



Unconfined Compressive Strength Characteristics of Overboulder Asbuton and Zeolite Stabilized Soft Soil

Noor Dhani ^{1*}, Ahmad Gasruddin ¹, Hartini ¹, La Baride ¹

¹ Universitas Dayanu Ikhsanuddin, Yos Sudarso Avenue 43, Bau-Bau City 93711, Indonesia.

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Abstract

Soft soil was one of the most widely encountered problems in construction, especially for archipelago countries which most of its area was lowland with a high deposit of soft soil. To overcome this problem, soil stabilization was one of the most widely used as a solution. Soil stabilization in general uses chemical substances that are classified as pozzolan material. Pozzolan material uses its capability to strengthen the cohesion of soil grains. Mostly, pozzolan material consists of silica. Overboulder asbuton and zeolite were examples of natural pozzolan material in Indonesia. Both materials have a high silica content. Thus, the author interested to figure out the mechanical behavior of these two substances as a soil stabilizer. This research was a correlating study to the previous paper with the same author which discusses the overboulder asbuton as a soil stabilizer. Overboulder added to the mix is determined as 15%, with varied zeolite percentages applied to examine the differences. The UCT was conducted according to ASTM D-2166 as a parameter. As the standard remolding method, a standard proctor test was conducted to determine the optimum moisture content and the maximum density of each mix. While the UCT specimens were tested at the certain curing time for each composition. The curing time applied was 0, 7, 14, and 28 days. By this curing period, the effective pozzolanic reaction that occurs for each composition could be determined. The result shows that zeolite addition to overboulder asbuton could increase the soil density and increase its compressive strength. It is indicated that overboulder asbuton and zeolite mix could be a proper alternative as a soil stabilizer.

Keywords: Asbuton; Overboulder; Soft Soil; Stabilization; Zeolite.

1. Introduction

Soil is an element closely linked to the planning of the building's structure. The soil has a crucial role because structures are erected directly above the ground. The soil has different specifications and behavior for each type, so it requires different treatment both mechanically and chemically so it could meet a certain technical specification. These treatments cannot be separated as they are closely related to each other. If the treatments are not carried out correctly, failure is assured. This study is a continuation of the author's previous experimental study which analyzes the effect of overboulder addition to increase the bearing capacity of soft soil. The previous study results were that the optimum overboulder asbuton content was 15%. To improve those result, natural zeolite was chosen as a local content that also has pozzolanic properties. By combining these materials using certain compositions, the effect of zeolite addition could be analyzed. The final result will be delivered systemically according to the general process which presented in several sections; Introduction to give the readers a brief review of the paper and the previous study, Literature Study to

* Corresponding author: noordhanitech@gmail.com

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provide supporting theories from previous study and findings which have been conducted by the authors and other corresponding topics, Methodology to state the process of the research, Result and Discussion to represent the data gathered along the experimental study, and Conclusion to state our final findings based on the results of the tests.

2. Literature Review

2.1. Overboulder Asbuton as Soil Stabilizer

Soil stabilization has been carried out to increase the mechanical capacity, so that it is possible to bear the load of a construction. Generally, the stabilization is carried out with ash, cement and lime to trigger a pozzolan reaction that able to enhance the cohesion between the soil grains, thus increasing the mechanical values of the soil. Overboulder asbuton was proofed capable to be used as a stabilizing material, an alternative substitute for cement or lime. Overboulder asbuton minerals generally consist of similar composition as limestone, due to its natural forming process which occurs when natural asphalt penetrates the topsoil layer. Usually, the asphalt content of overboulder asbuton as low as 2%, mainly 79.64% calcium and 9.63% silica, so it can be used as a pozzolanic material [1].

Previous study concluded that by adding overboulder as a soft soil stabilizer could improve the mechanical performance of soft soils. The soil's CBR value increased significantly up to 4, 9 times and the unconfined compressive strength was increased by 77 times compared to the untreated soil. This indicates that the overboulder can be used as a substitute material for cement [2].



Figure 1. Overboulder asbuton quarry in Buton Island, Southeast Sulawesi, Indonesia

2.2. Zeolite as Soil Stabilizer

The potential of zeolite mine in Indonesia is very abundant. Almost all areas with Limestone Mountains are rich in zeolites. Most Indonesian zeolites are dominated by Mordenite and Clinoptilolite minerals. For example, zeolite in Sangkaropi, North Toraja regency, in South Sulawesi Province, Indonesia, is estimated in amount of 168,480,000 tons over the area of 360,000 m². The natural zeolite contains crystals of alumina silicate, SiO₂, approximately 64.57% to 81.83% [3].



