Stabilization of Expansive Soil Using Dry Leaf Ash and Sea Shell Powder

Dr. D. Jyothi Swarup[1], B. Siva[2], K. Swaroopa Rani[3], B. Mahesh Babu[4], T.L. Bhaskar[5]
[1] *Associate Professor, St. Ann's college of Engineering and Technology*
[2,3,4,5]*Final Year Student, St. Ann's college of Engineering and Technology*

Abstract: **Expansive soils, known for their high swelling and shrinkage potential, present serious challenges to the stability and durability of civil engineering structures. Conventional stabilization techniques, while effective, often rely on materials that are costly and environmentally taxing. This study explores the use of dry leaf ash (DLA) and sea shell powder (SSP)—two abundant and sustainable waste materials—as alternative stabilizers for expansive soils. The soil was treated with varying proportions of DLA and SSP, both individually and in combination, and subjected to a series of geotechnical tests, including Atterberg limits, compaction characteristics, free swell index, unconfined compressive strength (UCS), and California Bearing Ratio (CBR). The results demonstrated a significant improvement in engineering properties, including reduced plasticity and swelling behaviour, along with enhanced strength and load-bearing capacity. These improvements are attributed to pozzolanic reactions and the filler effect, where reactive silica from DLA and calcium carbonate from SSP form cementitious compounds that improve the soil matrix. The findings suggest that the combined use of DLA and SSP is a viable, eco-friendly solution for the stabilization of expansive soils, offering both performance efficiency and environmental sustainability through the productive reuse of waste materials.**

I. INTRODUCTION

Expansive soil is a clayey soil that undergoes significant volume changes due to changes in moisture content. It swells when water enters the soil and shrinks when moisture evaporates, causing cracks and creating serious problems for foundations, pavements, and other civil engineering structures. These soils are commonly found in India, especially in black cotton soil regions, and contain montmorillonite mineral, which is responsible for high plasticity and swelling behavior. Due to high compressibility, low shear strength, and poor bearing capacity, expansive soil is unsuitable for construction without treatment. Structures built on untreated expansive soil may experience differential settlement, cracks, pavement failure, and reduced structural life. Therefore, soil stabilization is necessary to improve its engineering properties and make it suitable for construction.

Soil stabilization improves soil strength and reduces plasticity using mechanical or chemical methods. Although traditional stabilizers like cement and lime are effective, they increase cost and environmental impact, leading researchers to focus on sustainable alternatives. Dry leaf ash, an agricultural waste containing silica and alumina, contributes to pozzolanic reactions, while sea shell powder, rich in calcium carbonate, improves bonding between soil particles and increases strength. This study focuses on stabilizing expansive soil using dry leaf ash and sea shell powder as eco-friendly materials to enhance soil performance while promoting sustainable construction.

II. LITERATURE REVIEW

Many researchers have studied soil stabilization using waste materials such as fly ash, rice husk ash, lime, cement, and sea shell powder. These materials improve soil properties through pozzolanic reaction and particle bonding.

Amu et al. (2011) studied stabilization of soil using agricultural waste ash and reported reduction in plasticity index and improvement in compaction characteristics.

Ramesh and Prasad (2014) studied black cotton soil stabilized with sea shell powder and observed increase in maximum dry density and reduction in plasticity index.

Reddy and Kumar (2015) reported improvement in compaction characteristics and strength of soil due to addition of sea shell powder.

Kuzhali and Krishnan (2017) conducted laboratory tests on expansive soil stabilized with sea shell powder and concluded that the strength of soil increased significantly.

Saini and Garg (2018) investigated clay soil stabilized using combination of fly ash and sea shell powder and observed increase in CBR value.

Yathushan and Puswewala (2022) studied soil stabilization using leaf ash and reported improvement in shear strength and reduction in plasticity.

Recent studies indicate that waste materials containing silica and calcium compounds can improve soil strength and reduce swelling behavior. Based on previous research findings, dry leaf ash and sea shell powder are selected as stabilizing materials in the present study.

