

RESEARCH ARTICLE

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EXPERIMENTAL EVALUATION OF EGGSHELL WASTE AS AN ECO-FRIENDLY STABILIZER FOR MARLY SOIL

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ARTICLE INFO

Article History

Received: February 13, 2026

Reviewed: March 15, 2026

Accepted: April 05, 2026

Published: May 29, 2026

Keywords:

Eggshell waste,
Valorization,
Soil stabilization,
Shear strength,
Swelling,
Microstructural

ABSTRACT

This study investigates the potential use of eggshell waste as an eco-friendly stabilizing agent for marly soil (GCM) from the Manaa region, located in eastern Algeria. The increasing accumulation of eggshell waste represents an environmental concern, while its high calcium carbonate content offers promising potential for soil improvement. To evaluate this potential, eggshell powder (ESC) was incorporated into the natural soil at proportions of 3%, 6%, 9%, and 12% by dry weight. A series of laboratory tests were conducted, including Atterberg limits, methylene blue value (MBV), Standard Proctor compaction, direct shear, and total swelling tests. The results show that the addition of eggshell waste reduces the soil plasticity index and methylene blue value, indicating a decrease in clay activity. The optimum water content decreases slightly, while the maximum dry density increases with higher additive content. Furthermore, the shear strength parameters, cohesion and internal friction angle, show notable improvement, particularly at 9% eggshell content. The total swelling potential of the treated soil decreases significantly compared with the untreated sample, confirming the stabilizing effect of the additive. In addition, microstructural observations using scanning electron microscopy (SEM) reveal the formation of denser soil matrices and improved particle bonding after eggshell addition. X-ray diffraction (XRD) analyses further indicate the formation of new calcium-bearing phases and a partial reduction in clay mineral activity, providing insight into the chemical and structural mechanisms underlying soil stabilization. Overall, eggshell waste appears to be an effective and sustainable alternative material for improving the mechanical and volumetric behavior of marly soils.



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I. INTRODUCTION

The rapid expansion of the agri-food and poultry industries has led to a significant increase in organic waste generation, among which eggshell waste constitutes an important environmental concern. Large quantities of eggshells are produced and commonly disposed of in landfills, resulting in odor nuisance, increased disposal costs, and environmental pollution. Consequently, the valorization of eggshell waste has gained increasing attention as part of sustainable waste management and circular economy strategies. Eggshells are predominantly composed of calcium carbonate (CaCO_3), accounting for up to 96% of their total mass [1],[2], which makes them a valuable secondary resource.

Previous studies have reported a wide range of applications for eggshell waste, including agriculture, animal feed, biomedical materials, heavy metal adsorption, and catalytic processes [3-5]. More recently, eggshell-derived materials have attracted growing interest in civil and geotechnical engineering as environmentally friendly alternatives to conventional binders [6],[7]. Marly soils, characterized by a mixture of clayey and carbonate constituents, are widely encountered in many regions and often exhibit unfavorable geotechnical behavior, such as high plasticity, swelling potential, low shear strength, and sensitivity to moisture variations. These properties pose serious challenges for infrastructure projects, particularly in road construction and foundation engineering. Although traditional stabilization techniques based on lime or cement are effective, their high energy consumption and associated carbon emissions have motivated the search for sustainable and low-impact alternatives. Eggshell powder (ESP) has emerged as a promising bio-based calcium stabilizer due to its high CaCO_3 content and cementitious potential [8],[4]. Previous research has demonstrated the effectiveness of ESP in improving the mechanical performance of construction materials and soils.

Strength enhancement, reduction in plasticity, and swelling mitigation have been reported for clayey and expansive soils treated with non-calcined or calcined eggshell powder, either alone or in combination with other additives [7], [9-11]. In addition to mechanical improvements, life cycle assessments have shown that eggshell-based binders can significantly reduce environmental impacts compared to conventional lime production [4]. Despite these encouraging findings, limited research has addressed the stabilization of marly soils using eggshell waste, particularly through experimental studies focusing on local soil characteristics. The geotechnical behavior of marly soils varies significantly depending on mineralogy and clay activity, highlighting the need for region-specific investigations. Therefore, the present study aims to assess the effectiveness of eggshell waste valorization for improving the geotechnical properties of marly soil collected from the Manaa region in eastern Algeria. Eggshell powder was incorporated into the soil at varying proportions, and its influence on plasticity, clay activity, compaction behavior, shear strength, and swelling potential was evaluated through a comprehensive laboratory testing program. The study seeks to demonstrate the feasibility of using eggshell waste as a sustainable and eco-friendly alternative stabilizing material for marly soils.

