The Influence of Buton Tailing and Expanded Polystyrene (EPS) on The Shear Strength of Sandy Soil

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ABSTRACT

Buton tailings, which are a by-product of Buton asphalt, have not been optimally utilized. In fact, research shows that Buton tailings have the potential as an additive to improve soil characteristics, especially sandy soil. This study aims to analyze the effect of the addition of Buton tailings and Expanded *Polystyrene* (EPS) on the shear strength of sandy soil. The sandy soil used came from Padalarang, Indonesia. Tests were conducted by adding Buton tailings at 0%, 2.5%, 5%, 7.5%, 10%, and 12.5% of the soil weight, and EPS at 0.15%, 0.3%, and 0.45%. The results showed that the addition of Buton tailings increased the cohesion and shear angle of sand soil. The most significant increase occurred with the addition of 5% Buton tailings and 0.15% EPS which increased the inner shear angle by 44% from the initial condition. Based on these results, it can be concluded that the combination of Buton tailings and EPS has the potential to increase the shear strength of sand soil.

Keywords: Button Tailing, Expanded *Polystyrene*, Shear Strength, Sand.

1. INTRODUCTION

Humans have used soil as a building material and foundation to construct houses and roads for centuries. The geotechnical properties of soil can be improved in two ways: compaction and mixing with additives such as lime, cement, fly ash and natural materials. Existing soils at construction sites are not always suitable for supporting structures. For this reason, soil improvement techniques are employed to improve the geotechnical characteristics of the original soil. One additive that is interesting to study is Buton tailings. The remnants of Buton mining (Buton tailings) can be utilised as additives to improve soil characteristics. Based on [1] , the addition of Buton tailings to soil is effective in increasing the stiffness of soil material. Buton asphalt (Asbuton) is a natural asphalt found in rock deposits on Buton Island, Indonesia [2]. With a total deposit of 650 million tons, Indonesia is the largest and best producer of natural asphalt in the world with higher levels than natural asphalt in the United States and France [3]. The production process of Buton asphalt produces several products including Buton tailings. Tailings Buton (TAB) is the remaining production from the extraction process of natural asphalt raw materials located on the island of Buton. The extraction process of Buton asphalt raw materials produces about 15-35% asphalt and the remaining 65-85% is Buton tailings [4].

With the potential for abundant natural resources, Buton tailings can be utilized as an additive to improve soil characteristics, particularly sandy soils. Previous research has proven that the addition of Buton tailings can increase the compressive strength of concrete [5] [6]. However, the use of Buton tailings in soil stability, especially sand, has never been done. Buton tailings have not been utilized productively by the government or the local community, due to limited information and research on the development of Buton tailings. However, their application in soil stabilization, especially in sandy soils, has not yet been explored. Previous studies have focused on soil improvement using Asbuton mineral, which is not a by-product or waste material, to increase the CBR and caracteristic of cohesive soils. Additionally, improvements in expansive clay using Buton Rock Asphalt and the use of Over Boulder Asbuton as a pozzolanic material for soft soil stabilization have also been carried out. Almost all these studies were conducted on soft clay soils and used Buton asphalt materials that are not residual products [1] [7]. Currently, Buton tailings remain underutilized by both the government and local communities, largely due to limited information and insufficient research regarding their development and potential applications. Based on chemical and mineralogical analysis of asphalt tailings from Buton Island, Southeast Sulawesi, the primary components include asphaltene (39.45%), lime ($CaCO_3$) (72.9%), and silica (SiO_2) (17.06%).

Furthermore, based on the analysis of asphalt tailings from Buton Island, Southeast Sulawesi, the chemical compounds and mineral composition are dominated by Asphaltene (39.45%), Lime/CaCO3 (72.9%) and Silica/SiO2 (17.06%). This composition shows that asbuton tailings qualify as raw material for cement manufacture and utilization of cement-based construction materials [4]. Other researchers [7] also tested the mineralogical content of this material, including gypsum/$CaSO_4$ (63.63%), calcite/$CaCO_3$ (15.54%) and quartz/SiO_2 (16.46%), while the rest is in the form of Calcium sulfide Oldhamite (2.78%) and Magnesite (1.60%) compounds. Based on the parameters in soil improvement, it can be concluded from these results that Buton tailings have the potential to be an alternative solution in soil improvement [7].