III. MATERIALS USED

The materials used in this study include expansive soil, dry leaf ash (DLA), and sea shell powder (SSP). The expansive soil was collected from a local site, air dried, and sieved through a 4.75 mm sieve to remove unwanted particles and ensure uniformity. Basic index properties such as specific gravity, Atterberg limits, and grain size distribution were determined to classify the soil as clayey soil with high swelling potential. Dry leaf ash was obtained by burning dried fallen leaves collected from agricultural areas and sieved through a 425 micron sieve to obtain fine particles suitable for mixing with soil. It contains silica and alumina, which contribute to pozzolanic reaction and help improve soil strength.

Sea shell powder was prepared by washing, drying, and crushing sea shells into fine powder form. It mainly contains calcium carbonate, which increases bonding between soil particles and enhances strength characteristics. Different percentages of dry leaf ash and sea shell powder were mixed with soil samples for testing to evaluate their effectiveness in improving the engineering properties of expansive soil.

IV. METHODOLOGY

The methodology of this study involves preparation of expansive soil samples with different proportions of dry leaf ash (DLA) and sea shell powder (SSP) to evaluate their engineering properties through laboratory testing. Initially, expansive soil was collected, air dried, and sieved through a 4.75 mm sieve to remove unwanted particles. Dry leaf ash and sea shell powder were separately prepared and passed through a 425 micron sieve to obtain uniform fine particles.

The study was conducted on natural soil without admixtures and soil mixed with different percentages of stabilizers. The proportions used were 3% and 6%, and of dry leaf ash, 3% and 6%, of sea shell powder, and combined mixtures of 1.5%+1.5% (3%) and 3%+3% (6%).

Required water was added to each mix to achieve proper consistency and uniform mixing. The prepared samples were stored in airtight conditions for proper interaction between soil and stabilizing materials.

Atterberg Limits tests were conducted to determine liquid limit, plastic limit, and plasticity index. Free Swell Index test was performed to evaluate swelling behavior of expansive soil.

Modified Proctor Test was carried out to determine optimum moisture content and maximum dry density. These tests helped evaluate compaction characteristics of natural and stabilized soil.

Strength characteristics were determined using Unconfined Compressive Strength (UCS) test. The UCS test was used to evaluate shear strength improvement of stabilized soil samples.

Variable Head Permeability test was conducted to study the rate of water flow through soil. The results of all tests were compared with natural soil to determine the effectiveness of stabilization using dry leaf ash and sea shell powder.

V. RESULTS AND DISCUSSION

TABLE-1: PROPERTIES OF NORMAL SOIL WITHOUT ADDING ADMIXTURES

Properties	Value
Specific Gravity	2.14
Liquid Limit (%)	57.3
Plastic Limit (%)	18
Plasticity Index	39.3
IS Classification	CH — Clay of High Compressibility
Modified Proctor Test	MDD - 1.95 g/cc OMC - 16 %
Free Swell Index (%)	69.56
California Bearing Ratio (%)	2.5 mm -1.53 5.0 mm -1.41
Permeability (cm/sec)	$7.5 * 10^{-7}$
Unconfined Compressive Strength (KN/m^2)	110

The results obtained from laboratory testing of the given soil sample and provides a detailed discussion on its engineering behavior. The objective is to evaluate the suitability of the soil for construction purposes based on standard geotechnical parameters.

The soil is highly plastic, expansive clay with low bearing capacity and poor drainage characteristics. Without appropriate ground improvement measures, it may lead to excessive settlement, cracking, and structural instability in engineering applications.

TABLE-2: PROPERTIES OF NORMAL SOIL WITHADDING 3% ADMIXTURES

Properties	DLF	SSP	DLA+SSP
Liquid Limit (%)	55.4	56	54.9
Plastic Limit (%)	26	25	33.3
Plasticity Index	29.4	31	21.6
IS Classification	CH	MH	MH
Modified Proctor Test	MDD - 1.96 g/cc OMC – 16%	MDD - 2.04 g/cc OMC – 18%	MDD – 1.99 g/cc OMC – 18%
Free Swell Index (%)	57	35	45
California Bearing Ratio (%)	2.5 mm - 1.60 5.0 mm - 1.50	2.5 mm - 1.97 5.0 mm - 1.50	2.5 mm - 1.78 5.0 mm - 1.51
Permeability (cm/sec)	$4 * 10^{-7}$	$3 * 10^{-7}$	$1.5 * 10^{-7}$
Unconfined Compressive Strength (KN/m^2)	130	150	180

The study confirms that soil stabilization is an effective technique for enhancing weak and expansive soils, and the use of combined additives yields superior results compared to individual treatments, making it a viable solution for geotechnical and pavement engineering applications.

