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# Enhancing Strength of Expansive Soil Stabilized with Fly Ash: Investigating the Effects of Calcium Chloride and Waste Tyre Rubber

T. Sarada[1], Tirumala Deepika[2], Mohammad Abdul Shukoor[3*]
[1]Assistant Professor, Vidya Jyothi Institute of Technology, Aziz nagar Hyderabad, India
[2]Assistant Professor, Vidya Jyothi Institute of Technology, Aziz nagar Hyderabad, India
[3]Village Surveyor, Govt of AP, India
*Corresponding Author: *T.Sarada,* [1]Assistant Professor, Vidya Jyothi Institute of Technology, Aziz nagar Hyderabad, India
Email: sharada133civil@gmail.com; mallinadhkashyap@gmail.com

***Abstract***— *This study aims to investigate the impact of fly ash, calcium chloride, and curing period on the index properties of problematic expansive soil. The objective is to identify effective techniques to mitigate the challenges posed by expansive soil and propose suitable methodologies based on a critical review of existing literature. Laboratory experimentation is conducted to examine the influence of proposed additives and admixtures on the properties of expansive soils. The performance of the stabilized expansive soil with the suggested additives and admixtures is evaluated, considering its suitability as fill material and subgrade material. Additionally, the suitability and potential adoption of Waste Tyre Rubber (WTR) as discrete reinforcement are investigated. The experimental soil utilized in this study is a representative black cotton soil collected from the Kothapeta region near Amalapuram, in the East Godavari District of Andhra Pradesh, India. The soil properties are determined in accordance with the relevant Indian Standard (IS) specifications. By examining the impact of various materials and curing periods on the expansive soil properties, this research seeks to contribute to the development of effective strategies for soil stabilization. The findings of this study will provide valuable insights into improving the engineering characteristics of expansive soils and selecting appropriate techniques for their sustainable management.*

***Keywords***— *Expansive Soil, Fly Ash, Soil Stabilization, Laboratory Experimentation, Black Cotton Soil.*

## I. INTRODUCTION

Expansive soils pose significant challenges in geotechnical engineering due to their inherent volume change characteristics upon moisture variations. These soils, such as black cotton soil, exhibit significant swell-shrink behavior, leading to detrimental effects on infrastructure and construction projects. To mitigate these issues, various soil stabilization techniques have been explored, including the use of fly ash as a stabilizing agent.Fly ash, a byproduct of coal combustion in thermal power plants, has gained considerable attention as a potential soil stabilizer due to its pozzolanic properties and availability in large quantities. It has been extensively studied for its effectiveness in improving the engineering properties of expansive soils (Saride et al., 2019; Wu et al., 2020). The addition of fly ash to expansive soil has shown promising results in reducing swell-shrink behavior and enhancing strength characteristics (Mondal et al., 2017).

However, in order to further enhance the stabilization effectiveness, the incorporation of additional materials and additives has been explored. One such additive is calcium chloride, which has been investigated for its potential to improve the engineering properties of expansive soils (Hafeez et al., 2018; Saberi et al., 2021). Calcium chloride offers benefits such as increased compaction, reduced plasticity, and improved strength properties.

Another material being considered for enhancing the strength of stabilized expansive soil is waste tyre rubber (WTR). WTR has been studied for its potential as a discrete reinforcement to mitigate the volume change behavior of expansive soils (Nwobasi et al., 2019; Karthik et al., 2021). The use of WTR can potentially improve the soil's shear strength, reduce plasticity, and enhance its load-bearing capacity.

The objective of this study is to investigate the effects of incorporating fly ash, calcium chloride, and waste tyre rubber on the strength improvement of expansive soil. Laboratory experimentation will be conducted to evaluate the impact of these materials on the index properties of the problematic expansive soil. The performance of the stabilized soil will be assessed in terms of its suitability as fill material and subgrade material.

By examining the influence of these additives and admixtures, this research aims to contribute to the development of effective strategies for stabilizing expansive soils and overcoming their challenges. The findings of this study will provide valuable insights into the optimal combination of materials and techniques for enhancing the strength and reducing the swell-shrink behavior of expansive soils, thereby facilitating sustainable geotechnical practices.

## II. EXPERIMENTATION

The study investigated the effects of different stabilizing agents on the expansive soil by varying their percentage content. The variables studied included fly ash at content percentages of 0%, 5%, 10%, 15%, and 20%; calcium chloride at content percentages of 0%, 4%, 8%, and 12%; and waste tyre rubber (WTR) at content percentages of 0%, 0.5%, 1.0%, and 1.5%.

