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To cite this article: N Marfu'ah *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1117** 012021

IOP Conf. Series: Materials Science and Engineering 1117 (2021) 012021 doi:10.1088/1757-899X/1117/1/012021

Study of engineering properties of lightweight geomaterial (LWGM) stabilized by Waste of Buton Asphalt

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Abstract. Material with high strength but has the lightest density that can be tolerated is the main purpose of doing a research about soil improvement. This research aims to develop a lightweight geomaterial (LWGM) by substituting of the soft soil with Expanded Polysterene (EPS) which is stabilized with Waste of Buton Asphalt (WBA). The variation of the WBA used was 3%, 5%, 7% and 9%, while the variation of the EPS used was 0.15% and 0.30%. Curing of the specimens was carried out for 7 and 28 days to see the effect of curing on the pozzolanic reaction to the specimens strength. The test results shows that soil substitution with EPS reduce the density by 10% - 25%. Even though it decreased comparing to the strength of the sample without additional of EPS, the CBR and UCS LWGM values are still classified as good performance and can be tolerated. Based on the results of curing samples, during the curing period of 7 days, the CBR value increased up to 5 times at 0.15% EPS and 4 times at 0.30% EPS. Meanwhile, during the 28-day curing period, the CBR value increased up to 10 times at 0.15% EPS and 6 times at 0.30% EPS. Meanwhile, the UCS value after curing 7 days is 12 times - 48 times and after curing 28 days is 15 times - 63 times greater than untreated soils.

1. Introduction

Soil has an important role to support construction system such as dams, buildings, roads, backfill on retaining wall systems, bridges even landfill cover. That makes soil as supporting system must have high bearing capacity. Soft soil is very abundant in Indonesia, however they tend to have low shear strengths and also easy to lose shear strength. In order to increase its strength, soil improvement is needed. The interest in research about soil improvement with natural materials has grown rapidly nowadays. The most popular soil improvement methods known is a chemical stabilization using binder materials such as: cement [1], lime [2], fibres [3], fly ash [4] [5] and for this paper we used waste of Buton Asphalt (WBA) as another new binder materials.

Material with high strength but has the lightest density that can be tolerated is the main purpose of doing a research about soil improvement. In road constructions, high-density materials will easily cause deformation to the layer beneath them due to the effects of loading [5] while in the backfill of retaining wall systems it will increase lateral pressure to its retaining wall. To decrease its density, reducing its self weight with lightweight filling can be a solution. Lightweight material as an alternative for road pavement layer has been started since 1980 in Japan by using Expanded Polysterene (EPS) in the form of geoblocks. However, its utilization is still limited because it's expensive,has high buoyancy, and it's not flexible geometrically [6]. By considering the difficulties of utilization of geoblocks in some situation, the effort to mix soil with EPS beads by chemical stabilization methods is become a consideration now. Moreover, soil mixed with EPS beads are easier to be made with the density we desired

2. Materials and Method

2.1. Materials

2.1.1. Soil
Soil sampling in this study was taken around Hasanuddin University campus in Gowa district, South Sulawesi, Indonesia. This soil then put into a container to maintain its natural water content then transported to Hasanuddin University's Geoenvironmental Laboratory. The physical and mechanical characteristics of the soil was tested referring to ASTM testing standard which will be explained further in the results and discussions section.

2.1.2. Waste of Buton Asphalts (WBA)
In the stabilization process, as the alternative binder materials, we used waste of Buton Asphalt. Waste of Buton Asphalt as it's named, it's originally from Buton Island and processed on Waste of Buton Asphalt treatment plant on Baubau Island (geographically lies between latitude 5.21 ° S – 5.33 ° S and longitude 122.30 ° E – 122.47 ° E).

