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Cow Dung Ash on Engineering Properties of Lateritic Soil for Road Construction in Nigeria

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Abstract

The environmental impact and high cost of conventional stabilizers like cement and lime, coupled with the low strength and bearing capacity of lateritic soils that have been utilized in road construction, put focus on eco-friendly alternatives in the form of cow dung ash (CDA). The effects of CDA on the engineering properties of lateritic soil at the Ado Ekiti–Ikare Akoko axis with depth ranges of 1.2–1.5 m were investigated in this study. Tests conducted as per BS 1377 (1990) included moisture content, grain size analysis, Atterberg limits, compaction, California Bearing Ratio (CBR), unconfined compressive strength (UCS), and triaxial shear strength. Oxide analysis confirmed CDA to be a pozzolanic material. Stabilization tests at the 0%, 2%, 4%, 6%, 8%, and 10% CDA proportions fixed the optimal percentage of additive. The Plasticity Index (PI) ranged from 4.60% to 19.11%, and most were silty or clayey gravel sand and silty soils. Addition of CDA reduced PI, improving workability, and improved maximum dry density, CBR, UCS, and shear strength, with best performance at 4% CDA. These gains met requirements for the sub-base course, testifying to the effectiveness of CDA as a stabilizer. The study reveals that agricultural waste such as cow dung can be used as a sustainable soil stabilizer with environmental and engineering benefits for road construction.

KEYWORDS: Cow dung ash, lateritic soil, soil stabilization, geotechnical properties, Califonial bearing ratio, Un confined Compressive strength, and eco-friendly stabilizer.

1. INTRODUCTION

1.1 Introduction

The stability of a land-based structure relies primarily on its foundation and thus soil stabilization. There has been continuous research that has looked into the economical use of ash from waste materials to improve soil engineering properties (Adebisi et al., 2023). Conventional stabilizers like cement, while effective, are costly and not environmentally friendly since they release a high amount of carbon dioxide and consume the ozone layer (Adetoro et al., 2016; Bagheri et al., 2016). Soil stabilization, for improving soil suitability for construction, has been available since ancient times such as the Chinese, Romans, and Indians whose durable roads and buildings are proof of its effectiveness (Reddy et al., 2018; Correasilva et al., 2020). Environmental concerns of the modern world and technological advancement have led the way in material recycling hitherto seen as waste (Onyelowe, 2016). Suitable soils for embankment or road construction vary from choice granular soils to silts and clays, which can be subjected to stabilization due to poor engineering properties (Pande & Makarande, 2013). Poor soils, common in Nigeria and the tropics, include lateritic soils high silts and clays who are used for subgrade, fill, sub-base, and base courses (Marinela et al., 2017; Oke & Olowoyo, 2019). These soils, especially the high clay soils, have low bearing capacity and strength, especially in the wet state, leading to cracking and structural failure. Cement and lime are conventional stabilizers but expensive and environmentally unsuitable with respect to CO_2 emission. Options are thus being sought to counter these economic and environmental constraints. Industrial and agricultural waste material, typically illicitly disposed, can replace high-value stabilizers partly or even entirely, ruling out environmental hazards and the need for imported material (Adetoro & Adam, 2015). Using such waste materials in construction minimize reliance on conventional stabilizers, mitigate environmental waste issues, and improve the quality of life. One of the most promising waste materials is cow dung ash (CDA), which contains minerals like calcium, potassium, and phosphorus effective binders of soil particles and stability enhancers while erodion dampeners (Basha et al., 2005). Utilizing CDA to mix with lateritic soil appreciably improve the strength properties of the soil and serve as a nature-friendly, economical solution to road construction. This study focuses on the application of cow dung ash as an admixture to reinforce the geotechnical characteristics of Ado–Ikare lateritic soil for road construction purposes. By stabilizing the soil with CDA, this study aims to achieve sustainable infrastructure while addressing waste management and reducing the environmental impact of traditional soil stabilization methods.

