

STUDY THE EFFECT OF WASTE MATERIALS ASH (DATE SEED ASH) ON EXPANSIVE SOIL

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Abstract

Expansive soils experience volumetric expansion as they absorb water, resulting in pressure being exerted on the foundation soils and causing movement of the foundation. The forces generated by these variations in volume may cause substantial damage to the buildings above them. Date seeds are the leftover material from certain facilities that make date syrup. Laboratory experiments were conducted to examine the effects of DSA work as a soil stabilizer on the expansive soil's compressibility and expansion. Four different amounts of DSA (6%, 9%, 12 and 15%) were added to the bentonite soil to investigate the effect of DSA on bentonite soil properties. Compaction, Atterberg limits, and unconfined compression tests are selected to investigate the mechanical and swelling improvement in bentonite soil. According to test findings, adding DSA reduced bentonite soil's plasticity and expansive index with increasing DSA ratios. The unconfined compressive strength test was conducted during three curing ages (0, 7 and 28) curing ages day, and the best results were obtained when using 9% of DSA as stabilizer materials.

Keywords:

Date Seed Ash;
 Expansive Soil;
 Soil stabilization.

1 Introduction

Engineers and builders often face significant challenges with construction projects due to expansive soils, also known as shrink-swell soils, which undergo substantial volume changes with moisture fluctuations [1–4]. These soils expand upon water absorption and contract when moisture decreases, primarily due to clay minerals like montmorillonite and smectite [5]. These minerals, part of the phyllosilicate group, possess a layered structure that absorbs water, leading to soil swelling [6,7]. Addressing these issues often involves soil stabilization, one of the earliest techniques to enhance soil carrying capacity [8–11]. This can be achieved by replacing poor soils or modifying their properties using additives [3,12]. Material selection prioritizes local availability, environmental friendliness, affordability, and quality [3,13,14]. Sustainability plays a critical role, encouraging the integration of industrial byproducts and agricultural waste as building materials. These practices mitigate waste management challenges, reduce natural resource consumption, and promote innovative composite materials for improved construction solutions [15,16].

The occurrence of swelling in expansive soils is a significant issue that foundation engineers deal with regularly due to the risk of erratic upward movements of the various buildings erected on these soils [17], a global issue that manifests differently in many regions. Partially saturated clayey soil that exhibits significant volume fluctuations (swelling) from water absorption and shrinking from a decrease in moisture content is known as expansive soil [18]. Expanding soils may experience volume variations because of moisture differences, which can seriously harm buildings built on top of them, particularly lightweight constructions, road pavements, and canal linings [19]. Compaction enhances strength and compressibility, two of the engineering qualities of soils. In the case of expansive soils, compaction raises the soil's capacity for swell while increasing the degree of densification [20,21]. Therefore, compaction that exceeds a certain level of densification—mainly when the moisture content is below ideal—may harm the performance of buildings built on these types of soils. One well-known method for improving the physical characteristics of subpar soils is soil stabilization. Chemical stabilizers—lime and cement are the most often used examples—may work better in this situation.

For the stabilization of expansive soils, conventional stabilizers, including bitumen, fly ash, and Portland cement and lime, are well-known, often employed, and effective [22]. One may categorize this stability as electrical, chemical, or mechanical. In traditional stabilization, densification, blending, mixing, and altering the situation of the soil mass are the most crucial steps. These stabilizing approaches have the main advantages of increasing soil stiffness, strength, and durability while decreasing soil plasticity and swelling [23]. Lime has been used to enhance compaction density and make the soil more workable. A pozzolanic reaction occurs when lime is combined with clay soil particles [24,25]. However, [26–28] emphasized that using lime and cement requires a lot of energy and resources, producing significant quantities of carbon dioxide and, ultimately, harms human health.

Stabilizing soil is a challenge for expansive as well as weak soil kinds. Extremely malleable clay has a vast potential that might cause significant harm and financial expenses. Utilizing one of the various stabilizing techniques, it is frequently necessary to modify the engineering qualities of the topsoil layers in order to create a subgrade. These techniques include using chemical additives, rewetting, and replacing soil while controlling compaction, as well as surcharge loading and thermal techniques [29,30]. The behaviour of expanding soils with chemical additions has been extensively studied. Ali and Koranne examined the impact of varying percentages of fly ash and stone dust coupled in expanding soil [31]. Index characteristics, Proctor compaction, swelling pressure, and UCS of expansive clays combined with varying ratios of fly ash and stone dust were all evaluated in the test findings. The findings show that the swelling of clays is better controlled, and other soil qualities significantly improve at ideal admixture percentages of 20 to 30%. The study concludes that adding equal amounts of stone dust and fly ash to expansive soil helps manage its natural tendency to swell more effectively than adding either material alone. In order to ascertain the impact of lime and fly ash treatment on three expansive soils' Atterberg limits, compaction, unconfined compression, and swelling features, Ramadas et al. [32] conducted laboratory studies on the soils. The expanding soil's qualities improved, according to the trial findings.