There were several examples of failures that occurred on the bridge, namely the collapse of the approach retaining wall. This collapse was caused by overloading the soft embankment soil [8]. Technology is needed that is able to reduce the load of the bridge embankment. One method that can be used is to use lighter embankment materials. Soil stabilization by adding Expanded Polystyrene (EPS) that has developed so far, has succeeded in reducing the load carried by the subgrade so that the embankment is more stable, and the decline caused is smaller [9]. Expanded polystyrene (EPS) is a versatile thermoplastic material renowned for its lightweight, insulating, and shock-absorbing properties [10]. EPS, which is a polystyrene-based polymer of styrene monomer, is commonly used in packaging and transportation of goods. However, after use, EPS is often discarded and becomes a soil pollutant. Therefore, the utilization of EPS as an admixture in soil can be a better alternative, as its properties can improve soil characteristics [11].

EPS is a lightweight material that can be used as a mixture for highway embankment to reduce the weight of the embankment itself and improve its soil characteristics thereby reducing soil settlement [10]. Expanded Polystyrene (EPS) is an expanded polymer material and often used in various construction applications. EPS in the context of soil stabilization can be used for several purposes, most notably to improve the stability of soil beneath structures or transportation lanes. The performance of EPS can be used in soil stabilization, some of which are used to increase soil strength and reduce soil load because EPS has a low density, so the total weight of the soil can be reduced when EPS is used in large quantities [12] [13].

EPS is a lightweight material due to its composition of about 98% air. This high air content makes it much lighter than traditional fill materials such as soil or gravel. The light weight of Geofoam will reduce lateral forces on retaining walls or abutments. This characteristic results in several advantages in embankment construction. EPS has a much lower density compared to traditional embankment materials. This means that a given volume of EPS will have a much lower weight compared to the same volume of soil or gravel. The lower weight of EPS will reduce the lateral pressure on the retaining wall or structure. This is especially beneficial in areas with weak soils where excessive lateral pressure can cause instability. The use of geofoam, a type of expanded polystyrene, as a lightweight fill material can significantly decrease settlement (S) and lateral pressure on the underlying soil (⎞ increased) [14]. Due to its lightweight nature, less EPS is required to achieve the same embankment height as traditional materials. This reduces the overall volume and weight of the embankment. In previous research, mixing clay soil with fly ash and EPS can increase the CBR value and reduce the dry weight of the embankment [15].

Buton tailings will be used in sand soil to analyze how much it affects the shear strength of sand soil that serves as embankment material. Buton tailings will be used in conjunction with Expanded Polystyrene (EPS) which is proven to reduce the weight of the embankment thereby reducing the potential for settlement. Styrofoam (EPS) is a synthetic polymer material resulting from the polymerization of styrene with the aid of a catalyst. With the aim of reducing the volume weight of soil, Styrofoam powder was used as an admixture with percentages of 0.15%, 0.3%, and 0.45%. The percentage is adopted from previous research [7]. Previous research shows that using Prefabricated Vertical Drains (PVD) can significantly reduce consolidation time—from decades to just a few months without affecting total settlement. However, higher preloading stress results in faster and greater consolidation [16] In contrast to the previous study that used the stabilized soil as a road foundation layer, in this study, the geo-composite will be used as an embankment material.

In this paper, the geotechnical properties of the backfill soil are improved. The soil was taken from a commercial sand site in Padalarang, Indonesia. The effect of the addition of Buton waste on the shear strength parameters of the sand will be examined. With the addition of Buton tailings, the sand's internal friction angle (⎞) will increase and automatically increase the sand's shear strength. Buton tailings will be used together with Expanded *Polystyrene* (EPS), which has been proven to reduce the weight of the fill. The reduction in fill unit weight (©) will reduce the load borne by the subgrade, thus reducing the potential for land subsidence and reducing the need for fill material. In addition, construction waste in the form of Expanded Polystyrene is used to reduce the self-weight of the backfill soil. For this reason, cheap, safe and natural materials should be used for soil improvement. The utilization of Buton waste and Styrofoam is expected to be an alternative solution in soil improvement in Indonesia.

