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Experimental Investigation of Sandy Soil Stabilization Using Cement and Lime
"A Case Study from Ajdabiya City, Libya"

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Abstract
Weak sandy soils present significant challenges for civil engineering construction because of their low bearing capacity and poor mechanical performance. Soil stabilization using cementitious additives has become an economical and practical alternative to soil replacement. This study evaluates the effectiveness of ordinary Portland cement and quicklime in improving the engineering properties of sandy soils collected from two locations in Ajdabiya City, northeastern Libya. Natural soil samples were treated with cement and lime at 5%, 10%, and 15% by dry weight. Laboratory testing included grain-size distribution, Standard Proctor compaction, direct shear, and unconfined compressive strength (UCS) tests.

The untreated soils were classified as A-3 according to the AASHTO classification system and consisted predominantly of poorly graded fine sand with negligible fines. Experimental results demonstrated that cement stabilization significantly enhanced soil performance compared with lime treatment. Increasing cement content improved maximum dry density, shear strength, and compressive strength, with the greatest improvement observed at 15% cement. Lime treatment also improved the engineering behavior of the soils but produced lower strength gains than cement. The results indicate that cement stabilization provides an effective and economical technique for improving weak sandy soils in Ajdabiya and similar arid environments, thereby increasing bearing

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capacity and reducing settlement problems associated with shallow foundations.
Keywords: Soil stabilization; Cement; Lime; soil; Direct shear; Unconfined compressive strength; Ajdabiya; Libya.

دراسة تجريبية لتثبيت التربة الرملية باستخدام الأسمنت والجير: دراسة حالة من مدينة أجدابيا، ليبيا

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الملخص

تُشكل التربة الرملية الضعيفة تحديات كبيرة أمام مشاريع الهندسة المدنية نظرًا لانخفاض قدرتها على التحمل وضعف خصائصها الميكانيكية. وقد أصبح تثبيت التربة باستخدام الإضافات الأسمنتية بديلاً اقتصاديًا وعمليًا لاستبدال التربة. تُقيّم هذه الدراسة فعالية الأسمنت البورتلاندي العادي والجير الحي في تحسين الخصائص الهندسية للتربة الرملية المأخوذة من موقعين في مدينة أجدابيا، شمال شرق ليبيا. عُولجت عينات التربة الطبيعية بالأسمنت والجير بنسب 5% و10% و15% من الوزن الجاف. شملت الاختبارات المعملية توزيع حجم الحبيبات، واختبار بروكتور القياسي للدمك، واختبار القص المباشر، واختبار مقاومة الضغط غير المحصور.

صُنفت التربة غير المعالجة ضمن الفئة A-3 وفقًا لنظام تصنيف AASHTO، وتألفت في الغالب من رمال ناعمة ضعيفة التدرج مع كميات ضئيلة من المواد الناعمة. أظهرت النتائج التجريبية أن تثبيت التربة بالأسمنت حسّن أداءها بشكل ملحوظ مقارنةً بمعالجتها بالجير. أدى رفع نسبة الأسمنت إلى تحسين الكثافة الجافة القصوى، ومقاومة القص، ومقاومة الضغط، مع ملاحظة أكبر تحسن عند نسبة 15% من الأسمنت. كما حسّنت معالجة التربة بالجير من خصائصها الهندسية، ولكنها حققت مكاسب أقل في المقاومة مقارنةً بالأسمنت. تشير النتائج إلى أن تثبيت التربة بالأسمنت يُعد تقنية فعالة واقتصادية

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لتحسين التربة الرملية الضعيفة في أجدابيا والبيئات القاحلة المماثلة، مما يزيد من قدرة تحمل التربة ويقلل من مشاكل الهبوط المرتبطة بالأساسات الضحلة.

الكلمات المفتاحية: تثبيت التربة؛ الأسمنت؛ الجير؛ التربة؛ القص المباشر؛ مقاومة الضغط غير المحصور؛ أجدابيا؛ ليبيا

1. Introduction

To a geologist, soil represents the product of ancient surface processes; to a pedologist, it embodies ongoing physical and chemical weathering; and to a geotechnical engineer, it is a construction material that can serve as a foundation, be excavated for tunnels and basements, or be used in the construction of roads, embankments, dams, and retaining structures (Ogbuchukwu and Okeke, 2021). The primary concern for engineers is the mechanical behavior of soil particularly; strength, stiffness, and permeability.

