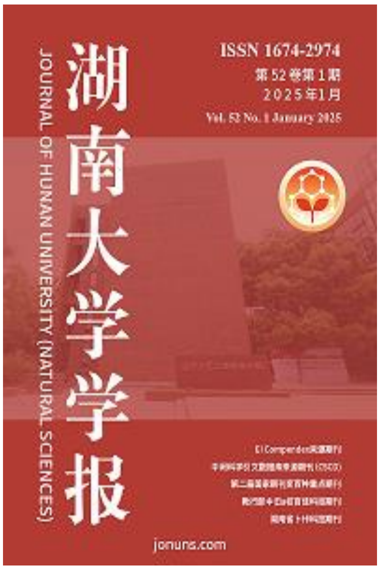

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Improvement of Clay Properties with Calcite and Silica Fume: Shear and Unconfined Compressive Strength Focus

Syahril[1*], Dian Adiputra Purba[1], Sandy D Sagala[1], R. Desutama Rachmat Bugi Prayogo[2]

[1]Magister of Applied Infrastructure Engineering Study Program, Department of Civil Engineering, Bandung State Polytechnic, 40599, Indonesia

[2]Department of Civil Engineering, Faculty of Engineering, Bandung State Polytechnic, 40599, Indonesia

* Corresponding author: syahril_polban@yahoo.com

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Abstract: This study introduces a novel approach to improve the mechanical properties of clay soil using a combination of calcite and silica fume, addressing the prevalent issues of low shear strength and high compressibility in clay soils that undermine construction stability. This study aims to explore the effectiveness of these additives in enhancing the soil shear strength and unconfined compressive strength (UCS) while analyzing the underlying microstructural changes. The methodology involved field sampling of West Bandung clay soils, followed by laboratory stabilization experiments. The clay samples were treated with 5% calcite and varying silica fume contents (6%, 8%, 10%, and 12%). These mixtures were prepared with the optimal moisture content, cured for 0, 3, 7, and 14 days, and tested using triaxial and UCS equipment. The triaxial test measured the cohesion and internal friction angle, whereas the UCS evaluated the uniaxial load-bearing capacity of the soil. The results demonstrated that the combined use of calcite and silica fume significantly improved clay properties. The internal friction angle increased from 9.90° to 35.31° with 12% silica fume and 14-day curing, indicating an enhanced shear strength. Similarly, the UCS values increased from 0.412 kg/cm^2 (soft soil) to 1.724 kg/cm^2 (stiff soil), which is attributed to pozzolanic reactions forming calcium silicate hydrate (CSH) and densification of the soil microstructure.

The study concludes that the calcite-silica fume combination is a sustainable soil stabilization method that offers practical benefits for geotechnical applications. The research provides insights into optimizing the additive proportions and curing periods to support infrastructure projects requiring improved ground stability.

Keywords: clay soil stabilization, calcite, silica fume, shear strength, unconfined compressive strength (UCS).

利用方解石和硅灰改善粘土性质：重点关注剪切强度和无侧限抗压强度

摘要：本研究介绍了一种使用方解石和硅粉组合来改善粘土机械性能的新方法，解决了粘土普遍存在的低剪切强度和高压缩性问题，这些问题会破坏建筑稳定性。本研究旨在探索这些添加剂在提高土壤剪切强度和无侧限抗压强度 (UCS) 方面的有效性，同时分析潜在的微观结构变化。该方法包括对西万隆粘土进行现场采样，然后进行实验室稳定化实验。粘土样品用 5% 的方解石和不同含量的硅粉 (6%、8%、10% 和 12%) 处理。这些混合物以最佳含水量制备，固化 0、3、7 和 14 天，并使用三轴和 UCS 设备进行测试。三轴试验测量了黏聚力和内摩擦角，而 UCS 评估了土壤的单轴承载能力。结果表明，方解石和硅粉的组合使用显著改善了粘土性能。内摩擦角从 9.90° 增加到 35.31°，添加 12% 硅粉并养护 14 天，表明剪切强度增强。同样，UCS 值从 0.412 kg/cm²（软土）增加到 1.724 kg/cm²（硬土），这归因于火山灰反应形成水合硅酸钙 (CSH) 和土壤微结构致密化。研究得出结论，方解石-硅粉组合是一种可持续的土壤稳定方法，可为岩土应用提供实际好处。这项研究为优化添加剂比例和养护期提供了见解，以支持需要改善地面稳定性的基础设施项目。

关键词：粘土稳定、方解石、硅灰、剪切强度、非收缩抗压强度（UCS).