2. MATERIAL AND METHODS

The soil was taken from a commercial sand site in Padalarang, Indonesia. This soil was used as filler material in the tests. The effect of the addition of Buton waste on the strength parameters of the sand will be examined. The maximum dry density and optimum moisture content of the sand soil were found. Samples were prepared using 5 different stabilization mixes of 2.5%, 5%, 7.5%, 10%, and 12.5% Buton waste. Buton waste was obtained from Buton Island, Southeast Sulawesi. Buton waste as an additive for filler material. After this process, this material was sieved with a 0.42 mm sieve (No.40) and added at a percentage of 2.5%, 5%, 7.5%, 10%, and 12.5% of the soil weight. Then, to reduce the volume weight of the backfill, Styrofoam was also used at percentages of 0.15%, 0.3%, and 0.45%. All samples were prepared at optimum moisture content. The direct shear test was conducted on these samples with a 14-day curing period (Table 1) Direct shear testing based on SNI 3420: 2016 (direct shear strength method of unconsolidated and undrained soil). The stages of implementation that will be carried out are briefly shown in Figure 1 in the Research Stages Diagram

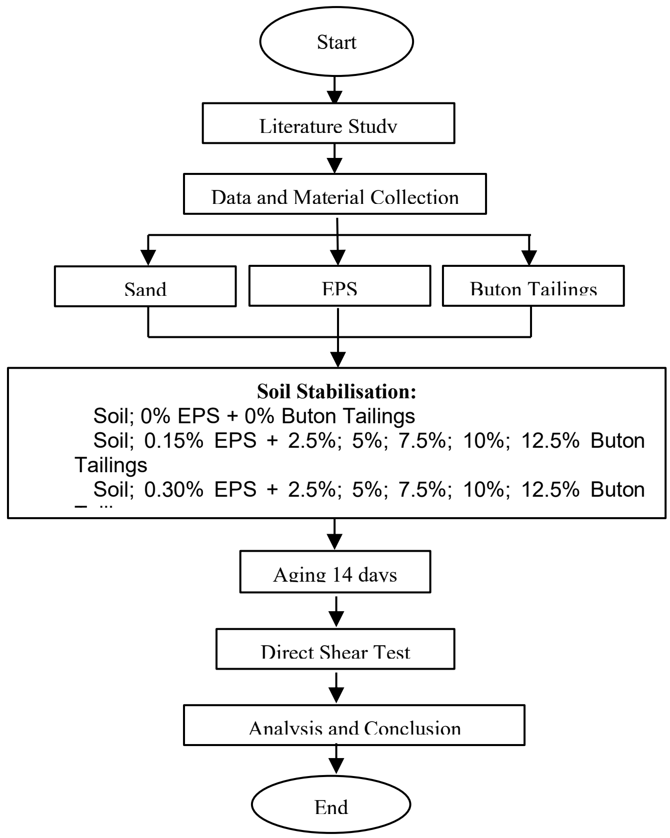

Figure1 Diagram of Research Stages

Table 1. Naming of Test Objects

No.	Soil Sample	EPS Percentage	Buton Tailings Percentage	Aging (days)
1.	Original Land	0%	0%	0
2.	Geo-composite A	0,15%	2.5%; 5.0%; 7.5%; 10; and 12.5%	14
3.	Geo-composite B	0,30%	2.5%; 5.0%; 7.5%; 10; and 12.5%	14
4.	Geo-composite C	0,45%	2.5%; 5.0%; 7.5%; 10; and 12.5%	14

3. RESULTS AND DISCUSSIONS

The grain size distribution of the soil is given in Table 2 and Figure 2. After sieve analysis and hydrometer test, the ratio of gravel, sand, silt and clay of the soil was determined to be 0%, 100%, 0% and 0% respectively. Thus, it was determined that this sand could be classified according to USCS and AASTHO as poorly graded sand (SP-SP) and A-1-B, respectively. After the stabilization samples were mixed with the predetermined percentages, the samples were cured for 14 days and then prepared for proctor density testing. From the compaction test results, the dry weight d is 1.157 gr/cm^3 with an optimum moisture content of 25.74%. The compaction result curve can be seen in Figure 3.

