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Article

Effect of Fosroc Cebex-100 and Fly Ash Stabilization on the Microstructural Properties of Soft Soil

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Abstract

This study investigates the microstructural effects of stabilizing soft soil using fly ash and Fosroc Cebex-100. The soft soil used in this study was collected from the construction site of the Northern Ring Road (JLU) Section 1 in Lamongan regency. Firstly, a series of laboratory soil test was performed to obtain the index properties of the soil sample including unit weight, specific gravity, Atterberg's limits, optimum moisture content, and maximum dry unit weight. The soil was then treated with three variations of fly ash (20%, 25%, and 30%), while the Fosroc Cebex-100 dosage was held constant at 0.45% of the fly ash weight. A CBR test indicated that a 20% fly ash and Fosroc Cebex-100 mixture achieved the highest CBR value. Consequently, this optimal mix was selected for SEM-EDX (Scanning Electron Microscopy - Energy-Dispersive X-ray Spectroscopy) analysis to further examine microstructural characteristics. Additional fly ash and Fosroc Cebex-100 to the soft soil will influence the microstructural properties of the soil. SEM analysis show that addition of fly ash and Fosroc Cebex-100 results in significant changes in the soil matrix, including increased particle bonding, reduced porosity, and a denser overall structure. Moreover, the addition of fly ash and Fosroc Cebex-100 contribute to the presence of iron (Fe) in the treated soil.

Keywords: Fosroc-Cebex 100, fly ash, SEM-EDX, soft soil, microstructure

1. Introduction

Soft soils, often characterized by low shear strength, high compressibility, and poor load-bearing capacity, pose significant challenges in civil engineering and construction projects. Their inherent properties make them unsuitable for direct construction applications, especially when stability and durability are essential. Therefore, soil stabilization methods have become a critical focus for enhancing the mechanical and physical properties of soft soils, particularly in infrastructure projects that demand a reliable foundation. Various stabilizers, such as lime, cement, and supplementary materials, have been explored, but achieving effective and sustainable results often requires a combination of chemical additives.

Among the recent advancements in soil stabilization, chemical admixtures such as Fosroc Cebex-100 and fly ash have shown promise. Fosroc Cebex-100 is a commercial admixture primarily used to grout concrete [1] but has demonstrated potential for soil improvement [2]. Its chemical composition and reactive properties can significantly influence the microstructure of treated soils, contributing to a denser, more cohesive matrix. Fly ash, a waste material byproduct of coal combustion. Numerous researchers have put effort to study about

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physical, chemical, and mineralogical properties of fly ash [3]–[9]. Due to its chemical properties, fly ash was divided into two classes: C and F. Class C fly ash exhibits both pozzolanic and cementitious properties due to its high CaO content, whereas Class F fly ash is solely pozzolanic. [10]. Fly ash is widely used for soil stabilization, either for clay soil [11]–[13] or expansive soil [14].

Understanding the microstructural changes in soil due to stabilization agents is crucial to assess the long-term stability and suitability of the treated material. Scanning Electron Microscopy (SEM) has been widely used as an effective technique to visualize and evaluate these microstructural changes at a detailed level. By providing insights into particle bonding, porosity, and changes in the soil matrix, SEM allows for a comprehensive analysis of the effects of stabilizing agents on soil properties.

This study aims to investigate the effect of fly ash and Fosroc Cebex-100 on the microstructural properties of soft soil. By comparing the SEM analysis of untreated and stabilized soil samples, this research provides insights into how these additives alter soil composition at the microscopic level. Additionally, Energy-Dispersive X-ray Spectroscopy (EDX) analysis was utilized to determine the elemental composition and distribution within both untreated and stabilized soil samples This investigation is essential to understanding the viability and performance of Fosroc Cebex-100 and fly ash in enhancing soft soil stability and durability, ultimately contributing to safer, more sustainable construction practices.