1.2 Statement of the Problem

The cost of construction of stabilized roads has continued to be expensive because of excessive reliance on industrially produced soil-improving additives such as cement, lime, and others. Road construction expenses in developing countries have been exorbitant because many of them are not within the reach of rural people who form a significant percentage of their population. In urban regions, selected material is not easy to find which has to be brought from a distant place. Since most of the soil which is found in town are plastic clay soils, in order to utilize such soil, conventional stabilizing agents utilized and sub-grade inferior soils replacement by borrow pit materials also, production of those stabilizing agents released in the atmosphere, among them 7% of $CO2$ released in the atmosphere are usually via cement production process, which leads to global warming, hence the stabilization needs to be done (Dang et al., 2016). In recent years, as a result of increased environmental consciousness, there has been a dramatic shift towards "green" and sustainable technology.As chemical grouts with the exception of sodium silicate are dangerous and toxic, their use for soil improvement is being questioned (Etim et al., 2017). A new method of soil improvement using waste has been found in recent years. Use of agro waste for soil improvement was discovered through interdisciplines of geotechnical engineering, geochemistry, and microbiology to find natural soil improvement treatments. Agro waste when incinerated to ash possesses some pozzolanic properties that are able to improve the engineering properties of the soil. Agro waste's environmental friendliness causes little, if any, damage to the soil, human life, and environment.

1.3 Aim and Objectives

The aim of the study is to evaluate the effects of Cow dung ash on the engineering properties of lateritic soil for road construction.

The objectives of the research are to:

i. conduct classification tests on all the soil samples;
ii. determine the chemical composition and properties of cow dung ash;
iii. determine the engineering properties of the lateritic soil samples stabilized with cow dung ash at 0, 2, 4, 6, 8, and 10%; and
iv. perform statistical analysis on the test results

1.4 Justification of the Study

Since soil stabilization is of immense important for the treating of soils in such a manner as to maintain, alter or improve the performance of the soil as a construction material. This research work will be of great help in providing first hand technical information for Ado Ikare soils, and in establishing the suitability of the additive for the same type of soil for stabilization purposes instead of wasting huge resources on cement since the additive are found in large quantities within the study area and its environment.

1.5 Significance of the Study

This study on the effect of cow dung ash on the engineering properties of lateritic soil on Ado-Ikare Road provide a sustainable and eco-friendly alternative to traditional materials, reducing environment impact and construction cost. This study contributes to the development of more durable and stable road infrastructure, reducing maintenance costs and improving road safety by enhancing the engineering properties of lateritic soil. The study also provide a cost effective solution for road construction and maintenance, particularly in rural and resource constrained areas.

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1.6 Scope of the Study

The scope of the study is limited to investigations on how cow dung ash improved the performance and engineering properties of lateritic soils stabilized with cow dung ash. Cow dung waste were collected from an animal farm within Ado-Ikare road and burned with a temperatures ranging from 650°C to 800°C after drying. The chemical composition of the lateritic soil and cow dung ash were determined and strength tests such as compaction, California bearing ratio, unconfined compression strength and tri axial shear strength were carried out on the stabilized lateritic soils.

1.7 Literature Review

1.7.1 Road Development in Ado-Ikare

The history of road development in Ado-Ikare, like in many regions of Nigeria, reflects the broader context of infrastructural evolution influenced by colonial and post-colonial developments. Before the advent of colonialism, road networks in Ado-Ikare (part of present-day Ondo State) were mainly footpaths and narrow trails used for local travel and trade Adetoro and Adam (2015). These paths were primarily used by pedestrians, traders, and those carrying goods to local markets. The roadways were rudimentary and were not suitable for wheeled transportation. The British colonial administration began to develop infrastructure in Nigeria to facilitate resource extraction and administrative control. In the early 20th century, the colonial government started constructing motorable roads to connect administrative centers, commercial hubs and ports. The roads in the Ado-Ikare area during this period were likely built to link it with more significant commercial centers and to facilitate the movement of agricultural produce (Adetoro & Adam 2015).

