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Numerical Modeling of Soil Embankment on Soft Soil Using Variation of Expanded Polystyrene (EPS) Geofoam Material Type

Mohammad Sahrul R.*

Civil Engineering Study Program, Faculty of Engineering, Sebelas Maret University

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*Correspondence: Mohammad Sahrul R.
Email: sahrulriski5780@gmail.com

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Abstract: Subgrade is the layer of soil that lies beneath the pavement. The subgrade plays an important role in supporting and spreading the load from the pavement to the underlying soil. Terzaghi, et al. (1967) state that soft soils can pose serious challenges in geotechnical engineering, due to their tendency to experience large settlement under structural loads. Handling soft soils often requires specialized methods such as preloading, vacuum consolidation, or the use of geosynthetics to improve stability. One of the geosynthetics used in handling soft soil is Expanded Polystyrene (EPS) Geofoam. This research aims to determine the settlement behavior of soil embankment on soft soil reinforced with EPS geofoam. The settlement behavior was obtained with the help of GeoStudio software. EPS geofoam has been used since 1960, this material weighs about 1% of the soil weight and less than 10% of the weight of other embankment materials. As a lightweight embankment material, EPS geofoam can reduce the load imposed on the embankment structure. Modeling of soil embankment on soft soil using various types of EPS geofoam material in this research uses GeoStudio software. The modeling analysis uses SIGMA/W in GeoStudio. Numerical modeling of variations in the type of EPS geofoam material in the embankment on soft soil gives the results of a decrease that is not too significant. The settlement results from modeling with GeoStudio are 0.33240 m for EPS 22, 0.33264 m for EPS 29, 0.33323 mm for EPS 39. EPS 39 provides 0.25% higher settlement than EPS 22.

Keywords: GeoStudio, EPS Geofoam, Variation of EPS Material Type, Settlement

Introduction

Soil is one of the important materials in the scope of civil engineering works, both road works, buildings, water buildings, and other works. Soil material has different characteristics depending on the type of soil. Soft soil can be found in the road structure layer in the form of subgrade. Subgrade is the layer of soil that lies beneath the pavement or other foundation structures. The subgrade plays an important role in supporting and spreading the load from the pavement or foundation layer to the underlying soil.

Wardoyo et al, (2019) state that soft soil is soil that has a high compressibility value, generally consisting of Holocene-aged clays (<10,000 years), naturally formed from the process of deposition on coastal alluvial plains, rivers, lakes and swamps. The properties of soft soils include soft-very soft consistency, high moisture content, small shear force, large compression, low bearing capacity and high settlement rate. Terzaghi, et al. (1967) state that soft soils can pose serious challenges in geotechnical engineering, due to their tendency to experience large settlement under structural loads. Handling soft soils often requires special methods such as preloading, vacuum consolidation, or the use of geosynthetics to improve stability (Amalu, 2024; Jauhari, 2024; Kavand, 2023). One of the uses of geosynthetics in soft soil treatment is Expanded Polystyrene (EPS) Geofoam (Akyelken, 2022; Firouzeh, 2022; Kılıç, 2023).

Geofoam is a geosynthetic material made from Expanded Polystyrene (EPS) and Xtruded Polystyrene (XPS) polymers (Jazebi, 2021; Özer, 2021; Tran-Nguyen, 2022). EPS is a polymer that is widely used as wrapping and building construction (Kamash, 2020; Khalaj, 2020; Soundara, 2020). The manufacture of EPS blocks starts from resin grains less than 3 mm in diameter and contains microscopic cells containing developer substances (Irpan Hidayat, 2011). EPS geofoam has been used since 1960, this material weighs about 1% of the soil weight and less than 10% of the weight of other backfill materials (AbdelSalam, 2019; Meguid, 2017; Witthoeft, 2018). As a lightweight backfill material, EPS geofoam can reduce the load imposed on the backfill structure (Akay, 2016; Edinçliler, 2014; Ekanayake, 2014; Liyanapathirana, 2016; Özer, 2016).

This research aims to determine the settlement behavior of soil embankment on soft soil reinforced with EPS geofoam. The settlement behavior is obtained by using GeoStudio software. GeoStudio software is a software that uses the concept of Finite Element Method (MEH). This research simulates several models applied with variations in the type of EPS geofoam material.