2. Material and Method

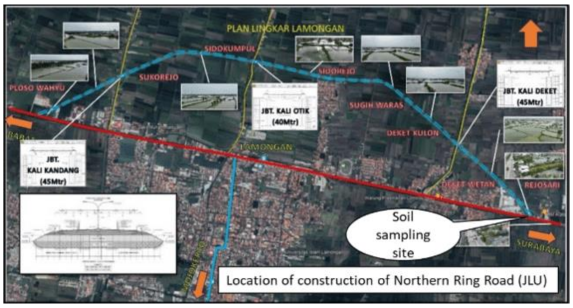

Fig. 1. Location of the study area and soil sampling sites

The soft soil used in this study was collected from the construction site of the Northern Ring Road (JLU) Section 1 in Lamongan regency, specifically between STA 1+000 and STA 1+100, in Rejosari Village (Fig. 1), Deket District, at a depth of 0.3 to 1.0 meters. Standard geotechnical tests were conducted to determine the initial physical properties, including grain size distribution, Atterberg limits, unit weight, specific gravity, maximum dry unit weight, and natural water content.

The soil was then treated with stabilization agents, which included Class C fly ash and Fosroc Cebex-100. Based on prior research findings [15], fly ash was incorporated at proportions of 20%, 25%, and 30% by weight of the soil sample. Fosroc Cebex-100 was subsequently added at a fixed concentration of 0.45% by weight of the fly ash. The percentage of Fosroc Cebex-100 was determined based on the results of prior study[16]. The soil samples were mixed with those three combinations with the water content kept at the optimum water content.

The soil samples were subsequently tested using the California Bearing Ratio (CBR) test. SEM analysis was performed on both untreated and stabilized soil samples, focusing specifically on samples with the highest CBR values. Additionally, EDX was conducted alongside SEM to determine the elemental composition of the stabilized samples, emphasizing the distribution of calcium, silicon, and aluminum, which indicate pozzolanic reactions and bond formation.

SEM and EDX images were analyzed qualitatively and quantitatively to compare microstructural features between untreated and treated samples. Findings were then evaluated to assess how the combination of Fosroc Cebex-100 and fly ash influenced soil properties, with a focus on increased particle bonding

3. Results and Discussion

The index properties of the soil samples, as obtained from laboratory testing, are summarized in Table 1. Particle size distribution analysis, represented in Figure 1, reveals that the soil sample contains 9.23% of sand and 90.77% of fine particles. Atterberg limits testing results show a liquid limit (LL), plastic limit (PL), and shrinkage limit (SL) of 71.75%, 54%, and 42.7%, respectively. Therefore, the plasticity index (PI) = LL – PL = 17.75%. Bases on the Unified Soil Classification System (USCS) according to ASTM D 2487-00, the soil sample is classified as sandy

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elastic silt (MH). Further classification using the American Association of State Highway and Transportation Officials (AASHTO) system identifies the soil as fair to poor clayey soil (A-7-5). Additionally, the specific gravity, determined by ASTM D 854-83, was found to be 2.72. The standard proctor test provided that the soil sample has OMC and γd_{max} of 31.55% and 1.2 g/cm^3, respectively.

Table 1. Index properties of soil sample.

Property	
Unit weight, γ (g/cm^3)	1.6
Specific Gravity, Gs	2.72
Particle size	
< 4.75 mm (%)	100
< 0.075 mm (%)	90.77
Atterberg limits	
Liquid Limit, LL (%)	71.75
Plastic Limit, PL (%)	54.00
Shrinkage Limit, SL (%)	42.7
Soil Classification	
USCS	MH
AASHTO	A-7-5
Optimum moisture content, OMC (%)	31.55
Maximum dry unit weight, γ_{dmax} (g/cm^3)	1.2