After Nigeria gained independence in 1960, there was a concerted effort to improve and expand the road network to foster national integration and economic development. The government invested in road construction to connect rural areas with urban centers, thus enhancing accessibility to markets, healthcare, and education. During this period, significant road projects would have been undertaken in Ado-Ikare to integrate it better with the rest of the region (Adebisi et al., 2023). In the late 20th and early 21st centuries, road development in Ado-Ikare saw improvements with increased government and private sector involvement. The rise of democracy in 1999 brought renewed focus on infrastructure development, including road construction and maintenance. Various state and federal government initiatives aimed at improving transportation infrastructure have led to better road connectivity in Ado-Ikare. Notably, the efforts have focused on:

a) Rehabilitation of existing roads: Many old roads have been resurfaced and widened to accommodate increasing traffic.
b) Construction of new roads: New road projects have been initiated to connect previously inaccessible areas.
c) Public-private partnerships (PPP): There has been an increase in PPPs to fund and maintain road infrastructure.
d) Community development initiatives: Local communities have also contributed to road development through self-help projects and collaboration with local governments.

2. MATERIALS AND METHODS

Sampling frame for this study includes a compressive selection of soil samples from different location of ado- Ikare road. The soil samples were collected in locations and three (3) samples from each locations total of nine (9) soil samples in all. The samples was collected in chainage across the road network. Samples were collected on sub grade layer at 1.2m to 1.5m after removal of top soil, rubbles and unsuitable materials, Three samples were collected at each location. Sample size nine (9) soil samples. Three (3) sacks bags for each soil samples per location, making totaling nine (9) bags in all. Nine lateritic soil samples were collected across Ado-Ikare in chainage along the road network, It was there after brought to the soil laboratory. Preliminary tests of the soils was carried out, the lateritic soils with the least plasticity index were selected for stabilization. After collection, of cow dung It was air dried and were subsequently burnt using open burning system using the method suggested by Oyekan and Kamiyo (2011) , using sieve No 200. Classification tests such as Atterberg's limits, particle size analysis, specific gravity, moisture content determination were conducted on the lateritic soils. Chemical composition test was carried out on the cow dung ash such as compaction test, California Bearing Ratio (CBR) test, Triaxial test and Unconfined Compression Strength (UCS) were conducted on stabilized soil with CDA in accordance with standard procedures.

3. RESULS AND DISCUSSION

Objective one: Conduct Classification Tests on all the soil samples

Table 4.1: Summary results of classification tests for natural soils samples

S/N-	LOCATION	SAMPLE LABEL	NMC	S G (GS)	PARTICLE SIZE ANALYSIS			ATTERBERG'S LIMITS TEST				AASHTO
					% GRAVEL	% SAND	% FINES	LL (%)	PL (%)	SL (%)	PI (%)	
1	A	LAS1	**11.47**	**2.53**	**12.14**	**50.30**	**37.55**	**33.20**	**28.60**	**5.71**	**4.60**	**A-4**
		LAS2	10.04	2.51	17.74	48.29	33.97	34.80	22.57	5.71	12.23	A-2-6
		LAS3	14.59	2.53	22.22	45.62	32.16	34.20	27.16	5.00	7.04	A-2-4
2	B	LBS1	17.11	2.47	20.31	50.83	28.86	34.50	22.28	4.29	12.22	A-2-6
		LBS2	11.21	2.49	22.22	40.15	37.63	40.00	26.76	7.86	13.24	A-6
		LBS3	**14.65**	**2.50**	**12.63**	**52.88**	**34.49**	**34.30**	**28.76**	**5.00**	**5.54**	**A-2-4**
3	C	LCS1	12.73	2.46	18.35	47.81	33.84	41.30	22.19	7.86	19.11	A-2-7
		LCS2	11.48	2.47	18.39	46.14	35.46	43.00	27.01	7.97	15.99	A-7-6
		LCS3	**14.02**	**2.50**	**21.60**	**46.66**	**31.74**	**41.40**	**27.48**	**7.14**	**13.92**	**A-2-7**