II. MATERIALS AND METHODS

The study involved comprehensive laboratory testing to evaluate the effects of eggshell powder on the engineering properties of marly soil from the Manaa region (Batna, Algeria). The eggshell waste was first calcined in an oven at 1000 °C (ESC) to enhance its reactivity, then incorporated into the natural soil at proportions of 3%, 6%, 9%, and 12% by dry weight to assess its stabilization potential. Laboratory investigations included Atterberg limit tests and methylene blue (VBS) tests to evaluate soil consistency and clay activity, as well as Standard Proctor compaction tests to determine maximum dry density and optimum water content. Shear strength parameters were assessed using direct shear tests, and total swelling tests were conducted to quantify volumetric stability.

To gain a deeper understanding of the stabilization mechanisms, microstructural analyses were performed using Scanning Electron Microscopy (SEM) and Energy-Dispersive X-ray Spectroscopy (EDS), while X-ray Diffraction (XRD) was used to identify changes in mineralogical composition and the formation of calcium-bearing phases. These analyses provided insights into particle bonding, clay stabilization, and the structural evolution of the soil matrix after ESC addition. Finally, a laboratory-controlled Dynamic Penetration test was conducted to simulate field performance and evaluate the practical impact of ESC stabilization on soil bearing capacity.

II.1 SOIL

The greenish clayey marl (GCM) layer, located between 3.00 and 4.00 m depth in the Manaa region (Batna, Algeria), was selected for detailed geotechnical characterization. The soils of this layer consist mainly of clay and marl with variable carbonate and silt content, which influence both plasticity and compressibility. Grain size analysis indicates that over 75% of the particles are finer than 0.08 mm, confirming a predominantly clayey texture.

Table 1: Summary of Geotechnical Properties of Soil.

Test	Parameter	Result
Physical properties[12]	Natural water content (w)	22.9 %
	Wet density (γ_h)	18.3 kN/m ³
	Dry density (γ_d)	14.9 kN/m ³
	Degree of saturation (Sr)	75.6 %
Grain size distribution [13]	% < 0.08 mm	> 75 %
	% < 2 μm	> 38 %
Atterberg limits [14]	Liquid limit (LL)	71.38 %
	Plastic limit (LP)	32.42 %
	Plasticity index (PI)	38.96 %
Methylene blue value [15]	MVB	12 %
Compaction (Proctor) [16]	γ_d max	17.4 kN/m ³
	Optimum water content (Wopt)	28.55 %
Shear strength [17]	Cohesion (c)	1.76 bar
	Friction angle (ϕ)	11.72°
Compressibility [18]	Compressibility index	29.45 %
	Swelling coefficient	9.44 %
Free swell [19]	Void ratio ($e_i \rightarrow e_f$)	0.991 $\rightarrow$ 1.199
	Swelling pressure	2.95 bar

Source: Authors, (2026).

Physical and consistency tests showed a natural water content of 22.9%, a dry density of 14.9 kN/m³, a liquid limit of 71.38%, a plastic limit of 32.42%, and a high plasticity index (PI = 38.96%), classifying the soil as highly plastic and expansive (A4 [20]). Compaction testing (Standard Proctor) yielded a maximum dry density of 17.4 kN/m³ at an optimum water content of 28.55%. Shear strength parameters, with cohesion $c=1.76$ bar and internal friction angle $\phi=11.72^\circ$, indicate low frictional resistance. Compressibility (29.45%), swelling coefficient (9.44%), and swelling pressure (2.95 bar) further confirm the strong expansive potential of this soil layer. These characteristics provide a baseline for evaluating the effects of eggshell powder stabilization on the mechanical and volumetric behavior of the GCM layer.

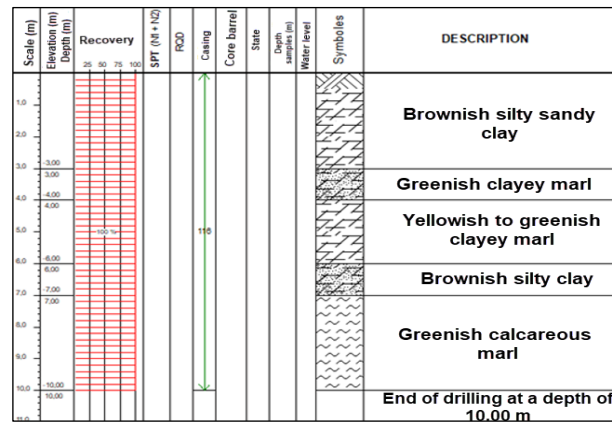


Figure 1: Lithological profile of the studied soil.