Geotechnical engineers frequently encounter challenges when constructing on problematic soils (Basu et al, 2019). Structures built on weak soils often suffer from excessive settlement, insufficient bearing capacity, and instability, which can lead to structural damage and significantly higher construction costs (Das and Sobhan, 2018). Soil stabilization has therefore emerged as one of the most effective and economical ground improvement techniques in geotechnical engineering. It enhances the mechanical properties of weak soils and reduces the need for costly excavation and replacement (Mitchell and Soga, 2005).

Among chemical stabilization methods, the use of cement and lime has gained wide acceptance due to its simplicity, proven effectiveness, and economic viability (Sherwood, 1993). Cement stabilization works primarily through hydration reactions that produce strong cementitious bonds between soil particles, thereby increasing density, stiffness, and compressive strength. Lime stabilization started in the beginning of the 20th century, to improve soil properties via cation exchange, flocculation, carbonation, and pozzolanic reactions, resulting in a more stable soil matrix (Johnson, 1948; Bell, 1996). Previous studies have consistently shown that both additives significantly enhance engineering performance, with

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cement generally providing superior strength gains and lime offering a more cost-effective option for certain soil types (Bell, 1993; Barman and Dash, 2022; Petry and Little, 2002).
Ajdabiya City, in northeastern Libya, has experienced rapid urban expansion in recent decades. While older districts were founded on competent limestone of the Ajdabiya Formation (Emhanna et al., 2026), newer unplanned development has extended into surrounding areas underlain by sandy soils with relatively poor geotechnical characteristics. These soils typically exhibit low shear strength and limited bearing capacity, posing serious challenges for foundation design and long-term structural stability. In this context, improving the engineering properties of locally available sandy soils has become essential for safe and sustainable urban development. Soil stabilization offers a practical and economical solution by enhancing soil strength and load-bearing capacity while minimizing the need for soil replacement.
The present study examines the stabilization of sandy soils collected from two locations in Ajdabiya City using ordinary Portland cement and lime. Laboratory tests were conducted on untreated soil samples and on samples stabilized with 5%, 10%, and 15% additive contents by dry weight. The effectiveness of stabilization was evaluated through grain-size distribution, compaction, direct shear, and unconfined compressive strength tests (Head, 1986). The main objective was to identify the more effective stabilizing agent and the optimum additive percentage for improving the engineering behavior of these local sandy soils.

2. Research Objectives

The main objective of this study is to investigate the effectiveness of cement and lime as stabilizing agents for sandy soils sourced from Ajdabiya City, Libya.
The specific objectives are as follows:

- To determine the physical and engineering properties of untreated sandy soils from two different locations in Ajdabiya.
- To evaluate the effect of ordinary Portland cement and lime on the compaction characteristics, shear strength and

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unconfined compressive strength of the stabilized soils at additive contents of 5%, 10%, and 15% by dry weight.

- To compare the performance of cement and lime in improving the geotechnical properties of the studied soils.
- To identify the optimum additive type and percentage that provides the most effective stabilization for the local sandy soils.

3. Materials and Methods

Two disturbed sandy soil samples were collected from eastern and northern Ajdabiya City, Libya, at depths ranging from approximately 0.5 to 1.0 m. The Soil 1 sampling location was situated at latitude 30°50'4.70"N and longitude 20°14'20.69" E, whereas the location Soil 2 was situated at latitude 30°46'34.73" N and longitude 20°10'26.75" E (Fig, 1).

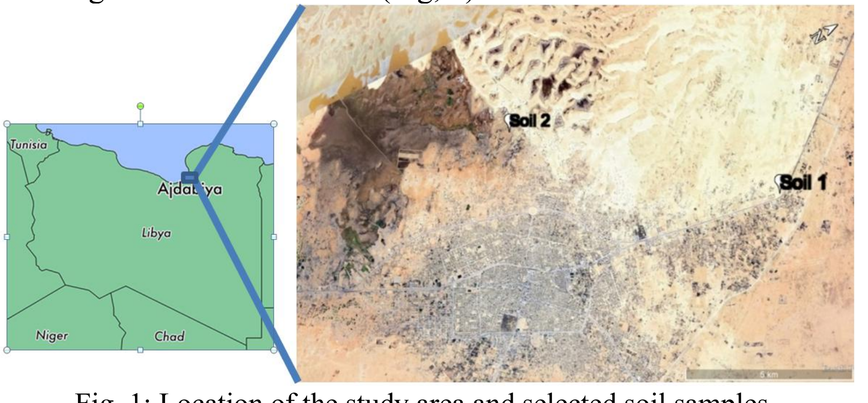

Fig. 1: Location of the study area and selected soil samples.