Figure 2. Natural zeolite from North Toraja, South Sulawesi, Indonesia

Zeolites are largely used in soil remediation technologies by exploiting their well-known high cation-exchange capacity. Besides this property, zeolites possess large pores and internal cavities. Such pores can be used to trap scarcely soluble HM precipitates, thus chemically reducing their solubility and physically isolating the contaminant at the microscopic level. Zeolite synthesis can be easily promoted in soil at low temperatures by adding Si- and Al-containing materials in alkaline conditions. As a consequence of this process, HM are stabilized as micro- or nanoclusters of oxides and hydroxides trapped inside the structure of crystalline zeolites or physically and chemically immobilized by amorphous geopolymers. In this process, waste materials such as coal fly ash, blast furnace slag, building wastes, glass, and aluminum refuses can be profitably employed, together with cheap alkali reagents (e.g., NaOH, KOH, and Lime) [4].

2.3. Pozzolan Materials

Pozzolan is a material that contains Silica and Alumina, in its fine form and the presence of water will react chemically with Calcium Hydroxide at room temperature which will form a compound that has properties like cement [5]. The fineness of a cement is an important factor affecting the rate of strength development [6]. The existence of natural pozzolan in Indonesia are often found in areas near the active mountains such as Nagrek (West Java), Mount Muria (Central Java), Mount Lawu (East Java) and other areas of Java, Sumatra, Sulawesi, Nusa Tenggara and Halmahera. Pozzolan material itself has long been known in Indonesia as a building material that is mixed lime outages [7]. Recently, pozzolan materials even studied to be implemented as waterproof material for DAM soil [8]. It is even possible to use alkali-activated natural pozzolans to prepare environmentally friendly geopolymer cement leading to the concept of sustainable development [9]. This material is a good candidate to partially replace Ordinary Portland Cement (OPC) in concrete as a major construction material that plays an outstanding role in the construction industry of different structures [10].

3. Materials and Methods

To provide details of materials used in experimental studies, a laboratory investigation program was carried out to evaluate the basic and mechanical properties of untreated and stabilized soils, in this case, soft soil stabilized using overboulder and zeolite. Asbuton overboulder material was brought from Buton Island and sampled at Lawele with coordinates $5^{\circ}13'53.56''\text{S}$ and $122^{\circ}58'0.40''\text{E}$ in chunks and then crushed to ease the mixing process and accelerate the reaction. The grain size used is to which pass sieve #100. While the natural zeolites were taken at Sangkaropi in North Toraja, South Sulawesi, which was brought in chunks. The natural zeolite used in this study was then ground and filtered using #40 sieve. This fine zeolite was then mixed with asbuton overboulder by 15% of overboulder asbuton and 1% up to 5% of zeolite. Unconfined compressive strength value was then analyzed as a parameter according to ASTM D 2166 for the Unconfined Compression Test of Cohesive Soil [11] and ASTM D-698 for the standard proctor [12].

