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STABILIZATION OF BLACK COTTON SOIL WITH COMBINATION OF BRICK POWDER

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Abstract: This study investigated the effects of various percentages of stabilizing materials, specifically Fly Ash Brick Powder (FABP) and Red Brick Powder (RBP), on the behavior of expansive soil. Key findings revealed significant enhancements in soil properties when incorporating these stabilizers at concentrations of 5%, 10%, 15%, and 20%. Notably, the liquid limit decreased substantially, from 53.8% to 48.08% for FABP and from 53.8% to 41.98% for RBP, with the most considerable reduction occurring at the highest replacement level. This decrease is beneficial for soil strength, improving stability, load-bearing capacity, and moisture resilience, thereby making the soil more suitable for construction applications. The plastic limit also declined with increasing stabilizer percentages, falling from 32.71% to 25.93% for RBP and from 32.71% to 28.66% for FABP, with a slight increase at 20% replacement. This reduction enhances soil strength by decreasing plasticity, increasing shear strength, and improving compaction, which collectively contribute to greater stability. The plasticity index exhibited a favorable decrease from 21.09% to 16.36% for FABP and from 21.09% to 16.05% for RBP, indicating enhanced compaction characteristics and reduced deformation potential. Compaction characteristics were reflected in the Maximum Dry Density (MDD), which decreased initially for FABP before increasing at 20% replacement, while RBP showed a steady rise, signifying improved load-bearing capacity and stability. The Optimum Moisture Content (OMC) decreased for both stabilizers, further enhancing compaction and reducing plasticity. The California Bearing Ratio (CBR) also increased significantly, from 4.70% to 5.46% for FABP and from 4.70% to 7.59% for RBP, underscoring RBP's superior performance as a stabilizer. Overall, the investigation concluded that Red Brick Powder was more effective than Fly Ash Brick Powder, demonstrating better performance in Atterberg's Limits, compaction characteristics, and CBR analysis, ultimately indicating its greater potential for enhancing the stability and durability of expansive soils in construction applications.

Keywords - Fly Ash Brick Powder (FABP) and Red Brick Powder (RBP), Stabilizing materials, Atterberg's Limits, Compaction characteristics, California Bearing Ratio (CBR), Expansive soil.

I. INTRODUCTION

Black cotton soil, or expansive soil, is unsuitable for foundation and pavement construction primarily due to its high clay content, which leads to significant volume changes with moisture fluctuations. This characteristic results in swelling when wet and shrinking upon drying, causing instability and uneven settling in structures. As a result, foundations may experience cracking and structural damage over time. Additionally, the soil's low load-bearing capacity and poor drainage properties can exacerbate these issues, leading to water accumulation and further weakening of the foundation. Consequently, effective stabilization or modification is essential before using black cotton soil in construction projects.

Soil stabilization is a critical process aimed at enhancing the physical and mechanical properties of weak or problematic soils, making them suitable for construction purposes. Expansive soils, for instance, can undergo significant volume changes with moisture variations, leading to structural instability and damage. Stabilization techniques, such as the use of additives or mechanical methods, improve soil strength, load-bearing capacity, and overall stability. These enhancements mitigate risks associated with settlement and deformation, ensuring safer and more durable infrastructure. As urbanization and construction demands increase, effective soil stabilization becomes increasingly important in promoting sustainable and resilient civil engineering solutions.

This study investigates the impact of stabilizing materials—Fly Ash Brick Powder (FABP) and Red Brick Powder (RBP)—on expansive soils, a common challenge in construction. By examining varying concentrations of these stabilizers (5%, 10%, 15%, and 20%), the research identifies significant enhancements in key soil properties. Notable findings include reductions in liquid and plastic limits, improved shear strength, and enhanced compaction characteristics. RBP outperformed FABP, demonstrating greater effectiveness in improving stability, load-bearing capacity, and moisture resilience. These insights highlight the potential of using RBP as a sustainable solution for enhancing expansive soils in construction applications, ultimately promoting safer infrastructure development.

II. LITERATURE REVIEW

S.P. Kanniyappan et al. (2019) emphasize that stabilizing sub-base and base soils improves their properties and strength. Red soil, the third largest soil group in India, has lower strength due to its porous and fragile structure and high swelling capacity, making stabilization essential. Common stabilization methods include lime, fly ash, granulated blast slag, and construction and demolition waste. This project aims to investigate the engineering properties of red soil and determine the required pavement thickness by adding varying percentages of debris. The California Bearing Ratio (CBR) will be calculated, with changes in CBR potentially leading to reduced pavement thickness.