Table 2. Initial Condition Sieve Analysis Results

Sieve Number	Diameter [mm]	Sieve Weight	Soil Weight + Sieve	Retained Weight	% Retained Weight	Somasi % Retained	% Passed
4	4.750	579.95	579.95	0.00	0.00	0.00	100.00
10	2.000	546.31	555.92	9.61	12.17	12.17	87.83
20	0.840	490.97	510.36	19.39	24.55	36.71	63.29
40	0.425	462.54	482.07	19.53	24.72	61.44	38.56
60	0.250	439.38	452.67	13.29	16.82	78.26	21.74
100	0.150	436.87	446.75	9.88	12.51	90.77	9.23
200	0.074	418.18	424.55	6.37	8.06	98.84	1.16
pan	< 0.074	432.07	432.99	0.92	1.16	100.00	0.00

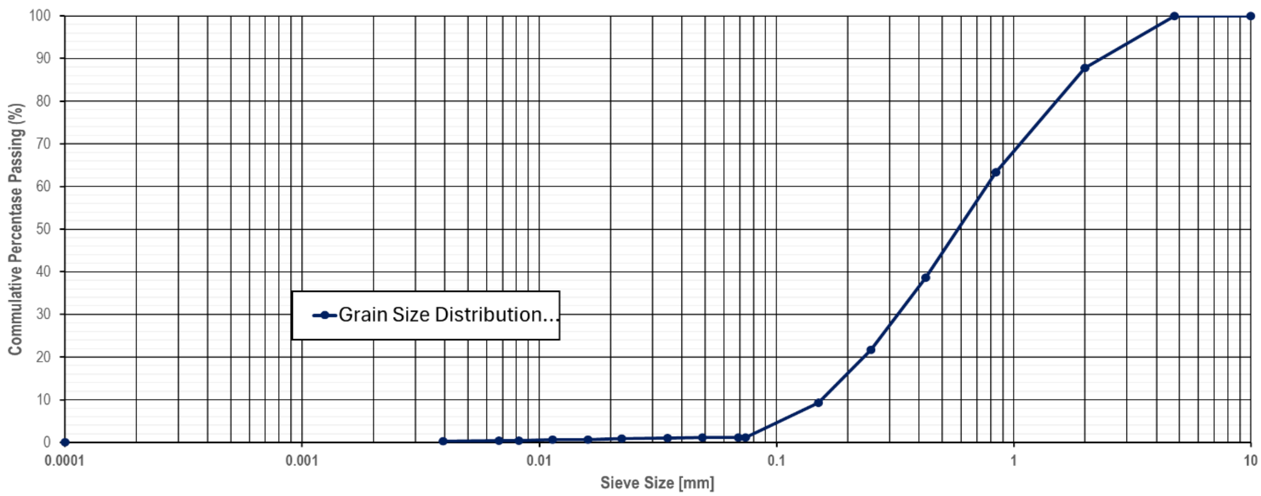

Figure 2. Sand Grain Size Distribution Curve

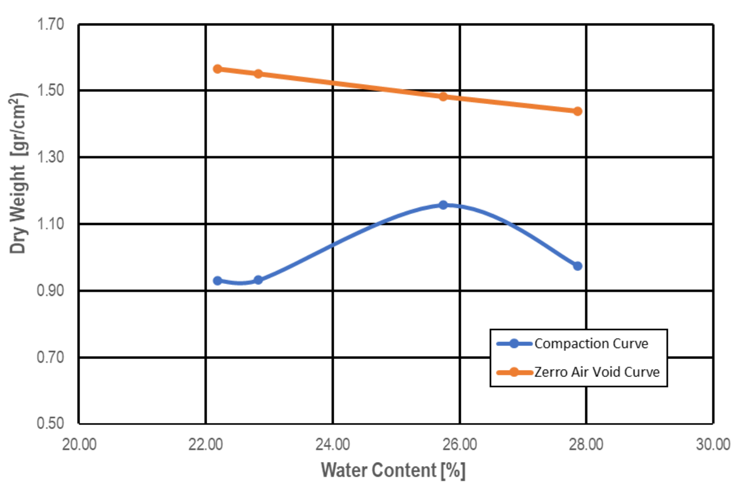

Figure 3. Proctor Compaction Test Results

The shear box test was conducted at a constant speed of 1 mm/min. The shear box test results of these samples are given in Figure 4 and Figure 5, the cohesion and internal friction angle values are plotted against the percentage of Buton tailings. The results show that the cohesion value of sand soil increases with the addition of Buton tailings, and the internal friction angle value also increases. The increase in the inner shear angle of the soil occurs because these Buton tailings still contain Asphaltene. Buton tailings contain asphaltene, which is a heavy fraction of asphalt that is sticky and has a high affinity for the surface of soil particles. This asphaltene acts as a binder between soil particles [17], thereby improving inter-particle bonding and soil cohesion. In addition, Buton tailings contain high amounts of pozzolanic materials, such as lime ($CaCO_3$), calcium, and silica, which have the potential to strengthen the soil through the pozzolanization process. This content can increase soil stiffness by inducing chemical binding reactions that result in strengthening the soil matrix and reducing deformation [18]. Pozzolanic materials can improve cohesion between soil grains through chemical reactions with water and other binding compounds. This reaction produces compounds that can strengthen the bonds between soil particles, thereby increasing the stiffness, stability and structural strength of the soil [1]. Moreover, the addition of Buton tailings will fill the soil pores and increase the bond between soil particles. This leads to the formation of a tighter and more stable soil structure, thereby increasing the resistance of the soil to shear deformation. The increase in soil internal friction angle can also be caused by the relatively rough surface of the Buton tailings particles which increases the frictional force between soil particles. This contributes to the increase in soil internal friction angle, which is one of the important parameters in determining soil shear strength