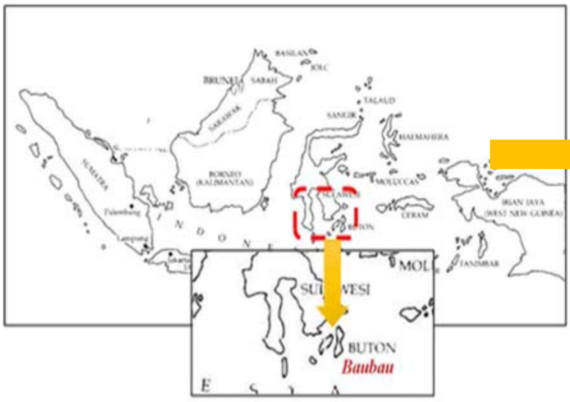

Figure. 1 Location of WBA's processing plant

(a) (b)

Figure. 2 WBA (a) boulder, (b) passed #100 WBA

In the process of extracting Buton Asphalt, besides producing bitumen it also produces a residual called Mineral of Buton Asphalt/ Waste of Buton Asphalt (WBA). WBA is one of natural material which is originally a byproduct of Buton Asphalt. At first, the WBA is in the sludge form which is dried at room temperature (28°C) and it turns into boulder as shown in Figure 2. then crushed into powder passes No. 100 sieves before used. This is based on the research of Janz [7] which states that the level of particle fineness greatly affects the reactivation of the binder material. The higher is the specific surface of the binder, the faster the reaction between the soil and the binder material is. Furthermore, mineral contents of WBA from X-Ray Diffraction test results is shown at Table 1 below.

Table 1. Chemical Composition of WBA [9] (Rauf,2019)

Compound	Unit	Value
Gypsum ($CaSO_4$)	%	63,63
Kalsit ($CaCO_3$)	%	15,54
Quartz SiO_2	%	16,46
Oldhamite (Ca,Mg,Fe,S)	%	2,78
Magnesite ($MgCO_3$)	%	1,60

IOP Conf. Series: Materials Science and Engineering 1117 (2021) 012021 doi:10.1088/1757-899X/1117/1/012021

Based on Table 1, it can be seen that the mineral contents of WBA are dominated by gypsum, so we expect that WBA has a similar behaviour with lime in general. Therefore, we consider it as a potential materials to be used as binder agents in future that need to be researched more. From this XRD results, we determined the amount of WBA based on the reference which will be explained in Mix Design part.

2.1.3. Expanded Polystyrene

Expanded Polystyrene or EPS which also known as Expanded Polystyrol is another form of geofoam materials which is very popular since early 90s. EPS is material that used as a lightweight fill in the constructions. It has so many advantages compared to the other foam because it's eco-friendly, more economical and also available worldwide [9]**.** It's even easier to be used in field because it's already in beads form so it's more flexible and we can avoid EPS blocks cutting to fit particular application. The density of EPS that we used is around 0,17 kN/m^3.

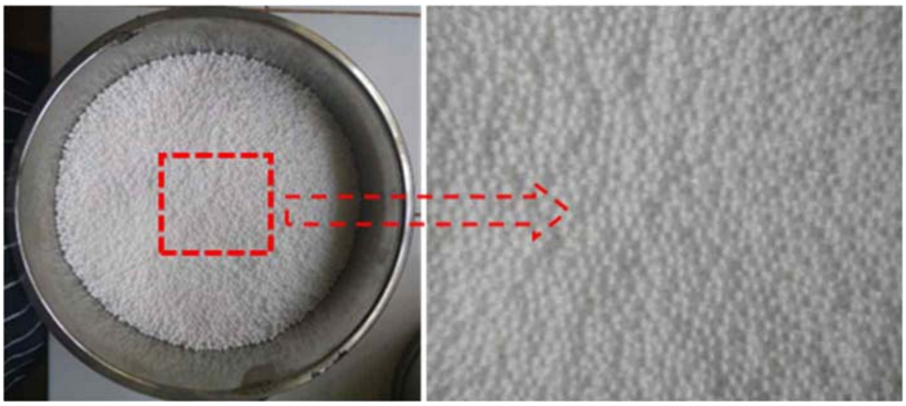

Figure. 3 EPS Bead

2.2. Methods

2.2.1. Mix Design

The specimens making and testing for these samples were using static compaction method as it's more accurate [10] [11], easy to control and approach the density that we desired. The following in Table 2. shows the mix design of the specimens.