Mallikarjun et al. (2018) investigate the modification of black cotton soil using Construction and Demolition (C&D) waste, identifying a 10% mix as optimal. The study shows that C&D waste effectively reduces swelling and enhances bearing capacity, demonstrating its potential as a viable stabilizer and promoting sustainable waste utilization in construction.

A.R. Makegaonkar et al. (2018) discuss the generation of construction and demolition (C&D) waste, which stems from construction activities and the dismantling of old structures like buildings and bridges. In India, the construction industry produces 20 to 32 million tons of waste annually, much of which is disposed of in landfills, contributing to environmental pollution. The paper emphasizes the urgent need to reduce landfill disposal and advocates for the reuse and recycling of C&D waste. It explores various strategies for reusing and recycling these materials, as implemented in different countries, highlighting the importance of effective waste management in the construction industry.

Neha Pundir et al. (2017) conducted an experiment to stabilize clayey soil by blending it with varying percentages of burnt brick dust, specifically 10%, 20%, 30%, 40%, and 50% by weight. The study aimed to evaluate the resulting properties of the soil following this stabilization process.

Er. Jasvir Singh and Er. Harpreet Singh Maan (2017) blended soil containing 8% fly ash with varying percentages of rice husk ash (4%, 8%, 12%, 16%, and 20%). They observed significant improvement in the California Bearing Ratio (CBR) at the combination of 8% fly ash and 12% rice husk ash. However, further increases in rice husk ash resulted in only gradual changes in the CBR values.

Saand et al. **(2020)** investigated the use of brick kiln waste (BKW) for stabilization clay soil with various percentages (5%, 10%, 20%, 25%, 30%, 35%, and 40% of BKW). Based on the test results, with the addition of BKW, the clay soil was improved and becomes an acceptable material for using as subgrade material.

Gupta et al. (2018) studied the effect of using brick kiln dust (BKD) for improving six different subgrade soil materials with various plasticity. Various percentages (10%, 20%, 30%, and 40%)of BKD were used for the stabilizing of soils, and results revealed that the use of BKD considerably increased the CBR as a main soil strength parameter

Aparna Roy (2014) recommended using 10% rice husk ash with 6% cement for optimal soil stabilization, noting that this combination achieves the maximum improvement in strength for practical applications.

III. MATERIAL & METHODOLOGY

3.1 Materials

Expansive Soil: For this investigation, the expansive soil was collected from Vinayakpur village in the Durg district (C.G.). The obtained black cotton soil was transported to the laboratory in sacks.

Fig.No: -01 Expansive Soil **Fig.No: -02 Fly Ash Brick Powder** **Fig.No: -03 Red Brick Powder**

Fly Ash Brick Powder: Fly ash brick powder is produced by crushing fly ash bricks into a powdered form. Waste bricks were collected from local sources near Vinayakpur and brought to the laboratory.

Red Brick Powder: Waste red bricks were also collected from Vinayakpur village and its surrounding areas. These bricks were used in powdered form for this investigation. Initially, the brick pieces were crushed using rammers and other crushing tools to obtain the powdered sample.

3.2 Methodology Adopted: various percentage of Brick powder is used with combination of soil. Replacement of stabilizer material is based on total weight of soil sample.

