IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

Compressive strength of lightweight geocomposit soil-eps stabilized with palm oil-tea fly ash

To cite this article: I Rauf *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **419** 012077

Compressive strength of lightweight geocomposit soil-eps stabilized with palm oil-tea fly ash

I Rauf[1], L Samang[2], T Harianto[3] and A Arsyad[3]

[1]Doctoral Student, Department of Civil Engineering, Hasanuddin University, Indonesia
[2] Professor, Department of Civil Engineering, Hasanuddin University, Indonesia
[3]Associate Professor, Department of Civil Engineering, Hasanuddin University, Indonesia

Abstract. This laboratory experiment intended to develop lightweight embankment material by using fly ash as a stabilizer agent on soft soil and the substitution of soil with expanded polystyrenes (EPS). The palm oil-tea fly ash (POTFA) derived from combustion of palm shells and tea in manufacture process. In order to analyse the performance of this geocomposite material, compressive strength test were applied to several composition and treatment on each sample. The samples were prepared with composition of binding agent for 5%,10%,15% and 20% based on dry weight of the soil, meanwhile the EPS composition are 10% and 20% based on sample's volume. The results showed that the substitution of EPS will reduce the unit weight of geocomposite material until 30% compared to untreated soil. The compressive strength will decrease slightly with the augmentation of bonding agent content on the samples as well as the addition of EPS, however that results are still higher than normal soil.

1. Introduction

Soil work is fundamental part on civil infrastructure development. KIMPRASWIL in 2002 release a data about soft soil distribution in Indonesia, where this area establish more than 20 million hectare or it almost 10% of Indonesia region. This condition will become a major problem on construction because soft soils have low bearing capacity and high compressibility. Meanwhile, material with high compressibility is easy to deform because of loading or displacement [1].

Febrijanto, 2008 present that the important point of materials specification applied as an embankment are: it must have a high bearing capacity and it didn't generate any impact to the layer below, due to his load [2]. In the other word, embankment materials applied on the civil infrastructure must have high strength and lightweight. The Lightweight embankment has become an alternative solution to be applied as an embankment on soft soil, for the reason that it could reduce vertical load on a subgrade layer and lateral pressure on the retaining wall.

In recent years, the utilisation of Expanded Polystyrene (EPS) to develop lightweight materials has been widely used as it can be easily incorporated in mortar. As for in geotechnical application, the utilisation of EPS as a lightweight fill has begun in Japan since 1980 by substitutes soft soil by EPS. BASF, 1990 has presented the technical specification of EPS, such as: lightweight, low density, temperature insulation, low absorption, and degradable in nature [3]. The application EPS on geotechnics it isn't a new thing, considering it already utilised as embankment in form of Geofoam/Geo-block since 1960 [3]. However, its utilization is still limited because its high price, influenced by buoyancy force, vulnerable to petroleum and heat [4]. Furthermore, the adjustment of material dimensions and the stiffness properties to the site topography became another problem in its application [5].

The studies of composite lightweight fill Soil-EPS cannot be separated from its stabilizer agent in order to improving composite material bearing capacity. Chemical stabilisation is common method used. Several research using cement as a bonding agent [5] [6] [7] [8] showed the increasing of soil bearing capacity. Even now, the utilisation of eco- materials has become an alternative solution related to environmental degradation issues, such as the utilisation of lime [8], [9] and the utilisation of fly ash [10]. After all, those researches showed that the substitution of soil by EPS will reduce the density of lightweight fill up to 40% and the strength will increase up to 200 kg/cm2 depending on stabilizer agent, EPS beads density, and soil properties.

Indonesia is one of the largest palm oil producer countries in the world. Generally, the waste of palm oil fruits like its shell and fibres, only used as a fuel material to produces boiler mechanical energy and heat. However, the problem arises after the combustion was the waste product called petroleum oil fuel ash (POFA). ASTM, 2001 describes that the waste produced by the incineration of this palm oil shell has pozzolanic properties due to the presence of silica and alumina compounds. Based on this considerations, the utilisation of POTFA as a stabilizing agent is then widely used for soil improvement.

2. Materials and Method

2.1. Materials

2.1.1. Clay Soil

The quarry of soft soil samples using in this research were excavated from University of Hasanuddin development site in Gowa (fig.1a). Visually, soil samples coloured with reddish brown with fine grain (fig. 1b). The basic properties analysis of soil presented that the soil classified as clay with high plasticity (CH) based on USCS standard. Properties of soil presented in table 1.