Source: Authors, (2026).

II.2 EGGSHELL POWDER

This study focuses on the recycling and valorization of local eggshell waste. A survey conducted by phone among bakeries and local food workshops in the Batna province revealed that most eggshells are typically discarded in landfills immediately after use, with only a small portion being reused as livestock feed or as an agricultural liming material. The eggshell waste used in this study was collected from these sources. The collected eggshells underwent a simple treatment: they were thoroughly washed, crushed, and then calcined in an oven at 1000 °C. Calcination was performed to remove organic matter, increase the material's reactivity, and convert the calcium carbonate in the eggshells into a more reactive form (calcium oxide), enhancing its effectiveness as a soil-stabilizing agent.

Calcined eggshells (ESC) primarily consist of calcium carbonate (CaCO₃), which makes up approximately 97% of their dry weight. The remaining 3% includes various other compounds (Table 2), [21],[22]. but calcium carbonate is the predominant component, giving eggshells their characteristic hardness and making them a promising candidate for soil stabilization applications. For this study, the eggshell powder was mixed with the natural soil at four proportions by dry weight: 3%, 6%, 9%, and 12%. All mixtures were prepared in the laboratory under controlled moisture conditions to ensure homogeneity before testing.

Table 2: Chemical composition of the eggshell.

Elements	CaO	Na ₂ O	SO ₃	MgO	SiO ₂	P ₂ O ₅	K ₂ O	Al ₂ O ₃	MnO
Percent (%)	96,88	1,22	0,31	1,00	0,32	0,21	0,01	0,03	0,005

Source: Authors, (2026).

II.3 LABORATORY TESTING PROGRAM

This study implemented a comprehensive laboratory testing program to evaluate the effects of calcined eggshell (ESC) on the mechanical and volumetric behavior of greenish clayey marl (GCM) from the Manaa region (Batna, Algeria).

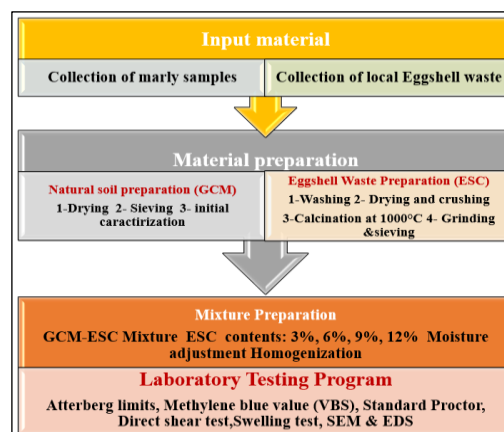


Figure 2: Schematic diagram of the laboratory testing program.

Source: Authors, (2026).

To quantify the improvement in soil performance, ESC was incorporated into the natural soil at proportions of 3%, 6%, 9%, and 12% by dry weight. Untreated soil samples were also tested to serve as reference specimens for comparative analysis. The experimental program included Atterberg limits, methylene blue value (MVB), Standard Proctor compaction, direct shear, and total swelling tests to assess changes in soil plasticity, clay activity, compaction characteristics, shear strength, and swelling potential. In addition, microstructural investigations using X-ray diffraction (XRD) and scanning electron microscopy coupled with energy-dispersive spectroscopy (SEM-EDS) were performed to elucidate the physicochemical mechanisms governing soil stabilization by ESC.

III. RESULTS AND DISCUSSIONS

III.1 ATTERBERG LIMITS AND METHYLENE BLUE VALUE

The variation of the Atterberg limits and methylene blue value with different percentages of eggshell waste is presented in Figure 3. The experimental results show a consistent reduction in the liquid limit (LL) and plasticity index (PI) as the eggshell content increases. The LL decreases from 71.38 % for the untreated soil to 59.23 % at 12 % eggshell addition, while the PI drops from 38.92 % to 24.09 %. In contrast, the plastic limit (PL) exhibits a slight increase from 32.42 % to 35.14 %. This reduction in LL and PI indicates a significant improvement in soil consistency and workability. The decrease in plasticity is primarily due to the chemical interaction between the calcium carbonate (CaCO_3) in eggshell powder and the clay minerals. Calcium ions (Ca^{2+}) released from eggshells replace the monovalent cations (Na^+ , K^+) present on the clay particle surfaces, leading to flocculation and aggregation of the fine particles.