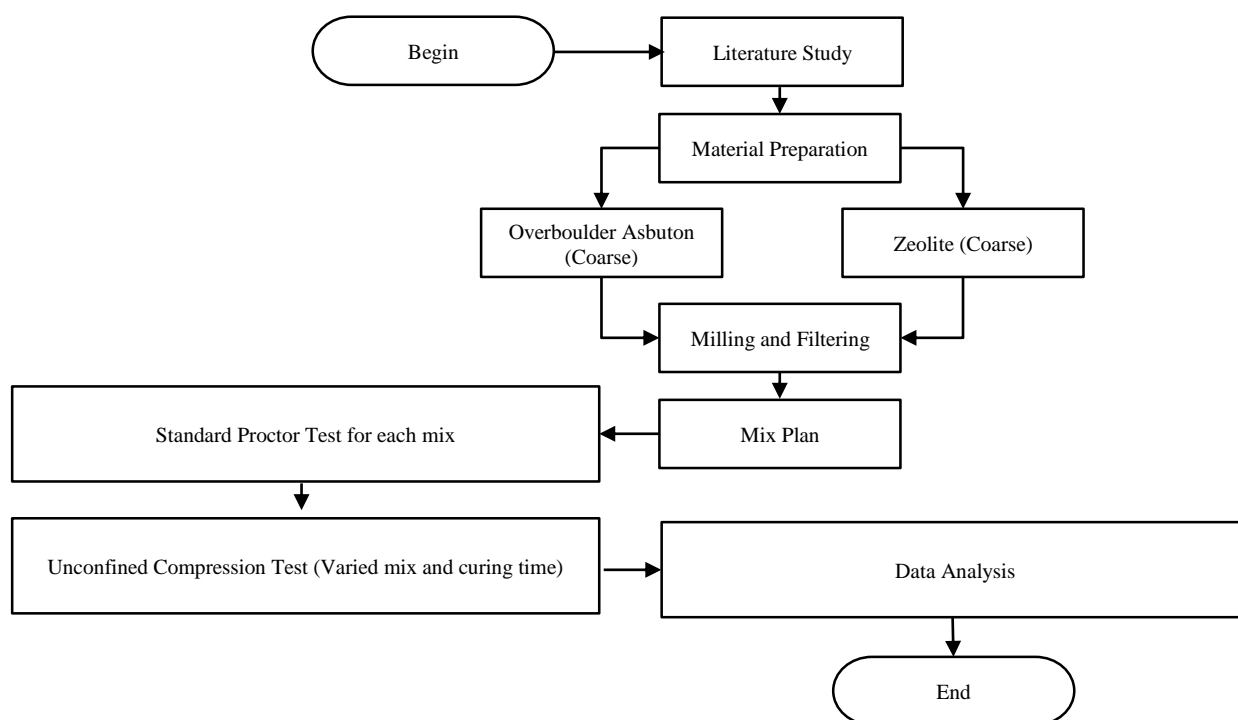


Figure 3. Flowchart of the experimental study

4. Results and Discussions

Basic properties testing such as specific gravity, sieve analysis, and Atterberg limits were conducted to classify the soil type precisely [13]. Standard proctor tests were conducted to obtain the maximum dry density [14] of each mix along with the required optimum water content to achieve the correlated density of each mix. This compaction standard is then used to calculate the required energy to make UCS specimens with the same density as the proctor specimens [15]. The results of the basic properties and mechanical properties of soft soil are shown in the following table.

Table 1. Basic properties and mechanical properties of soft soil

Test	Result	
	Value	Units
<i>Basic Properties of Soft Soil</i>		
Initial Water Content (w)	35,72	%
Specific Gravity (Gs)	2,65	-
<i>Sieve Analysis and Hydrometer</i>		
a Sand	35,20	%
b Silt	34,55	%
c Clay	30,25	%
<i>Atterberg Limits</i>		
a Liquid Limit (LL)	60,76	%
b Plastic Limit (PL)	46,35	%
c Plasticity Index (PI)	14,40	%
d Shrinkage Limit (SL)	26,51	%
<i>Standard Proctor</i>		
a Maximum Dry Density, (γ_d)	1,35	gr/cm ³
b Optimum Moisture Content (OMC)	29,84	%
Classification According USCS : MH, AASHTO : A-7-5		
<i>Engineering Properties of Soft Soil</i>		
Unconfined Compressive Strength (qu)	0,47	kN/m ²
California Bearing Ratio – Unsoaked (CBR)	7,79	%

According to the USCS (Unified Soil Classification System), the soil used in this study classified as MH, namely, silt with high plasticity with 35.20% sand fraction, 34.55% silt fraction, and 30.25% clay fraction. Meanwhile, according to AASHTO, this sample is included in sample type A-7-5 with an estimated poor to medium quality [16]. The untreated soil has a UCS value of 46 kN/m² which classified as soft soil due to UCS value less than 50 kN/m² [17].

