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Effect Of Cow Dung Ash On The Plasticity Characteristics Of Jamshoro Shale

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ABSTRACT

This study investigates the effect of cow dung ash (CDA) on the plasticity characteristics of Jamshoro shale. Shale samples were treated with CDA at 0%, 2%, 4%, 6%, 8%, 10%, and 12% by weight, and Atterberg limits were determined for each blend. Results showed that the Liquid Limit decreased progressively from 51% at 0% CDA to 42% at 12% CDA, while the Plastic Limit increased from 29% to 38% over the same range. Consequently, the Plasticity Index decreased markedly from 22% at 0% CDA to just 4% at 12% CDA, representing a reduction of approximately 81.8%. These findings indicate that CDA treatment substantially reduces the plasticity of Jamshoro shale, likely due to cation exchange and flocculation-agglomeration reactions between the shale particles and the pozzolanic CDA, improving the soil's suitability for use in geotechnical applications such as subgrade and embankment construction.

Keywords: Cow Dung Ash, Jamshoro Shale, Plasticity Index

INTRODUCTION

Shale is a fine-grained sedimentary rock composed predominantly of clay minerals, and is frequently encountered in geotechnical engineering practice across Sindh, including in the vicinity of Jamshoro. Owing to its clay mineralogy, shale often

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exhibits high plasticity, significant moisture sensitivity, and a marked tendency toward volumetric instability, expanding when wetted and shrinking upon drying. These characteristics pose considerable challenges for construction on or with shale, including reduced bearing capacity, differential settlement, and distress in overlying pavement and foundation structures. Consequently, shale is frequently classified as a problematic soil requiring stabilization before it can be reliably used in embankments, subgrades, or as a foundation material.

Soil stabilization techniques aim to improve the engineering behavior of such problematic soils, most commonly by reducing plasticity and moisture sensitivity while enhancing strength and volumetric stability. Traditional stabilizers such as lime and ordinary Portland cement (OPC) have long been employed for this purpose, typically acting through cation exchange, flocculation-agglomeration of clay particles, and pozzolanic reactions that bind soil particles into a more stable matrix. However, the production of lime and cement is energy-intensive and associated with substantial carbon dioxide emissions, prompting growing interest in sustainable, low-cost alternatives derived from agricultural and livestock waste streams.

Cow dung ash (CDA), obtained through the controlled combustion of cow dung, an abundant livestock waste product in agrarian regions such as Sindh, Pakistan, is one such material. CDA contains calcium, potassium, and silica compounds that impart pozzolanic and cementitious characteristics, enabling it to react with clay minerals in a manner similar to conventional stabilizers. Cow dung is traditionally used in rural Pakistan as a domestic fuel source, and its combustion residue is generally regarded as waste; its beneficial reuse in soil stabilization therefore offers both an environmentally sound disposal route and a virtually cost-free alternative to conventional stabilizers. When blended with clayey or shaley soils, CDA has been reported to alter the soil's Atterberg limits, typically reducing the Liquid Limit and Plasticity Index while increasing the Plastic Limit, indicating a reduction in plasticity and an improvement in workability.

Despite encouraging findings for the use of agricultural and livestock waste ashes in stabilizing various clayey soils, research specifically addressing the effect of cow dung ash on the plasticity behavior of Jamshoro shale remains limited. This study aims to address this gap by experimentally evaluating the influence of CDA, at varying percentages, on the Liquid Limit, Plastic Limit, and Plasticity Index of Jamshoro shale, with the objective of assessing its suitability as a sustainable stabilizing additive for this locally significant geomaterial.

MATERIALS AND METHODOLOGY

Soil

Jamshoro shale was collected from the vicinity of Mehran University of Engineering and Technology (MUET), Jamshoro, Sindh, Pakistan. The soil retained on the No. 40 sieve was discarded, and the remaining material was thoroughly mixed to ensure uniform testing conditions.

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Table 1: Engineering Properties of Untreated Jamshoro Shale

Property	Standard	Value
Natural Moisture Content (%)	AASHTO T265	3.81
Specific Gravity	ASTM D854	2.69
Liquid Limit (%)	ASTM D4318	51
Plastic Limit (%)	ASTM D4318	29
Plasticity Index (%)	ASTM D4318	22
USCS Classification	ASTM D2487	CH (high plasticity clay)
AASHTO Classification	—	A-7-6
Group Index (GI)	—	17

The Group Index of 17 exceeds the maximum allowable value of 10 for highway subgrade material, classifying the untreated Jamshoro shale as a poor subgrade material and confirming the need for stabilization.