Table 2. Mix Design

Composition	EPS %	WBA %	Curing time (days)
Untreated Soil	0	0	0
WBA- treated soil	0	3,5,7,9	7, 28
Lightweight Geomaterial(LWGM) 0,15%	0.15	3,5,7,9	7,28
Lightweight Geomaterial(LWGM) 0,30%	0,30	3,5,7,9	7,28

Based on Table 2, there are 4 types of samples tested for UCS and CBR. UCS and CBR specimens were made based on the OMC and MDD values obtained from standard proctor test results. CBR specimens were made with dimensions of 15.2 cm x 17.8 cm meanwhile UCS specimens were made with d= 5,5 cm and h= 11 cm. The amount of WBA were determined based on 3 references which are INDOT, Ingles and Metcalf, and Alaska Department of Transportation and Public Facilities Research and Technology Transfer [11].

The UCS test is carried out to determine the compressive strength while CBR test is carried out to determine the bearing capacity of the specimens, especially those that aims to be used as road pavement layer. The UCS test is the standard test that usually carried out for cement-treated soil [12], since WBA is also pozzolanic materials which similar to lime and cement, the specimens will be cured for 7 days, 14 days, until 28 days to optimize the pozzolanic reaction.

3. Result and Discussions

3.1. Soil Properties

The following in table 3. shows the data on the characteristics of the original soil used in this study.

Table 3. Soil Properties

No.	Name	Standard Method (ASTM)	Value	Unit
	A. Physical Properties			
1.	Specific Gravity	D-162	2,71	-
2.	Natural Water Content	D2216-98	12,17	%
3.	Classification System			
	a. USCS	C-136-06	CH	-
	b. AASHTO		A-7-6	-
4.	Atterberg Limit			
	a. Liquid Limit (LL)	D-423-66	58,37	%
	b. Plastic Limit (PL)	D-424-74	29,08	%
	c. Plasticity Index (PI)	D-4318	29,29	%
	B.Mechanical Properties			
5.	Standard Proctor Test	D-698		
	a. ɤdry max (MDD)		14,12	kN/m3
	b. Optimum Moisture Content (OMC)		25,28	%
6.	Unconfined Compression Strength (UCS)	D-633-94	57	kN/m2
7.	California Bearing Ratio Test (CBR)	D-1833	6,84	%

Table 3 shows the data on the characteristics of untreated soil, both its physical and mechanical characteristics. Based on the results of the sieve analysis and hydrometer tests and the Atterberg limit test, the soil used in this study are classified as CH according to the USCS and A-7-6 according to AASHTO classification, which means that the soil is very soft clay with high plasticity.

3.2. Unconfined Compression Strength (UCS)

The following is the effect of additional of WBA as a binder material shown in Figure 4. Based on the data obtained by Rauf [12], the additional of WBA increased the UCS value with the maximum UCS value obtained at the additional of 7% WBA and decreased along with the additional of 9% WBA. This is happened both in specimens with or without EPS. It can be seen in Figure 4. Adding EPS to the specimens decreased the UCS value, but this value is still above untreated soil which is only 57 kN /m^2.

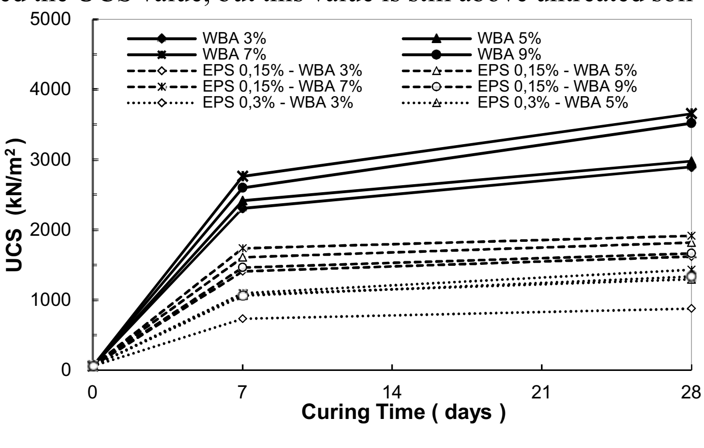

Figure. 4 Compressive Strength of Various Sample

The additional of WBA increased the UCS value 12 times - 48 times in the 7-day curing period and increased 15 times - 63 times in the 28-day curing period. Based on Figure 4. we can conclude that the UCS value tends to increase along with increasing curing period, the same behavior is also shown by cement-treated soil.