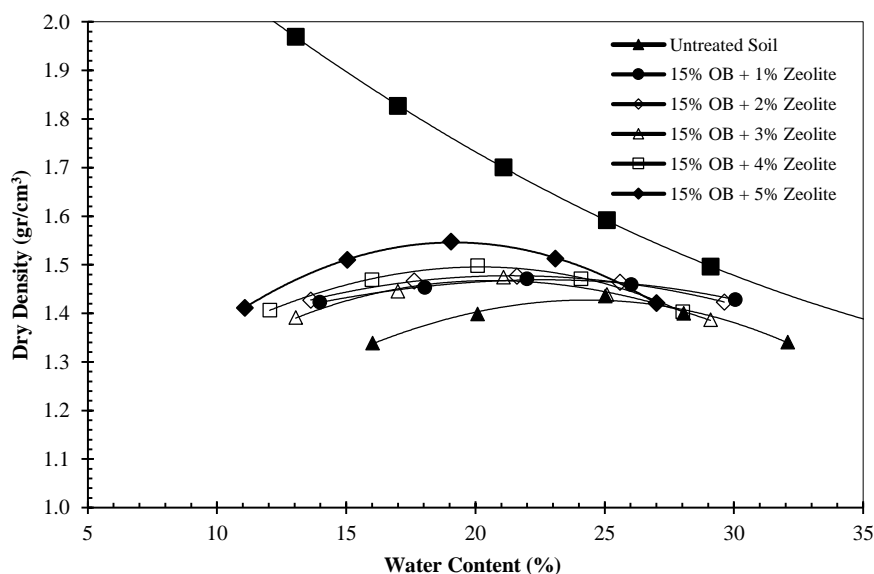


Figure 4. Correlation between the moisture content and the dry density of each mix

Based on the results of the standard proctor that refers to ASTM D-698 shows that with the addition of zeolite, the dry density increases while the optimum moisture content decreases. It indicates that zeolite tends to have the same behavior as limestone and silica in general. By the increasing dry density value, we can also conclude that zeolite could strengthen the soil's cohesion.

Table 2. Basic properties and mechanical properties of soft soil

Soil (%)	OB (%)	Zeolite (%)	$\gamma_{Dry}(gr/cm^3)$	OMC (%)
100	0	0	1.44	25.02
84	15	1	1.47	21.99
83	15	2	1.48	21.59
82	15	3	1.47	21.08
81	15	4	1.50	20.08
80	15	5	1.55	19.05

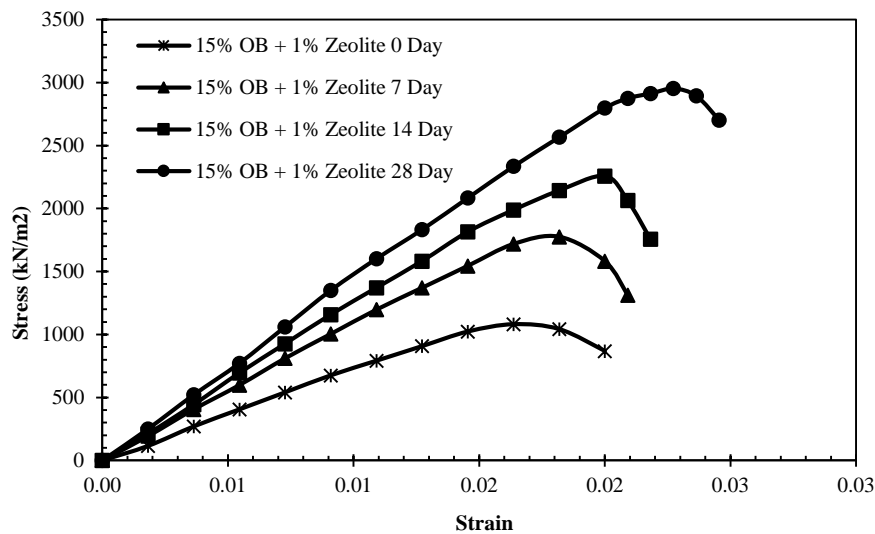


Figure 5. Stress-strain behavior of soft soil stabilized by overboulder and 1% zeolite

Based on Figure 5, the ultimate compressive stress increases with increasing curing time. This illustrates that as the curing period increases, the pozzolan reaction that occurs is stable, thereby strengthening cohesion. With the addition of 1% zeolite to 15% overboulder showed an increase in soil UCS value of 1080 kN/m² in 0 days of curing period, 1775 kN/m² in 7 days of curing period, 2258 kN/m² in the 14 days of curing period, and 2952 kN/m² in the 28 days of curing period.