The natural soils were first characterized to determine their engineering properties before stabilization. Ordinary Portland Cement (42.5 N) and quicklime were used as stabilizing agents. Each additive was incorporated into the soil at proportions of 5%, 10%, and 15% by dry weight. Before testing, all soil samples were oven-dried at 110 ± 5°C for 24 hours and sieved through a No. 4 sieve. Laboratory testing was then performed on untreated and stabilized specimens.

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The experimental program included:

- Grain-size distribution analysis.
- Standard Proctor compaction tests.
- Direct shear tests.
- Unconfined compressive strength (UCS) tests.

Grain-size analysis was performed to classify the soils and determine particle-size distribution. Standard Proctor compaction tests established the optimum moisture content (OMC) and maximum dry density (MDD). Direct shear testing evaluated the shear strength characteristics, while UCS testing quantified improvements in compressive strength resulting from stabilization (Fig, 2).

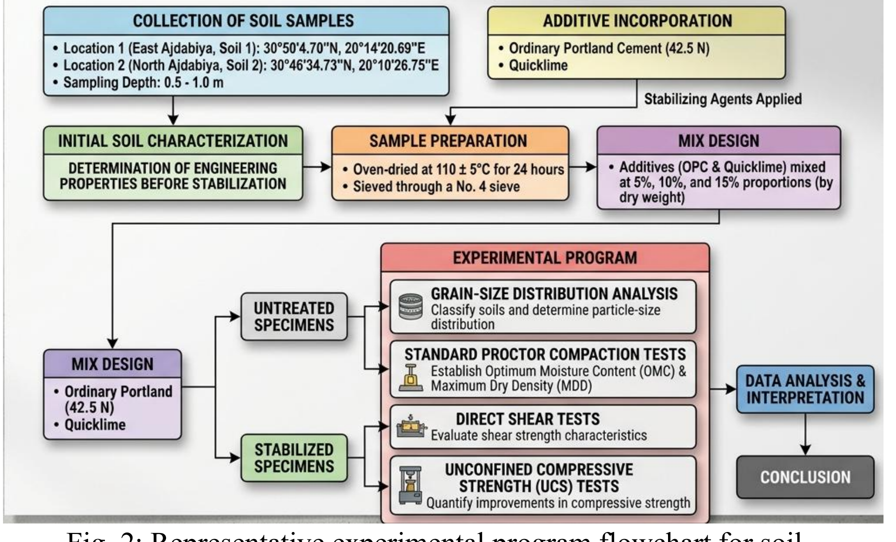

Fig. 2: Representative experimental program flowchart for soil stabilization.

4. Results and Discussion

4.1. Grain Size Distribution

The grain size distribution curves for the two natural soil samples are presented in Tables 1 and 2. Both soils are composed predominantly of fine sand with negligible fines and very small gravel fractions. According to the AASHTO classification system

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(Hogentogler and Terzaghi, 1929), both soils are classified as **A-3**, indicating fine sandy soils that generally possess low cohesion and limited bearing capacity for engineering applications.
The grain size parameters showed that Soil 1 had a coefficient of uniformity (Cu) of 4.28 and a coefficient of curvature (Cc) of 0.49, whereas Soil 2 exhibited Cu and Cc values of 1.91 and 0.88, respectively (Figs 3 and 4). T
hese values indicate that both soils are poorly graded sands with a relatively narrow particle-size distribution. The percentage of fines was almost negligible, accounting for only 0.15% in Soil 1 and 0.01% in Soil 2. Consequently, the natural soils possess limited particle interlocking and negligible natural cohesion, making them susceptible to settlement under structural loading.

TABLE 1: Grain Size Distribution for Soil 1.