The Middle East, especially Iraq, produces date seeds comprising 6-15% of mature date weight. Date seeds provide carbohydrates, fibre, fat, ash, and protein. Date seed oil (DSO) has antioxidant levels equivalent to olive oil, making it a feasible antioxidant source to fulfil market needs [33]. Date seeds remain after removing stones from dates to make pitted dates or date paste. Date seeds are hard-shelled, grooved, and contain a tiny embryo. Date pits weigh 0.5 to 4 g and comprise about 6 to 20% of the fruit's weight, depending on age, variety, and grade [34]. Agricultural waste building is a primary environmental concern in many countries, especially those without waste recycling facilities or the knowledge to recycle it [35].

Date seeds are dry waste because they are lightweight and big, resulting in poor density and quality. Waste accumulates in large amounts, causing problems. Their burning pollutes the environment [36]. They also house insects and rodents. It is essential to find ways to integrate these waste products into green and sustainable engineering applications as an environmentally friendly and cost-effective alternative to synthetic materials in the feed industry. Date seed debris may be used to make composite technological components [37]. These applications encourage real growth or sustainable development. They may communicate and preserve stability by managing natural resources wisely and promoting environmental balance. The numerals are 1–7. Babylonians practice sustainable development and employ composite materials in production. They build using hay and mud to strengthen their homes. Iraq was the first to embrace sustainable building development.

A composite mixes two or more materials with different mechanical and physical features to create a hybrid material with unique features. The novelty of this study lies in the innovative utilization of date seed ash (DSA), a sustainable byproduct of agricultural waste, as an eco-friendly and cost-effective soil stabilizer for expansive soils. Unlike conventional stabilizers such as lime and cement, which are resource-intensive and environmentally detrimental, DSA offers a greener alternative with significant potential to reduce soil plasticity and swelling while enhancing mechanical properties. This research uniquely investigates the optimal DSA percentage and its effects on expansive soil properties. It bridges sustainability with effective soil stabilization methods and addresses environmental and engineering challenges in a region abundant in date seed waste. The current article aims to use sustainable materials (Date seed ash (DSA)) in chemical soil stabilization methods to improve the mechanical features of soil and increase its strength. However, the aim of the study will be achieved by applying different DSA (6%, 9%, 12 and 15) % by the dry soil weight.

2 Experimental work

2.1 Selective soil

The selected soil has been supplied by (MAWASIM ALRAAFIDYAN & COMPANY Trade& General Contracting), which is Bentonite powder for pile drilling (Drilling grade) characterized by the chemical and physical analysis mentioned in Tables 1 and 2. Moreover, the soil particle size distribution and X-ray diffraction (XRD) for the selected bentonite have been illustrated in Figs. 1 and 2, respectively.

Table 1. Physical Features of Bentonite

Physical characteristics		Specifications
Colour	Light Yellow	-
Sieve Analysis Size	Pass from 200 microns	100%
Free swell	90% by volume	-
Nature	Pozzolanic	-
Relative humidity %	50%	-

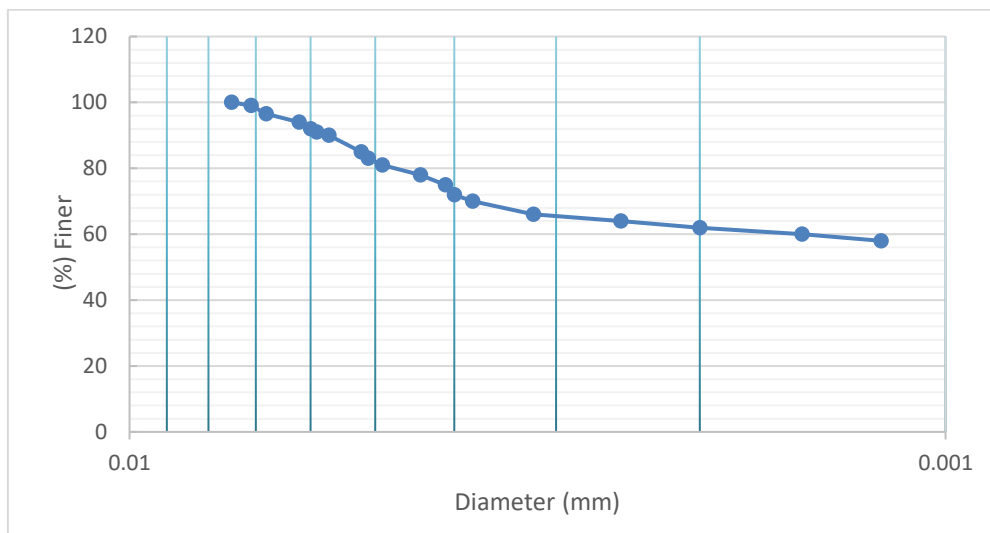


Fig. 1: Particle size distribution for bentonite.