The model used is a six-meter high and forty-seven-meter wide soil embankment. The embankment material used is assumed data, while the soft soil material is laboratory testing data obtained from soil samples in Semanding District, Tuban Regency. All models were assumed to receive a load of 15 kN/m^2, this load was considered as pavement dead load and live load from vehicles. EPS geofoam was placed one meter from the bottom of the embankment. The variation of EPS material type will be investigated on its settlement performance, this settlement is investigated in a short period of twenty days after each embankment layer construction.

Methodology

Modeling of soil embankment on soft soil using various types of EPS geofoam material in this research using GeoStudio software. The modeling analysis uses SIGMA/W in GeoStudio. The soil material is modeled with the Total Stress Parameters category and the model material is Elastic-Plastic (Total). The EPS geofoam material is modeled with the Total Stress Parameters category and the material model is Linear Elastic (Total).

Properties of soil material for embankment are assumed data, while soft soil material is laboratory testing data obtained from soil samples in Semanding District, Tuban Regency. EPS geofoam used are EPS 22, EPS 29, and EPS 39. The material properties of EPS geofoam are taken from Foam Concepts.

Embankment Geometry and Material Properties

Table 1 shows the embankment soil parameters used in the form of assumed data, while Table 2 shows the soft soil parameters obtained from laboratory testing. Table 3 shows the EPS parameters used in the MEH analysis obtained from Foam Concepts.

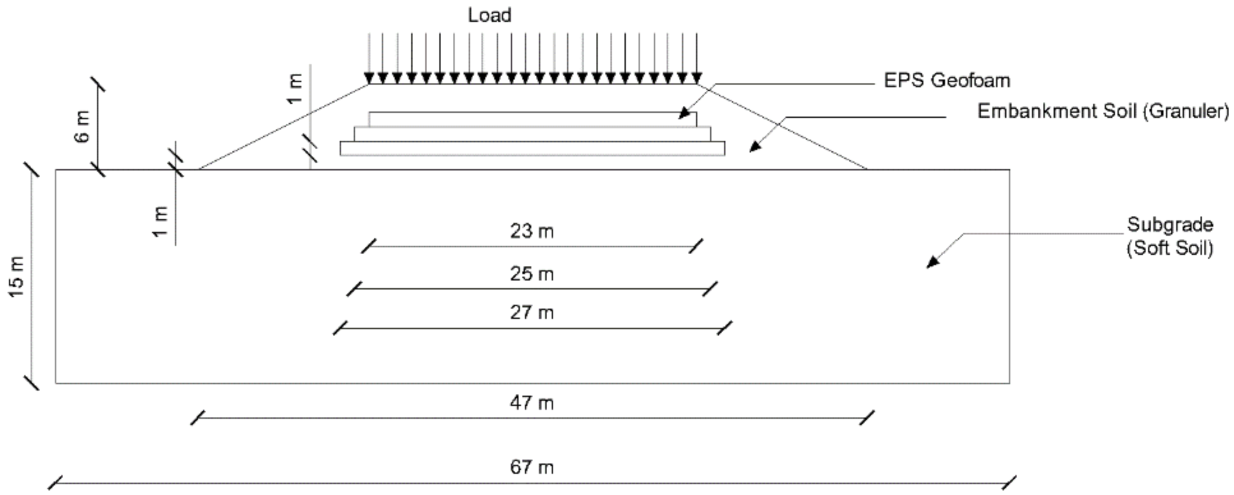

Figure 1. Embankment Geometry in GeoStudio Modeling

Table 1. Backfill Soil Parameters

Material	Material Category	Parameter	Value	Unit
Backfill soil	Elastic-plastic	Unit Weight (γ)	17	kN/m³
		Modulus of Elasticity (Young) (E)	20000	kPa
		Poisson Ratio (ν)	0.33	-
		Cohesion undrained (c_u)	2000	kN/m²
		Friction angle (φ)	30	°
		Saturated Unit Weight (γ_{sat})	20	kN/m³
		Effective cohesion (c')	200	kN/m²

