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Leachate Contaminated Soil Stabilization Using Fly Ash

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***Abstract* - Leachate-contaminated soil possesses poor engineering properties such as high plasticity, low strength, and excessive compressibility, making it unsuitable for construction purposes. In this study, improvement of leachate soil was attempted using fly ash as an additive material. Different percentages of fly ash were mixed with the soil to evaluate improvements in geotechnical properties. Laboratory tests such as Atterberg limits, compaction, Unconfined Compressive Strength (UCS), were conducted to assess the performance of the soil. The results depict reduction in Plasticity characteristics admixed improvement in compaction characteristics (OMC & MDD) with the addition of fly ash. Unconfined Compressive Strength (UCS) significantly improved up to optimum percentage of fly ash due to pozzolanic reactions and formation of cementitious compounds. Microstructural studies further confirm development of binding gels that enhanced particle bonding and reduced void spaces. Overall, fly ash proved to be an effective and economical stabilizing material for selected leachate soil.**

Keywords: Leachate soil, Atterberg limits, Fly ash, Unconfined Compressive Strength (UCS), Plasticity Index, Compaction Characteristics.

I. INTRODUCTION

Leachate-contaminated soil is a major geotechnical and environmental concern in areas surrounding municipal solid waste landfills. Leachate is a highly polluted liquid formed when rainwater or waste water percolates through waste materials and dissolves organic and inorganic constituents. When this liquid infiltrate the underlying soil, it alters the soil structure and significantly affects its engineering behaviour. Leachate soil generally exhibits high plasticity, low shear strength, excessive compressibility, and poor bearing capacity, making it unsuitable for construction works such as pavements and foundations.

To improve the performance of such problematic soils, stabilization techniques are commonly adopted. Among various stabilizing materials, fly ash has gained considerable attention due to its pozzolanic properties and cost-effectiveness. Fly ash is an industrial by-product obtained from thermal plants. It contains Silica, Alumina, and Calcium Compounds. When mixed with soil in the presence of water, fly ash undergoes pozzolanic reactions, leading to the formation of cementitious compounds that bind soil particles together.

Therefore, improvement of Leachate soil properties using fly ash provides an effective and sustainable solution for improving weak contaminated soils while promoting a beneficial utilization of industrial waste materials.

II. MATERIALS AND METHODOLOGY

2.1 Leachate Soil

Leachate soil refers to soil that has been contaminated by landfill Leachate soil, a liquid generated when rainwater infiltrates through layers of municipal solid waste and dissolves soluble materials. When Leachate soil percolates into the surrounding ground, it alters the physical, chemical, and mechanical properties of the soil. Leachate soil-contaminated soil often exhibits meager strength there by lower bearing capacity. These changes occur due to the interaction between dissolved chemicals and soil structure. Leachate soil poses serious risks such as groundwater contamination and long-term land degradation

2.2 Fly Ash

Fly ash is a fine industrial by-product generated during the combustion of pulverized coal in thermal power plants. It is collected from flue gases using electrostatic precipitators or bag filters before being released into the atmosphere. Due to its pozzolanic properties, fly ash is widely used in construction and geotechnical engineering applications. Chemically, fly ash mainly consists of Silica (SiO_2), Alumina (Al_2O_3), Iron Oxide ($Fe2O_3$), and Calcium Oxide (CaO). The presence of reactive Silica and Alumina enables fly ash to react with Calcium in the presence of water and from compounds that lead to improve strength and durability. Fly ash was obtained from thermal power plant and stored in bins to ensure dry conditions.

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2.3 Methodology

The methodology adopted for this study involves systematic laboratory investigation to evaluate the effectiveness of fly ash in improving the engineering properties of leachate-contaminated soil.

The leachate soil was collected from landfill affected area at Renigunta near Tirupati of ANDHRA PRADESH at 2.0m depth. The collected soil was air-dried, pulverized, and sieved to remove unwanted particles

2.3.1 Test Conducted

Initial tests were conducted on untreated leachate soil to determine its basic properties, including:

- Natural moisture content
- Specific gravity
- Grain size distribution
- Atterberg limits
- Compaction Characteristics
- Unconfined Compressive Strength

These tests help in understanding the original behaviour of the contaminated soil.

2.3.2 Soil–Fly Ash Mixes

Fly ash was mixed with leachate soil in different percentages (5%, 10%, 15%, and 20% by dry weight of soil). The materials were thoroughly blended to ensure uniform distribution. Optimum water content obtained from contained soil Compaction Test was added to prepare samples for further testing on curing (0,3,7 and 14 days).

The Variation of behaviour (soil-Fly ash) mixes was analyzed based on the following tests:

i. Compaction Characteristics
ii. Unconfined Compressive Strength

In additional Micro-structural studies were carried out using XRD and SEM techniques.

The test results of (Leachate soil-Fly ash) mixes were analyzed for plasticity, compaction behaviour, and strength parameters to determine the optimum percentage of fly ash. The mixes were designated as $M0$, $M1$, $M2$, $M3$ and $M4$ Corresponding to 0%, 2%, 5%, 10%, 15% and 20% Fly ash additions.