Cow Dung Ash (CDA)

Cow dung is the waste product of bovine animal species, consisting of the undigested residue of plant matter that has passed through the animal's digestive tract. The resultant faecal matter is rich in minerals derived from the plant material consumed. Cow dung ash (CDA) is obtained through the combustion of cow dung; in this study, cow dung was burnt under controlled conditions at 600°C for 6 hours to produce the ash used for stabilization. The resulting ash was characterized using Energy Dispersive Spectrometry (EDS) to confirm its elemental composition and pozzolanic potential.

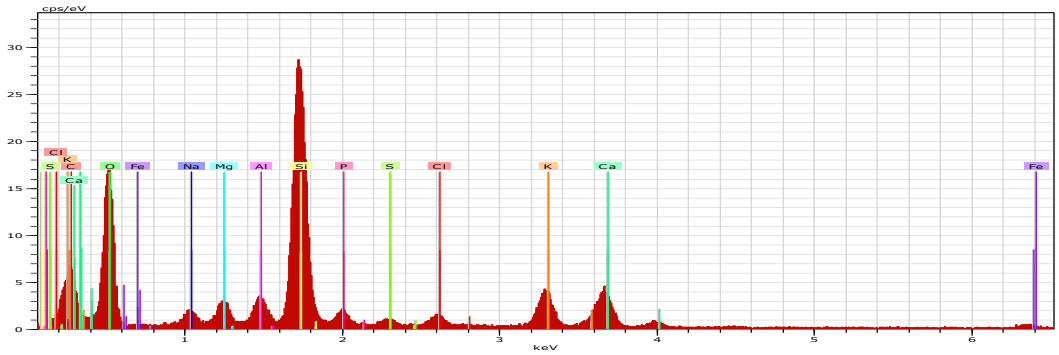

Figure 1: Energy Dispersive Spectrometer EDS of CDA at 600 C-6hr

Table 2: Elements Percentage by Weight in CDA (600°C–6hr)

Element	Series	Weight (%)	Error (%)
Silicon	K-series	34.71	0.6
Calcium	K-series	4.37	0.4
Potassium	K-series	2.12	0.1
Iron	K-series	1.73	0.1
Aluminium	K-series	1.71	0.3
Magnesium	K-series	1.09	0.1

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Sodium	K-series	0.62	0.1
Phosphorus	K-series	0.58	0.1

The high silicon content (34.71%) confirms the amorphous silica-rich, pozzolanic character of the CDA produced under these calcination conditions, comparable to that observed for both RHA and WSA. Notably, CDA also contains the highest calcium content (4.37%) among the three ashes studied, which may contribute to enhanced cation exchange capacity and more effective flocculation of clay particles.

Soil-Ash Blending and Testing Program

CDA was thoroughly blended with untreated Jamshoro shale at 0%, 2%, 4%, 6%, 8%, 10%, and 12% by dry unit weight. Each blended sample was tested for Liquid Limit and Plastic Limit in accordance with ASTM D4318, and the Plasticity Index was calculated as the difference between the two (PI = LL − PL).

RESULTS AND DISCUSSION

Effect of CDA on Liquid Limit

Table 3: Effect of CDA Content on Liquid Limit, Plastic Limit, and Plasticity Index

CDA (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
0	51	29	22
2	47	33	14
4	46	34	12
6	45	35	10
8	44	36	8
10	43	37	6
12	42	38	4

Figure 2 shows the variation of Liquid Limit with CDA content. The Liquid Limit of the Jamshoro shale decreased progressively with increasing CDA content, from 51% at 0% CDA to 42% at 12% CDA, a reduction of approximately 17.6%. This reduction is attributed to cation exchange reactions between the calcium and potassium ions present in CDA and the exchangeable cations on the clay particle surfaces, promoting flocculation and agglomeration of the finer clay particles into coarser aggregations, which reduces the specific surface area available for water adsorption. The relatively high calcium content of CDA (4.37%) compared to RHA and WSA likely contributes to this pronounced reduction.

