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Experimental study of unconfined compression strength of Clay-Expanded Polystyrene (EPS) stabilized with alkaline

R Tenreng¹, M W Tjaronge², T Harianto³ and A B Muhiddin³

¹Doctoral Student, Department of Civil Engineering, Universitas Hasanuddin, Indonesia

²Professor, Department of Civil Engineering, Universitas Hasanuddin, Indonesia

³Associate Professor, Department of Civil Engineering, Universitas Hasanuddin, Indonesia

E-mail: ramdania.tenreng@gmail.com

Abstract. Concern for the global environmental impact of industrial waste disposal and the strict legal rules on the environment has led to various studies of recycled materials. One of the most widely used and recycled materials is Expanded Polystyrene. Expanded Polystyrene has a low mass compared to its volume. This has made many breakthroughs in EPS waste recycling as a substitute material, one of which is in the manufacture of lightweight materials used in the field of civil engineering. Therefore, this study focused on the development of soil composites made by mixing recycled EPS with quicklime stabilization clay activated by gum rosin and iron oxide (hereinafter referred to as alkaline) based on the weight ratio with variations of 0%, 0.3%, 0.6% and 0.9% using the slurry method. The parameters to be analyzed are the Unconfined Compressive Strength values of each mixture variation in a certain curing period. So that the optimum composition between clay, activator, and EPS will be obtained. The test results show that the addition of activator and EPS can significantly reduce the weight of the specimen. So it can be concluded that the addition of EPS and activator can reduce weight with an optimum composition of 0.9% EPS in 28 days of curing where the compressive strength of the specimen is higher than the value of the compressive strength of the clay.

1. Introduction

Rapid technological advance has an impact on the increase in all areas of human needs in the field of civil engineering construction to encourage researchers to study ways to meet these needs [1]. So far, researchers have tried different alternative materials to meet the needs of construction. One type of material that becomes the focus of research is a lightweight material that can be used in various parts of the construction.

Expanded polystyrene is a material used in the manufacture of lightweight materials [2]. Expanded polystyrene (EPS) or also called polystyrene. Use of Styrofoam to perform human activities such as packaging and security of electronic products, for decoration, etc. Polystyrene waste is an increasingly important environmental problem and can not decompose (non-biodegradable) [3].

This research was therefore conducted to overcome the environmental problems encountered and meet the needs of lightweight materials in the development of construction. The output of this research is the optimal composition of the soil, alkaline, and EPS with curing time refined the lowest weight with the compressive strength is not too much compared to the compressive strength of the clay, without stabilization.



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2. Literature study

Soft soil is a fine-grained soil containing clay. The clay minerals have four characteristics, each being the following: kaolinite, consisting of a base layer of a silica sheet and aluminum bonded by hydrogen ions [4]. Halloysite is almost identical to kaolinite, but its structure is stacked more randomly so that water molecules can penetrate between units [5]. Montmorillonite consists of a set of silica-aluminum-silica layers separated by H₂O ions so that it is easily released and very unstable. Water interrupts easily between layers, causing minerals to expand and when the water between coats dries out, the minerals contract. Besides, the arrangement of the layers is the same as that of montmorillonite, but the separation ion is an easy-to-expand K⁺ ion. The formation of the crystalline structure is similar to that of montmorillonite.

2.1. Alkali

2.1.1. Lime

Chemically, limestone is formed from calcium carbonate and other minerals that accompany it. The physical, chemical and geological processes that accompany its formation make nature a variety of limestone features. The limestone (limestone) used in this study is CaCO₃ which contains more than 80% of calcium [6]. The potential of limestone in Indonesia is very important and spreads in almost every province. The limestone reserves are already known about 28.7 billion tons, the highest in the West Sumatra province, namely 23.23 billion tons, or about 81.02% of the reserves throughout Indonesia [4].

2.1.2. Damar resin

Resin is a sap (exudate) of many types of plants, especially conifers. In general, it freezes to form a hard mass and tends to be transparent. Having gurjunik acid content (C₂H₃4O₄), as well as some volatile and crystallized napa. At a temperature of 30 ° C, switch to gelatin if it is dry and solid. Physically transparent, plastic and hard, but exposed to heat becomes soft. Chemically is a complex mixture of resinat, alkoholresinat, resinotanol, ester, and Resene-Resene acids. It contains little oxygen and does not have a weak nature. Soluble in alcohol, ether, acetone, petroleum ether and chloroform. Once separated and purified, it becomes solid, brittle and amorphous. At a high level of viscosity and a strong bond between the particles. The quality of the gum resin is obtained from SNI 2900-2-2013.