As a result, the diffuse double layer surrounding the clay particles becomes thinner, and the soil structure becomes more granular and less cohesive. This mechanism limits the ability of clay minerals to retain water, thereby reducing plasticity and shrink-swell potential. The methylene blue value (MVB), which reflects the specific surface area and cation exchange capacity of the soil, also decreases from 12 g/100 g for the natural soil to 9.33 g/100 g at 12 % eggshell content. This reduction confirms a decrease in active clay mineral surfaces and the adsorption capacity of the soil. The reduction in MVB may also be explained by the coating of clay particles with fine CaCO_3 particles from eggshells, which physically block exchange sites and reduce surface reactivity. Similar findings have been reported by other researchers [23-25] showing that calcium-rich industrial and agricultural by-products, such as lime, cement dust, and eggshell powder, induce flocculation and reduce the plasticity of clayey soils.

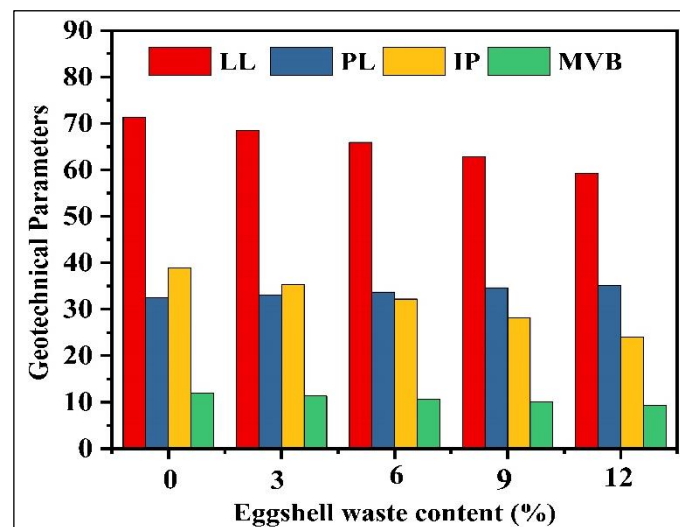


Figure 3: Effect of eggshell powder on geotechnical parameters of soil.

Source: Authors, (2026).

III.2 COMPACTION CHARACTERISTICS

Compaction is a key physical property governing the mechanical performance and long-term stability of soils, as it directly influences strength, compressibility, and settlement behavior. Soil stabilization techniques commonly incorporate additives to improve moisture density relationships and enhance compaction characteristics [23] and [24]. Figure 4 illustrates the effect of calcined eggshell (ESC) addition on the maximum dry density (MDD) and optimum moisture content (OMC) of the studied marly soil, as determined from the Standard Proctor test.

As shown in Figure 4, the MDD of the untreated soil is 17.4 kN/m³ and increases progressively with increasing ESC content, reaching a maximum value of 18.5 kN/m³ at 12% ESC. This increase in dry density indicates improved compactability and a denser soil structure following stabilization. The enhancement in MDD can be primarily attributed to the filler effect of the finely ground calcined eggshell particles, which effectively occupy the voids between soil grains and improve particle packing. In addition, the presence of calcium oxide (CaO) derived from calcined eggshell promotes physicochemical interactions with clay minerals, leading to flocculation and aggregation of clay particles. These mechanisms reduce interparticle repulsion and facilitate closer packing under compaction energy, resulting in higher dry density [26],[27].

Conversely, the optimum moisture content increases slightly from 28.55% for the natural soil to 31.20% at 12% ESC. This increase in OMC may be explained by the higher specific surface area of the calcined eggshell powder and its affinity for water, which requires additional moisture to ensure adequate lubrication during compaction. Furthermore, part of the added water may be consumed in early-stage hydration reactions involving CaO, contributing to the observed increase in optimum moisture demand.

Overall, the combined increase in MDD and moderate rise in OMC demonstrate that calcined eggshell waste enhances the compaction behavior of marly soil by producing a denser and more stable soil matrix. These improvements are expected to positively influence subsequent mechanical strength and swelling performance, confirming the suitability of calcined eggshell as an effective and sustainable soil stabilization material for geotechnical applications.

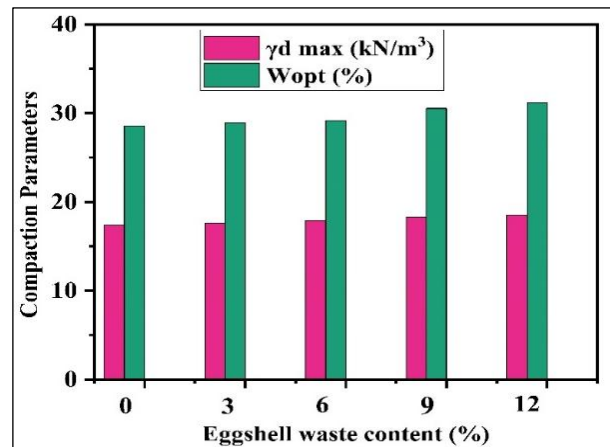


Figure 4: Effect of eggshell powder on Compaction parameters of soil.
Source: Authors, (2026).