Source: Authors Computation (2025)

Table 4.2: Summary results of classification tests for the selected natural soils samples

Property	Sample A	Sample B	Sample C
Natural moisture content	11.47	14.65	14.65
Specific gravity	2.53	2.50	2.50
% Gravel (>4.75mm)	12.14	12.63	21.60
% Sand (0.075-4.75mm)	50.30	52.88	46.66
% Fines (< 0.075mm)	37.55	34.49	31.74
Liquid limit (LL) (%)	33.20	34.30	41.40
Plastic limit (PL) (%)	28.60	28.76	27.45
Plasticity index (PI)	5.71	5.00	7.14
Shrinkage limit (SL)	4.60	5.54	13.92
AASHTO classification	A-4	A-2-4	A-2-7

Source: Authors Computation (2025)

Discussion of findings:

Objective One:
Classification Test

The selected soil samples were classified using AASHTO (1996) soil classification system. Sample A as A-4 i.e., silty soil, , sample B as A-2-4 i.e., Silty or clayey gravel and sand, sample C as A-2-7 i.e silty or clayey gravel and sand Following are the standard requirement of Plasticity index. This is an indication that the soils fall below recommendation standard for road construction therefore stabilization is required.

Objective Two:
Chemical Composition Test

Chemical composition of the selected cow dung ash (CDA) is classified as pozzolan materials as sum of SiO_2 + Fe_2O_3 + Al_2O_3 equals 75.53% which is greater than 70%.
CDA is classified as a Class N natural pozzolan, pozzolanic materials must contain a minimum of 70% SiO_2 + Al_2O_3 + Fe_2O_3, per ASTM C618 (2020).

Table 4.3: Summary Results of Chemical Composition of Cow Dung Ash

Additive Content/Location	A		B		C			
	MDD (kg/m^3)	OMC (%)	MDD (kg/m^3)	OMC (%)	MDD (kg/m^3)	OMC (%)		
0	1795	8.60	1807	10.20	1796	11.60		
2	1819	9.60	1833	12.20	1820	15.00		
4	1860	10.40	1812	13.00	1817	12.80		
6	1810	10.2	1797	13.80	1818	14.60		
8	1806	10.8	1794	13.80	1796	16.80		
10	1768	13.0	1770	15.40	1742	16.80		

Source: Authors Computation (2025)

Table 4.4: Summary results of MDD and OMC with varying percentages of CDA content

Oxides Composition (%)	Cow dung ash (CDA)
SiO_2	65.80
Al_2O_3	3.92
Fe_2O_3	3.81
K_2O	3.10
MgO	2.10
CaO	1.00
P_2O_5	1.50
LOI	3.90
$SiO_2+Al_2O_3+Fe_2O_3$	73.53
Classification	Pozzolan

Source: Authors Computation (2025)

Objective Three: evaluate the engineering properties of soil stabilized with cow dung ash COMPATION
Source: Authors Computation (2025)