2.1.3. Iron oxide

Iron oxide can affect some soil properties, which affect the earth in a reddish color, aggregates between soil particles and cation exchange capacity [7]. In particular restriction of iron oxide may indicate pH conditions, redox potential, soil moisture and temperature environment [3]. Iron oxide can react with calcium carbonate to form iron carbonate oxide.

2.2. Expanded polystyrene

EPS or expanded polystyrene itself is a kind of polystyrene material, the same as the physical, but different in the ingredients. EPS is made with a denser density and with special addictive substances, so this EPS does not spread fire when burned. While Styrofoam spreads fire in all parts of the body when burned by fire, EPS is a plastic material that has special properties with structures composed of granules containing air and low density. There are gaps between grains that can not deliver heat. This makes the EPS good thermal insulation. With its thermal insulation properties, the EPS can be used as a wall or skin of a building where it prevents the penetration of the sun's heat from outside into the room. EPS as a heat-inhibiting building material may be an exterior wall, a roof covering or simply a layer on the outer wall of the building, of course with each appropriate dimension.

3. Experimental program

3.1. Laboratory tests

The properties and mechanical index of the soil were tested with various methodology, the following tests are carried out:

Table 1. Standard testing method.

Tests	Standards
Water Content	(ASTM D 2216-98)
Sieve Analysis and Hydrometer	(ASTM D 1140-54)
Atterberg Limits	(ASTM D 424-59)
Standard Proctor Test	(ASTM D 698)
Unconfined Compression Test	(ASTM D 2166-66)

3.2. *Sample preparation*

The soft soils used in this study come from around the Campus II Engineering Faculty at Hasanuddin University in Gowa, South Sulawesi, Indonesia. The alkali used is the result of manufacturing with constituent materials, including quicklime, resin, and iron oxide. Expanded polystyrene used as EPS seed having passed sieve number 4 and suspended by filter number 10. The compositions of mixing materials are described in table 1.

Table 2. The Mix composition of materials.

Activator	EPS	Curing Time (Days)	Sample Quantity
	0.30%	7	3
		14	3
		28	3
2%	0.60%	7	3
		14	3
		28	3
	0.90%	7	3
		14	3
		28	3

The samples are printed with the suspension method provided that the total water content of the sample is soil mixed with water based on the liquid limit value from the Atterberg Limits test results and all is mixed with water 1.5 times alkaline dry weight. The sample is then made in a cylindrical shape with a height of 11 cm and a diameter of 5.5 cm in diameter. The samples that have been remolded are then dried for 7, 14 and 28 days so that the soil and the alkalis can react well so that they can bind to the EPS granules. After reaching the specified curing time, the sample is tested for free compressive strength.

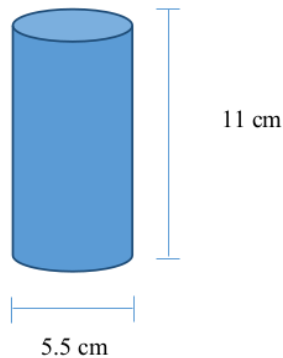


Figure 1. Unconfined compression test specimen.

4. Results and discussion

4.1. Summary of soil properties index test results

The following is a summary table of the results of the soil property index test carried out in the laboratory

Tabel 3. Test summary.

Test	Result
Specific Gravity (Gs)	2.650
Water Content (ω)	32.20%
Atterberg Limits	
Plastic Limit (PL)	46,35%
Liquid Limit (LL)	60,76%
Plasticity Index (IP)	14,41%
Sieve Analysis and Hydrometer	
Gravel	6,8%
Sand	28,4%
Silt	30.25%
Clay	34.55%
Standard Proctor	
$\gamma_{dry\ max}$	1,411 gr/cm ³
Optimum Moisture Content (ω_{opt})	29.75 %
Unconfined Compressive Strength (q_u)	0,751 kg/cm ²