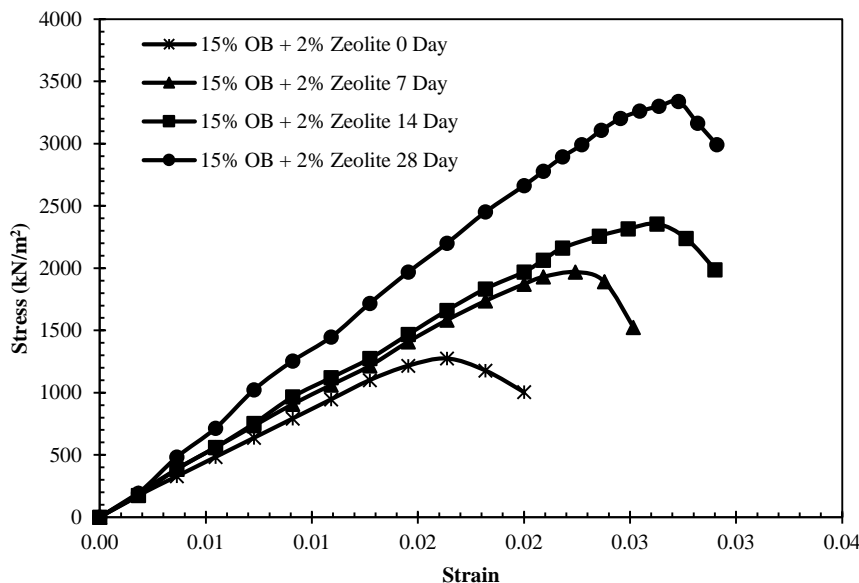


Figure 6. Stress-strain behavior of soft soil stabilized by overboulder and 2% zeolite

Based on Figure 6, the ultimate compressive stress increases with increasing curing time. With the addition of 2% zeolite to 15% overboulder showed an increase in soil UCS value of 1273 kN/m² in 0 days of curing period, 1968 kN/m² in 7 days of curing period, 2354 kN/m² in the 14 days of curing period, and 2952 kN/m² in the 28 days of curing period.

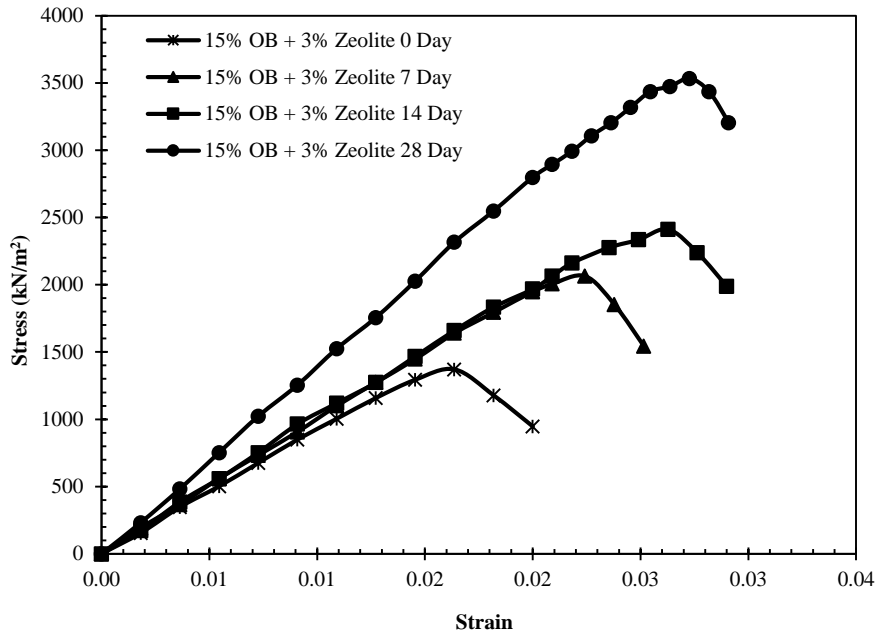


Figure 7. Stress-strain behavior of soft soil stabilized by overboulder and 3% zeolite

Based on Figure 7, the ultimate compressive stress increases with increasing curing time. With the addition of 3% zeolite to 15% overboulder showed an increase in soil UCS value of 1370 kN/m² in 0 days of curing period, 2065 kN/m² in 7 days of curing period, 2412 kN/m² in the 14 days of curing period, and 3531 kN/m² in the 28 days of curing period.