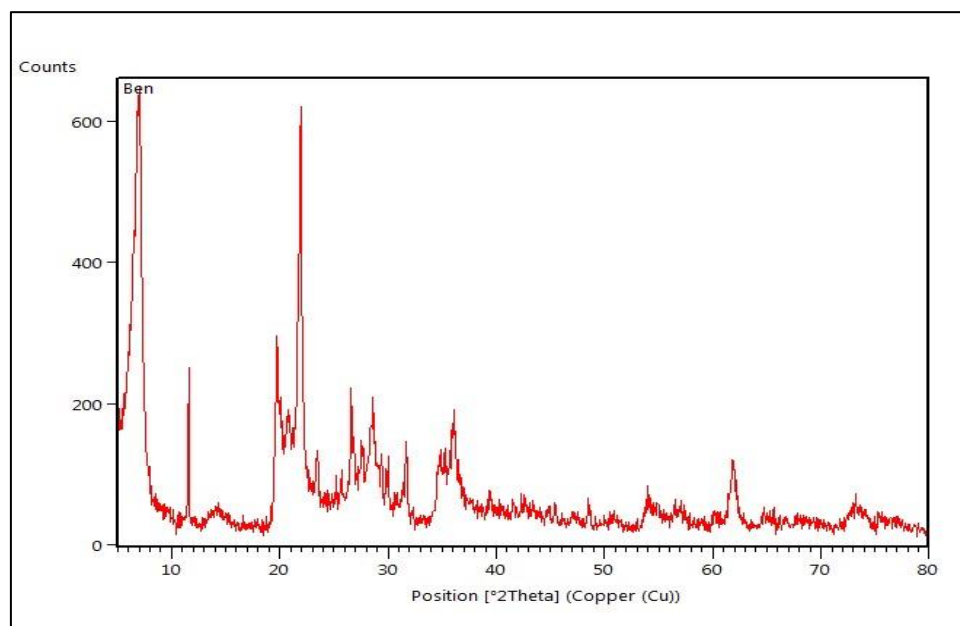


Fig. 2: XRD for Bentonite powder utilized in the current study.

Table 2. The chemical composition of Bentonite and DSA powder is utilized in the current study.

Chemical composition	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	SO ₃	Cl	LOI
Bentonite	60.80	17.33	1.72	3.62	3.00	1.89	4.45	0.29	0.06	-
Date ash	39.76	20.65	0.78	13.04	6.36	7.40	3.60	-	-	8.41

2.2 Date seed ash (DSA)

In this study, date seeds were utilized for soil stabilization, collected from flying spray of date seed mills, and then subjected to a temp of 900 °C in a furnace for burning. This study's stabilizer material (pozzolanic) was date seed ash. Date seeds have been gathered from trees in Hilla and Karbala towns. The date seeds were incinerated in a furnace at a temperature of 900°C for about 2 hours, as shown in Fig. 3. The combustion of the seed took place in the laboratory of the Civil Engineering Department at Al-Mustaqbal University. Figs. 4 and 5 display the distribution of particle sizes and XRD for the date seed ash utilized in this investigation, respectively.

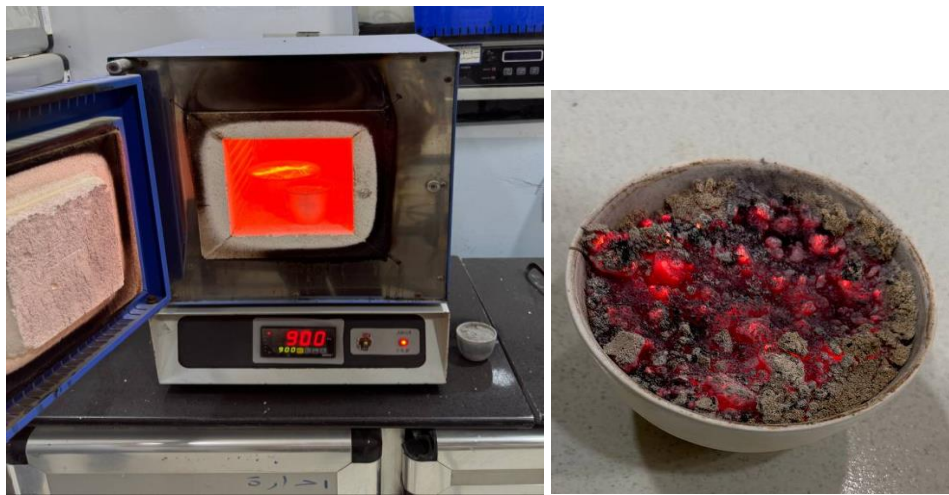


Fig. 3: Date Seed ash burning process.