Sieve Number	Diameter (mm)	Soil Retained (g)	% Retained	% Cumulative	% Passing
4	4.75	28.5	4.95	4.95	95.05
10	2	13.8	2.39	7.34	92.66
20	0.84	34.1	5.92	13.25	86.75
40	0.425	147.1	25.57	38.83	61.17
100	0.15	151.9	26.41	65.24	34.76
200	0.075	199.7	34.6	99.59	0.15
Total		575.1			
RESULTS					
D 60	0.41	Cu =	4.28	% Gravel	4.95
D30	0.14	Cc =	0.49	% Sand	94.9
D10	0.10			% Fines	0.15

TABLE 2: Grain Size Distribution for Soil 2.

Sieve Number	Diameter (mm)	Soil Retained (g)	% Retained	% Cumulative	% Passing
4	4.75	4	0.487	0.487	99.513
10	2	2.5	0.3044	0.7914	99.208
20	0.84	7.5	0.913	1.704	98.296
40	0.425	28	3.4	5.1044	94.895
100	0.15	306.6	37.33	42.434	57.566
200	0.075	472.6	57.54	99.9	0.01
		821.2			
RESULTS					
D 60	0.17	Cu =	1.91	% Gravel	0.49
D30	0.11	Cc =	0.88	% Sand	99.50
D10	0.09			% Fines	0.01

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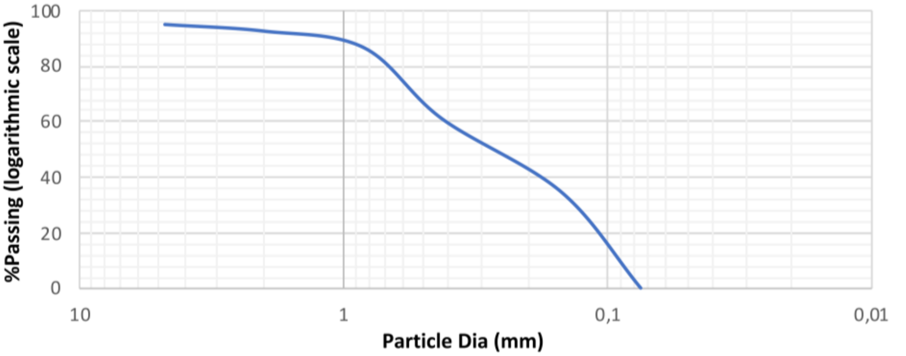

Fig. 3: Grain Size Analysis for Soil 1.

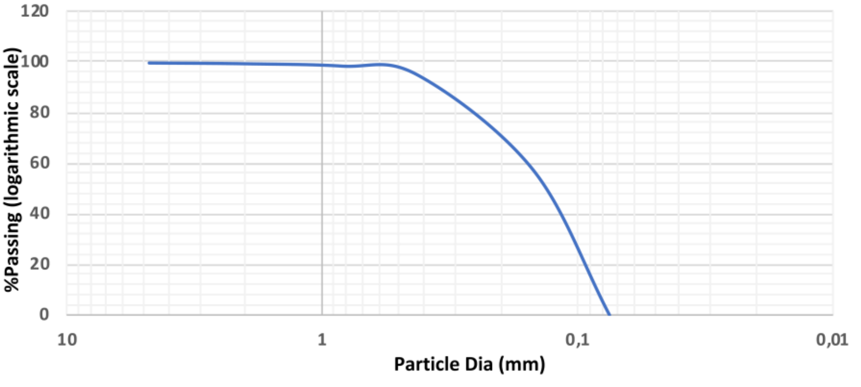

Fig. 4: Grain Size Analysis for Soil 2.

The predominance of sandy particles explains the relatively low engineering performance of the untreated soils and justifies the need for stabilization using chemical additives. Cement and lime introduce cementitious bonds between particles, increasing interparticle adhesion and improving the load-bearing behavior of the soil matrix.

4.2. Effect of Cement and Lime on Compaction Characteristics Soil 1

The compaction results indicate that the untreated Soil 1 exhibited a maximum dry density (MDD) of 20.33 kN/m³ at optimum moisture content (OMC) of 11.73% (Table 3). Following stabilization with cement, the compaction behavior changed

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noticeably. The optimum moisture content generally increased with increasing cement content because additional water was required to hydrate the cement particles and facilitate pozzolanic reactions. Although slight fluctuations were observed in the maximum dry density, the treated soil exhibited improved compactability and greater structural stability.