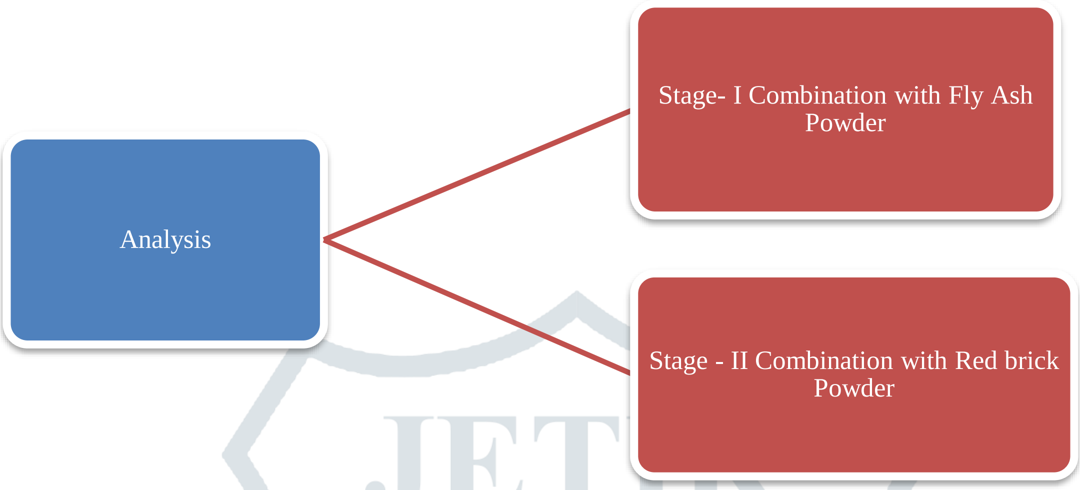

Fig. No.- 04 Stages of Analysis

3.2.1 Description of soil specimen

The replacement percentage of brick powder is the same for both types of brick powder waste. In the first stage, the soil is investigated using the combination of Fly Ash Brick Powder, while in the second stage, Red Brick Powder is utilized for the investigation.

Table No.: -01 Expansive soil and Fly ash brick Powder Blended Specimen & Red Brick Powder Blended Specimen

S.N.	Expansive soil	F.A. Brick Powder	Red Brick Powder
1	Virgin Soil	0 %	0 %
2	95	5 %	5 %
3	90	10 %	10 %
4	85	15 %	15 %
5	80	20 %	20 %

3.2.2 Following experiments were selected in this investigation process: -

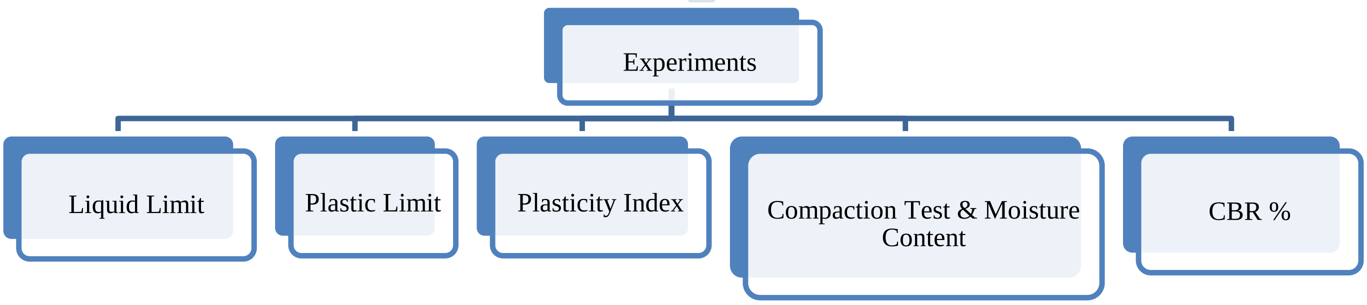

Fig. No.-05 Performed Tests

Table No.: -02 Experiment and Reference code

S.N.	Experiment	Reference Code
1	Liquid limit	IS 2720 (Part 5) - 1985

2	Plastic limit	IS 2720 (Part 5) - 1985
3	Plasticity Index	IS 2720 (Part 5) - 1985
4	Maximum Dry Density (MDD)	IS 2720 (Part 8) - 1983
5	Optimum Moisture Content (OMC)	IS 2720 (Part 8) - 1983
6	California Bearing ratio (CBR)	IS 2720 (Part 16) - 1987

IV. Result & Discussion

Properties of Virgin Soil: The soil properties are as follows: the liquid limit is 53.8%, the plastic limit is 32.71%, and the plasticity index is 21.09%. The maximum dry density (MDD) is 1.742 g/cc, while the optimum moisture content (OMC) is 17%. Additionally, the California Bearing Ratio (CBR) is 4.705%.