1. Introduction

Clay soils are often a challenge in geotechnical engineering owing to their low shear strength and susceptibility to settlement. This problem often causes instability in construction projects [1, 2], particularly in roads and foundations [3, 4]. Geotechnical engineers have developed and applied various techniques to address the challenges associated with clayey soils [5]. One approach that is often used is soil stabilization [4], which is a technique used to improve the mechanical properties of soil by adding certain materials that are capable of strengthening the soil structure [6, 7]. Among the various stabilization methods available, the use of additives, such as calcite and silica fume, has attracted attention as a promising solution for improving the engineering properties of clay soils. Calcite, a form of calcium carbonate, is known to react with minerals contained in clay soils. This reaction produces more stable compounds that can increase the strength of soil and reduce its plasticity. This process is often referred to as a pozzolanic reaction, in which calcium ions from calcite interact with the silica and alumina found in clay. This reaction leads to the creation of compounds such as calcium silicate hydrate (CSH) [8], which significantly increases the strength and structural stability of soil. CSH is a known strong and durable compound that also contributes to reducing soil volume changes due to the influence of water, thus making the soil more stable for geotechnical applications.

In addition to calcite, silica fume is also an additive that has been extensively studied in the field of soil stabilization. Silica fume, a byproduct of silicon metal and ferrosilicon production, is distinguished by its large surface area and high chemical reactivity. Owing to these properties, silica fume can play an active role in pozzolanic reactions, similar to calcite. The very fine particles of silica fume accelerated the chemical reaction between the additive and soil minerals [9], ultimately increasing the strength and durability of the stabilized clay soil. The use of silica fume also reduces soil porosity, such that the soil becomes denser and has a higher load-bearing capacity [10].

This study aims to explore the effectiveness of calcite and silica fume in improving the mechanical properties of clay soils, with a particular focus on improving the shear strength and unconfined compressive strength. This research will focus on analyzing the mechanical and microstructural changes that occur due to the addition of these additives [11]. By studying the mechanisms behind these improvements in soil properties, it is hoped that this research will provide greater insights into the potential applications of calcite and silica fume in various geotechnical engineering projects.

In addition, this study is expected to make an important contribution to the development of more effective and sustainable soil stabilization methods. The use of materials such as calcite and silica fume, which are relatively inexpensive and readily available, offers an economical and environmentally friendly solution to the problems associated with clay-soil stability [12]. The results of this study can be broadly applied to enhance the stability and durability of various engineering structures, including those used in transportation, infrastructure, and commercial building projects [13].

The selection of clay soils in the West Bandung region was based on their frequent use in local construction projects and unique geotechnical challenges, such as low shear strength and high compressibility. These soils are commonly found in infrastructure construction projects, such as roads, foundations, and slope stabilization projects, making them representative research objects for soil stabilization studies.

The results of this study can be applied in various geotechnical applications. In particular, the increase in shear strength and free compressive strength (UCS) achieved through calcite and silica fume stabilization can improve the safety and resilience of infrastructure in regions with similar soil properties.

Overall, the results of this research are expected to provide a better understanding of the interaction between clay and additives, such as calcite and silica fume. By understanding the changes that occur at the microstructural level and their effects on the mechanical properties of soil, geotechnical engineers can design more appropriate and efficient solutions to stabilize clay soils, thereby improving the quality and durability of future construction projects.

Most previous studies have focused only on macroscopic changes, without delving into the microstructural mechanisms that occur because of the interaction between additives and clay minerals. Studies have rarely explored variations in additive proportions to identify the optimal combination that yields the best results. Furthermore, the effects of using calcite and silica fume on the long-term stability of soil under various environmental conditions have not been thoroughly evaluated.