III.3 SHEAR STRENGTH PARAMETERS

The cohesion and internal friction angle are fundamental shear strength parameters governing the stability and deformation resistance of soils under applied loads in geotechnical design. Figure 5 presents the Mohr–Coulomb failure envelopes and the variation of shear strength parameters for the natural marly soil treated with different percentages of eggshell waste. As illustrated in Figure 5, the cohesion (c) of the untreated soil is 1.76 bar and increases progressively with increasing eggshell content, reaching a maximum value of 2.93 bar at 12% eggshell addition. Similarly, the internal friction angle (ϕ) increases from 11.72° for the natural soil to 13.09° at 12% eggshell content. These results clearly indicate a significant enhancement in the shear strength behavior of the soil following stabilization. The observed increase in cohesion is mainly attributed to the cementing effect induced by calcium ions (Ca^{2+}) released from the eggshell waste. These ions promote physicochemical interactions with clay minerals, leading to flocculation and aggregation of fine particles and the formation of interparticle bonds. This bonding mechanism enhances soil cohesion by increasing particle contact and reducing the mobility of clay platelets. In addition, the fine eggshell powder acts as a micro-filler, occupying voids within the soil matrix and contributing to a more compact and stable structure.

The improvement in the internal friction angle can be explained by enhanced particle interlocking and surface roughness resulting from the incorporation of eggshell particles. The filling of micro-voids and the aggregation of soil particles lead to increased resistance against sliding at particle contacts, thereby improving frictional resistance. Similar trends have been reported in previous studies using calcium-rich waste materials, where increases in friction angle were linked to improved granular interaction and reduced plasticity [28],[29]. It is noteworthy that the most pronounced improvements in both cohesion and friction angle occur in the range of 9 and 12% eggshell content, suggesting that this interval represents an optimal dosage for effective stabilization of the studied marly soil. Beyond this range, further improvements are expected to be limited due to particle saturation effects within the soil structure. Overall, the results confirm that eggshell waste significantly enhances the shear strength characteristics of marly soil through combined cementation, flocculation, and void-filling mechanisms. These improvements contribute to greater soil stability and load-bearing capacity, reinforcing the potential of eggshell waste as a sustainable and effective soil stabilization material for geotechnical engineering applications.

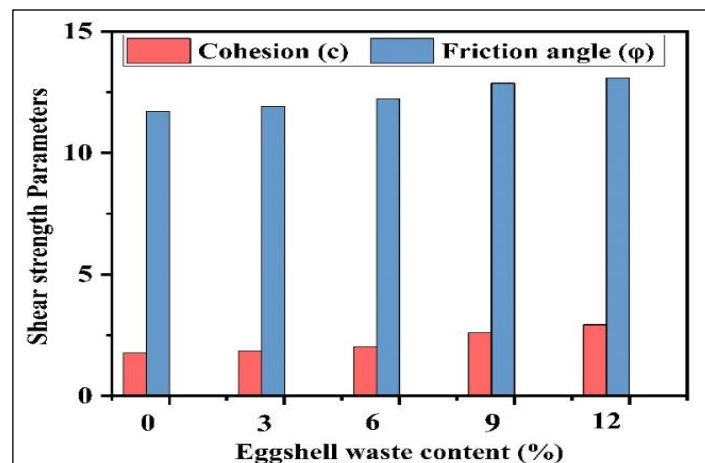


Figure 5: Effect of eggshell powder on shear strength parameters of soil.
Source: Authors, (2026).

III.4 SWELLING PRESSURE AND SWELLING POTENTIAL

Swelling pressure is a critical parameter in geotechnical engineering, as it represents the force exerted by expansive soils on foundations and structures due to volumetric changes induced by moisture variations. Excessive swelling pressure can lead to severe structural damage, including cracking, heaving, and foundation instability [30-32]. To evaluate the effectiveness of eggshell waste in controlling volumetric deformation, laboratory swelling tests were conducted on both untreated and treated marly soil samples. Figure 6 illustrates the variation of swelling pressure and swelling potential of the studied soil as a function of eggshell content. The results show that the swelling pressure of the natural soil decreases significantly from 2.95 bar to 1.43 bar with the addition of 12% eggshell waste, corresponding to a reduction of approximately 52%. Similarly, the swelling potential decreases from 13.54% for the untreated soil to 7.94% at 12% eggshell content, representing a reduction of about 41%. These results clearly demonstrate the positive effect of eggshell waste on improving the volumetric stability of the marly soil. The observed reduction in swelling behavior can be primarily attributed to the flocculation and aggregation of clay particles induced by calcium ions (Ca^{2+}) released from the calcium carbonate (CaCO_3) present in the eggshell waste.