TABLE 3: Compaction Test for Soil 1.

MOISTURE-DENSITY RELATIONSHIP				
Water Content Determination				
Sample no	**1**	**2**	**3**	**4**
Moisture can no	**35**	**33**	**9**	**1**
Wt. of can + wet soil	**136.9**	**133.7**	**143.2**	**123**
Wt. of can + dry soil	**128.7**	**123.7**	**130.4**	**110.8**
Wt. of water	**8.2**	**10**	**12.8**	**12.2**
Wt. of can	**21**	**21.2**	**21.3**	**21.3**
Wt. of dry soil	**107.7**	**102.5**	**109.1**	**89.5**
Water content, Wt%	**7.61**	**9.75**	**11.73**	**13.63**
Density Determination				
Assumed water Content	**5%**	**7%**	**9%**	**11%**
Water content, W%	**7.61**	**9.75**	**11.73**	**13.63**
Wt. of soil + mold	**8597**	**8750**	**8866**	**8794**
Wt. of mold	**6747**	**6747**	**6747**	**6747**
Wt. of soil in mold, (g)	**1850**	**2003**	**2119**	**2047**
Wet Unit Weight, KN/m³	**19.84**	**21.5**	**22.72**	**21.95**
Dry Unit Weight , KN/m³	**18.43**	**19.6**	**20.33**	**19.31**
RESULTS	**Maximum Dry Unit Weight**			**20.33 KN/m³**
	Optimum Moisture Content			**11.73%**

At 15% cement content, the soil achieved its highest engineering performance despite a slightly lower dry density than the untreated

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specimen (Table 4). This behavior suggests that cement stabilization improves soil strength primarily through cementation rather than simple densification. The hydration products formed between cement and soil particles produce rigid interparticle bonds that substantially increase stiffness and resistance to deformation.

Lime stabilization also modified the compaction characteristics. However, compared with cement-treated specimens, lime-treated soils generally exhibited lower maximum dry densities (Table, 5). The addition of lime caused particle flocculation and aggregation, producing a more open soil structure with reduced compacted density. Although lime increased the optimum moisture content because of its water demand during chemical reactions, its influence on density improvement was less pronounced than that of cement.

Overall, cement demonstrated superior performance over lime in improving the compaction characteristics of Soil 1.

TABLE 4: Results of Compaction Test for Soil 1 with Cement.

	5% Cement	10% Cement	15% Cement
Maximum Unit Weight	**19.6 KN/m³**	**19.3 KN/m³**	**19.6 KN/m³**
Optimum Moisture Content	**12.70%**	**10.82%**	**14.92%**

TABLE 5: Results of Compaction Test for Soil 1 with Lime.

	5% Lime	10% Lime	15% Lime
Maximum Unit Weight	**18.33 KN/m³**	**17.67 KN/m³**	**17.96 KN/m³**
Optimum Moisture Content	**10.9%**	**11.50%**	**15.38%**

Soil 2

A similar trend was observed for Soil 2 (Table, 6). Cement treatment progressively enhanced compaction behavior and produced more stable soil structures than lime stabilization (Table 7). The increase in optimum moisture content reflected the higher water requirement for hydration reactions, while the resulting cementitious compounds improved particle bonding and reduced soil compressibility.

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TABLE 6: Compaction Test for Soil 2.

MOISTURE-DENSITY RELATIONSHIP				
Water Content Determination				
Sample no	1	2	3	4
Moisture can no	22	43	17	21
Wt. of can + wet soil	142.1	166.2	165	163.7
Wt. of can + dry soil	133.6	153.4	149.4	146.3
Wt. of water	8.5	12.8	15.6	17.4
Wt. of can	21	21.2	20.5	21
Wt. of dry soil	112.6	132.2	128.9	125.3
Water content, Wt%	7.5	9.6	12.2	13.8
Density Determination				
Assumed water Content	5%	7%	9%	11%
Water content, W%	7.50	9.60	12.20	13.80
Wt. of soil + mold	8505	8631	8711	8709
Wt. of mold	6747	6747	6747	6747
Wt. of soil in mold, (g)	1758	1884	1964	1962
Wet Unit Weight , KN/m³	18.85	20.14	21.1	21
Dry Unit Weight , KN/m³	17.53	18.37	18.8	18.4
RESULTS	Maximum Dry Unit Weight			18.8 KN/m³
	Optimum Moisture Content			12.20%

Lime treatment produced moderate improvement but was less effective in increasing the compacted density of the sandy soil (Table, 8). Since sandy soils contain relatively small quantities of clay minerals, the beneficial effects of lime stabilization are inherently limited compared with fine-grained soils where cation exchange and pozzolanic reactions are more significant.