The images of the samples after the shear box test, changes in internal friction angle and cohesion are given in Figure 4. The test results show that the addition of Buton tailing, and EPS can improve the strength parameters of the soil. The addition of Buton tailing is 2.5% and gives significant results with an increase in internal friction angle ( ) up to 37% to 44%. However, with the increasing percentage of EPS, the increase in soil internal friction angle value decreases. This can be seen in Figure 5 with the addition of EPS 0.15%, 0.3%, and 0.45% respectively resulting in soil internal friction angle values in Geo-composite B of 37.96°, 41.74°, and 44.00°. This is because the addition of EPS reduces the dry volume weight by 6% and 9%, respectively [14] [19]. Also, the shifting resistance characteristic of EPS plays a role in limiting the mobility of soil particles to achieve optimum density. As the number of EPS added increases, there is a decrease in the soil internal shear angle value due to the restricted movement of soil particles, which inhibits the formation of a denser soil structure [10]. Therefore, the addition of Buton waste and EPS with a total percentage of 5% and 0.15% provides the maximum strength and dry volume weight desired for foundation base and embankment applications. Unlike the internal friction angle of the soil, the cohesion value of the stabilized sand soil tends to decrease from the initial condition. This is due to the absorption of EPS (Expanded *Polystyrene*) which fills the soil pores. EPS, being a lightweight and water-insoluble material, can fill empty spaces in the soil structure, thus affecting the physical and mechanical properties of the soil, including its bearing capacity and permeability. Similar research was also conducted by [7] where from the measurement of lightweight geo-composite density (EPS +tailing Buton), a linear relationship was obtained between the variation of EPS percentage and geo-composite density. At 0.15% EPS content, the variation of geo-composite density varies between 1268kg/m^3-1287kg/m^3. At 0.30% EPS addition, it was 1159 kg/m^3- 1174 kg/m^3. However, although it has successfully increased the CBR value from the original condition of 6%, the CBR of this geo-composite soil only reaches a maximum of 20%, which can only utilize this lightweight geo-composite material as a lower foundation layer (LPB) in road construction, the composition that can be used is LPB with a percentage of 5% - 7% as well as, and EPS of 0.15% and 0.30%.