Table 2. Effect of fly ash and Fosroc Cebex-100 on CBR

Fly ash and Fosroc Cebex-100 content (%)	**CBR (%)**
0% of Fly ash + Fosroc Cebex-100	5.87
20% of Fly ash + Fosroc Cebex-100	8.23
25% of Fly ash + Fosroc Cebex-100	6.44
30% of Fly ash + Fosroc Cebex-100	6.08

The California Bearing Ratio (CBR) tests were conducted to assess the strength and load-bearing capacity of the soil samples. Table 2 presents the CBR values for samples stabilized with varying percentages of fly ash and Fosroc Cebex-100. For the untreated soil sample or natural soil (0% fly ash and Fosroc Cebex-100), a CBR of 5.87% was recorded. With the addition of 20% fly ash and Fosroc Cebex-100, the CBR increased significantly to 8.23%, marking the highest strength improvement observed among all samples. However, a further increase to 25% fly ash and Fosroc Cebex-100 content resulted in a CBR of 6.44%. At 30% fly ash and Fosroc Cebex-100 content, the CBR slightly increased to 6.08%. These findings suggest that while a 20% dosage notably enhances the soil's load-bearing capacity, higher percentages may reduce effectiveness. The sample containing 20% fly ash and Fosroc Cebex-100 was subsequently selected for SEM-EDX analysis and compared with the untreated sample to assess microstructural changes.

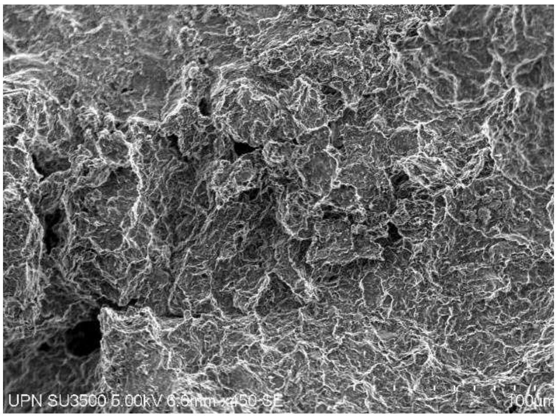

Fig. 2. SEM analysis of untreated soil with 450x magnifications

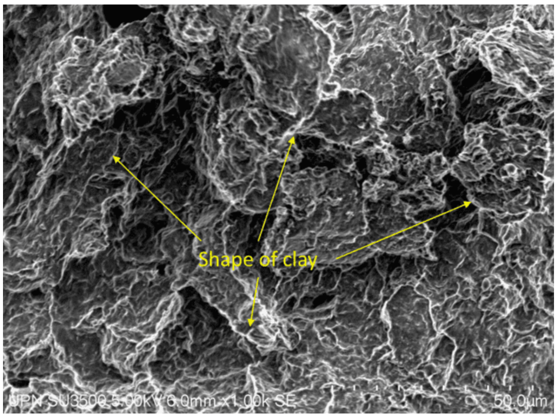

Fig. 3. SEM analysis of untreated soil with 1000x magnifications

Table 3. Chemical compositions of untreated soil using EDX

No.	**Element**	**Concentration by % weight**
1.	O	59.05
2.	Na	0.24
3.	Al	13.6
4.	Si	24.02
5.	Ca	3.09

The SEM analysis results for untreated soil, displayed in Figures 2 and 3 at 450x and 1000x magnifications, respectively, reveal a clay

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microstructure similar to that reported in previous studies [17], [18]. The texture and particle shape of the clay appear plate-like, with fine cracks visible across the surface. Additionally, Elemental analysis of untreated soil, conducted through EDX and presented in Table 3, identified five main elements with the following proportions: O (59.05%), Na (0.24%), Al (13.6%), Si (24.02%), and Ca (3.09%). These results align with previous findings [18], confirming that the predominant elements in soil are O, Si, and Al.