Fig. 4: Utilized materials.

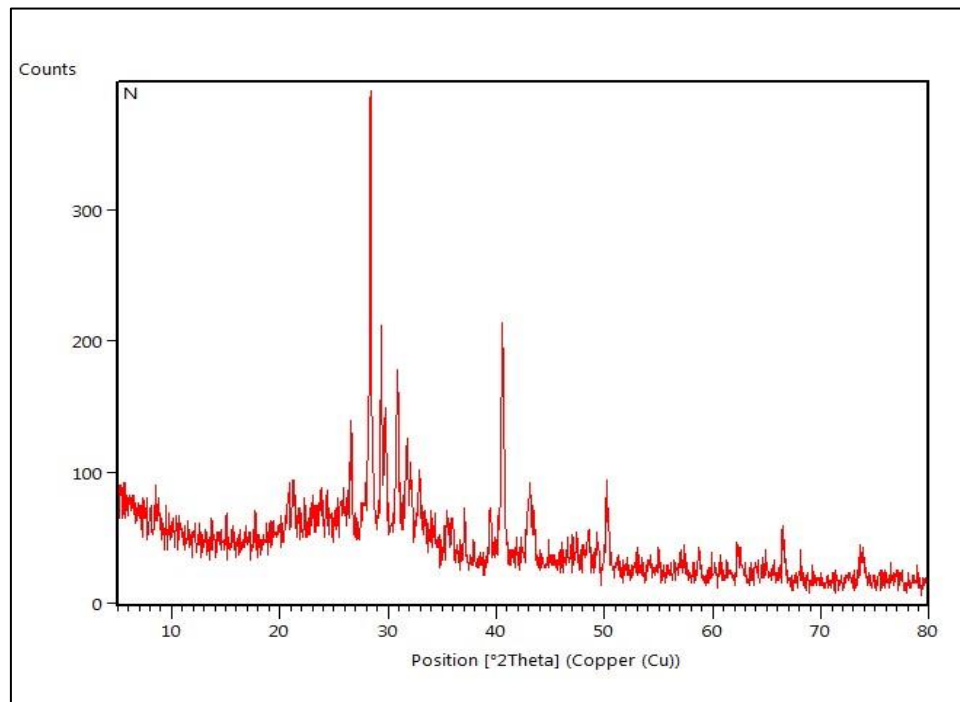


Fig. 5: XRD for Date seed ash was utilized in the current study.

3 Tests

3.1 Atterberg limits

This test procedure is conducted to ascertain the soil's liquid limit, plastic limit, and plasticity index. ASTM D4318 [38] specifies two methods: multipoint and one-point tests. A multipoint test was utilized in this inquiry due to its inherent accuracy. Three samples were created, each comprising about 450 grams of soil combined with 6%, 9%, 12%, and 15% DSA by weight. In each case, the percentage of DSA was combined with 150 g of soil. The samples were subjected to a 24-hour vacuum treatment. Approximately 20 gm were obtained from every sample for plastic limit tests, while the rest of the soil was utilized for the liquid limit tests. During the liquid limit test, the number of drops was measured when the groove closed at roughly 13 mm. Subsamples were extracted from the closing groove and transferred to empty containers. These containers were then put in a furnace and maintained at 110 ± 5 C° for one day. This process aimed to determine the water content of the samples.

$$\text{Water content \%} = \frac{\text{water mass}}{\text{dry soil mass}} \quad (1)$$

$$\text{Plastic limit (PL)} = 100 \times \frac{\text{water mass}}{\text{dry soil mass}} \quad (2)$$

$$\text{Plasticity index (PI)} = \text{LL} - \text{PL} \quad (3)$$

The soil's expansion index was calculated using the formula (4) According to [39] to assess its capability for expansion, as outlined in Table 3 of ASTM D 4829.

$$\text{EI} = 1.8 \times \text{PI} \quad (4)$$

Table 3. The expansion potential associated with the expansion index based on ASTM D 4829

Expansion potential	Expansion Index (EI)
Very low	0-20
Low	21-50
Medium	51-90
High	91-130
Very high	>130

3.2 Proctor compaction test

This test technique establishes the correlation between the amount of moisture and the compacted weight of soil by determining the optimal moisture content and the highest density when the soil is arid by the ASTM D698 standard [40]. These determinations are essential for enhancing the engineering qualities of soil that will be utilized for road pavements, embankments, and foundations.