Table 2. Soft Soil Parameters

Material	Material Category	Parameter	Value	Unit
Soft soil	Elastic-plastic	Unit Weight (γ)	17.2188	kN/m³
		Modulus of Elasticity (Young) (E)	3500	kPa
		Poisson Ratio (ν)	0.45	-
		Cohesion undrained (c_u)	34.0658	kN/m²
		Friction angle (φ)	4.92	°
		Saturated Unit Weight (γ_{sat})	20,3942	kN/m³
		Soil coefficient at rest (K_0)	0,0285	-
		Effective cohesion (c')	3,4066	kPa

Table 3. EPS Geofoam Parameters

Material	Material Category	Parameter	Value	Unit
Geofoam EPS 22	Linier elastic	Unit Weight (γ)	21.,0681	N/m³
		Modulus of Elasticity (Young) (E)	5033.1728	kPa
		Poisson Ratio (ν)	0.1235	-
Geofoam EPS 29	Linier elastic	Unit Weight (γ)	282.7574	N/m³
		Modulus of Elasticity (Young) (E)	7515.2854	kPa
		Poisson Ratio (ν)	0.1639	-
Geofoam EPS 39	Linier elastic	Unit Weight (γ)	377.0099	N/m³
		Modulus of Elasticity (Young) (E)	10342.1359	kPa
		Poisson Ratio (ν)	0.2177	-

Modeling Stages

The construction of the earthen embankment is divided into six stages with each layer being one meter thick. After the earth fill stage is completed, the road is opened for use. The pavement construction stage is considered to be completed with the last layer of embankment soil. The load received by the embankment is 15 kN/m2 in the form of rigid pavement (concrete) load as well as live traffic load. Table 4 and Table 5 show the stages of embankment construction in the model. The time required to construct the earthen embankment is 121 days.

Table 4. Embankment Construction Stages

Construction Stage	Time (days)	Backfill Height (m)
Original condition	1	0
First layer backfill	21	1
Second layer backfill	41	2
Third layer backfill	61	3
Fourth layer backfill	81	4
Fifth layer backfill	101	5
Sixth layer backfill	121	6
Service life	141	6
Post-service life	161	6

The completed earth fill construction will be reviewed for service and post-service periods assumed to be 20 days each. This review time assumes that the settlement is direct settlement so consolidation settlement is not applied.

Results and Discussion

The results of numerical modeling using GeoStudio software are shown in this section. The analysis results are taken from twelve nodal points, which are the points with coordinates (68,-1) to (79,-1). These nodal points were selected because they are located in soft soil locations.

Settlement of Soft Soil Using Variation of EPS Geofoam Material Type

Table 5 shows the settlement results for the model performed in GeoStudio. The settlement results reviewed are the settlement after the post-service construction stage.

Table 5. Results of Modeling Decrease at Nodal Point (73,-1)

EPS Geofoam Material Type	Settlement (m)
EPS 22	0.33240
EPS 29	0.33264
EPS 39	0.33323

Effect of Variation of EPS Geofoam Material Type

The EPS geofoam used is EPS 22, EPS 29, and EPS 39. The variation of EPS material type has an influence on the settlement as shown in Figure 2. It can be seen that the higher the EPS geofoam material type, the higher the settlement. This is not appropriate because the higher the EPS geofoam material type, the higher the material parameters such as compressive strength, elastic modulus, and strength. In addition, the higher the type of EPS geofoam material, the higher the stiffness of the EPS geofoam material so that a larger load is needed to deform the EPS geofoam material.