Table No.: - 5 Properties of Virgin Soil

S.N.	Experiment	Value
1	Liquid limit	53.8 %
2	Plastic limit	32.71 %
3	Plasticity Index	21.09 %
4	Maximum Dry Density (MDD)	1.742 (g/cc)
5	Optimum Moisture Content (OMC)	17 %
6	California Bearing ratio (CBR)	4.705 %

4.1 Determination of liquid Limits

The impact of stabilizer percentages on the liquid limit of expansive soil was observed as follows: at 0% stabilizer, both Fly Ash Brick Powder (F.A.B.P.) and Red Brick Powder (R.B.P.) had a liquid limit of 53.8%. At 5% stabilizer, the liquid limit decreased to 46.82% for F.A.B.P. and 49.9% for R.B.P. At 10%, F.A.B.P. recorded a liquid limit of 47.06%, while R.B.P. was at 47.38%. At 15%, the liquid limit for F.A.B.P. was 48.12% and for R.B.P. it dropped to 44.30%. Finally, at 20% stabilizer, F.A.B.P. showed a liquid limit of 48.08%, and R.B.P. decreased further to 41.98%.

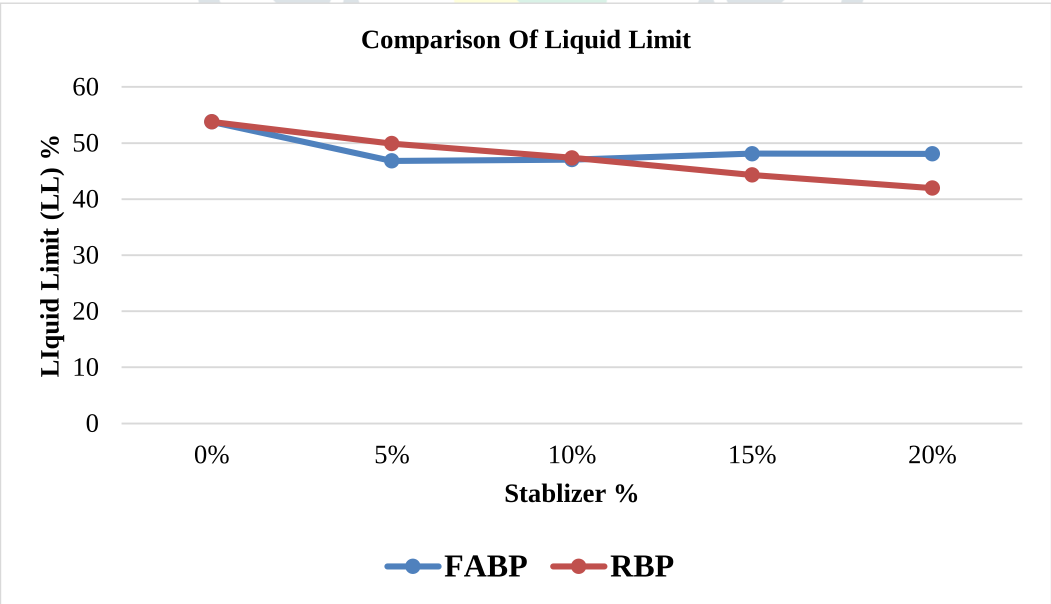

Fig. No.- 06 Comparison of Liquid Limit

4.2 Determination of Plastic Limits

The effect of stabilizer percentages on the plastic limit of expansive soil was as follows: at 0% stabilizer, both Fly Ash Brick Powder (F.A.B.P.) and Red Brick Powder (R.B.P.) had a plastic limit of 32.71%. At 5% stabilizer, the plastic limit decreased to 29.67% for F.A.B.P. and increased slightly to 30.52% for R.B.P. At 10%, F.A.B.P. recorded a plastic limit of 27.58%, while

R.B.P. was at 28.63%. At 15%, F.A.B.P. rose to 28.66%, and R.B.P. decreased to 27.02%. Finally, at 20% stabilizer, F.A.B.P. had a plastic limit of 31.72%, and R.B.P. further decreased to 25.93%.