The equipment utilized was a mould with a diameter of 152.4 mm, and a rammer was dropped from a height of 30 cm to generate a compaction effort, as seen in Fig. 7. This test technique is used for soil without prior compaction operations and was passed on the sieve 200. In this investigation, 6 kg of soil was sieved using sieve 200. The sieved soil was split into three equal portions, weighing about 2 kilograms. Each part was mixed with a different amount of DSA, namely 6%, 9%, 12%, and 15%. The soil was first moistened with water, which accounted for 6% of the soil's weight. After mixing, each sample was placed in plastic bags for twenty-four hours to cure and prevent any particles from drying out. Each sample was placed in the mould in three layers, with each layer being compacted using a free fall rammer from a distance of 12 inches, with 25 blows applied to each layer. The weight of the mould base containing soil was measured.

Additionally, the weight of the samples extracted from the compacted soil was measured twice: once before and once after being placed in an oven for 24 hours at a temperature of 110 ± 5 degrees Celsius, which was done to determine the optimal water content and max dry density. Formulas 5 and 6 compute the dry density for the acquired soils.

3.3 Unconfined compressive strength

The test technique has been utilized to ascertain the UCS of clay soil, yielding an approximate measure of the cohesive soil's strength. The test procedure was conducted by the ASTM D2166 standard [41], designed explicitly for cohesive soil that does not release or retain water.

This experiment was conducted on bentonite soil, exhibiting cohesive features without and with different DSA ratios. A total of 12-cylinder samples were generated from each soil sample. The samples had a length of 7.6 cm and a diameter of 3.8 cm. Every sample was put separately in the unconfined strength device. The top platen was positioned in contact with the specimen, and the deformation indicator was calibrated to a reading of zero. The stress-strain curve was defined by recording load, deformation, and duration data at 15 sites. The samples were weighed before and after the test and placed in the oven to ascertain their water amount. Two suitable techniques in this case are trimming or using the complete sample.

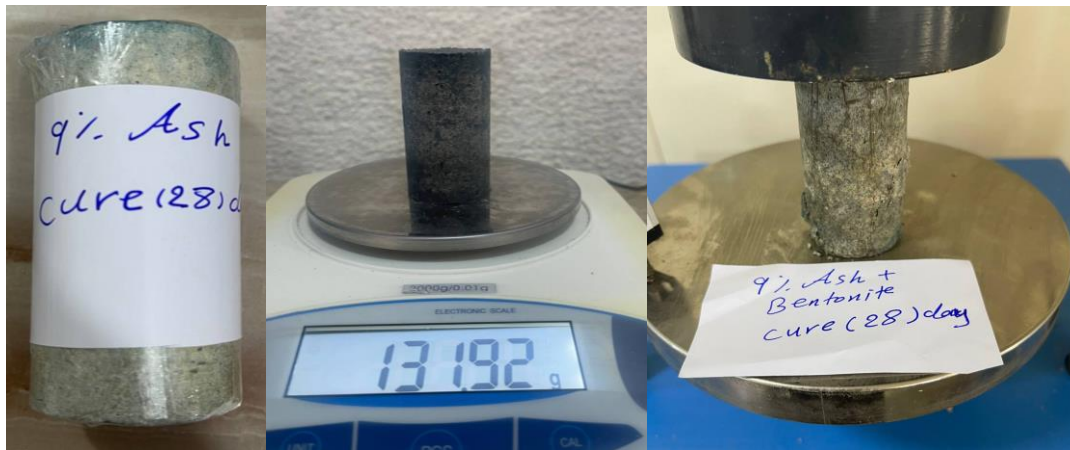


Fig. 6: Unconfined compressive strength sample during curing and testing.

4 Results and Discussion

4.1 Atterberg limits

Table 4, Figs. 7 and 8 present the limits of liquid limits plastic findings for the untreated soil specimen and the treated soil specimen containing DSA at different percentages (6%, 9%, 12%, 15%).

Table 4. Atterberg limit test results.

	L.L %	P.L%	P.I.%	Expansion index (EI)%	Expansion potential
Virgin soil	138	86	52	154.8	Very High
6%	128	59.8	68.8	107.64	High
9%	120	48	71.4	86.4	Medium
12%	118	46	72	82.8	Medium
15%	119	41	78	73.8	Medium

Fig. 7 shows that increasing DSA leads to decreasing both liquid and plastic limits of the soil specimen due to the pozzolanic effect of date seed ash, which reduces the swelling index as illustrated in Fig. 8, and these results are compatible with [42,43].