These divalent cations replace monovalent ions on the clay mineral surfaces, reducing diffuse double-layer thickness and limiting the soil's capacity for water absorption. As a result, the soil structure becomes more compact and less susceptible to swelling. In addition, the fine eggshell particles act as a micro-filler, occupying pore spaces and restricting water ingress into the soil matrix, further reducing swelling pressure and potential. The most pronounced reductions in both swelling pressure and swelling potential are observed at eggshell contents between 9% and 12%, suggesting that this range provides an optimal dosage for effective stabilization. Similar findings have been reported in previous studies, where calcium-based additives were shown to significantly reduce the swelling behavior of expansive soils through chemical interaction and microstructural modification [31],[33]. Overall, the results confirm that eggshell waste is an effective stabilizing agent for controlling swelling-induced deformation in marly soils. The substantial reduction in swelling pressure and swelling potential highlights its potential application in foundation and pavement engineering, where volumetric stability is a key design requirement.

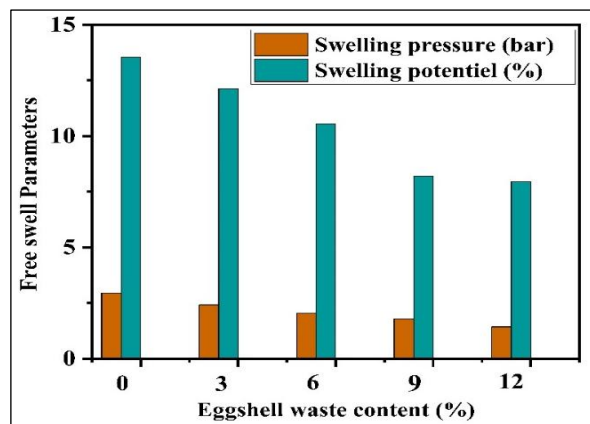


Figure 6: Effect of eggshell powder on free swell parameters of soil.

Source: Authors, (2026).

III.5 MICROSTRUCTURAL ANALYSIS

To better understand the mechanisms responsible for the improvement in mechanical and volumetric properties of the marly soil (GCM) stabilized with calcined eggshell waste (ESC), microstructural analyses were performed using Scanning Electron Microscopy (SEM) Figure 7a-e and Energy-Dispersive X-ray Spectroscopy (EDS) Figure 8a-e. These techniques were employed to examine changes in soil fabric, pore structure, and elemental composition induced by the addition of ESC.

III.5.1. Sem Analysis

SEM observations were carried out on untreated GCM and ESC-treated soil specimens. The SEM image (figure 7a) of the untreated soil reveals a highly porous and heterogeneous microstructure, characterized by the presence of numerous macropores and micropores and loosely arranged clay aggregates. The clay platelets appear randomly oriented with weak interparticle bonding, which is typical of highly plastic and expansive soils. This open and discontinuous structure facilitates water penetration and retention, explaining the high swelling potential, low shear strength, and poor volumetric stability observed in the untreated soil. Similar microstructural features have been reported for expansive clayey soils in previous studies [31] and [34]. In contrast, SEM images of the soil treated (figure 7b, c, d and e) with calcined eggshell waste show a remarkable densification of the soil matrix. With increasing ESC content, both macropores and micropores become progressively smaller, and the soil structure evolves from a loose fabric to a more compact and cemented matrix.

The fine ESC particles partially fill the voids between soil grains, contributing to a reduction in pore size and improved particle packing. In addition, the release of calcium ions from calcined eggshell promotes flocculation and aggregation of clay particles, resulting in a more stable microstructure. More importantly, the treated samples exhibit the formation of cementitious products, identified as calcium silicate hydrate (C-S-H) gel, which bridges adjacent soil particles and binds them together. The presence of this C-S-H gel leads to the development of a continuous cemented network within the soil matrix, significantly enhancing interparticle bonding and reducing soil deformability. This cemented structure explains the observed increase in cohesion, internal friction angle, and maximum dry density, as well as the substantial reduction in swelling pressure and swelling potential. Overall, the SEM results confirm that calcined eggshell waste effectively modifies the soil microstructure by reducing pore spaces, enhancing particle contact, and promoting the formation of cemented bonds, leading to improved mechanical and volumetric performance.