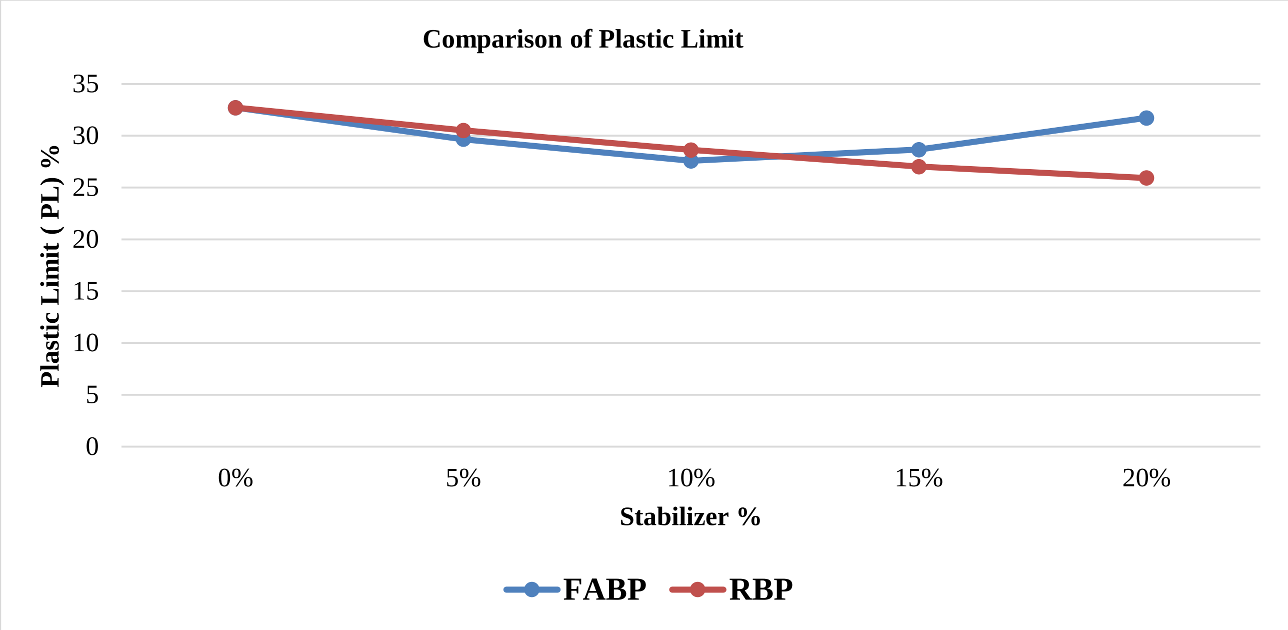

Fig. No.-07 Comparison of Plastic Limit

4.3 Determination of Plasticity Index

The impact of stabilizer percentages on the plasticity index of expansive soil was observed as follows: at 0% stabilizer, both Fly Ash Brick Powder (F.A.B.P.) and Red Brick Powder (R.B.P.) had a plasticity index of 21.09%. At 5% stabilizer, the plasticity index decreased to 17.15% for F.A.B.P. and increased to 19.38% for R.B.P. At 10%, F.A.B.P. recorded a plasticity index of 19.48%, while R.B.P. dropped to 18.75%. At 15%, the plasticity index for F.A.B.P. was 19.46%, and for R.B.P. it decreased to 17.28%. Finally, at 20% stabilizer, F.A.B.P. showed a plasticity index of 16.36%, while R.B.P. was at 16.05%.