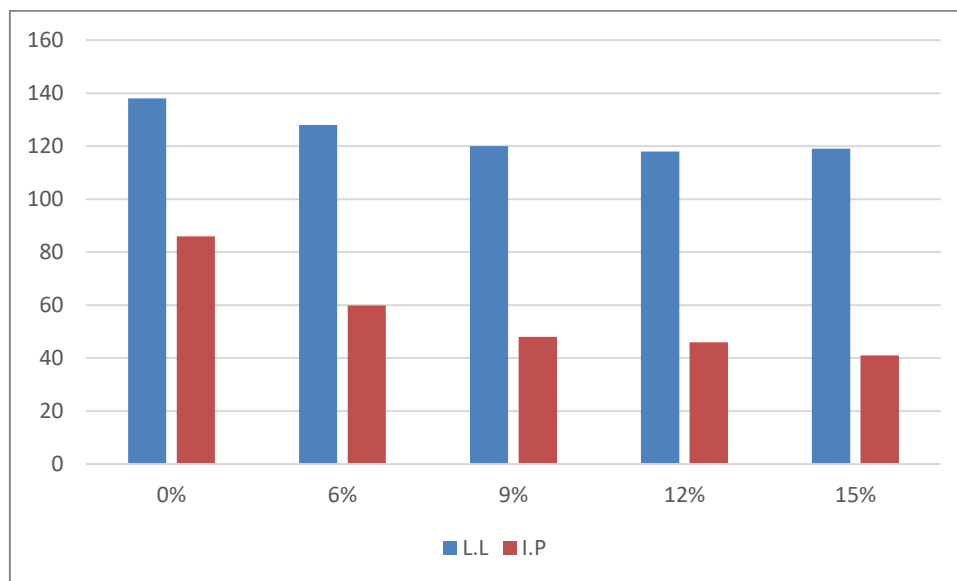


Fig. 7: Atterberg limits results.

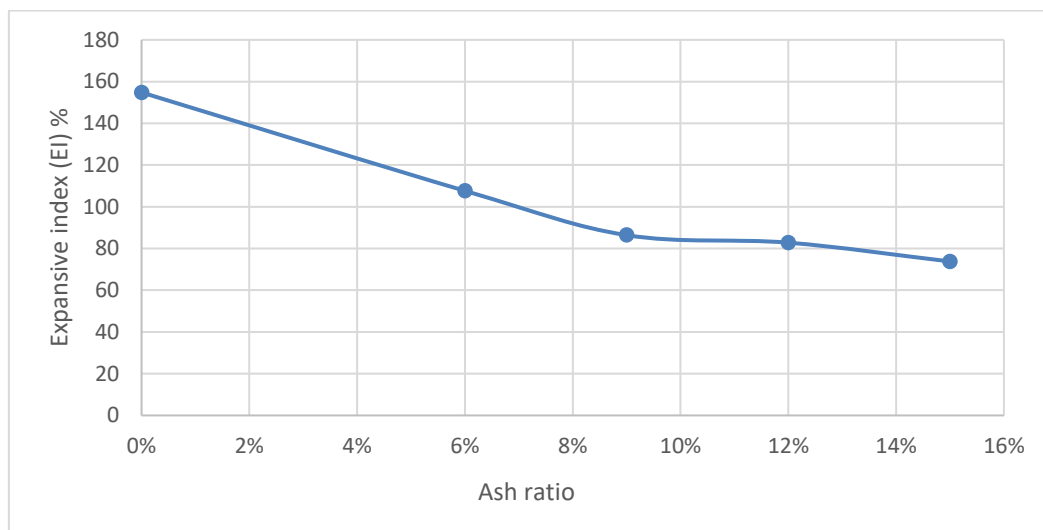


Fig. 8: The relationship between Bentonite ratios and Expansive soil index.

4.2 Compaction test results

This test procedure was utilized to establish the correlation between the moisture content during the moulding process and the density of the soil after it had dried. The maximum dry density "MDD" and the optimal moisture content "OMC" may be found using the conventional method by analyzing the dry density vs moisture content curves, as seen in Figure 9. Table 5 presents a comparison of the data obtained from soil samples with varying percentages of DSA. The aim was to assess the variations in dry density and water content at various quantities. The test technique was conducted in accordance with the ASTM D 698 standard [40].

Table 5. The compaction test results.