III. RESULTS AND DISCUSSIONS

3.1 Basic Properties of Leachate soil

3.1 Tested the Properties of collected Leachate Soil are given below table.

S. No	Property	Values
1	Liquid Limit	59 %
2	Plastic Limit	23 %
3	Plastic Index	36
4	Specific Gravity	2.8
5	Maximum Dry Density	17.50 KN/m^3
6	Optimum Moisture Content	15.6%
7	Unconfined Compressive Strength	162.20KN/m^2

3.2 OMC and MDD of (soil Fly ash) Mixtures Compaction Characteristics.

S. No	Mix Designation	% Fly Ash	OMC (%)	MDD (KN/m^3)
1	M0	0%	17.50	15.67
2	M1	2%	17.70	13.25
3	M2	5%	18.20	12.33
4	M3	10%	18.30	12.28
5	M4	15%	18.10	13.94
6	M5	20%	18.00	14.08

The variation of OMC and MDD of (soil-Fly ash) mixtures are presented figure 3.1 and 3.2.

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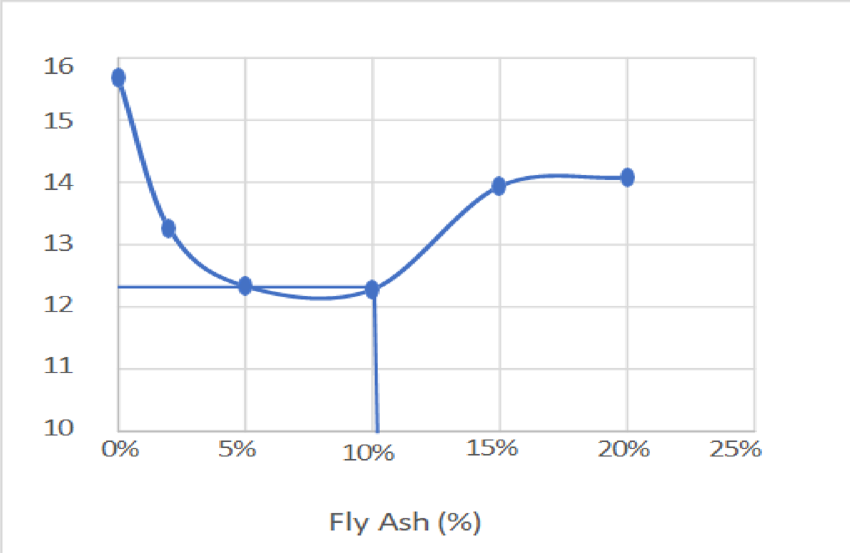

Figure 3.1: Variation of OMC of soil with Fly ash addition

3.3 Strength UCS of (Soil Fly ash) mixtures is given in table below.

The peak stress obtained from the stress–strain curve represents the Compressive strength of the soil and was used to assess its ability in improvement of soil strength.

The variation of Unconfined Compressive Strength($\boldsymbol{KN/m^3}$) mixed with Fly ash (%) in different percentages and Curing days is plotted in figure 3.2.

3.3 Unconfined Compressive Strength (KN/m^3) with curing is given in table below.

S. No	Mix Designation	Fly Ash	0 days	3 days	7 days	14 days
1	M0	0%	160.20	160.20	160.20	160.20
2	M1	2%	170.60	192.00	210.30	250.40
3	M2	5%	180.20	210.60	270.60	312.60
4	M3	10%	210.30	260.90	326.90	398.40
5	M4	15%	193.70	220.00	290.00	321.20

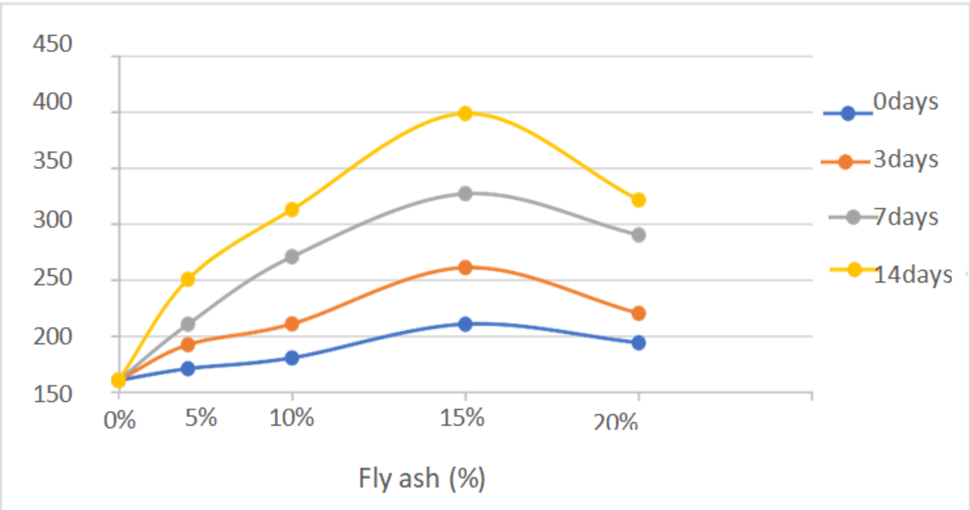

Figure 3.2: Variation of UCS of soil with Fly ash addition (%) and Curing days

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IV. CONCLUSION

The study concludes that the addition of leachate-contaminated soil using fly ash significantly improved the strength and reduced plasticity, making the Leachate soil suitable for subgrade and foundation applications.

The improvement in strength is attributed to the pozzolanic reaction between fly ash and soil minerals, leading to the formation of cementitious compoSunds. An optimum percentage of fly ash yields maximum strength gain, while further addition reduce performance. Curing time enhances strength due to continued formation of bonding compounds. Overall, fly ash is an effective and economical stabilizing agent for improving selected leachate soil.

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