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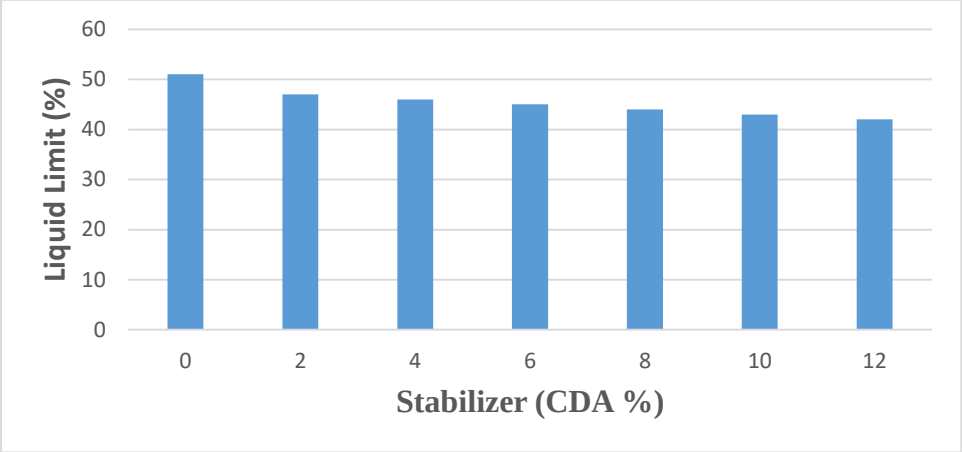

Figure 2: Liquid Limit vs. CDA Content (%)

Effect of CDA on Plastic Limit

Figure 3 presents the trend of Plastic Limit with increasing CDA content. The Plastic Limit increased steadily with CDA content, from 29% at 0% CDA to 38% at 12% CDA, an increase of approximately 31.0%, the largest Plastic Limit increase among the three ashes studied. This increase reflects the coarser, more granular texture imparted by CDA particles, which alters the soil-water interaction at the plastic state and requires additional moisture for the blended material to reach a workable, plastic consistency.

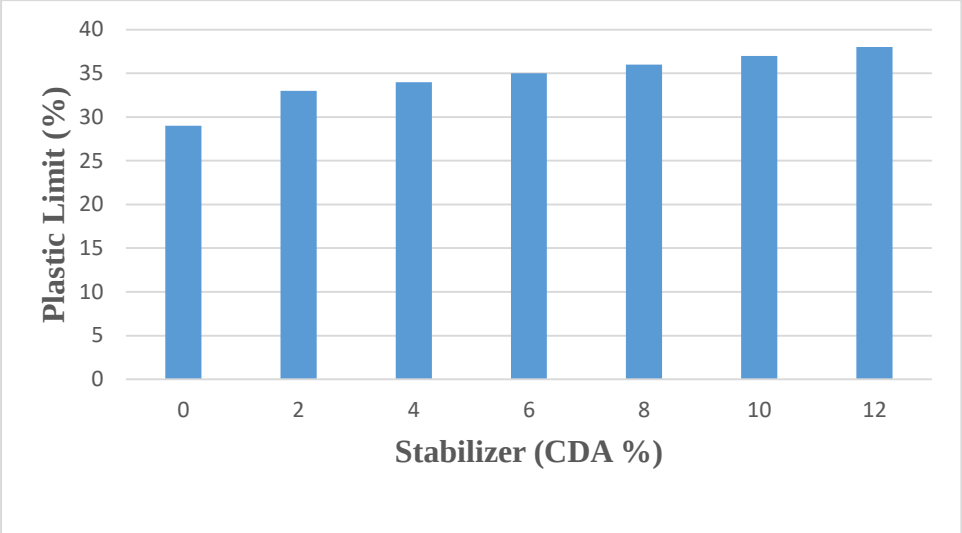

Figure 3: Plastic Limit vs. CDA Content (%)

Effect of CDA on Plasticity Index

Figure 4 illustrates the combined effect of CDA content on the Plasticity Index. The combined effect of decreasing Liquid Limit and increasing Plastic Limit produced a marked reduction in Plasticity Index, from 22% at 0% CDA to just 4% at 12% CDA, representing an overall reduction of approximately 81.8%, the greatest reduction observed among the ashes tested on Jamshoro shale (RHA: 73%; WSA: 63.6%). This superior performance may be attributed to CDA's comparatively higher calcium

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content, which enhances cation exchange capacity and promotes more effective flocculation-agglomeration of clay particles, alongside its silica content (34.71%), which is comparable to that of RHA and WSA and supports pozzolanic reactivity. These results suggest that CDA is a highly effective additive for reducing the plasticity of Jamshoro shale.