3.3. California Bearing Ratio

The following Figure 5. is the result of WBA-treated soil specimens which we compared to LWGM 0.15% and LWGM 0.30% at the 7-day curing period. [13]

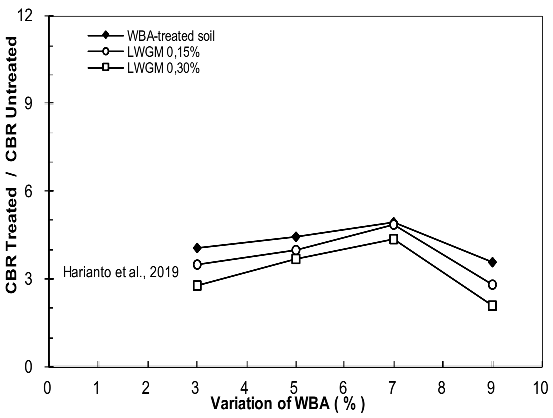

Figure. 5 CBR Ratio sample cured for 7 days

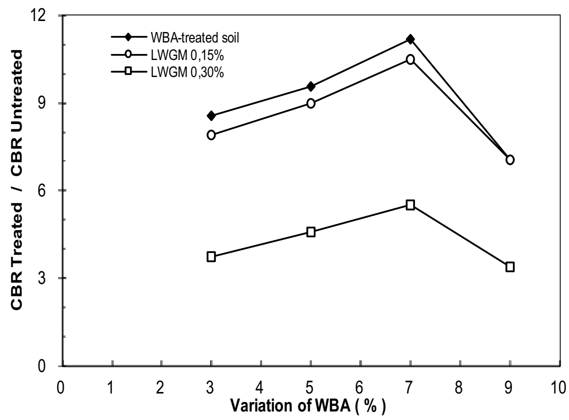

Figure 6. CBR Ratio sample cured for 28 days.

Based on the data shown in Figure. 5, both WBA-treated soil and LWGM increased the CBR value with maximum value obtained at 7% WBA addition and it decreased after additional of 9%. However, the CBR value of WBA-treated soil was higher than the value of LWGM specimens due to additional of EPS. WBA-treated soil had the highest CBR value of 4.9 times that of untreated soil, while LWGM 0.15% and LWGM 0.30% were 4.8 times and 4.3 times, respectively. Meanwhile, in Figure 6. is shown specimens testing results after curing 28 days. For WBA-treated soil specimens, the CBR value increased up to 11 times, while for LWGM 0.15% was 10.5 times and LWGM 0.30% was 5.5 times compared to untreated soil. These results proved that the treated samples especially samples that treated with pozzolanic materials need time to react optimally. That's why curing period are needed for specimens treated with chemical stabilizations.

3.4. Correlation of Mechanical Properties Parameters

The relationship between all parameters (UCS, CBR and E) is shown in Figure 7. The figure below is a comparison of 3 cases which are 1.) WBA-treated soil (without additional of EPS), 2.) LWGM which stabilized by WBA and 3.) BM+C treated soil which are taken from previous research of Harianto [1].