Figure 1. (a) Soil samples quarry. (b) Soft soil visualisation

Table 1. Soft Soil Properties

Properties	**Value**
Specific Gravity (Gs)	2.705
Water Content	38.63%
Plasticity Index (IP)	40.27
Liquid Limit (LL)	71.77 %
Plasticity Limit (PL)	31.51 %
Classification	CH

2.1.2. Palm Oil-Tea Fuel Ash (POTFA)

The fly ashes used in this study were taken from the beverage processing industry in Gowa Regency. This fly ash is the residue of the incineration of oil palm shells and tea leaves with a ratio of 70%: 30%. POTFA used in this study after passing the No. sieve 200, with specific gravity (Gs) 2.04.

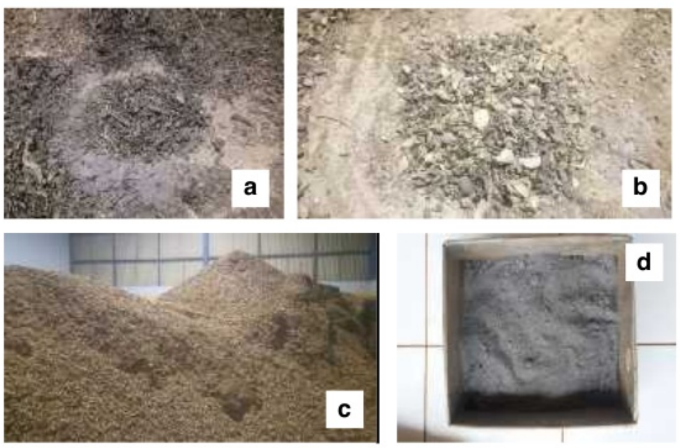

Figure 2. POTFA production process. (a) tea leaves, (b) palm oil shell, (c) mixing of palm oil and tea leaves, (d) Combustion residue as the **palm oil-tea fuel ash** (POTFA).

2.1.3. Expanded Polysterene (EPS)

Expanded Polystyrene (EPS) used in this study is a manufacturing material that has EPS diameter that varies between 2-4 mm with a density value of 17 kg/m^3.

Figure 3. EPS beads

2.2. Sample Preparation

2.2.1. Samples Ratio
The mechanical characteristic of lightweight composite material analyzed in this laboratory study is the compressive strength of lightweight composite material elements. The correlation between POTFA and the EPS to compressive strength will analyse. The variation of POTFA used as stabilization material in this study varies from 5%, 10%, 15%, and 20% based on weight. Meanwhile, the substitution of expanded polystyrene (EPS) beads by 10% and 20%.

2.2.2. Specimen Preparation
The specimen of Unconfined Compression Test (UCT) were made with dimension of 11 cm in height and 5.5 cm in diameter and compacted on optimum water content. To avoid damage on EPS beads on specimens, static compaction method were applied. The procedure of static compaction based on 2 aspect, constant volume and constant pressure [11] [12] [13].

Figure 4. Specimens made by static compaction

The samples made using constant volume approach by use CBR testing machine. Composite lightweight mixture divided in three parts. First part was compacted until it reaches 1/3 of mould volume. Stress value on dial noted as the basic stress that we will use as a control to compaction second and third part.

2.3. Testing Procedure
In this experiment samples were cured for 7 days. The compressive strength testing was carried out by using universal testing machine (UTM) with the strain speed 0.3 mm / minute. In addition to obtaining maximum tension, the strain that occurs due to loading is also measured by installing LVDT at the time where the test is carried out.

3. Experimental result and discussion

3.1. Density Lightweight Composite Material
The measurements of geocomposite materials density by comparing the specimens mass to their volumes. Figure 4 shows the tendency of density values as a function of variation in POTFA and EPS, where it can be described that POTFA and EPS significantly reduce the value of sample density up to 30%.