Therefore, this study aims to fill this gap by evaluating the combined effect of calcite and silica fumes on improving the shear strength and UCS of clay soils, and by understanding the underlying mechanisms of change, both at the mechanical and microstructural levels.

2. Theoretical Framework

2.1. Clay Soil Properties

Clay soils exhibit unique characteristics that significantly influence their behavior in construction contexts. The key characteristics of clay soils include their fine particle size, high plasticity [14], and ability to retain water, which can lead to substantial volume changes with moisture fluctuations. This property, known as expansive behavior, causes clay soils to swell when wet and shrink upon drying, posing challenges for their structural integrity. The moisture content directly affects the shear strength and compressive strength. As the moisture content increases, these strengths typically decrease, making the soil more susceptible to deformation and failure under load [15-17].

Common problems associated with clay soils in construction include differential settlement, foundation cracking, and instability under wet weather conditions. These issues arise because of the variable moisture retention indicators of the soil and their tendency to undergo significant volume changes. For instance, structures built on expansive clay may experience severe damage if not properly designed or if adequate soil stabilization techniques are not employed [18]. Engineers often address these challenges through various methods, such as soil stabilization with additives (such as cement kiln dust or polymers), proper drainage systems, and careful foundation design to mitigate the adverse effects of the inherent properties of clay [16, 17, 19].

2.2. Stabilization Techniques

Soil stabilization is a crucial technique in geotechnical engineering and is designed to enhance the physical and mechanical properties of soil, thereby ensuring its suitability for various construction projects. These approaches can be broadly categorized into two types: mechanical and chemical approaches [20]. Mechanical stabilization involves mechanical processes, such as compaction or mixing of the soil with other materials, such as sand or gravel, to improve its bearing capacity [21]. Examples of applications include soil compaction and the use of geosynthetics to strengthen soil structures. However, this method has limitations for certain soil types, particularly clay soils with a high plasticity index [22]. Chemical stabilization uses additives to change the structure and properties of the soil. This process often involves chemical reactions that increase the strength and durability of soil. Commonly used additives include Lime, Portland cement, fly ash, silica fumes, and calcite [23].

2.3. Calcite And Silica Fume

Calcite ($CaCO_3$) and silica fume are two highly effective additives for improving soil properties, especially in clay soils. Calcite, which is a natural calcium carbonate-based mineral, increases soil strength through various mechanisms. One example is its interaction with the silica and alumina present in the soil, leading to the formation of compounds such as calcium silicate hydrate (CSH) and calcium aluminate hydrate (CAH) [14, 24, 25]. These compounds strengthen the soil structure and reduce its plasticity. In addition, calcite particles can fill the gaps between the soil grains, increase the density level, and reduce soil permeability. This resulted in a reduced risk of deformation and subsidence. Another advantage of calcite is its abundant availability and relatively affordable cost, making it an economical alternative for soil stabilization.

On the other hand, silica fume is a by-product of the silicon or ferrosilicon industry. The particles were extremely fine and composed of amorphous silica (SiO_2), which has a very large surface area [26]. Silica fumes can react with free calcium in the soil or from other additives, producing CSH compounds that significantly strengthen the soil. It also reduces soil porosity, increases cohesion between grains, and increases the resistance to environmental changes. When calcite and silica fume are used together, they create a synergistic effect: calcite provides calcium ions, whereas silica fume accelerates the formation of strong binding compounds. This combination effectively increases the shear strength and bearing capacity of soil, making it an ideal solution for various construction needs, such as roads, pavement layers, and building foundations.

2.4. Unconfined Compressive Strength (UCS)

Unconfined compressive strength (UCS) testing is an important parameter in soil stabilization analysis, particularly when evaluating soil strength without the influence of lateral pressure. The UCS value directly indicates the ability of the soil to resist compressive loading up to the collapse point. From a stabilization perspective, an increase in the UCS value indicates successful improvement of the mechanical properties of the soil [27], as is often seen in projects with the addition of materials such as calcite or fumed silica. In addition, the test is relatively quick and easy; therefore, it is often used as an early indicator of the strength of a stabilized soil [25]. The UCS is particularly relevant to the design of shallow foundations, where the soil must withstand the vertical load of the overlying structure without collapse.