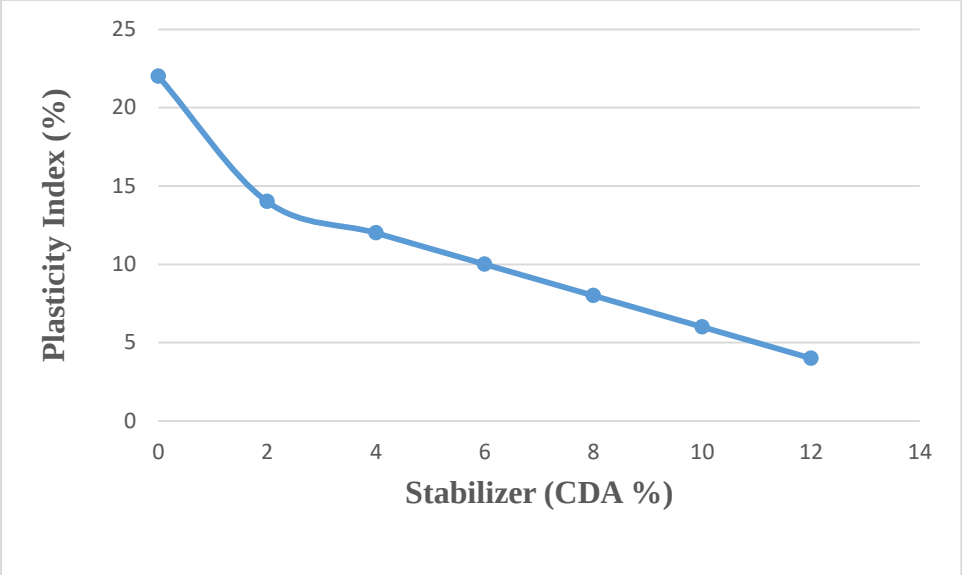

Figure 4: Plasticity Index vs. CDA Content (%)

CONCLUSION

The untreated Jamshoro shale was classified as CH (inorganic clay of high plasticity) under the USCS and as A-7-6 under the AASHTO classification system, with a Group Index of 17, indicating a poor subgrade material requiring stabilization.

Cow dung ash (CDA), produced by burning cow dung at 600°C for 6 hours, was confirmed to be silica-rich (34.71% Si by EDS) and pozzolanic in nature, with the highest calcium content (4.37%) among the ashes studied on this shale.

The Liquid Limit of the Jamshoro shale decreased progressively with increasing CDA content, from 51% at 0% CDA to 42% at 12% CDA, a reduction of approximately 17.6%.

The Plastic Limit increased with increasing CDA content, from 29% at 0% CDA to 38% at 12% CDA, an increase of approximately 31.0%.

The Plasticity Index decreased markedly, from 22% at 0% CDA to just 4% at 12% CDA, a reduction of approximately 81.8%, the largest reduction observed among the three agricultural/livestock waste ashes tested on Jamshoro shale (RHA: 73%; WSA: 63.6%).

This superior performance is attributed to CDA's higher calcium content, which likely enhances cation exchange and flocculation-agglomeration of clay particles, in addition to its comparable silica-driven pozzolanic reactivity.

The results demonstrate that CDA is a highly effective and virtually cost-free additive for reducing the plasticity of Jamshoro shale, improving its suitability for use as a subgrade or embankment material in highway construction.

Given the progressive nature of the improvement observed up to 12% CDA, further

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studies extending beyond this range, along with strength-based testing (UCS, CBR) and direct comparative analysis of RHA, WSA, and CDA under identical conditions, are recommended to establish the optimum ash type and content for stabilizing Jamshoro shale.

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