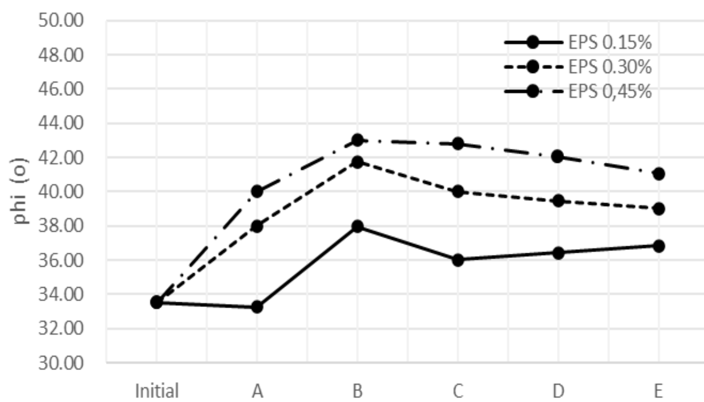

Figure 4. The Effect of Buton Tailings and EPS Addition on Internal Friction Angle of Sand

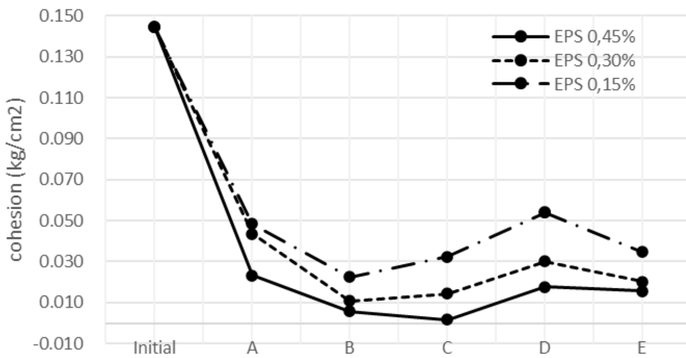

Figure 5. The Effect of Buton Tailings and EPS Addition on Cohesion of Sand

4. CONCLUSION

Based on the results of research and discussion on the effect of the addition of Buton tailings and Expanded Polystyrene on the shear strength of sand soil, the following points can be concluded:

1. The addition of Buton tailings to sand soils gave significant improvements to the soil strength parameters, namely cohesion and inner shear angle. This indicates that Buton tailings has the potential to be an alternative solution for soil stabilization, especially sandy soil.
2. The addition of EPS to sandy soil stabilized with Buton tailings proved effective in reducing the dry volume weight of the soil. This indicates the potential of using EPS to minimize embankment loads and reduce the risk of landslides.
3. The combination of 5% Buton tailings and 0.15% EPS gave optimal results in increasing shear strength and reducing dry volume weight of sand soil. With the improvement of soil parameters, the results of this study can be considered for application as embankment over soft soil.
4. The use of Buton tailings and EPS as soil stabilization materials is expected to be a sustainable solution in improving soil quality and supporting infrastructure development in Indonesia.

Suggestions for future research:

1. Further research needs to be conducted on the effect of buton tailings and EPS on other soil strength parameters, such as free compressive strength and tensile strength.
2. This research should be conducted on other soil types (silty soil, clay soil, or expansive soil) to determine the effect of bouton tailings mixture.
3. Field research is needed to test the effectiveness of using Buton tailings and EPS on a larger scale.
4. It is necessary to conduct an economic analysis to determine the feasibility of using Buton tailings and EPS as soil stabilization materials.

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