2.5. Shear Strength

Shear strength is another important parameter in soil analysis, particularly in geotechnical applications where structural stability is a concern. Soil shear strength determines the ability of the soil to resist the shear forces caused by lateral loading and deformation [7]. When designing foundations, retaining walls, or slopes, shear strength is the main factor that determines whether the soil can support the structure without slipping or collapsing. The shear strength is also closely related to the stability of the entire structure. Low values can lead to deviation or complete failure. The risk of collapse can be minimized by increasing the shear strength through stabilization techniques. Therefore, this parameter is essential in various civil engineering applications.

3. Materials and Methods

In this stage, a plan for the activities that will be carried out in the research is prepared. For the implementation of the research, several stages were carried out, namely information collection along with a literature study, soft clay soil sampling in the field, preparation for laboratory testing, and data analysis of the stabilization test results.

3.1. Materials

In this study, soil samples were collected from the Cihampelas area of the West Bandung Regency. Calcite and silica fume were used as stabilizers. PT Akbar Budi Sakti is a silica fume producer that produces materials through an industrial plant processing process that utilizes high-temperature reactions from quartz-based raw materials. Silica dust, also known as microsilica, consists of a very high percentage of amorphous silica (SiO_2), often exceeding 90%. Silica fume consists of very small fine particles, which can increase the strength and durability of concrete by filling microscopic pores and increasing the structural density of the material. Overall, both calcite and silica fume contributed significantly to improving the quality of the building materials in terms of strength, corrosion resistance, and long-term stability. This research was conducted at the Soil Mechanics Laboratory, Department of Civil Engineering, Bandung State University of Technology. The mixture content in this test consisted of 5% calcite and 6%, 8%, 10%, and 12% silica fume from soft clay, followed by triaxial and UCS (unconfined compressive strength) testing.

3.2. Methods

Clay soil samples were collected from the Cihampelas area in West Bandung Regency. The soil was treated with calcite (5%) and various proportions of silica fume (6%, 8%, 10%, and 12%) dry weight, with water added to achieve the optimum moisture content. The prepared samples were cast into cylinders and cured for 0, 3, 7, and 14 d under controlled conditions to optimize the chemical reactions. The mechanical properties were evaluated using triaxial and UCS tests.