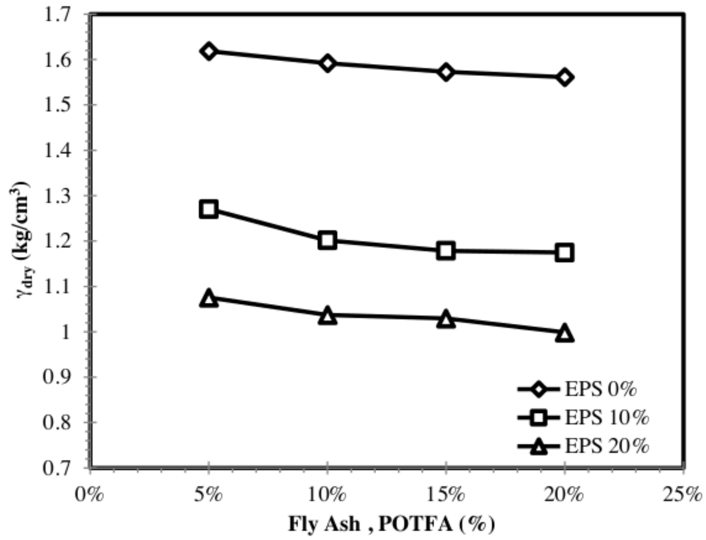

Figure 5. Density of Lightweight Geocomposite

3.2. Stress and Strain Behaviour

The trend of the stress-strain curves for 7 days curing periods presented in figure 6 and figure 7. Its shows that all of the specimens collapsed at strain value in range 1.00 – 2.00%. Those graphics also presented that the compressive strength and stress-strain behavior is significantly affected by the POTFA and beads composition. Furthermore, the increasing POTFA proportion on specimens, compressive strength as well as geocomposite material stiffness decreases and the stress-strain curves become more ductile. In the other word, it can be concluded that all mix composition have significant effect on the compressive strength and stiffness characteristics of lightwieght geocomposit material.

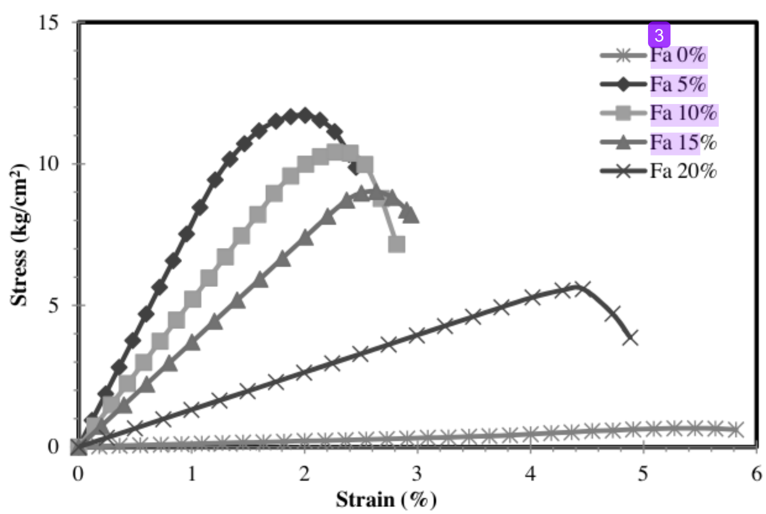

Figure 6. Correlation stress-strain with POTFA variation.

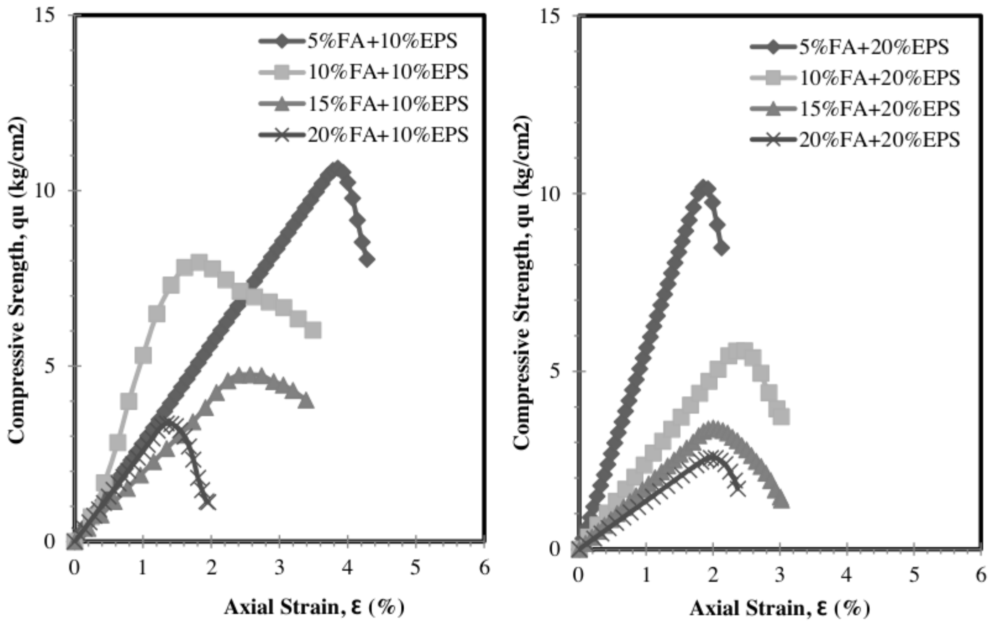

Figure 7. Correlation stress-strain with EPS and POTFA variation.