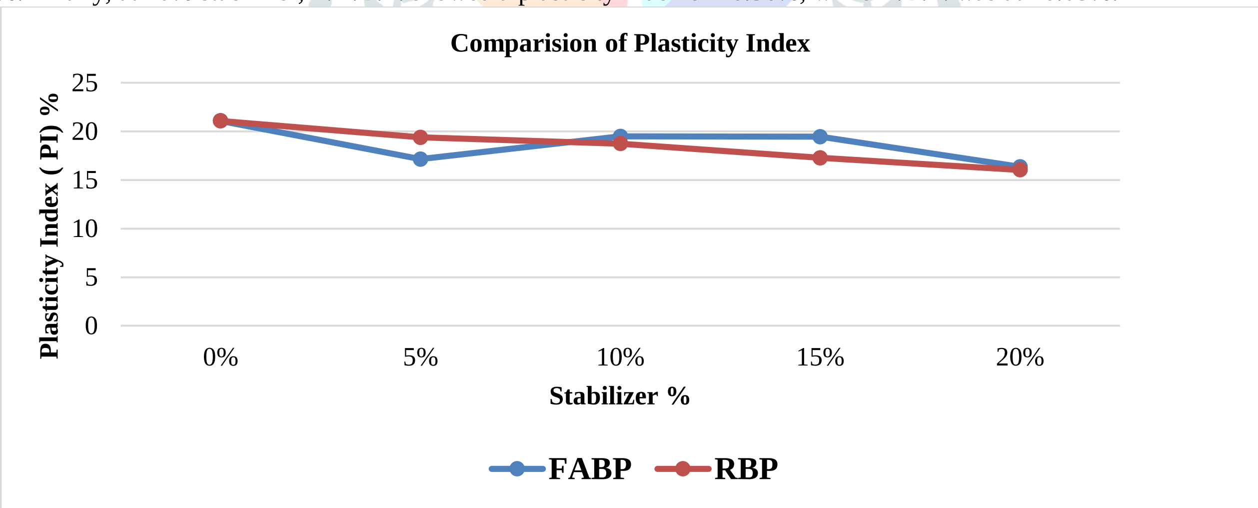

Fig. No.- 08 Comparison of Plasticity Index

4.4 Determination of Maximum Dry Density (MDD)

The effect of stabilizer percentages on the Maximum Dry Density (MDD) of expansive soil was as follows: at 0% stabilizer, both Fly Ash Brick Powder (F.A.B.P.) and Red Brick Powder (R.B.P.) had a density of 1.742 g/cc. At 5% stabilizer, the density decreased to 1.683 g/cc for F.A.B.P. and increased to 1.748 g/cc for R.B.P. At 10%, F.A.B.P. recorded a density of 1.663 g/cc, while R.B.P. rose to 1.760 g/cc. At 15%, the density for F.A.B.P. was 1.733 g/cc, and for R.B.P., it was 1.768 g/cc. Finally, at 20% stabilizer, F.A.B.P. increased to 1.783 g/cc, while R.B.P. reached 1.812 g/cc.

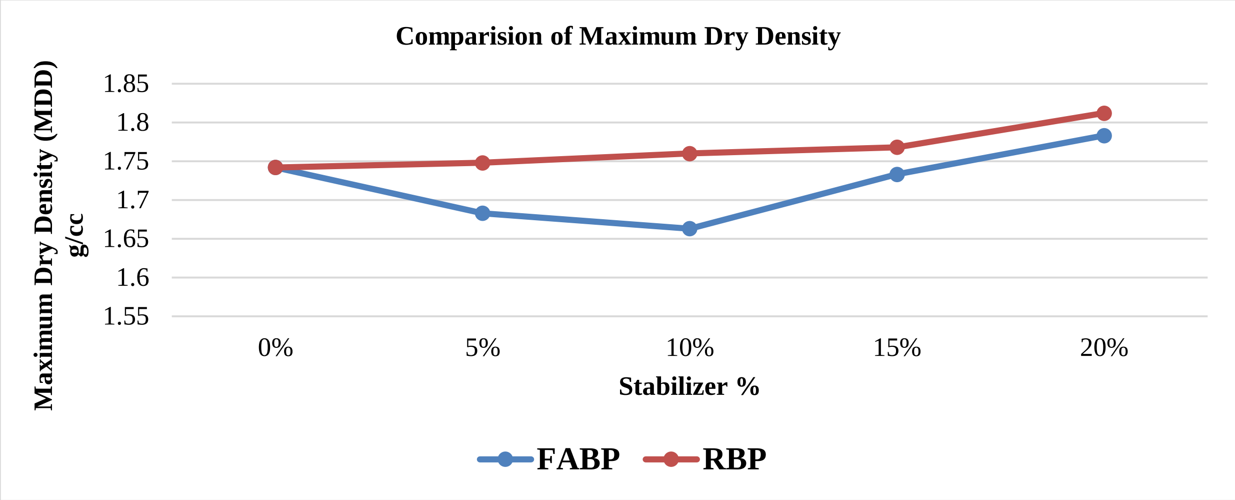

Fig. No.-09 Comparison of Plastic Limit

4.5 Determination of Optimum Moisture Content

The effect of stabilizer percentages on the Optimum Moisture Content (OMC) of expansive soil was as follows: at 0% stabilizer, both Fly Ash Brick Powder (F.A.B.P.) and Red Brick Powder (R.B.P.) had an OMC of 17%. At 5% stabilizer, the OMC decreased to 15% for F.A.B.P. and increased to 16.8% for R.B.P. At 10%, F.A.B.P. recorded an OMC of 14%, while R.B.P. was at 16.3%. At 15%, the OMC for F.A.B.P. remained at 14%, and for R.B.P., it decreased to 15.95%. Finally, at 20% stabilizer, F.A.B.P. rose to 16%, while R.B.P. decreased to 15.80%.