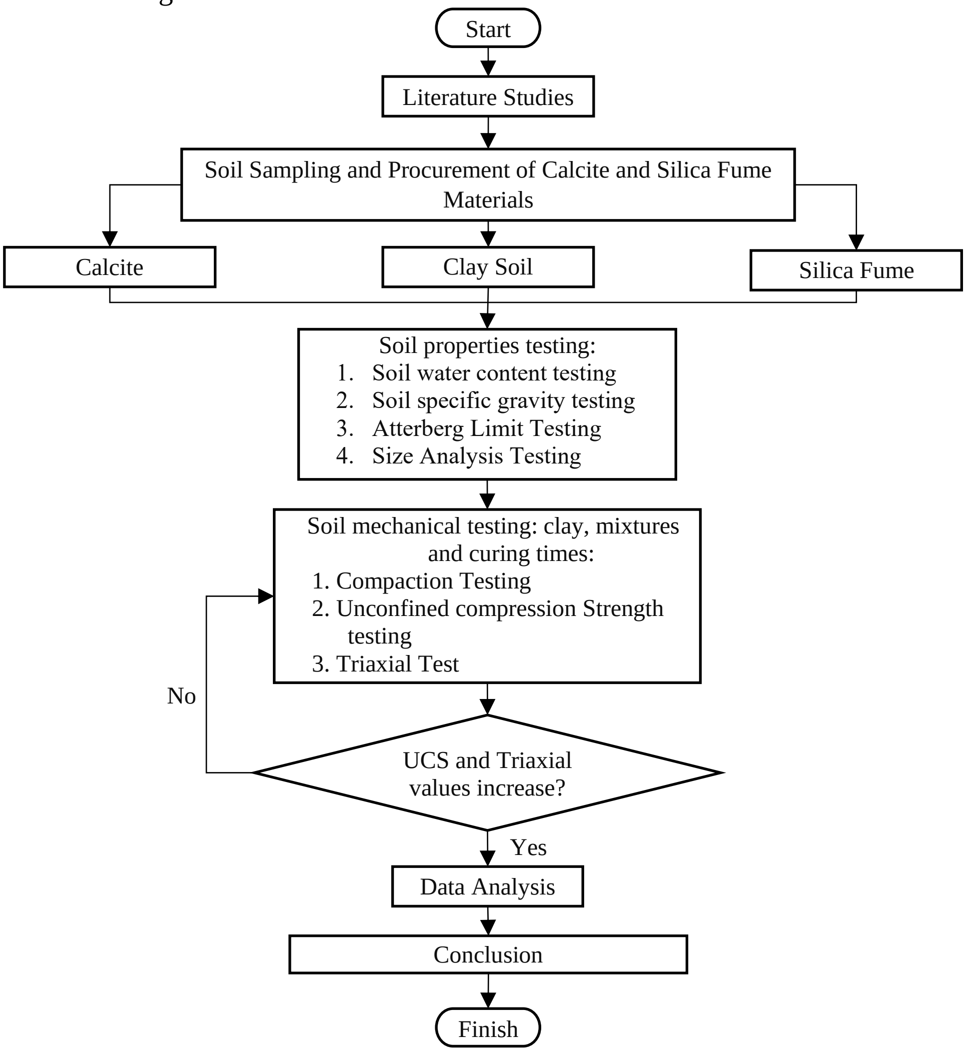

Figure 1. The research flow chart (Source: developed by the authors)

The triaxial test determined the cohesion and internal friction angle, and the uniaxial compressive strength was assessed using the UCS test. Finally, the changes in soil strength were analyzed to assess the effects of the additives. The research flowchart is shown in Figure 1.

3.3. Sample Preparation

The first step in the sample preparation is to prepare clay soil that has been screened to remove rocks or large unwanted materials. The soil was then divided into fractions containing varying proportions of calcite and silica fume admixtures. In this experiment, the proportion of additives used was varied, with a calcite content of 5% and silica fume contents of 6%, 8%, 10%, and 12% based on the dry soil weight. Silica fume, which consists almost entirely of amorphous silica (SiO_2), is mixed with the soil to increase the density and strength of the soil, while calcite ($CaCO_3$) acts as a binder that can improve the soil structure and increase its stability. Afterwards, the soil mixture and additives were added with water at adjusted rates to achieve the optimum moisture content required for tests, such as density and shear.

Strength and unconfined compression tests. Once the mixing was complete, the soil sample that had been mixed with calcite and silica fume was placed into a mold to form a cylinder. The curing process began by keeping the samples moist and protected from extreme temperature changes to ensure that the chemical reaction between the additives and the soil was optimized. Curing was carried out at room temperature for 0, 3, 7, and 14 d to observe changes in the mechanical properties of the soil over time. During the curing period, the relative humidity was maintained to avoid drying, which could hinder the chemical reaction between silica fume, calcite, and soil. Shear strength and unconfined compressive strength tests were conducted after the predetermined curing period to measure the changes in the soil-bearing capacity owing to the addition of additives. The mixtures of soil, calcite, and silica fume are listed in Table 1.

In total, 102 samples were used in this study. The addition of calcite at 5% and silica fume at 6%, 8%, 10%, and 12% with the number of samples used in the mixture variation of each of the four curing times (0, 3, 7, and 14 days) is shown in Table 2.