### *2.1 Material Characteristics*

| S.No | Property | Value |
|---|---|---|
| 1. | Soil Type | Black Cotton Soil |
| 2. | Collection Location | Kothapeta, Andhra Pradesh, India |
| 3. | Experimental Standard | Indian Standard (IS) Specifications |

### *2.2 Experimental Procedure*

The following are the steps involved in the experimental procedure that is adopted in this study

(a) Soil Sample Collection: Collect representative black cotton soil samples from the Kothapeta region near Amalapuram, Andhra Pradesh, India.

(b) Preparation of Specimens: Prepare specimens of the expansive soil for testing according to the desired dimensions and requirements of the experimental program.

(c)Determination of Initial Properties: Conduct initial tests to determine the index properties of the expansive soil, including but not limited to liquid limit, plastic limit, plasticity index, specific gravity, and particle size distribution.

(d)Preparation of Stabilized Mixtures: Prepare different mixtures of the expansive soil with varying proportions of fly ash, calcium chloride, and waste tyre rubber (WTR) as per the experimental design.

(e)Mixing and Compaction: Mix the soil, fly ash, calcium chloride, and WTR thoroughly using a suitable mixing procedure. Compact the mixtures using the desired compaction energy and technique, such as Proctor compaction.

(f)Curing Period: Subject the compacted specimens to a specified curing period to allow for the development of strength and stabilization.

(g)Testing of Stabilized Soil: Perform a series of tests on the stabilized soil specimens, including unconfined compression tests, California bearing ratio (CBR) tests, swell tests, and moisture content determination.

(h)Evaluation of Results: Analyze the test results to evaluate the impact of fly ash, calcium chloride, and WTR on the strength and index properties of the stabilized expansive soil. Compare the results with the control (unstabilized) soil samples.

(i)Interpretation and Conclusions: Interpret the findings from the laboratory experimentation and draw conclusions regarding the effectiveness of the proposed additives and admixtures in enhancing the strength and stability of expansive soil. Assess the suitability of the stabilized soil as fill material and subgrade material.

By following this experimental procedure, the study aims to gain insights into the effects of fly ash, calcium chloride, and WTR on the expansive soil properties and contribute to the development of effective strategies for soil stabilization.

## III. Test Results & Discussion

### *3.1 Effect of % Fly Ash Replacement on the Properties of Expansive Soil*

TABLE 1. Variation of Optimum Moisture Content and Maximum Dry Density with Percentage replacement of Fly Ash in Expansive Soil

| S. No | Percentage of Fly Ash (%) | Optimum Moisture Content (%) | Maximum Dry Density (g/cc) |
|---|---|---|---|
| 1 | 0 | 30.6 | 1.56 |
| 2 | 5 | 28.8 | 1.58 |
| 3 | 10 | 27.1 | 1.59 |
| 4 | 15 | 25.8 | 1.61 |
| 5 | 20 | 24.2 | 1.6 |

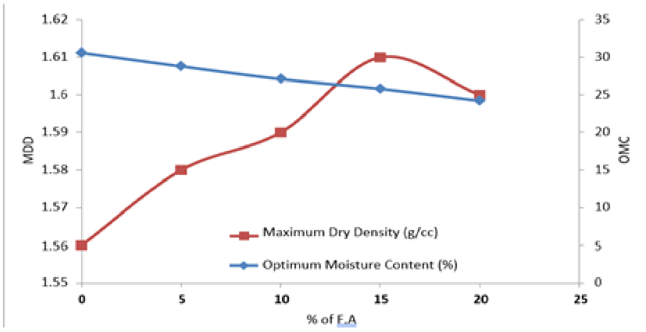


Fig.1

### *3.2 Effect of % Calcium Chloride on the Properties of Expansive Soil - Fly Ash Mix*

TABLE 2. Variation of Optimum Moisture Content and Maximum Dry Density with Percentage of Calcium chloride

| S. No | Percentage of Fly Ash (%) | Optimum Moisture Content (%) | Maximum Dry Density (g/cc) |
|---|---|---|---|
| 1 | 0 | 25.8 | 1.61 |
| 2 | 4 | 26.4 | 1.62 |
| 3 | 8 | 27.3 | 1.64 |
| 4 | 12 | 28.1 | 1.63 |