These findings indicate that cement stabilization is the more suitable improvement technique for the sandy soils encountered in Ajdabiya.

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TABLE 7: Results of Compaction Test for Soil 2 with Cement.

	5% Cement	10% Cement	15% Cement
Maximum Unit Weight	20.11 KN/m³	20.4 KN/m³	20.7 KN/m³
Optimum Moisture Content	11.50%	13.10%	11.26%

TABLE 8: Results of Compaction Test for Soil 2 with Lime.

	5% Lime	10% Lime	15% Lime
Maximum Unit Weight	20 KN/m³	19.8 KN/m³	19.6 KN/m³
Optimum Moisture Content	14.50%	14.20%	14.33%

4.3. Direct Shear Strength

The direct shear test was conducted to determine the shear strength parameters of the untreated sandy soils, namely the cohesion (C) and the angle of internal friction (φ). The results indicate that both soils exhibit negligible cohesion (C = 0 kg/cm²), which is typical of clean sandy soils where the shear resistance is mainly controlled by interparticle friction rather than particle bonding.

For Soil 1 (Table 9), the shear stress increased almost proportionally with the applied normal stress. At normal stresses of 0.25, 0.50, and 1.00 kg/cm², the corresponding shear stresses were 0.35, 0.57, and 1.10 kg/cm², respectively. The calculated angle of internal friction was approximately 45.25°, indicating relatively dense and well-compacted sand with high frictional resistance. Such a high friction angle suggests good grain interlocking and a strong resistance to sliding under increasing normal loads.

TABLE 9: Direct Share Test for Soil 1.

Test No	Normal Force (N)	Load Dial Reading	Horizontal Shear Force (kg)	Normal Stress (kg/cm²)	Shear Stress (kg/cm²)
1	5	100	35	0.25	0.35
2	50	164	57	0.5	0.57
3	100	315	110	1	1.1
RESULTS		**Cohesion (C)**			**0**
		Angle of internal friction (φ)			**45.25°**

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TABLE 10: Results of Direct Share Test for Soil 1 with Cement.

	5% Cement	10% Cement	15% Cement
Cohesion (C)	**0**	**0**	**0**
Angle of internal friction (φ)	**45.37°**	**42.74°**	**46.63°**

TABLE 11: Results of Direct Share Test for Soil 1 with Lime.

	5% Lime	10% Lime	15% Lime
Cohesion (C)	**0**	**0**	**0**
Angle of internal friction (φ)	**40°**	**30°**	**17°**

In contrast, Soil 2 (Table 12) also showed an increase in shear stress with increasing normal stress, recording values of 0.25, 0.49, and 1.05 kg/cm² under the same normal stress levels. However, the calculated friction angle was only 22°, which is considerably lower than that of Soil 1. This lower friction angle indicates that Soil 2 possesses a weaker particle arrangement, poorer interlocking, or a higher proportion of fine particles, resulting in lower shear resistance.
The comparison between the two soils clearly demonstrates that Soil 1 has superior shear strength characteristics. Although the maximum shear stresses at the highest normal load are relatively close (1.10 kg/cm² for Soil 1 and 1.05 kg/cm² for Soil 2), the much higher internal friction angle of Soil 1 reflects a significantly greater capacity to resist shear failure over a wide range of loading conditions.

TABLE 12: Direct Share Test for Soil 2.

Test No	Normal Force (N)	Load Dial Reading	Horizontal Shear Force (kg)	Normal Stress (kg/cm²)	Shear Stress (kg/cm²)
1	25	70	25	0.25	0.25
2	50	140	49	0.5	0.49
3	100	300	105	1	1.05
RESULTS		**Cohesion (C)**			**0**
		Angle of internal friction (φ)			**22°**

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TABLE 13: Results of Direct Share Test for Soil 2 with Cement.