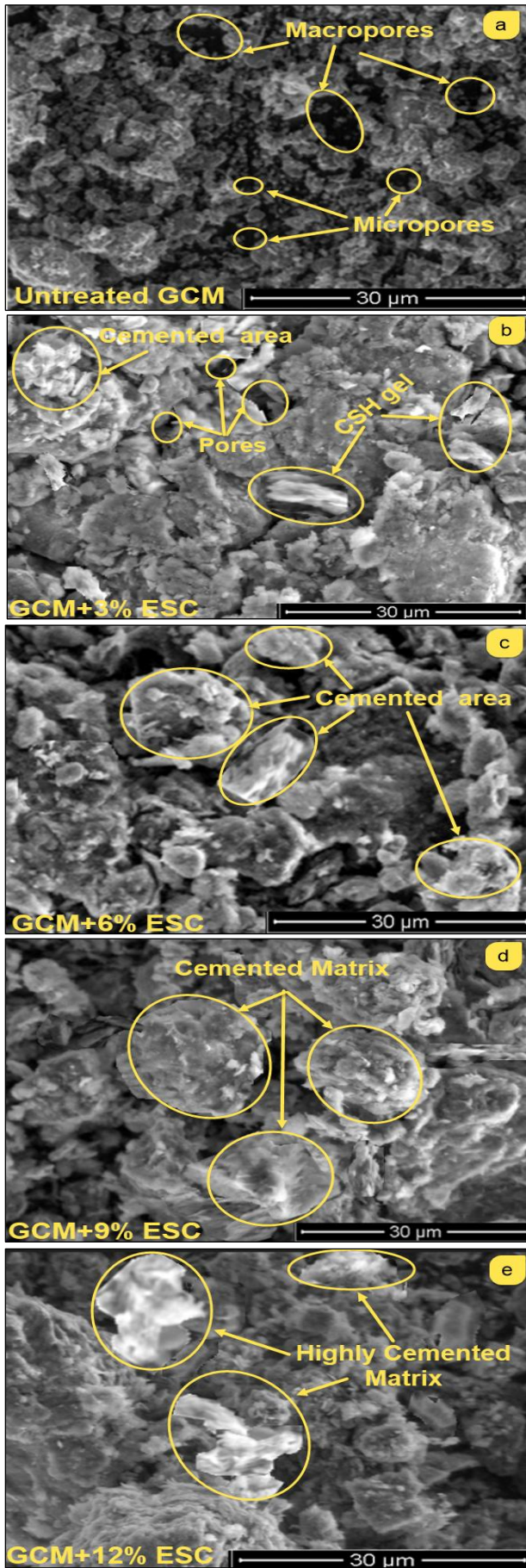


Figure 7: SEM images of untreated and ESC-treated marly soil.
Source: Authors, (2026).