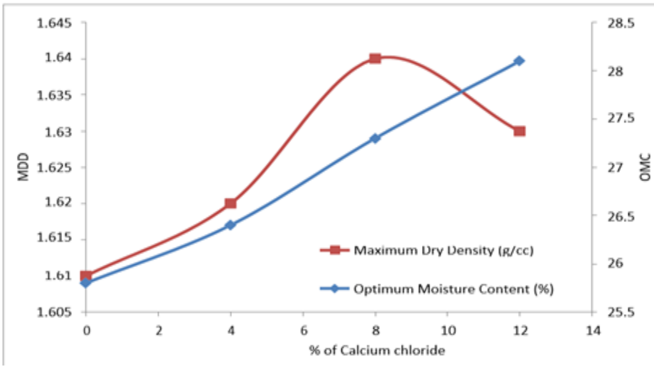


Fig.2

### *3.3 Effect of Waste Tyre Rubber Inclusions on the Behaviour of Calcium Chloride - Fly Ash - Expansive Soil Mix*

TABLE 3. Variation of Optimum Moisture Content and Maximum Dry Density with Percentage of WTR.

| S. No | Percentage of Fly Ash (%) | Optimum Moisture Content (%) | Maximum Dry Density (g/cc) |
|---|---|---|---|
| 1 | 0 | 27.3 | 1.64 |
| 2 | 0.5 | 26.9 | 1.63 |
| 3 | 1 | 26.7 | 1.62 |
| 4 | 1.5 | 26.1 | 1.61 |

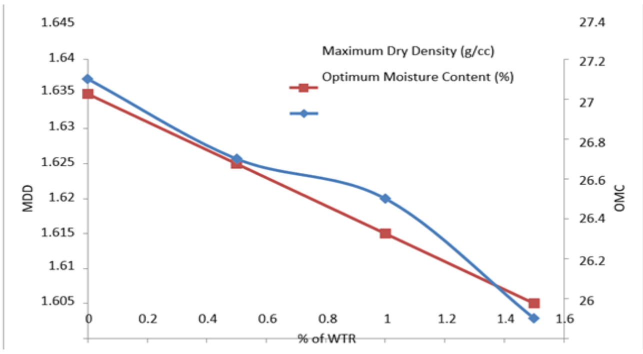


Fig.3

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TABLE 4. Variation of Cohesion and Angle of Internal Friction with Percentage of WTR.

| S. No | Percentage of WTR (%) | Cohesion, $C_u$ | % Increase in cohesion | Angle of internal friction, $Ø_u$ | % Increase in Angle of Internal Friction |
|---|---|---|---|---|---|
| 1 | 0 | 102 | - | 4 | - |
| 2 | 0.5 | 104 | 1.9 | 5 | 25 |
| 3 | 1 | 108 | 5.9 | 8 | 100 |
| 4 | 1.5 | 107 | 4.9 | 7 | 75 |

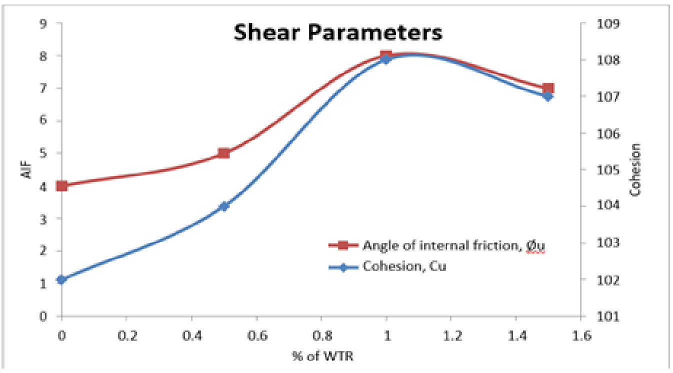

Fig.4

TABLE 5. Variation of CBR values with Percentage of WTR

| S. No | Percentage of WTR (%) | UnSoaked | % of Increasein UnSoaked Value | Soaked | % Increasein Soaked Value |
|---|---|---|---|---|---|
| 1 | 0 | 7.4 | - | 7.9 | - |
| 2 | 0.5 | 7.9 | 6.7 | 8.3 | 5.1 |
| 3 | 1 | 8.1 | 9.5 | 8.8 | 11.4 |
| 4 | 1.5 | 8 | 8.1 | 8.5 | 7.6 |