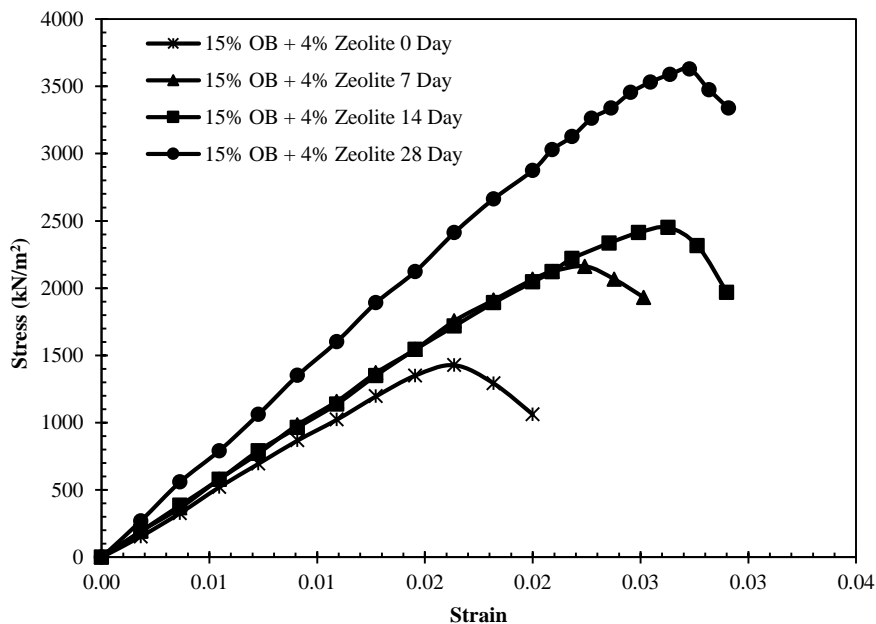


Figure 8. Stress-strain behavior of soft soil stabilized by overboulder and 4% zeolite

Based on Figure 8, the ultimate compressive stress increases with increasing curing time. With the addition of 4% zeolite to 15% overboulder showed an increase in soil UCS value of 1428 kN/m² in 0 days of curing period, 2161 kN/m² in 7 days of curing period, 2450 kN/m² in the 14 days of curing period, and 3821 kN/m² in the 28 days of curing period.

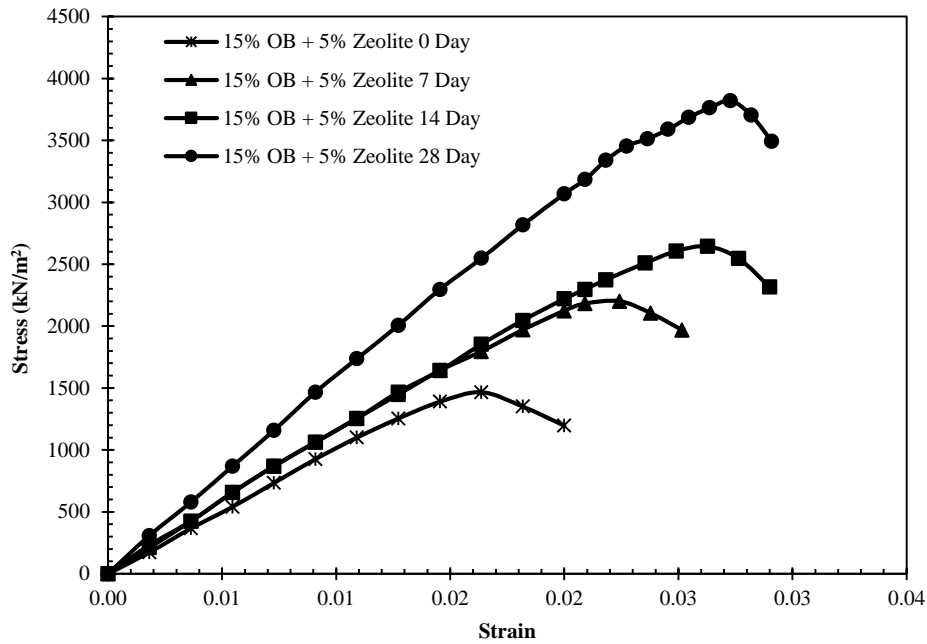


Figure 9. Stress-strain behavior of soft soil stabilized by overboulder and 5% zeolite

Based on Figure 9, the ultimate compressive stress increases with increasing curing time. With the addition of 5% zeolite to 15% overboulder showed an increase in soil UCS value of 1466 kN/m² in 0 days of curing period, 2200 kN/m² in 7 days of curing period, 2643 kN/m² in the 14 days of curing period, and 3821 kN/m² in the 28 days of curing period. This is the highest UCS value achieved, compared to other compositions.

