of exact characteristics of EPS geofoam and design formulae is regarded a major limitation.
- It's advisable to install a geofoam as a backfill with thickness from 0.4 H to 0.7 H to get reduction from 60 to 80 % to total stresses and bending moment at the base of the wall.
- It is possible to lower the lateral earth bending moment induced to the wall base by more than 80%. this leads to reduce wall designing sections to small section or just use shotcrete system. For financial reasons, this is strongly recommended.

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تقليل ضغط التربة الجانبي على الحوائط الساندة الكابولية باستخدام مادة الجيوفوم

الملخص:

حبيبات البولى استرين المضغوطة (الجيوفوم) تم استخدامها كمادة بديلة في الهندسة الجيوتقنية لانضغاطها وخفة وزنها في العديد من البلدان مثل النرويج والولايات المتحدة الامريكية واليابان .سمات مادة الجيوفوم في كثير من الأحيان مفيدة في المنشأت الجيوتقنية .هذه السمات تتضمن كثافة صغيرة ومقاومة عالية نسبة للوزن مع عدم وجود انبعاج او وجود انبعاج قليل تحت الحمل الانضغاطي وسعرها المعقول .تم استخدامها كرديم خلفي للحوائط الساندة والجسور لكل من الميول الراسية والمائلة .تم مناقشة كفاءة الجيوفوم للانضغاط في خفض ضغوط الأرض الجانبية التي تؤثر على الحوائط الساندة في هذا العمل وقد تم إنشاء علاقة بين ارتفاع وطول وكثافة الجيوفوم والتقليل الحاصل في القوى الداخلية المؤثرة على الحوائط الساندة باستخدام أنواع مختلفة من التربة وتم التحقق من ذلك من خلال إجراء محاكاة FEM على نطاق كامل باستخدام نموذج متقدم على برنامج البلاكسيس.