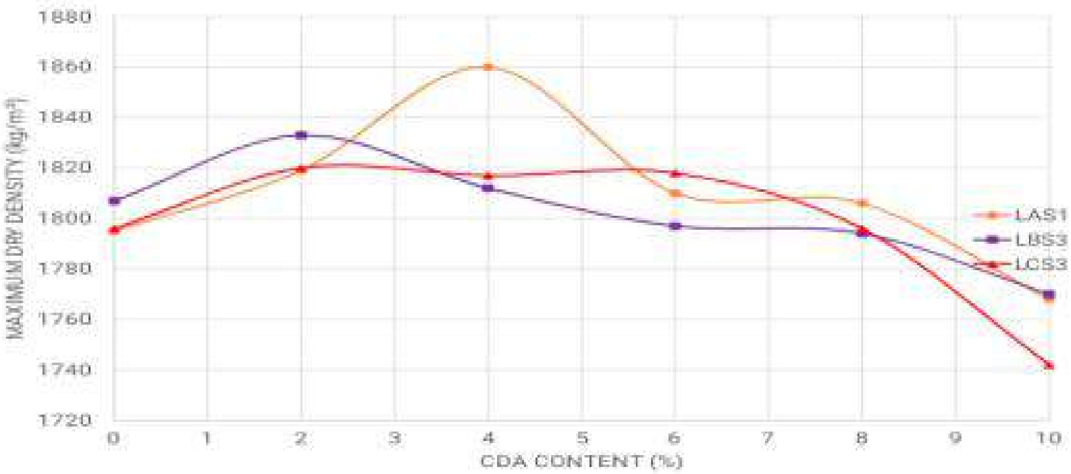

Fig.1 : Graph of MDD with varying percentages of CDA Content
Source: Authors Computation (2025)

Table 4.4 and Figure 4.4 present the results of Compaction characteristics (MDD) as Cow dung ash (CDA) is been increased, optimum MDD values were recorded at 4% additions in all samples aside soil sample from location B which achieved its optimum at 4% addition.

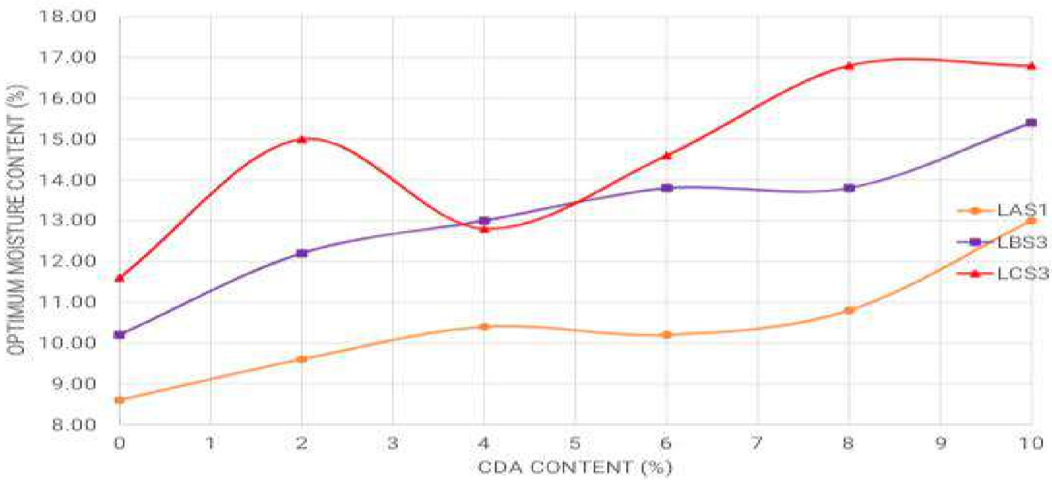

Fig.2: Graph of OMC with varying percentages of CDA content
Source: Authors Computation (2025)

Table 5.1 and Figure 5.1.1 present the results of Compaction characteristics (OMC) as Cow dung ash (CDA) is been increased, decreased in OMC were recorded in all samples aside soil sample from location B which achieved its optimum at 6% addition.