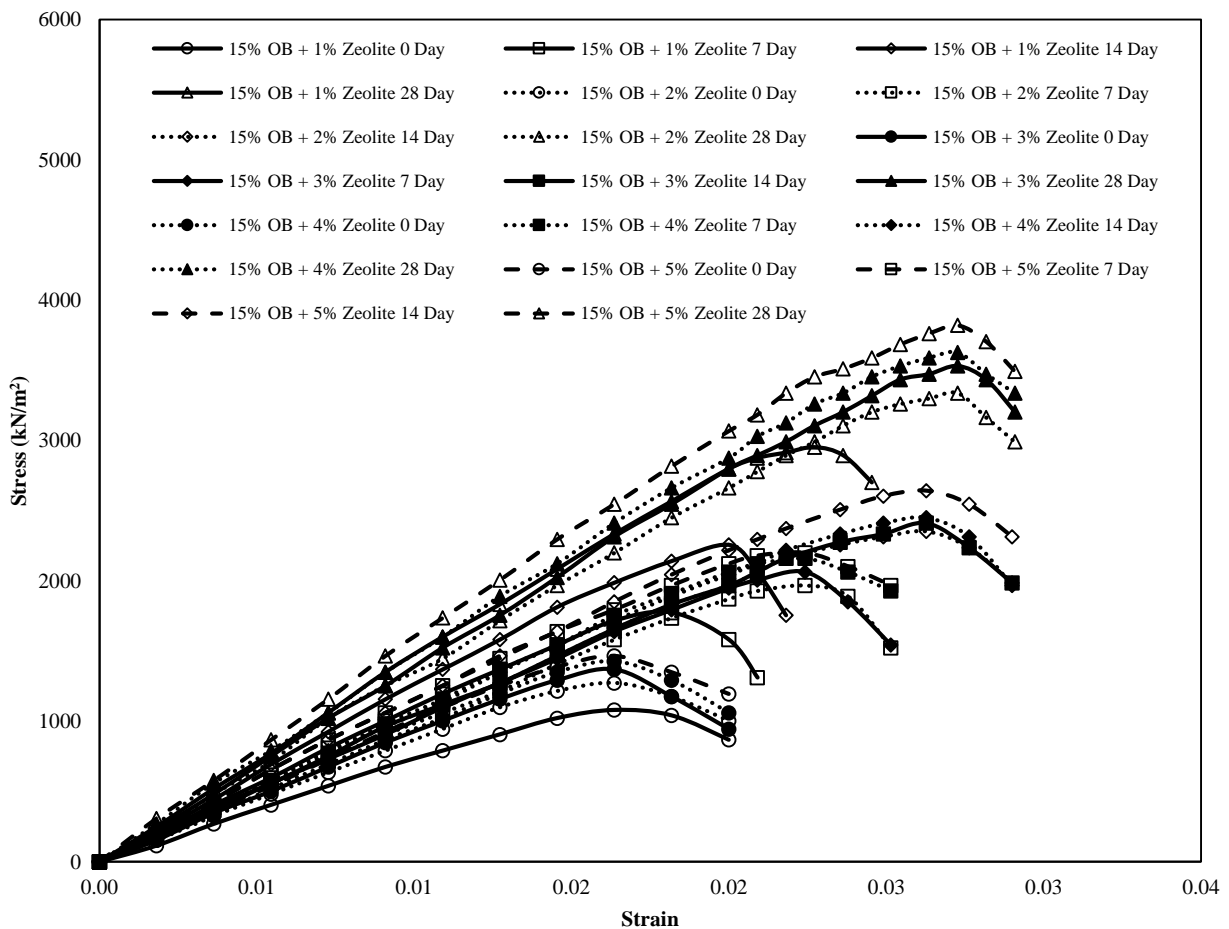


Figure 10. Recapitulation of stress-strain behavior of soft soil stabilized by overboulder and zeolite