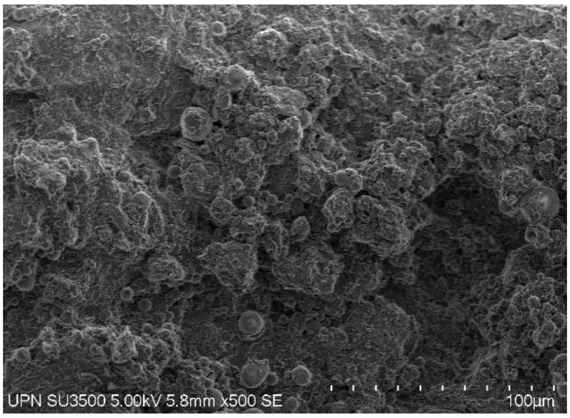

Fig. 4. SEM analysis of treated soil (20% of Fly ash + Fosroc Cebex-100) with 500x magnifications

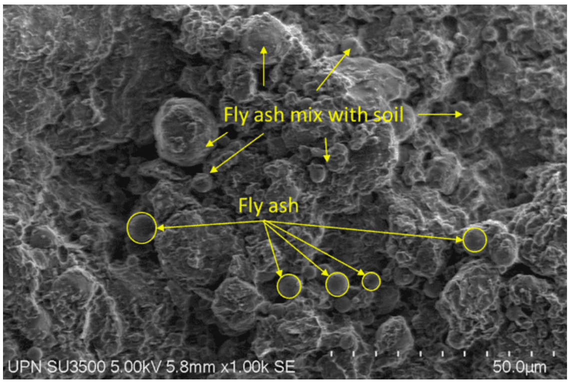

Fig. 5. SEM analysis of treated soil (20% of Fly ash + Fosroc Cebex-100) with 1000x magnifications

The SEM analysis of the treated soil (20% of Fly ash + Fosroc Cebex-100), shown in Figures 4 and 5 at 500x and 1000x magnification, respectively, highlights significant microstructural changes. Elemental analysis via EDX, summarized in Table 4, identified seven primary elements with the following proportions: O (51.48%), N (2.38%), Al (12.35%), Si (21.92%), Ca (5.97%), Fe (3.27%), and Mg (2.16%). These findings are consistent with prior research [19], which identified oxygen, silicon, and aluminum as dominant soil elements, followed by elements with lower percentages (Ca and Mg).

The SEM analysis of untreated and treated samples clearly demonstrates that the addition of fly ash promotes bonding between soil particles, evidenced by the appearance of rounded particles within the soil matrix. This formation indicates an effective chemical reaction between fly ash and soil, resulting in the integration of spherical particles within the soil structure. As particle bonding strengthens, porosity decreases, resulting in a denser soil structure. Increased density enhances soil stability, highlighting the effectiveness of fly ash as a stabilizing agent for improving the microstructural integrity of soft soils. Moreover, the addition of fly ash and Fosroc Cebex-100 controbute to the presence of iron (Fe) in the treated soil. Since class C fly ash includes Fe_2O_3 [20] and Fosroc Cebex-100 contains Fe_2O_3 in concentrations ranging from 0.01% to 0.4% [2].

Table 4. Chemical compositions of treated soil using EDX

No.	Element	Concentration by % weight
1.	O	51.48
2.	N	2.38
3.	Al	12.35
4.	Si	21.92
5.	Ca	5.97
6.	Fe	3.27
7.	Mg	2.16

4. Conclusions

This study demonstrates soil stabilization method that combines fly ash, commonly used for soil stabilization, with Fosroc Cebex-100, a material typically used in concrete applications. Stabilizing soft soil with fly ash and Fosroc Cebex-100 will influence the microstructural properties of the soil. SEM analysis show that addition of fly ash and Fosroc Cebex-100 results in significant changes in the soil matrix, including increased particle bonding, reduced porosity, and a denser overall structure. Moreover, the addition of fly ash and Fosroc Cebex-100 contribute to the presence of iron (Fe) in the treated soil.

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