Table 1. The proportion of the weight of the sample soil (compiled by the authors)

Weight of Soil (gram)	Weight of Calcite (gram)	Weight of Silica Fume (%)	Weight of Silica Fume (gram) (1x3)	Weight of Soil Sample (gram) (1-2-4)
(1)	(2)	(3)	(4)	(5)
4000	0	0	0	4000
4000	200	6	240	3560
4000	200	8	320	3480
4000	200	10	400	3400
4000	200	12	480	3320

Table 2. Quantity of samples (compiled by the authors)

No.	Soil & Mixtures	UCS Test	Triaxial Test	Sample Quantity
1	Soft clay	3	3	6
2	Soil + Calcite 5% + SF 6%	12	12	24
3	Soil + Calcite 5% + SF 8%	12	12	24
4	Soil + Calcite 5% + SF 10%	12	12	24
5	Soil + Calcite 5% + SF 12%	12	12	24
	Total			102

3.4. Shear Strength Testing

To measure the shear strength of the soil, triaxial tests were conducted, which provide more in-depth information on the behavior of the soil under multidimensional stresses. In this test, soil samples mixed with silica fume and calcite were loaded into a triaxial cell, a device that allows for testing at controlled lateral and vertical pressures. The soil sample was subjected to a constant pressure (cell pressure) adjusted to field conditions and then subjected to a gradual axial load until shear failure occurred. During the test, the data on the axial deformation and shear force received by the sample were recorded. From these data, the shear coefficient (τ) and shear angle (φ) of the soil can be calculated using the Mohr-Coulomb shear strength equation, which describes the relationship between normal stress and shear stress at the time of soil failure. Triaxial tests provide information on changes in soil shear strength parameters due to the addition of silica fume and calcite and make it possible to examine the effects of additives on more in-depth soil properties, such as cohesion (c) and internal shear angle (φ).

3.5. UCS Testing

UCS testing measures the compressive strength of soil in the absence of lateral restraint, which is often used to determine the initial stability of the material. The first step was to prepare soil samples that were mixed with different proportions of calcite and silica fume, with a calcite content of 5% and silica fume contents of 6%, 8%, 10%, and 12% based on dry soil weight. The soil samples were then compacted in cylindrical molds according to the test standard and left for specified curing periods of 0, 3, 7, and 14 days. During the curing process, the samples were kept moist to ensure that the chemical reaction between the silica fume, calcite, and soil was optimized. After the curing period was completed, the samples were tested using a uniaxial compressive testing machine that gradually applied a vertical load until the samples failed. The free compressive strength (UCS) was calculated by dividing the maximum load received by the sample by its cross-sectional area. The UCS results indicated the extent to which the compressive strength of the soil stabilized with calcite and silica fume increased.

4. Results and Discussion

4.1. Testing of the Soft Clay

A soil property index test was conducted to classify the soil type used in the study. The results of the soil physical properties test included the soil specific gravity test, Atterberg test, sieve analysis test, soil mechanical properties test, especially the compaction test, shear strength test, and free compressive strength test of the clay soil. Physical property tests were carried out on soft clay soil, and the test results are shown in Table 3.

Table 3. Index properties of soft clay soil (compiled by the authors)

No	Index Properties	Symbol	Unit	Value
1	Water Content	ω	%	41.48
2	Specific Gravity	Gs	-	2.591
3	Weight of Content	γ	gr/cm^3	1.895
4	Dry Weight	γ_d	gr/cm^3	1.339
5	Pore Value	e	-	0.9344
6	Porosity	n	-	0.4831
7	Atterberg Limit	%		
	- Plastic Limit	PL	%	29.93
	- Liquid Limit	LL	%	59
	- Plasticity Index	PI	%	29.45

The mechanical properties of soft clay determined from the test results are listed in Table 4.

Table 4. Mechanical properties of the soft clay (compiled by the authors)

No	Mechanical Properties	Symbol	Unit	Value
1	Compaction	ω_{opt}	%	20.5
2	Unconfined Compression Strength	q_u	kg/cm²	0.412
		C_u	kg/cm²	0.206
3	Shear Strength Testing	φ	°	9.90
		c	kg/cm²	0.83

4.2. Shear Strength Testing

Shear strength testing was conducted to determine the value of the shear angle and cohesion of the soil that had been stabilized with a mixture of calcite and silica fume. Soil shear strength testing was performed using triaxial testing. The following results of the shear angle (φ) and cohesion (c) values of the soil from triaxial testing are listed in Table 5.