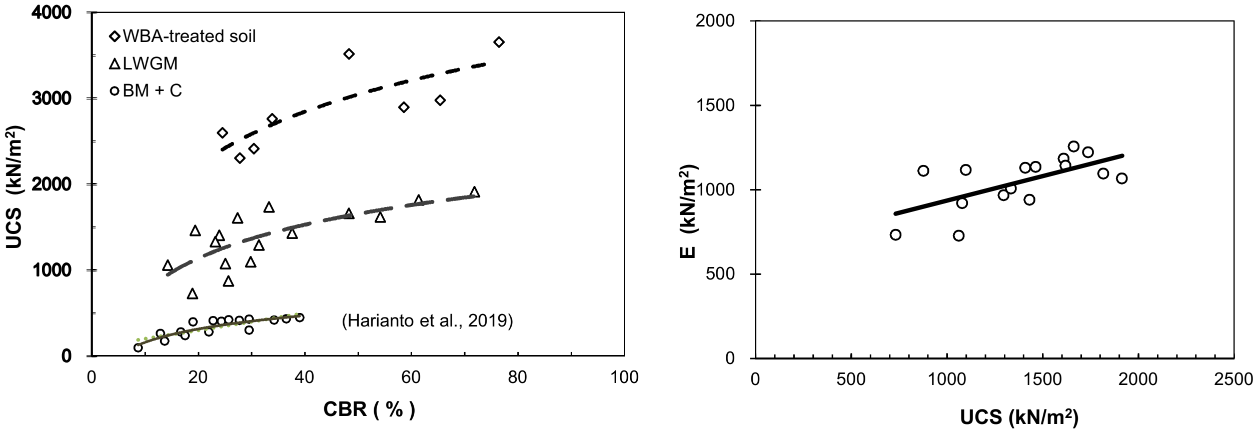

Figure 7. Relationships beetween parameters: (a) UCS and CBR (b) E and UCS LWGM

In those figures above, we can see the performance of each sample with different treatments. WBA-treated soil has the best performance when compared to LWGM and BM + C treated soil with the highest CBR value of 76.38% and UCS value of 3653.9 kN / m^2. LWGM performed below the WBA-treated soil sample with the highest CBR value of 71.820% and UCS value of 1913.9 kN / m^2, but the results were still above the performance of the BM + C treated soil sample which had the highest CBR value of 39% and UCS value of 446,7 kN / m2. From Figure 8 (b) we can see that the modulus elasticity tend to increase along with increasement of UCS value. This is related to calcium hydrate silicate (CHS) formation which are sides products of hydration and hydrolitics reactions on cement/pozzolanic-treated soil. These compounds are crystallized and get hardening over time [16]

3.5. The Impact to Density Reductions

The following in Figure 8 shows the density ratio of all samples compared to untreated soil.

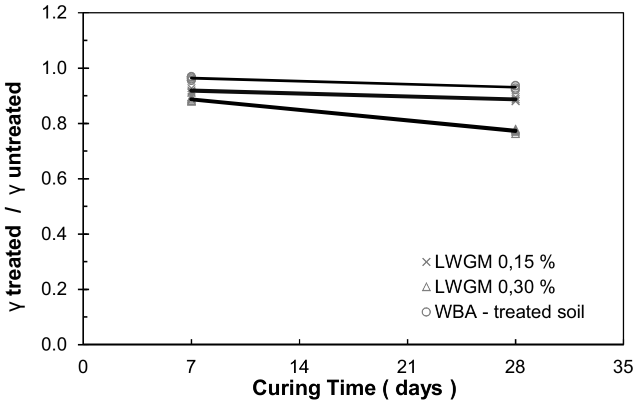

Figure 8. Ratio γ sample

As we can see, the WBA-treated soil is the heaviest and the closest to the density of untreated soil with a ratio of 0.922 - 0.970. While for LWGM 0.15% and LWGM 0.30%, respectively 0.881-0.928 and 0.764-0.839. EPS is added to a sample to obtain a lightweight sample. The EPS used in this study has a density 0.17 kN / m^3 while the soil's density is 14.12 kN / m^3. EPS is 83 times lighter than soil within the same volume unit. This is the reason why EPS is used as a substitute material to obtain lightweight geomaterials. However, the additional of 0,15% and 0,30% EPS for this research still have good performances by referring to its UCS and CBR results.

Conclusion

- Additional of WBA as the binder materials affect the UCS and CBR Value more than the impact of BM+C on treated soil because WBA's pozzolanic content is more than BM+C.
- Additional of EPS affect the UCS and CBR value. The less is the amount of EPS, the greater UCS and CBR Value were obtained. These amount of EPS (0,15% and 0,30%) still can be tolerated by referring its UCS and CBR Value. However, it's still needs further research for the other characteristics and also another amount of EPS.

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