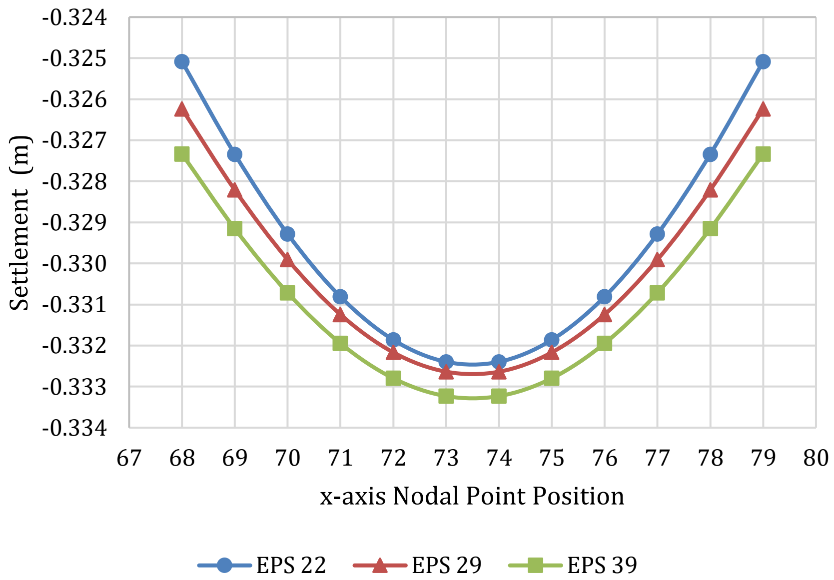

Figure 2. Decrease Results of EPS Geofoam Material Type Variations

Conclusion

Numerical modeling of variations in the type of EPS geofoam material in the embankment on soft soil gives the results of a decrease that is not too significant. The settlement results from modeling with GeoStudio are 0.33240 m for EPS 22, 0.33264 m for EPS 29, 0.33323 mm for EPS 39. EPS 39 provides a 0.25% higher settlement than EPS 22. This is not appropriate because the higher the type of EPS geofoam material, the higher the properties of the EPS material. The inconsistent results are caused by several things.

The first thing is the lack of suitability of soft soil modeling which should be suitable using Coupled Stress/PWP analysis type modeling. This modeling is considered more suitable because the soil parameters used take into account consolidation settlement. Secondly, because consolidation settlement is not considered, the time series used is not suitable. Finally, material modeling in GeoStudio SIGMA/W is limited to certain parameters such as specific gravity, modulus of elasticity, and Poisson ratio for linear elastic materials. This affects the modeling of EPS geofoam where the EPS geofoam material properties are not limited to the three GeoStudio linear elastic parameters.

References

AbdelSalam, S. S. (2019). Long Term Behavior of EPS Geofoam for Road Embankments. *Sustainable Civil Infrastructures*, 97–107. https://doi.org/10.1007/978-3-030-01944-0_8

Akay, O. (2016). Slope stabilisation using EPS block geofoam with internal drainage system. *Geosynthetics International*, *23*(1), 9–22. https://doi.org/10.1680/jgein.15.00028

Akyelken, F. A. (2022). Experimental and Numerical Analyses of Buried HDPE Pipe with Using EPS Geofoam. *KSCE Journal of Civil Engineering*, *26*(9), 3968–3977. https://doi.org/10.1007/s12205-022-1541-z

Amalu, P. A. (2024). Geofoam integrated separation layer for enhancing seismic resilience in modified piled raft foundations. *Multiscale and Multidisciplinary Modeling, Experiments and Design*. https://doi.org/10.1007/s41939-024-00474-8

Edinçliler, A. (2014). Effects of EPS bead inclusions on stress-strain behaviour of sand. *Geosynthetics International*, *21*(2), 89–102. https://doi.org/10.1680/gein.14.00001

Ekanayake, S. (2014). Attenuation of ground vibrations using in-filled wave barriers. *Soil Dynamics and Earthquake Engineering*, *67*, 290–300. https://doi.org/10.1016/j.soildyn.2014.10.004

Firouzeh, S. H. (2022). Efficiency of various mitigation schemes in the alleviation of the destructive effect of reverse dip-slip fault rupture on surface and embedded shallow foundations using upper bound finite element limit analysis. *Computers and Geotechnics*, *142*. https://doi.org/10.1016/j.compgeo.2021.104548

Geofoam Technical Data Sheets. (n.d.). GeoFoam Concepts. Retrieved May 29, 2024, from https://geofoamconcepts.com/geofoam-technical-data/

Hidayat, I., & Suhendra, A. (2011). Aplikasi Geofoam Sebagai Material Timbunan di Atas Tanah Lunak. *ComTech: Computer, Mathematics and Engineering Applications*, *2*(1), 106. https://doi.org/10.21512/comtech.v2i1.2722