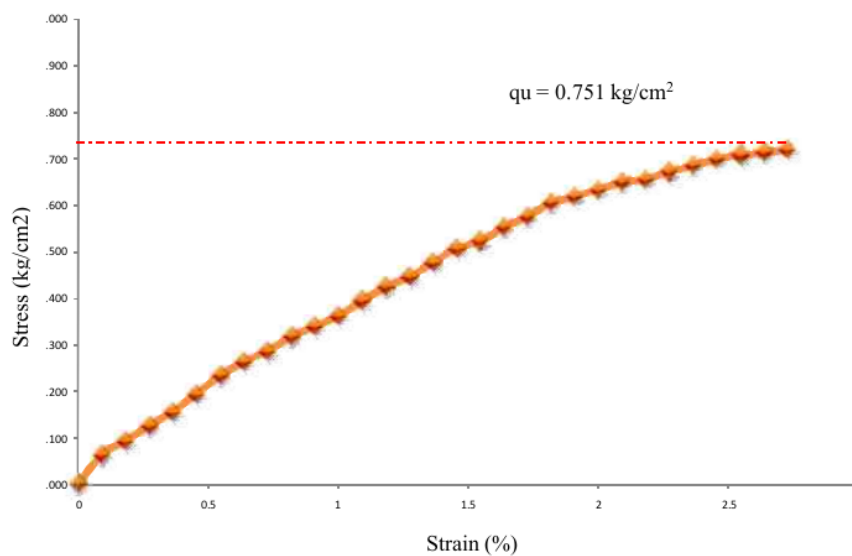


Figure 2. The relation between Stress-Strain of Clay soil.

In the absence of alkaline stabilization and EPS addition, the initial compressive strength of the soil is 0.751 kg/cm² and classified as clay soil classification with a medium soil consistency.

3.2. Effect of EPS stabilization and addition to the value of soil resistance and weight of specimen. The addition of alkali can increase the value of the compressive strength of the soil. However, the addition of EPS can reduce the density value, so that the compressive strength decreases. Besides, the addition of EPS can significantly reduce the weight of the sample. The scheme of reducing the load and decreasing the compressive strength can be seen in the following graph.

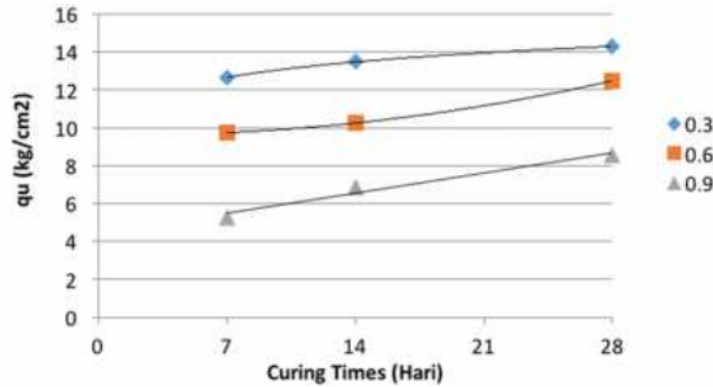


Figure 3. Relationship between compressive strength and curing time with various types of EPS.

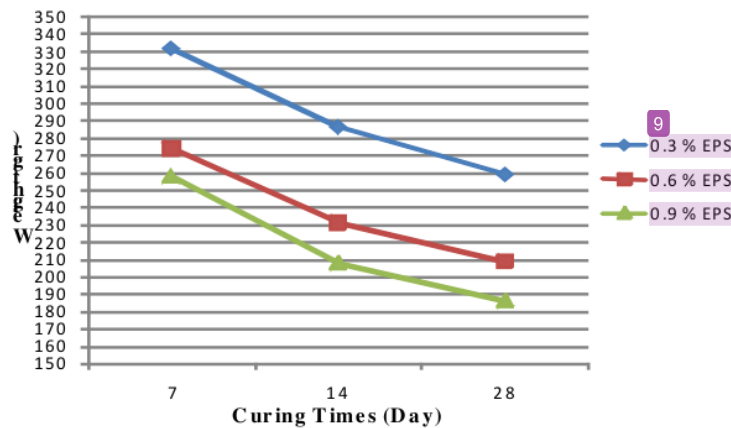


Figure 4. Relationship Between Sample Weight and Curing Time with various types of EPS.

If the soil sample weight is 456 grams and the addition of EPS to 0.9% of the sample weight is reduced to 186.506 grams, this means that with the addition of EPS, it can reduce by 59% from the initial weight for 28 days. The use of alkali is a binder material so that the EPS can be mixed and well distributed in the sample. However, the compressive strength will decrease as the EPS increases.

5. Conclusion

Based on the results of the soil physical characteristics tests, it was obtained according to USCS included in the CL classification, namely the moderate plastic silt. The addition of EPS is 0.3%, 0.6% and 0.9%. The optimum composition is obtained with the addition of 0.9% EPS with 28 days of

ripening, with a final compressive strength of 12.258 kg / cm². Due to weight reduction and compressive strength value, it can be used as partition wall material (shear wall)

6. Acknowledgments

The authors are appreciated the LPDP by providing financial support for this research to work.

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