Table 5. Triaxial test results (compiled by the authors)

No	Soil & Mixtures	Curing (Days)	φ (°)	c (Kg/cm²)
1	Soft Clay	0	9.90	0.826
2	Soil + Calcite 5% + SF 6%	0	14.27	1.195
		3	16.94	1.232
		7	20.29	1.286
		14	25.78	1.325
3	Soil + Calcite 5% + SF 8%	0	20.73	1.288
		3	22.20	1.318
		7	25.41	1.346
		14	27.38	1.367
4	Soil + Calcite 5% + SF 10%	0	22.54	1.322
		3	25.22	1.367
		7	27.27	1.408
		14	32.89	1.452
5	Soil + Calcite 5% + SF 12%	0	25.64	1.666
		3	29.30	1.694
		7	32.68	1.725
		14	35.31	1.757

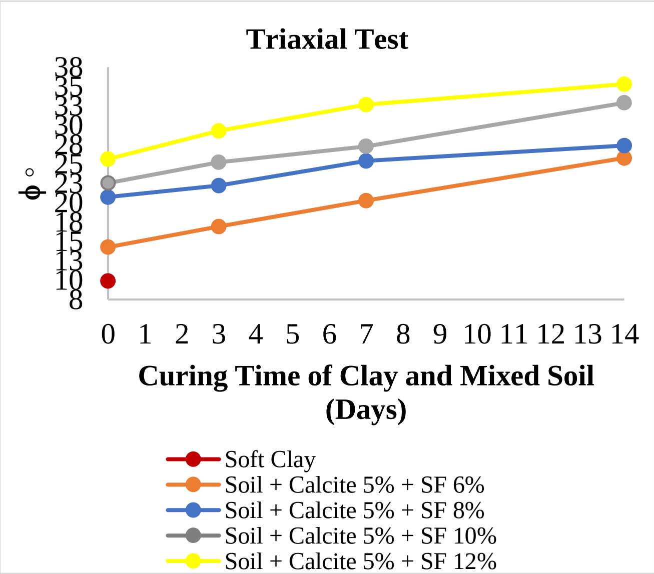

Figure 1. Triaxial test results (developed by the authors)

According to the triaxial test results presented in Table 5 and Figure 2, the shear angle of the clay soil increased with a higher admixture content and longer curing periods. The shear angle of the clay soil increased from 9.90° to 35.31° with the addition of 5% calcite and 12% silica fume and a 14-day curing period. This increase indicates that the admixture effectively increased the shear strength of the soil by altering its microstructure, resulting in greater consolidation and better interaction between the clay particles and admixture [28]. In addition, a longer curing period strengthened the bonds between the soil particles. Overall, these results indicate that soil stabilization with admixtures and curing improves soil mechanical properties, particularly shear strength, which is important for soil stability during construction.

4.3. Unconfined Compressive Strength Testing (UCS)

The unconfined compressive strength test involves applying an axial load to a cylindrical soil sample while keeping it free from lateral pressure until failure. The unconfined compressive strength is the maximum load that a soil sample can withstand before it collapses. After the UCS test, the qu and cu values of the clay soil with calcite and silica fume mixtures were obtained, as shown in Table 6.

Table 6. Result of unconfined compression strength testing (compiled by the authors)

No	Soil and Mixtures	Curing (Days)	q_u kg/cm²	C_u kg/cm²
1	Soft Clay	-	0.412	0.206
2	Soil + Calcite 5% + SF 6%	0	0.594	0.297
		3	1.036	0.518
		7	1.146	0.573
		14	1.235	0.618
3	Soil + Calcite 5% + SF 8%	0	0.942	0.471
		3	1.122	0.561
		7	1.222	0.611
		14	1.246	0.623
4	Soil + Calcite 5% + SF 10%	0	1.181	0.590
		3	1.233	0.617
		7	1.259	0.629
		14	1.297	0.648
5	Soil + Calcite 5% + SF 12%	0	1.284	0.642
		3	1.569	0.784
		7	1.661	0.831
		14	1.724	0.862

Based on the UCS test results listed in Table 6 and Figure 3, it can be concluded that the addition of calcite and silica fume, as well as the curing period of the mixture, caused an increase in the qu value of the soil. This is because calcite and silica fume contain compounds that can form a binding paste when hydrated [29]. They react with water and soil to produce an adhesive medium that binds the soil particles.