3.3. Compressive Strength of Lightweight Geocomposit Material

The compressive strength value of the geocomposite material is obtained from the reading of the maximum stress value when the sample has collapsed. The test results of the compressive strength of lightweight geocomposite material due to variations in POTFA, substitution of soil for EPS are shown in Table 2.

Table 2. Compressive strength geocomposit material

POTFA	Compressive Strength (kg/cm2)		
	EPS 0%	EPS 10%	EPS 20%
5	11.74	10.981	10.211
10	10.43	7.961	5.599
15	9.31	4.749	3.418
20	5.59	3.384	2.589

Based on the testing results, generally, the compressive strength decrease with the increasing of POTFA as a binder agent. This behavior is probably happen in reason that the composition of cellulose and lignin on the Palm Oil Fibre as the dominant component of POTFA. Those compounds have a tendency to have high water absorption [14]. The maximum compressive strength of material without EPS for 7 days curing periode is 11,74 kg/cm^2, meanwhile the EPS inclusion significantly reduce the specimen compressive strength varies as presented in figure 8.

The replacement of EPS for 10% will decrease compressive strength varies from 40% to 60% compared to the the specimens without EPS inside for 7 days curing periode. As for the substitution of EPS for 20%, the compressive strength value decline in average 73% for the samples without EPS. This behavior explained that the compressive strength value is depends only on matrix of soil and

POTFA. More beads EPS filled on the lightweight composite will reduce the contact matrix area, finally it induce less resistance between soil particles with POTFA [15]. Although all the specimens present a downtrend in compressive strength, those values still higher than the untreated soils that have 0,703 kg/cm^2.

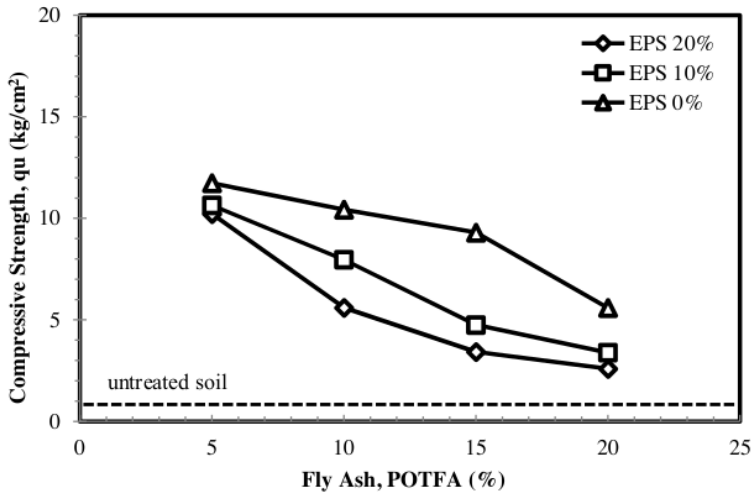

Figure 8. Correlation compressive strength with POTFA and EPS variation.

4. Conclusion

- POTFA made by incineration of palm shell and tea leaves can be used as stabilization material for soft soil, optimum mix to upgrade the bearing capacity is recommended for less than 10% of soil's oven dry weight.
- The inclusion of EPS as a substitution material can reduce the density of embankment material, so that it can be used as an alternative for lightweight material as filler in a retaining wall. But adding it have to be adjusted to technical need in the field.

References

[1] J. S. Horvath, "The Compressible Inclusion Function of EPS Geofoam," *Geotextiles and Geomembranes,* pp. 77-120, 1997.

[2] D. Hidayat, Y. M. Purwana and F. P. Pramesti, "Analisis Material Ringan Dengan Mortar Busa Pada Konstruksi Timbunan Jalan," Yogyakarta, 2016.