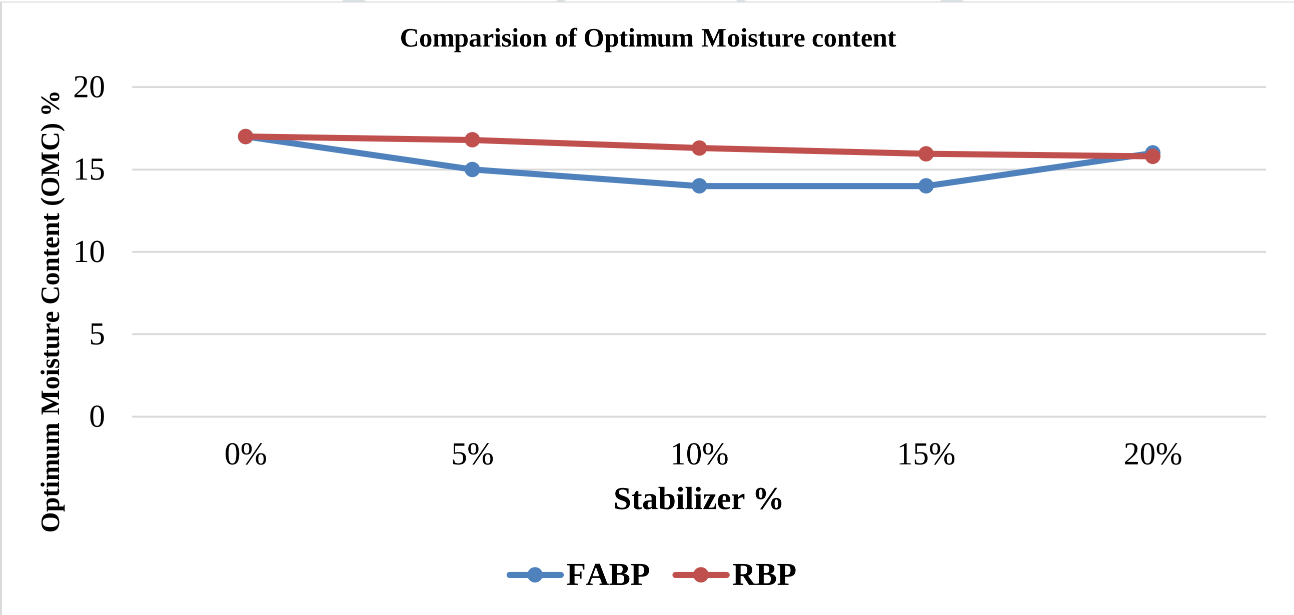

Fig No: -10 Comparision of OMC

4.6 Determination of CBR %

The effect of stabilizer percentages on the California Bearing Ratio (CBR) of expansive soil was as follows: at 0% stabilizer, the CBR was 4.70% for Fly Ash Brick Powder (F.A.B.P.) and 4.705% for Red Brick Powder (R.B.P.). At 5% stabilizer, the CBR increased to 4.89% for F.A.B.P. and 5.16% for R.B.P. At 10%, the CBR rose to 5.11% for F.A.B.P. and 6.57% for R.B.P. At 15%, F.A.B.P. recorded a CBR of 5.38%, while R.B.P. increased to 7.15%. Finally, at 20% stabilizer, the CBR for F.A.B.P. was 5.46%, and for R.B.P., it reached 7.59%.