This cementation process caused the soil mixture to harden and form a stronger mass [30]. The q_u value of the soft clay soil, which was initially 0.412 kg/cm² and C_u 0.206 kg/cm², increased significantly after the addition of 5% calcite and 12% silica fume, and after 14 days of curing, to 1.724 kg/cm² for the q_u value and 0.862 kg/cm² for the C_u value.

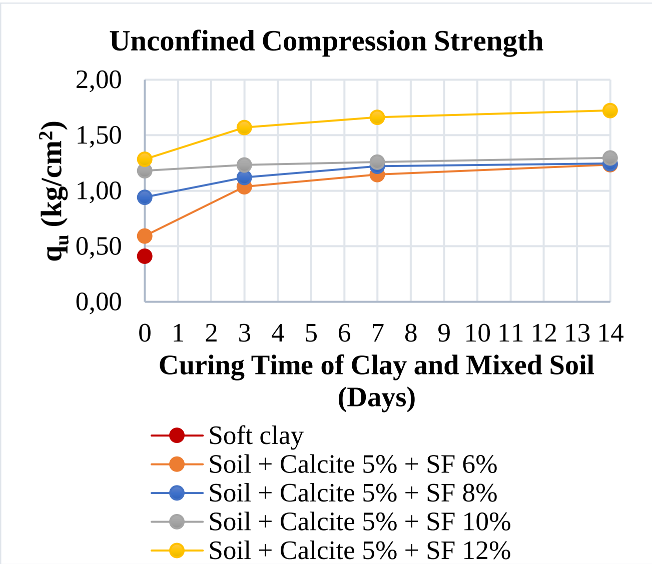

Figure 2. Result of unconfined compression strength testing (developed by the authors)

5. Conclusion

The addition of calcite (5%) and silica fume (up to 12%) significantly enhanced the mechanical properties of the clay soils, as demonstrated by substantial improvements in the shear strength and unconfined compressive strength (UCS). The shear strength, indicated by the internal friction angle, increased from 9.90° in the untreated soil to 35.31° after 14 d of curing with 12% silica fume. This improvement indicates that the admixtures effectively enhance the shear strength of the soil by promoting a more consolidated microstructure and better interaction between the clay particles and additives. In addition, a longer curing period strengthened the bonds between the soil particles. Additionally, the UCS improved from an initial value of 0.412 kg/cm² for untreated soil to 1.724 kg/cm² for soil treated with the same combination of additives and curing durations.

These findings confirm that the combined use of calcite and silica fume provides an effective, sustainable, and economical solution for improving the geotechnical properties of clay soils, making them suitable for various infrastructure applications that require enhanced load-bearing capacity and stability. Moreover, these results align with previous studies that reported enhanced soil stability through the use of calcite and silica fume, although this study uniquely explored the combined effects of these additives, optimizing proportions to achieve superior results. These findings underscore the potential of calcite and silica fumes as sustainable and economical soil stabilizers, supporting their use in critical infrastructure applications and reducing the risks associated with clay soil instability. To further improve the practical application of these findings, future research should investigate the long-term stability of treated soils under varying environmental conditions, explore additional curing techniques to further optimize chemical reactions, and evaluate the economic feasibility of large-scale applications in infrastructure projects.

Declarations

Author Contributions

Conceptualization, S. and D.A.P.; methodology, S.; software, S. and D.A.P.; validation, S. and D.A.P.; formal analysis, S.; investigation, S., D.A.P., S.D.S. and R.D.R.B.P.; resources, S. and D.A.P.; data curation, S.; writing-original draft preparation, S., D.A.P., S.D.S. and R.D.R.B.P.; writing-review and editing, S., D.A.P., S.D.S. and R.D.R.B.P.; visualization, S. and D.A.P.; supervision, S.; project administration, S.; funding acquisition, S. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The data presented in this study are available upon request from the corresponding author.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this manuscript. In addition, ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies, have been completely observed by the authors.

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