	5% Cement	10% Cement	15% Cement
Cohesion (C)	0	0	0
Angle of internal friction (φ)	14.31°	19.30°	19.50°

TABLE 14: Results of Direct Share Test for Soil 2 with Lime.

	5% Lime	10% Lime	15% Lime
Cohesion (C)	0	0	0
Angle of internal friction (φ)	20°	21°	20.30°

Overall, the direct shear test results indicate that Soil 1 possesses excellent frictional strength and higher stability, whereas Soil 2 exhibits moderate shear strength and would require stabilization if it is intended for heavy engineering applications. These findings are consistent with the behavior commonly observed in sandy soils, where particle size distribution, density, and particle interlocking are the primary factors controlling shear strength (Tables 10. 11. 13 and 14).

4.4. Unconfined Compressive Strength (UCS)

The unconfined compressive strength (UCS) tests were conducted to evaluate the effectiveness of cement and lime in improving the mechanical behavior of the two investigated soils. The results clearly indicate that both stabilizing agents enhanced the compressive strength compared with the untreated soils, although the magnitude of improvement depended on the type of soil and the percentage of additive.

For Soil 1 (Table, 15), the untreated specimen recorded a compressive strength (Qu) of 0.420 g/cm². Cement treatment produced mixed results at lower dosages (Table 16), where the UCS decreased to 0.228 g/cm² and 0.180 g/cm² for 5% and 10% cement, respectively. However, increasing the cement content to 15% significantly increased the compressive strength to 0.471 g/cm², representing the highest strength obtained for Soil 1. This improvement is attributed to the formation of cement hydration

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products, mainly calcium silicate hydrate (C–S–H) and calcium aluminate hydrate (C–A–H), which bind soil particles into a dense and rigid matrix capable of resisting higher axial loads.
Lime stabilization also improved the strength of Soil 1 (Table 17), although the increase was considerably smaller than that achieved with cement. The UCS values increased from 0.145 g/cm² at 5% lime to 0.252 g/cm² at 15% lime. The relatively limited improvement is associated with the low clay content of the soil, which restricts the pozzolanic reactions responsible for long-term strength development.

TABLE 15: Unconfined Compressive Test for Soil 1.

Load dial (g)	Sample deformation dL (mm)	Unit strain (dL / L0)	Area CF (1-Strain)	Corrected area (cm²)	Total load on sample (col.1 x LRC)	Sample unit load (g/cm²)
13	0.5	0.0070	0.9930	8.0970	0.9672	0.1195
31	1	0.0141	0.9859	8.1549	2.3064	0.2828
42	1.5	0.0211	0.9789	8.2135	3.1248	0.3804
46	2	0.0282	0.9718	8.2730	3.4224	0.4137
47	2.5	0.0352	0.9648	8.3334	3.4968	0.4196
40	3	0.0423	0.9577	8.3947	2.9760	0.3545
RESULT			**Qu**		0.420 g/cm²	
			Su		0.210 g/cm²	

TABLE 16: Results of Unconfined Compressive Test for Soil 1 with Cement.

	5% Cement	10% Cement	15% Cement
Qu g / cm²	0.228	0.180	0.471
Su g / cm²	0.114	0.090	0.236

TABLE 17: Results of Unconfined Compressive Test for Soil 1 with Lime.

	5% Lime	10% Lime	15% Lime
Qu g / cm²	**0.145**	**0.127**	**0.252**
Su g / cm²	**0.072**	**0.063**	**0.126**

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For Soil 2 (Table, 18), the untreated specimen exhibited a much lower compressive strength (Qu = 0.054 g/cm²) than Soil 1, indicating weaker natural bonding between soil particles. Cement stabilization markedly improved the compressive strength, particularly at 15% cement, where the UCS increased to 0.661 g/cm², representing more than a twelvefold increase compared with the untreated specimen (Table 19). In contrast, the improvements at 5% and 10% cement were moderate, with UCS values of 0.170 g/cm² and 0.172 g/cm², respectively.
The behavior of lime-treated Soil 2 differed from that of cement-treated specimens. The UCS increased from 0.234 g/cm² at 5% lime to a maximum of 0.319 g/cm² at 10% lime, but then decreased slightly to 0.238 g/cm² at 15% lime (Table 20). This suggests that the optimum lime content for Soil 2 is approximately 10%, beyond which additional lime does not contribute to further strength gain and may even reduce efficiency because excess lime remains unreacted.