Jauhari, N. (2024). Vibration mitigation using dual-open and infilled trenches in layered soil media: Field tests and numerical simulations. *Computers and Geotechnics*, *170*. https://doi.org/10.1016/j.compgeo.2024.106283

Jazebi, M. (2021). Efficiency of in-filled (geofoam) trenches in mitigating train-induced vibrations: A case study of Tehran-Tabriz railway. *Construction and Building Materials*, *309*. https://doi.org/10.1016/j.conbuildmat.2021.125075

Kamash, W. El. (2020). Optimizing the Unconnected Piled Raft Foundation for Soft Clay

Soils: Numerical Study. *KSCE Journal of Civil Engineering*, *24*(4), 1095–1102. https://doi.org/10.1007/s12205-020-0567-3

Kavand, A. (2023). Field Testing on active isolation of vibrating foundations in Middle-frequency range. *Construction and Building Materials*, *374*. https://doi.org/10.1016/j.conbuildmat.2023.130893

Khalaj, O. (2020). The experimental investigation of behaviour of expanded polystyrene (EPS). *IOP Conference Series: Materials Science and Engineering*, *723*(1). https://doi.org/10.1088/1757-899X/723/1/012014

Kılıç, H. (2023). A Numerical Investigation of Induced and Embedded Trench Installations for Large-Diameter Thermoplastic Pipes under High Fill Stresses. *Applied Sciences (Switzerland)*, *13*(5). https://doi.org/10.3390/app13053040

Liyanapathirana, D. (2016). Application of EPS geofoam in attenuating ground vibrations during vibratory pile driving. *Geotextiles and Geomembranes*, *44*(1), 59–69. https://doi.org/10.1016/j.geotexmem.2015.06.007

Meguid, M. A. (2017). Earth Pressure Distribution on a Rigid Box Covered with U-Shaped Geofoam Wrap. *International Journal of Geosynthetics and Ground Engineering*, *3*(2). https://doi.org/10.1007/s40891-017-0088-4

Özer, A. T. (2016). Laboratory study on the use of EPS-block geofoam for embankment widening. *Geosynthetics International*, *23*(2), 71–85. https://doi.org/10.1680/jgein.15.00033

Özer, A. T. (2021). Shear strength characteristics of interlocked EPS-block geofoam-sand interface. *Geosynthetics International*, *28*(5), 521–540. https://doi.org/10.1680/jgein.21.00009

Soundara, B. (2020). Experimental Investigation on the Swelling Behavior of Expansive Soils with EPS Geofoam Inclusion. *Indian Geotechnical Journal*, *50*(4), 519–530. https://doi.org/10.1007/s40098-019-00385-3

Terzaghi, K., & Ralph Brazelton Peck. (1967). *Soil mechanics in engineering practice [by] Karl Terzaghi [and] Ralph B. Peck.* New York Wiley.

Tran-Nguyen, H. H. (2022). Investigation of Key Properties of EPS Geofoams for Highway Embankments on Soft Ground. *Geotechnical Engineering*, *53*(2), 35–42.

Witthoeft, A. F. (2018). Impacts of EPS inclusion density and backfill soil type on earth pressure reduction around a buried pipe. *11th International Conference on Geosynthetics 2018, ICG 2018*, *2*, 1680–1689.

Wardoyo, Sarwondo, Farah Destiasari, Wahyudin, Wiyono, Ginda Hasibuan, & William Pradana Sollu. (n.d.). Atlas Sebaran Tanah Lunak Indonesia (Andiani, Sugalang, & Dodid Murdohardono, Eds.; 2019th ed., p. 6) [Review of Atlas Sebaran Tanah Lunak Indonesia]. BADAN GEOLOGI Kementerian Energi dan Sumber Daya Mineral. (Original work published 2019)

Zianal, N. F. A., Yusof, M. F., Madun, A., Pakir, F., Abu Talib, M. K., & Abu Talib, Z. (2022). Numerical Modelling of Soft Soil Improvement Using Expanded Polystyrene Geofoam for Road Embankment. *Journal of Sustainable Underground Exploration*, 2(1).