It is observed that the liquid limit of the soil is reduced and the plastic limit of the soil is increased with the addition of 3% Dry leaf Ash and also the permeability of soils is reduced considerably with the addition of DLA. The free swell index of the soil is reduced with the addition of 3% SSP.

Based on the obtained values of LL and PI the soil is classified as Inorganic Silt with High Compressibility (MH) as per the IS soil classification system and also the free swell index of the soil is reduced with the addition of 3% Combination of SSP and DLA.

TABLE-3: PROPERTIES OF NORMAL SOIL WITHADDING 6% ADMIXTURES

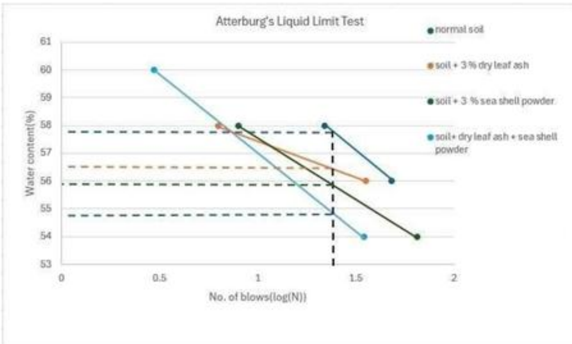
Properties	DLF	SSP	DLA+SSP
Liquid Limit (%)	49.8	50	49.5
Plastic Limit (%)	28.5	28	36.2
Plasticity Index	21.3	22	13.33
IS Classification	CI	MI	MI
Modified Proctor Test	MDD - 1.99 g/cc OMC – 16%	MDD - 2.04 g/cc OMC – 16%	MDD – 2.04 g/cc OMC – 16%
Free Swell Index (%)	38	23	29
California Bearing Ratio (%)	2.5 mm – 4.80 5.0 mm - 4.50	2.5 mm – 5.40 5.0 mm – 4.80	2.5 mm – 5.30 5.0 mm – 4.60
Permeability (cm/sec)	$2.8 * 10^{-7}$	$2 * 10^{-7}$	$1 * 10^{-7}$
Unconfined Compressive Strength (KN/m^2)	245	285	320

The present set of results represents the behavior of soil after stabilization using DLF, SSP, and DLA+SSP, showing considerable improvement compared to untreated soil. The discussion explains the influence of stabilizers on various engineering properties.

It is observed that the liquid limit value is reduced significantly with the addition of 6% DLA when compared with normal soil and the soil is classified as

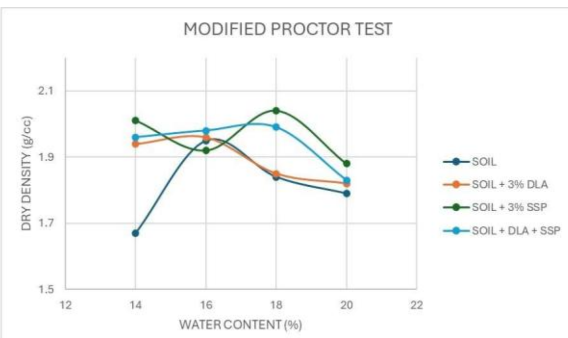
Inorganic clay with Intermediate compressibility (CI) and also observed that the dry density value is also increased as compared with normal soil.

It is observed that the shear strength of the soil is increased in a significant percentage as compare with the normal soil and also observed a reduction in the free swell index of the soil.