MIX	MDD (%)	OMC (g/cm3)
Pure	1.147	37.5
6% DSA	1.189	36
9% DSA	1.32	30
12% DSA	1.2	34
15% DSA	1.21	32.5

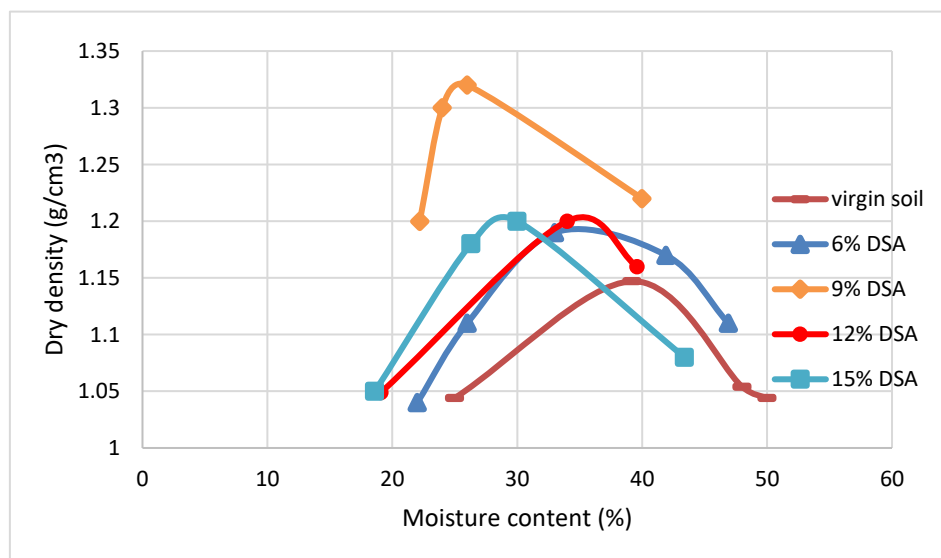


Fig. 9: Compaction test results.

4.3 Unconfined compressive strength test

Unconfined compression experiments were conducted on bentonite soil and soils treated with date seed ash to determine and compare their UCS. Figs. 10-12 show the curves for unconfined compression, categorized according to curing ages. All specimens in the unconfined compression tests were compacted at the natural soil's optimal moisture content and then subjected to unconfined compression testing. The Fig demonstrates that applying date seed ash to the naturally expanding material enhances the UCS of the treated soil. A substantial increase in the UCS of the treated soils was achieved when using bentonite soil with a 9% concentration of Date seed ash. The rise in the density of the treated soils leads to an improvement in the UCS, which this phenomenon may explain. Applying date seed ash to expansive soil led to an increase in dry density and, subsequently, an increase in UCS [44].

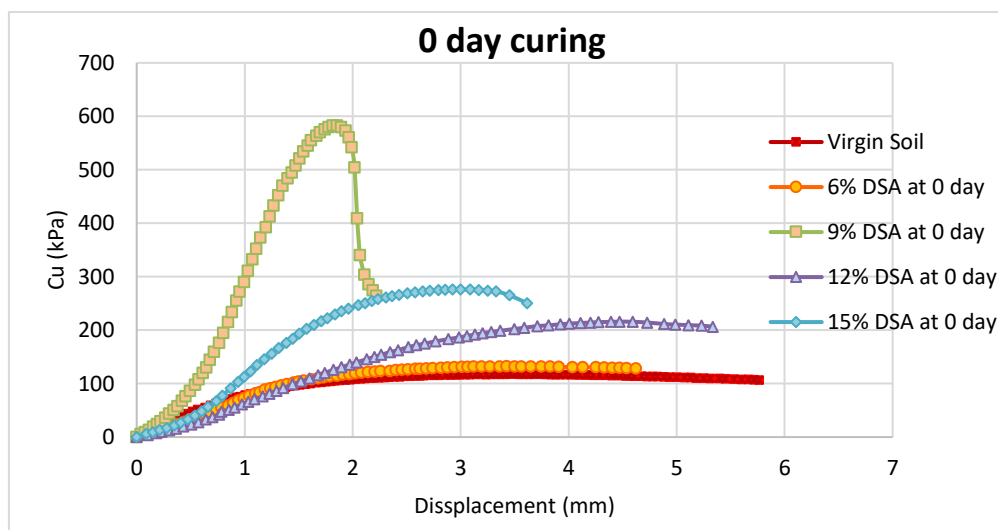


Fig. 10: The relationship between displacement and applied load at 0-day curing.