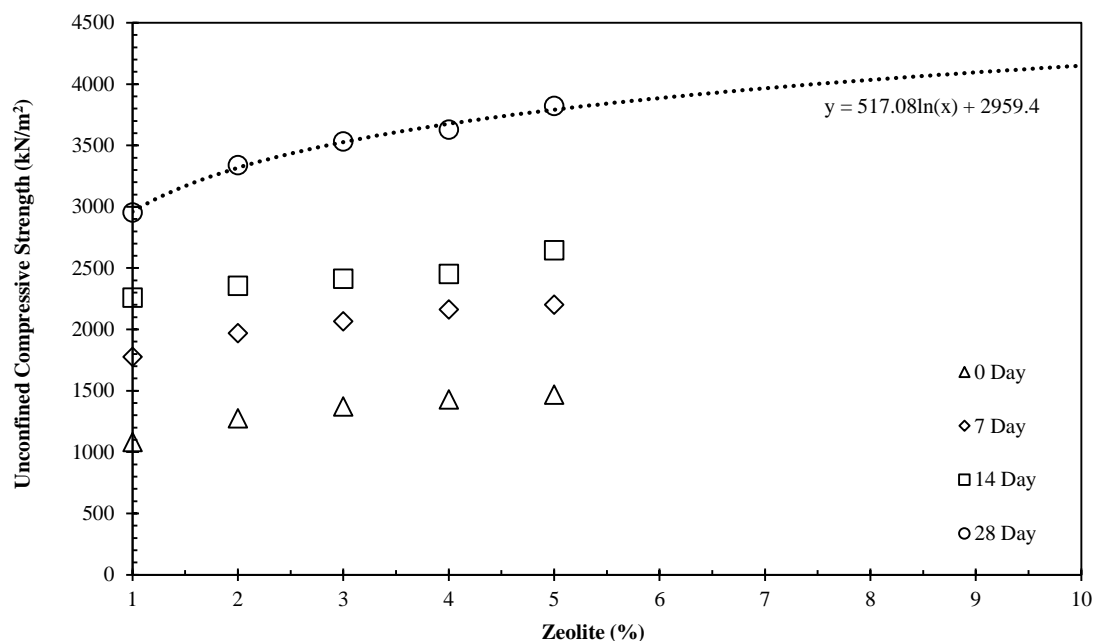


Figure 11. Unconfined compression strength values of soft soil stabilized by overboulder asbuton and zeolite

In Figure 11, it can be seen that the addition of zeolites and the curing period show an increasing trend. The addition of zeolites and curing periods increased the Unconfined Compressive Strength of the soil relatively significantly [18]. The highest UCS value achieved was 3821 kN/m² or nearly 82 times compared to the untreated soil. While figure 10 shows that with increasing zeolite content, the unconfined compressive strength also increased. Logarithmic forecasting trendline shows that even until 10% of zeolite addition, it still shows an increasing UCS value up to about 4000 kN/m². This shows us that it needs a further study to analyze the limits of zeolite addition, and possible application in the field, considering that both overboulder and zeolite has an abundant amount and could be used as stabilization material. With this result, stabilization using overboulder asbuton and zeolite can be used as an alternative to cement, lime, or any silica in common as a pozzolan material used as soil stabilizer.

5. Conclusion

Based on the results achieved through the unconfined compression test, it can be concluded that zeolite addition to overboulder asbuton-stabilized soft soil improves the soil's engineering properties. The unconfined compressive strength of the soil has increased significantly and from those results, it can also be concluded that adding overboulder asbuton and zeolite to soft soil could add stiffness behavior. By the final result, zeolite and overboulder asbuton addition could increase the UCS value of the soil 83 times compared to the untreated soil, achieved by adding 15% overboulder asbuton and 5% zeolite with 28 days of curing time. As for other engineering properties such as CBR value can be assured would be increased significantly as well by adding overboulder asbuton and zeolite. This result may be marginally vary depending on the untreated soil's engineering properties, which suitable only for soft soil or fine-grained soil in general with UCS value below 50 kN/m². However, it is still possible to increase the UCS value even more by adding more zeolite to the mix, or by adding activator such as alkali. By these results, overboulder asbuton and zeolite could be used as alternatives pozzolan materials for soil stabilization. It could widely be used considering materials with similar chemical composition maybe existed in many areas in the world. As local content in Indonesia itself, overboulder asbuton and zeolite, which has large deposits in Indonesia, should be developed to be applied in certain areas with abundant source of natural silica such as zeolite and overboulder asbuton. In further a implementation, cost reduction may be achieved as well.

6. Declarations

6.1. Data Availability Statement

The data presented in this study are available in article.

6.2. Funding

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6.3. Acknowledgements

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6.4. Conflicts of Interest

The authors declare no conflict of interest.

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