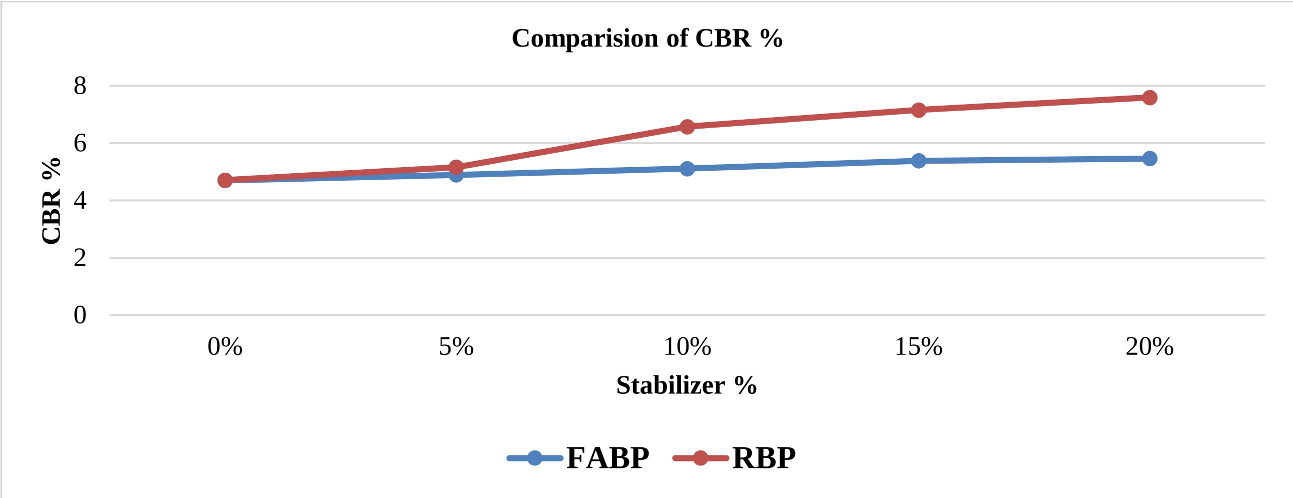

Fig No: - 11 Comparision of CBR %

V. Conclusion & Future Scope

5.1 Conclusion

Based on the investigation into the behaviour of expansive soil with various percentages of stabilizing materials, the following key findings have been summarized:

• The properties and behaviour of expansive soil were significantly enhanced through the use of Fly Ash Brick Powder (FABP) and Red Brick Powder (RBP) stabilizers at concentrations of 5%, 10%, 15%, and 20%.

• The liquid limit of the soil notably decreased with increasing stabilizer percentages, falling from 53.8% to 48.08% for FABP and from 53.8% to 41.98% for RBP. The most substantial reduction occurred at a 20% replacement. This decrease in the liquid limit benefits soil strength by improving stability, load-bearing capacity, and resilience against moisture-related issues, making it more suitable for construction and engineering applications.

• The plastic limit also declined with higher stabilizer percentages, decreasing from 32.71% to 25.93% for RBP. For FABP, it dropped from 32.71% to 28.66% at a 15% replacement, then slightly increased to 31.72% at 20%. A reduction in the plastic limit enhances soil strength by lowering plasticity, increasing shear strength, improving compaction, reducing swelling potential, and enhancing workability—all of which contribute to greater stability and performance in engineering applications.

• The plasticity index decreased from 21.09% to 16.36% for FABP, while RBP consistently dropped from 21.09% to 16.05%. A decrease in the plasticity index is beneficial for soil strength as it leads to improved shear strength, reduced deformation, lower swelling and shrinkage potential, enhanced compaction characteristics, and better workability. These factors together enhance stability and performance in engineering contexts.

• Compaction characteristics, as indicated by Maximum Dry Density (MDD), showed a decrease from 1.742 g/cc to 1.663 g/cc with 0-10% stabilizer replacement for FABP, but increased to 1.783 g/cc at 20%. In contrast, RBP exhibited a steady increase from 1.742 g/cc to 1.812 g/cc. An increase in dry density is beneficial for soil strength because it enhances load-bearing capacity, improves shear strength, reduces voids, facilitates better compaction, lowers permeability, and minimizes settlement, contributing to a more stable and durable foundation for construction.

• The Optimum Moisture Content (OMC) for FABP decreased from 17% to 14% with 0-15% replacement but rose to 16% at 20%. RBP consistently decreased from 17% to 15.80% across all replacements. A reduction in OMC is advantageous for soil strength, allowing for better compaction, reduced plasticity, and enhanced load-bearing capacity. These improvements contribute to the overall stability and durability of the soil, making it more suitable for construction projects.

• The California Bearing Ratio (CBR) for FABP increased from 4.70% to 5.46%, while RBP showed a more significant rise from 4.70% to 7.59%, indicating that RBP is a more effective stabilizer. An increased CBR value strongly indicates improved soil strength and load-bearing capacity, benefiting construction projects by enhancing stability, reducing settlement, and providing economic advantages, ultimately resulting in safer and more durable infrastructure.

In summary, the investigation highlighted that Red Brick Powder was more effective, strong, and stable compared to Fly Ash Brick Powder, showing superior performance in Atterberg's Limits, compaction characteristics, and CBR analysis.

5.2 Future Scope

Future research could explore the effectiveness of other pozzolanic materials, such as silica fume, for stabilizing expansive soil. Additionally, a wider range of stabilizer proportions—such as 30%, 40%, and 50%—could be examined for comparative analysis.

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