Table 5.2: Summary results of CBR with varying percentages of CDA content

Additive Content/Location	LAS1	LBS3	LCS3	
	CBR (%)			
0	10.00	14.70	12.30	
2	12.60	15.10	13.80	
4	13.20	15.50	13.80	
6	13.20	14.10	11.70	
8	13.20	14.10	11.70	
10	10.90	13.00	11.30	

Source: Authors Computation (2025)

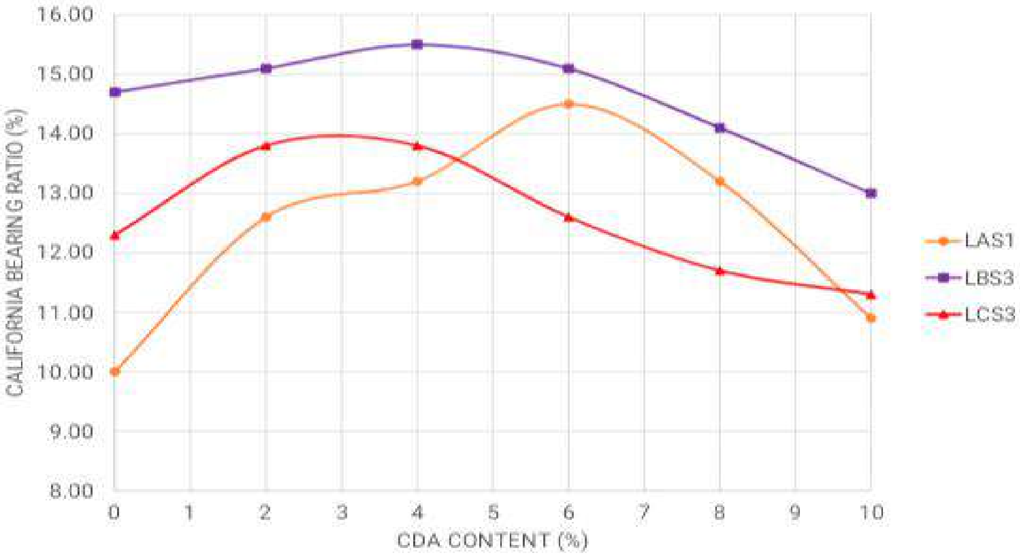

Fig.3: Graph of CBR with varying percentage of CDA content
Source: Authors Computation (2025)

Table 5.2 and Figure 3 present the results of California bearing ratio as Cow dung ash CDA is been increased, optimum strength were achieved at sample A 4%, for soil samples from LBS3 and LCS3 while optimum for sample LASI was achieved at 6%.

Table 5.3: Summary results of UCS with varying percentages of CDA content

Additive Content	A	B	C	
	UCS (kN/m²)			
0	142.90	203.80	219.50	
2	120.30	151.30	158.20	
4	139.50	175.80	194.00	
6	168.50	162.60	179.80	
8	151.80	146.90	192.00	
10	155.70	188.60	199.90	

Source: Authors Computation (2025)

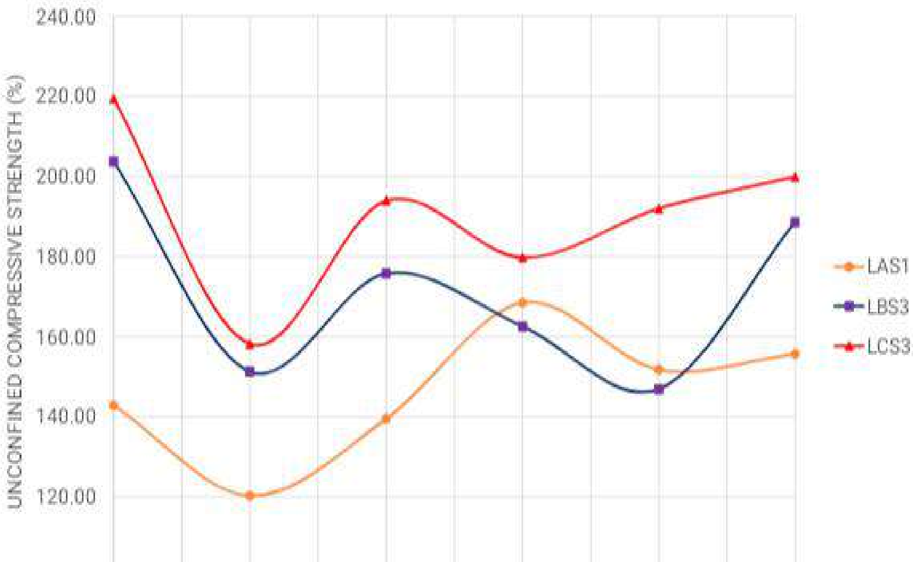

Fig.4: Uncofrimed compresive stregbht (UCS) cow dung ash (CDA)
Source: Authors Computation (2025)