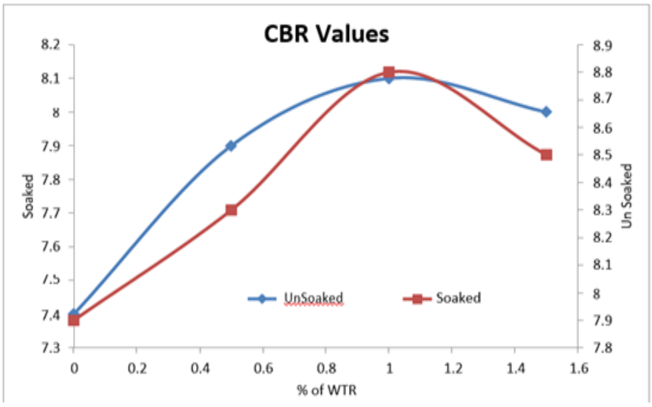

Fig.5

The results of the study indicate that the addition of fly ash to the expansive soil resulted in improvements in various properties. The maximum dry density of the soil increased by approximately 3.2% with fly ash alone and further increased to 5.1% when blended with calcium chloride. The optimum moisture content initially reduced with fly ash addition but slightly increased when calcium chloride was introduced. The shear parameters of the soil also showed improvement with the addition of fly ash, calcium chloride, and waste tyre rubber (WTR). Cohesion increased by 45% when the soil was replaced with 15% fly ash, and further blending with calcium chloride led to an additional 26% improvement. The addition of calcium chloride also mobilized some friction in the mix. The angle of internal friction improved by approximately 100% when blended with 1% WTR scrap, and cohesion improved by about 93% compared to the virgin expansive soil. The unconfined compressive strength showed a significant improvement of approximately 245%.

The C.B.R (California Bearing Ratio) values, both unsoaked and soaked, also exhibited substantial improvement—approximately three times and eleven times, respectively. These findings demonstrate a significant enhancement in the shear and C.B.R parameters of the virgin expansive soil through the addition of fly ash, calcium chloride, and WTR. The stabilized expansive soil with these additives presents itself as a useful fill material with increased safe bearing capacity. Furthermore, the improved C.B.R parameters make it suitable for subgrade material in pavement constructions. The study includes figures depicting various parameters, showing the behavior of the expansive soil when treated with fly ash, calcium chloride, and different percentages of WTR scrap.

By replacing a portion of the expansive soil with fly ash and blending it with calcium chloride and WTR, the plasticity of the soil was reduced. This reduction in plasticity contributed to the improvement in shear and C.B.R parameters, indicating the potential for the stabilized soil to serve as a viable fill material and effective subgrade material. Additionally, the comparison of pavement thickness based on the C.B.R parameters of the expansive soil treated with different stabilizing materials revealed a significant reduction in thickness, particularly when 15% fly ash replacement, 8% calcium chloride addition, and 1% WTR dosage were used. This reduction in pavement thickness demonstrates the effective utilization of waste materials and addresses the issue of waste disposal. Overall, the results suggest that fly ash, calcium chloride, and waste tyre rubber have shown promising effects on the properties of problematic expansive soil, providing a dual advantage of soil improvement and waste management. The findings of this study contribute to the development of sustainable solutions for dealing with expansive soil and waste materials.

## IV. Conclusions

The laboratory studies revealed that the selected expansive soil exhibited problematic characteristics, including high swelling, high plasticity, and low strength. The maximum dry density of the soil gradually increased up to a 15% replacement of fly ash, resulting in a 3.2% improvement, after which there was a marginal decrease. The corresponding optimum moisture content decreased by 21% with the reduction in fly ash content. The addition of fly ash, calcium chloride, and waste tyre rubber improved the shear parameters of the soil, with a 45% increase in cohesion when 15% fly ash replaced the virgin soil. Further blending with calcium chloride led to an additional 26% improvement. Blending the mix with 1% WTR scrap resulted in a 100% improvement in the angle of internal friction and a 93% improvement in cohesion compared to the virgin expansive soil. The unconfined compressive strength improved by approximately 245%, and the unsoaked and soaked C.B.R values increased by about three times and eleven times, respectively. Notably, the soaked CBR condition exhibited a reduction in pavement thickness by approximately 288%.

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These findings highlight the significant improvement achieved by stabilizing the expansive soil with fly ash, calcium chloride, and WTR, indicating its potential as a viable fill material and subgrade material. The study demonstrates the effective utilization of waste materials, such as fly ash and waste tyre rubber, in addressing both soil improvement and waste management concerns.

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