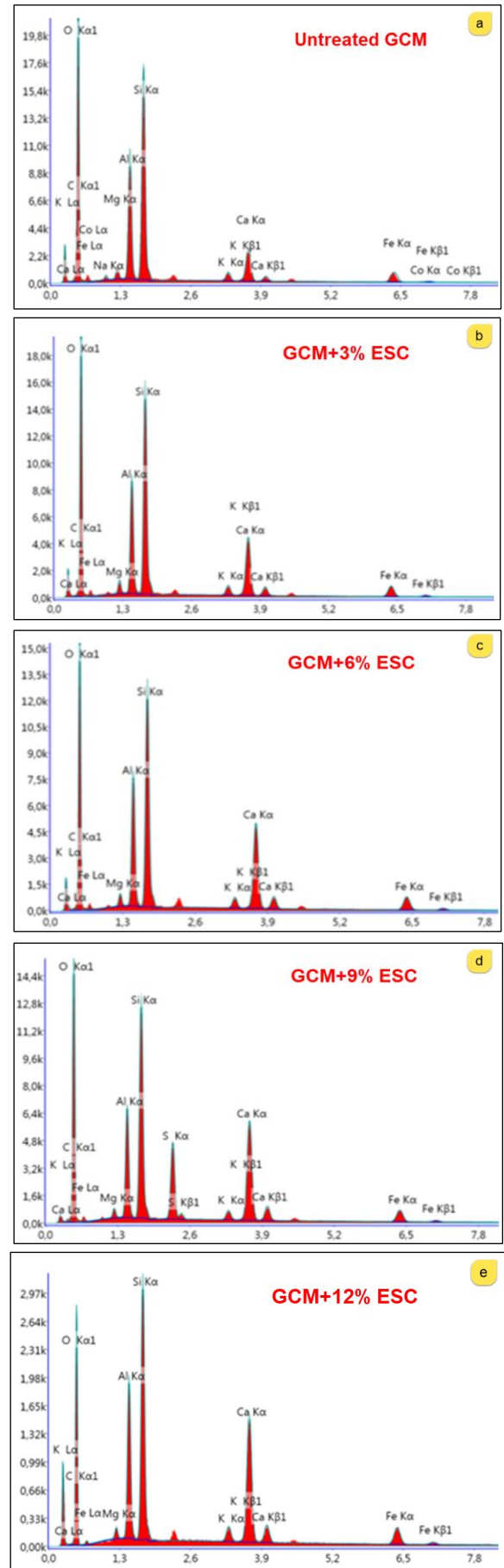


Figure 8: EDS images of untreated and ESC-treated marly soil.
Source: Authors, (2026).

III.5.2. EDS Analysis

EDS analysis was conducted to investigate the elemental composition of the untreated (figure 8a) and ESC-treated soil (Figure 8 b,c,d and e) samples and to support the SEM observations. The EDS spectrum of the untreated GCM shows dominant peaks of O, Si, and Al, indicating the prevalence of aluminosilicate clay minerals, along with relatively low calcium content. This composition is consistent with the weak natural cementation and poor bonding observed in the untreated soil. For the ESC-treated samples, EDS results reveal a significant increase in calcium (Ca) content, confirming the incorporation of calcined eggshell waste into the soil matrix. The elevated calcium concentration facilitates chemical interactions with silica and alumina present in the soil, leading to the formation of cementitious compounds such as C–S–H. As the percentage of calcined eggshell waste decreases, a corresponding decrease in Ca content is observed in the EDS spectra, indicating a direct relationship between ESC dosage and calcium availability within the soil structure.

This variation in calcium content explains the progressive changes in microstructure and engineering behavior observed in the treated soils. Higher ESC content results in greater calcium availability, enhanced cementation, and improved soil stability, whereas lower ESC content leads to a reduced degree of bonding and densification. The EDS findings therefore corroborate the mechanical test results and confirm that calcium plays a key role in the stabilization mechanism. In summary, the combined SEM and EDS analyses demonstrate that the stabilization of marly soil with calcined eggshell waste is governed by void filling, particle flocculation, and cementitious gel formation, all of which contribute to a denser, stronger, and less expansive soil structure. These microstructural transformations provide strong evidence for the effectiveness of calcined eggshell waste as a sustainable soil stabilization material.

IV. CONCLUSIONS

This study clearly demonstrates that calcined eggshell waste (ESC) constitutes an effective, sustainable, and environmentally responsible stabilizing agent for marly soil from the Manaa region. The comprehensive laboratory investigation confirmed that the incorporation of ESC leads to significant improvements in both the physical and mechanical behavior of the soil. The marked reduction in plasticity index and methylene blue value highlights a decrease in clay activity, resulting in improved soil workability and reduced sensitivity to moisture variations. Compaction characteristics were favorably affected by ESC addition, as evidenced by an increase in maximum dry density accompanied by a slight rise in optimum moisture content. These changes indicate the formation of a denser and more stable soil structure, which is beneficial for construction applications. Furthermore, the enhancement of shear strength parameters namely cohesion and internal friction angle was particularly pronounced at ESC contents ranging from 9% to 12%, reflecting the development of stronger interparticle bonding and improved load-bearing capacity.

The substantial reduction in swelling pressure and swelling potential further confirms the effectiveness of ESC in mitigating volumetric instability, a critical concern when dealing with expansive marly soils. Microstructural analyses using SEM and EDS provided strong supporting evidence for these macroscopic improvements, revealing soil matrix densification, reduced pore spaces, increased calcium availability, and the formation of cementitious products such as calcium silicate hydrate (C–S–H) gel. These microstructural transformations are indicative of pozzolanic and cementation reactions that play a key role in soil stabilization. Overall, the convergence of physical, mechanical, and microstructural findings validates the high potential of calcined eggshell waste as a low-cost and eco-friendly alternative to conventional chemical stabilizers. The valorization of this agricultural waste not only enhances soil performance but also contributes to waste management and sustainability objectives. Consequently, ESC presents a promising solution for geotechnical engineering applications, particularly in regions where expansive marly soils and eggshell waste are readily available.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Hizia Bekhouche, Ouassila Bahloul, Aidoud Assia and Laid Lekouara

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Discussion of results: Hizia Bekhouche, Ouassila Bahloul, Aidoud Assia and Laid Lekouara

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Supervision: Hizia Bekhouche, Ouassila Bahloul, Aidoud Assia and Laid Lekouara

Approval of the final text: Hizia Bekhouche, Ouassila Bahloul.

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