Table 5.3 and Figure 4 present the results of Unconfined compressive strength (UCS) cow dung ash (CDA) is been increased, decreased in strength was first notice at 2% addition before increased in strength were later noticed in all stabilized soil samples.

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Table 5.4: Summary results of Shear strength with varying percentages of CDA content

Additive Content	A	B	C	
	SS (kN/m²)			
0	99.66	128.60	138.01	
2	87.39	92.80	125.18	
4	101.30	113.34	121.23	
6	97.80	182.91	74.04	
8	117.14	214.53	110.04	
10	93.10	134.63	136.72	

Source: Authors Computation (2025)

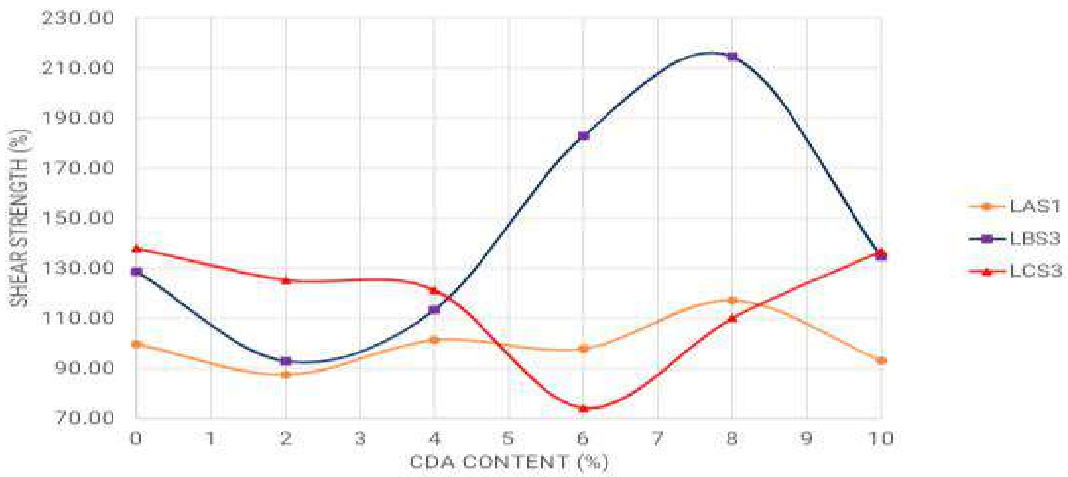

Fig.5: Graph of Shear strength with varying percentages of CDA content
Source: Authors Computation (2025)

4. CONCLUSIONS

The study concluded that some of the selected lateritic soil samples were classified as silty or clay gravel sand and silty soil according to (AASHTO) Standard and this soil is not suitable to be used as base materials for road pavement structure and require stabilisation to improve its strength and durability.

i. The chemical analysis of the selected additive of cow dung ash reveals that CDA is a good pozollan, since the total content of $SiO_2+Al_2O_3+Fe_2O_3$ were 73.53% greater than 70% and
ii. it shows that the cow dung ash meets the ASTM Standerd for a good pozzolan.
iii. The stabilized soil samples mixed with 6% cow dung ash additive caused improvement in engineering property (strength tests) and decrease in the OMC of the soil.
iv. Statistical analysis revealed that the P-values were less than the confidence level which means they are

statistically significant. The atterberg limits showed that the incorporation of cow ash reduced the plasticity index of all the selected soil sample.

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