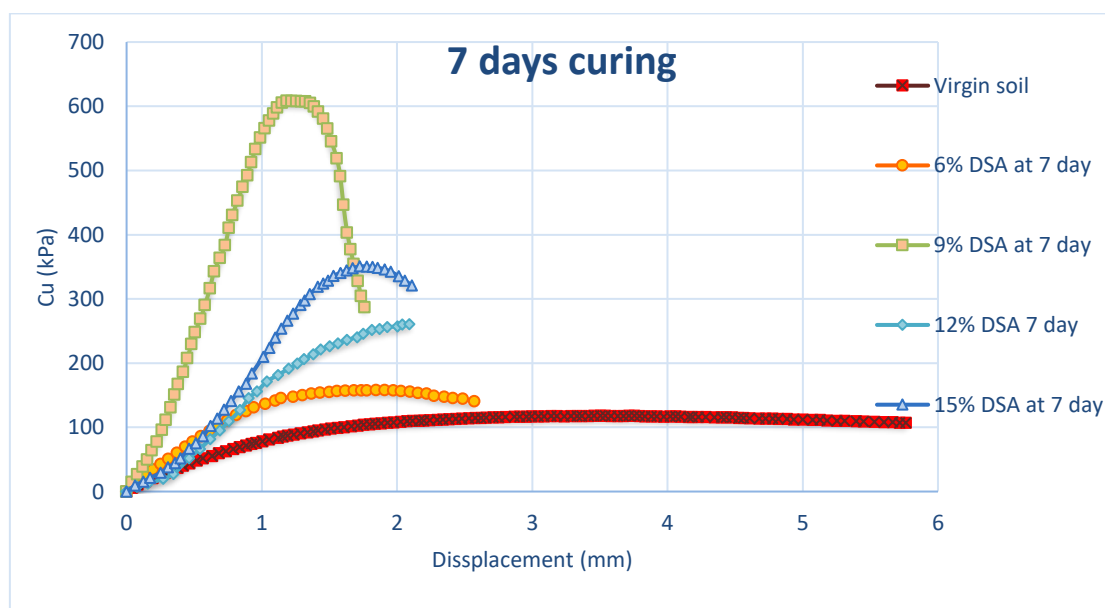


Fig. 11: The relationship between displacement and applied load at 7 days curing.

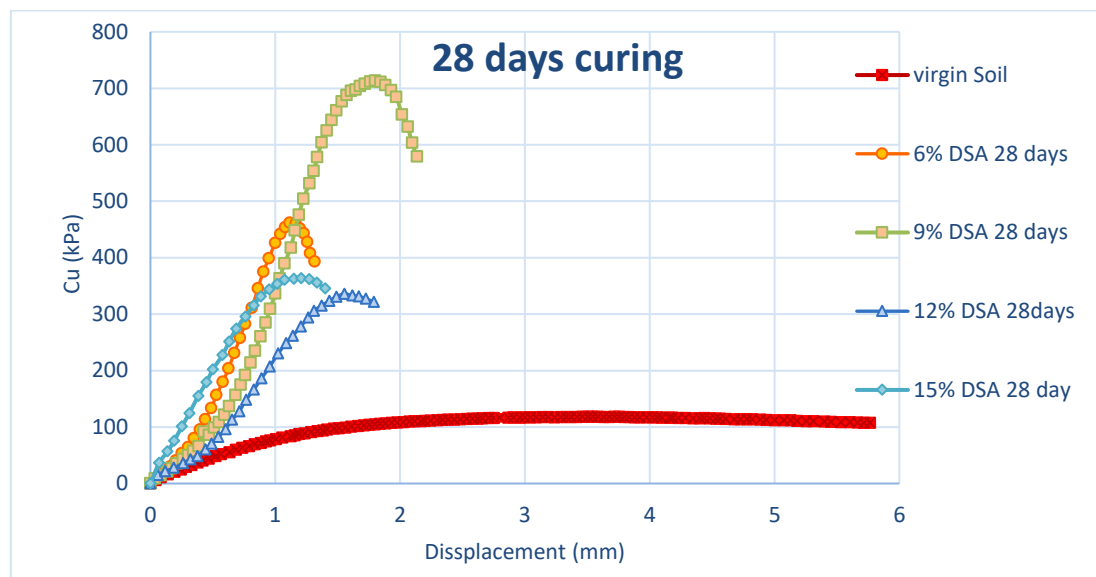


Fig. 12: The relationship between displacement and applied load at 28 days of curing.

5 Conclusion

The present study explored the potential of date seed ash (DSA) as a sustainable material for improving the strength and stability of expansive soils. The findings reveal several significant outcomes:

- The pozzolanic nature of DSA effectively altered the soil's liquid and plastic limits, reducing its plasticity.
- Unconfined compressive strength (UCS) tests demonstrated a notable increase in soil strength with the addition of DSA, particularly at an optimal ratio of 9%. Beyond this ratio, the dry density and UCS decreased, highlighting the need for balanced application. Furthermore, curing significantly enhanced strength over time, achieving a UCS of 700 kPa at 28 days.
- The application of DSA improved soil expansion characteristics, effectively reducing swelling and associated foundation issues.
- These results underscore the viability of DSA as an eco-friendly and cost-effective stabilizer, offering sustainable solutions for mitigating the challenges posed by expansive soils.

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