TABLE 18: Unconfined Compressive Test for Soil 2.

Load dial (g)	Sample deformation dL (mm)	Unit strain (dL/L0)	Area CF (1-Strain)	Corrected area (cm²)	Total load on sample (col.1xLRC)	Sample unit load (g / cm²)
4	0.5	0.0070	0.9930	8.0970	0.2976	0.0368
5	1	0.0141	0.9859	8.1549	0.3720	0.0456
5.5	1.5	0.0211	0.9789	8.2135	0.4092	0.0498
6	2	0.0282	0.9718	8.2730	0.4464	0.0540
6	2.5	0.0352	0.9648	8.3334	0.4464	0.0536
RESULT			**Qu**		0.0540 g/cm²	
			Su		0.0270 g/cm²	

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TABLE 19: Results of Unconfined Compressive Test for Soil 2 with Cement.

	5% Cement	10% Cement	15% Cement
Qu g / cm²	0.170	0.172	0.661
Su g / cm²	0.085	0.086	0.331

TABLE 20: Results of Unconfined Compressive Test for Soil 2 with Lime.

	5% Lime	10% Lime	15% Lime
Qu g / cm²	0.234	0.319	0.238
Su g / cm²	0.117	0.160	0.119

Overall, cement proved to be the most effective stabilizing agent for both soils, particularly at 15% cement content, which produced the highest unconfined compressive strengths. The superior performance of cement is attributed to its rapid hydration and the formation of abundant cementitious compounds that significantly improve particle bonding and reduce soil compressibility. Although lime also enhanced soil strength, its effectiveness was lower because the investigated soils are predominantly sandy and therefore contain limited reactive silica and alumina necessary for extensive pozzolanic reactions.

These findings are consistent with previous studies reported by Bell (1996), Sherwood (1993), and Ingles and Metcalf (1972), who concluded that cement generally provides greater improvements in strength than lime for coarse-grained or sandy soils, whereas lime stabilization is more effective for highly plastic clay soils.

5. Discussion

The experimental results demonstrate that both cement and lime affected the engineering properties of the tested soils, although their effectiveness depended on soil type and additive content.

For Soil 1 (A-3 fine sand), cement caused a slight reduction in maximum dry density and an increase in optimum moisture content. The friction angle remained relatively unchanged, while the highest unconfined compressive strength (UCS) (0.471 g/cm²) was achieved with 15% cement, indicating that higher cement content was required to improve strength. Lime, however, reduced both the

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friction angle and UCS, showing limited effectiveness for stabilizing sandy soil.
For Soil 2, cement significantly improved the soil properties. The maximum dry density increased, and the UCS rose from 0.054 g/cm² to 0.661 g/cm² at 15% cement, demonstrating excellent strength improvement. Lime also increased the UCS, with the best performance at 10% lime (0.319 g/cm²), but the improvement was considerably lower than that achieved with cement.
Overall, cement proved to be more effective than lime for stabilizing both soils. The optimum performance was obtained with 15% cement, while lime provided only moderate improvement, particularly in the finer soil. These findings are consistent with previous studies reporting that cement produces stronger cementitious bonds and greater strength development than lime.

6. Conclusions

The following conclusions can be drawn from this study:

1. The investigated soils from Ajdabiya are predominantly poorly graded sands (AASHTO A-3) with very low fines content and are unsuitable for heavy construction without stabilization.
2. Both cement and lime improved the engineering properties of the investigated soils.
3. Cement stabilization was more effective than lime, showing superior results in compaction, shear strength, and unconfined compressive strength.
4. The best overall performance was achieved with 15% cement addition.
5. Due to the non-plastic sandy nature of the soils, lime was less effective compared to cement.
6. Cement stabilization is recommended as a practical and effective technique for improving sandy soils in Ajdabiya and similar arid regions.

7. Recommendations

- The use of 15% cement or 15% lime is recommended for stabilizing sandy soils in Ajdabiya City, with cement

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providing higher strength and lime offering better cost-effectiveness.

- Stabilized soils can be utilized as subgrade material, embankment fill, or foundation support.
- Field trials and long-term performance monitoring under local conditions are strongly advised.
- Future studies should explore combined cement-lime stabilization and the incorporation of local waste materials for improved sustainability.

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