[3] J. S. Horvath, "Expanded Polystyrene (EPS) Geofoam: An Introduction to Material Behaviour," *Geotextiles and Geomembranes,* pp. 263-280, 1994.

[4] D. Negussey and M. Jahanandish, "Comparison of Some Engineering Properties of Expanded Polysterene with Those of Soils," vol. 1418, 1993.

[5] G. E. Abdelrahman, "Lightweight Fill Using Sand, Polystyrene Beads and Cement," in *Proceedings of the Institution of Civil Engineers*, 2009.

[6] F. Yong and P. Yu-bin, "Research on the deformation characteristic of EPS silt light-weight soil," *Advanced Materials Research,* pp. 1614-1617, 2014.

[7] J. L. H. L. Hongmei Gao, "Geotechnical Properties of EPS Composite Soil," International *Journal of Geotechnical Engineering,* pp. 69 -77, 2011.

[8] G. E. Abdelrahman, H. M. Mohamed and H. M. Ahmed, "New Replacement Formations on Expansive Soils Using Recycled EPS Beads," in *Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering*, Paris, 2013.

[9] A. Haghi., M. Arabani and M. V. Karami, "Applications of Expanded Polystyrene (EPS) beads and Polyamide 66 in Civil Engineering, Part Two : Stabilization of Clayey Sand by Lime/polyamide-66," *Composite Interfaces,* pp. 451-459, 2006.

[10] N. T. Rocco, Characterization of Expanded Polystyrene (EPS) and Cohesive Soil Mixtures, Missouri: Doctoral Dissertation, 2012.

[11] A. H. Padade and J. N. Mandal, "Expanded Polystyrene-Based Geomaterial with Fly Ash," International *Journal of Geomechanic,* pp. 1-7, 2014.

[12] B. V. Reddy and K. Jagadish, "The Static Compaction of Soils," *Geotechnique,* pp. 337-341, 1993.

[13] P. D. Y. J. CUI, "Yielding and plastic behaviour of an unsaturated compacted silt," Geotechnique *,* pp. 291-311, 1996.

[14] B. Sharma and A. Deka, "Static Compaction Test and Determination of Equivalent Static Pressure," in *Indian Geotechnical Conference*, India, 2016.

[15] S. Nurdin, L. Samang, J. Patanduk and T. Harianto, "Performance of Soft Soil Stabilized by Fly Ash with Natural Fiber Reinforcement as Landfill Cover Layer," *International Journal of Innovative Research in Advanced Engineering (IJIRAE),* **3**, no. 12, pp. 15-22, 2016.

[16] T. Harianto, S. Hayashi, Y.-J. Du and D. Suetsugu, "Effects of Fiber Additives on the Desiccation Crack Behavior of the Compacted Akaboku Soil as A Material for Landfill Cover Barrier," *Water Air Soil Pollution,* **194**, pp. 141-149, 2008.

Tri_Harianto_7.pdf

ORIGINALITY REPORT

%7	%	%7	%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	A. H. Padade, J. N. Mandal. "Expanded Polystyrene-Based Geomaterial with Fly Ash", International Journal of Geomechanics, 2014 Publication	%2
2	Day, J J, J C Hargreaves, J D Annan, and A Abe-Ouchi. "Sources of multi-decadal variability in Arctic sea ice extent", Environmental Research Letters, 2012. Publication	%2
3	Weiyu Yao, Yanjun Zhao, Kai Wu, Lei Han, Haifeng Cai, Weihong Guo. "Effect of fly ash on the structure and properties of polyolefin elastomer/fly ash/polypropylene composites", Materials Research Express, 2018 Publication	%1
4	Devi Oktaviana Latif, Ahmad Rifa'i, Kabul Basah Suryolelono. "Impact of Volcanic Ash and Lime Adding on Expansive Soil for Subgrade Layer", International Review of Civil Engineering (IRECE), 2017 Publication	<%1

5 Fusheng Zha, Songyu Liu, Yanjun Du, Kerui Cui. "Behavior of expansive soils stabilized with fly ash", Natural Hazards, 2008
Publication <%1

6 Uma Chaduvula, B.V.S. Viswanadham, Jayantha Kodikara. "A study on desiccation cracking behavior of polyester fiber-reinforced expansive clay", Applied Clay Science, 2017
Publication <%1

EXCLUDE QUOTES	ON	EXCLUDE MATCHES	< 5 WORDS
EXCLUDE BIBLIOGRAPHY	ON		