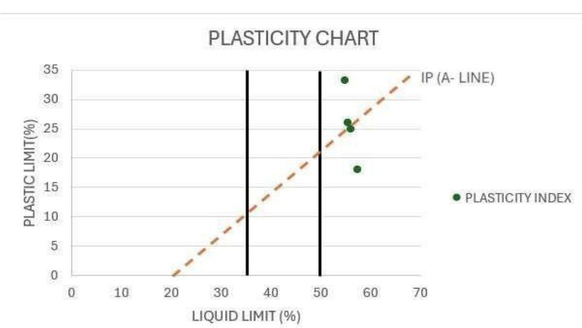
GRAPH-1 ATTERBERG'S LIQUID LIMIT

The graph shows the relationship between water content and log of number of blows for natural soil and soil mixed with 3% DLA, 3% SSP, and DLA + SSP.



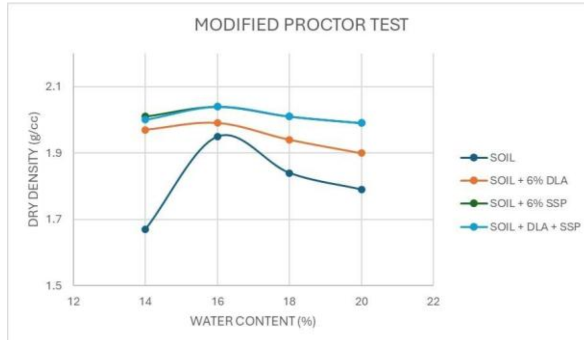
GRAPH-2 MODIFIED PROCTOR TEST

The graph shows the relationship between Dry Density and Water Content for soil mixed with 3% DLA, 3% SSP, and DLA + SSP.



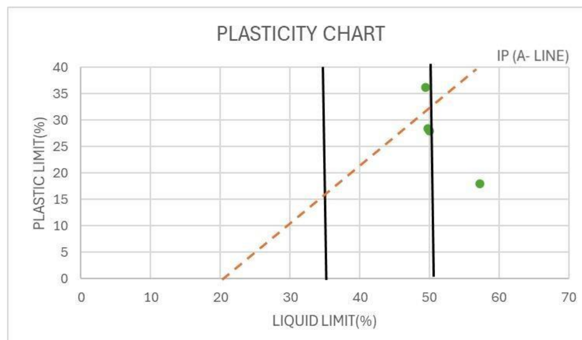
GRAPH-3 PLASTICITY CHART

The plasticity chart shows the relationship between Liquid Limit (LL) and Plasticity Index (PI) for soil treated with 3% DLA, 3% SSP, and DLA + SSP



GRAPH-4 MODIFIED PROCTOR TEST

The Modified Proctor Test shows the relationship between dry density and water content for untreated and stabilized soil.



GRAPH-5 PLASTICITY CHART

The plasticity chart shows the relationship between Liquid Limit (LL) and Plasticity Index (PI) of soil samples.

VI. CONCLUSION

- The study confirms that Dry Leaf Ash (DLA) and Sea Shell Powder (SSP) are effective stabilizing materials for improving the engineering properties of expansive soil.
- The natural soil is classified as CH – Clay of High Compressibility with Liquid Limit = 57.3%, Plasticity Index = 39.3%, MDD = 1.95 g/cc, CBR = 1.53%, and UCS = 110 kN/m², indicating weak and highly expansive soil.
- Addition of 3% stabilizer (DLA, SSP, and DLA+SSP) reduced plasticity index up to 21.6% and increased MDD up to 1.99 g/cc, showing initial improvement in compaction and strength.
- With 6% stabilizer, soil classification changed

from CH to CI/MI, plasticity index reduced to 13.33%, and CBR increased up to 5.4%, showing significant improvement in soil strength.

- The Unconfined Compressive Strength (UCS) increased from 110 kN/m² (natural soil) to 320kN/m² at 6% DLA + SSP, which is the maximum shear strength obtained.
- Overall, 6% combination of DLA + SSP gives the best performance with maximum strength, maximum dry density (2.04 g/cc), maximum CBR (9.1%), and maximum UCS (320 kN/m²), making stabilized soil suitable for subgrade, foundation, and embankment construction.

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