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A Systematic Study to Strengthen the Sub Grade of the Pavement by Stabilization of Expansive Soil with Molasses and Jute Fibre

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Abstract: ***Expansive soils, commonly referred to as Black cotton soils (BC), possess undesirable engineering properties such as low bearing capacity and high compressibility. To address these challenges, various stabilizers have been used to enhance the strength of expansive soil, including jute fiber and molasses. This thesis focuses on investigating the effects of incorporating jute fiber as a stabilizer and molasses as an additive to improve the properties of expansive soil. The objectives of this study are to enhance the shear strength of expansive soil by blending jute fiber and molasses mixtures. Jute fibers of different lengths (1cm, 2cm, 3cm, and 4cm) and various percentages (0.5%, 1%, 1.5%, and 2%) are used as stabilizers. Molasses is employed as an additional stabilizer with varying percentages (5%, 8%, 12%, and 15%). Laboratory investigations reveal that the addition of 12% molasses and 1.5% jute fiber significantly reduces the liquid limit, plastic limit, and plasticity index of the expansive soil, while simultaneously increasing the maximum dry density and California Bearing Ratio (CBR). Furthermore, cyclic load test results demonstrate a 62% improvement in the load carrying capacity of the treated expansive soil subgrade flexible pavement compared to untreated expansive soil flexible pavement.***

Utilizing construction wastes like molasses offers an alternative to reduce road construction costs, especially in rural areas of developing countries. Additionally, jute fiber provides effective reinforcement for expansive soils. These findings highlight the potential of jute fiber and molasses as sustainable and cost-effective stabilizers for enhancing the performance of expansive soils in construction projects.

Keywords: Expansive soil, Molasses, Jute Fiber, California Bearing Ratio (CBR)

I. INTRODUCTION

Flexible pavements are a common choice for road construction due to their ability to accommodate varying traffic loads and provide a smooth and comfortable driving surface. However, one of the major challenges in constructing flexible pavements is dealing with expansive soils, which are known for their undesirable engineering properties such as low bearing capacity and high compressibility. These soils, also referred to as Black cotton soils (BCS), are predominantly found in central states and certain regions of South India.To overcome the limitations posed by expansive soils, various stabilization techniques have been employed. In recent years, the utilization of natural and waste materials as additives has gained attention for its potential to improve the properties of expansive soils and enhance the performance of flexible pavements. This research focuses on the use of two such additives: jute fiber and molasses. Jute fiber, a natural reinforcement material derived from the jute plant, has been widely studied for its ability to enhance the mechanical properties of soils. On the other hand, molasses, a byproduct of the sugar industry, offers potential benefits as a stabilizing agent due to its chemical composition. Both jute fiber and molasses have shown promise in improving the engineering characteristics of expansive soils.This study aims to investigate the effectiveness of incorporating jute fiber and molasses as stabilizers in expansive soil for flexible pavement applications. Laboratory investigations were conducted to evaluate the impact of varying percentages of jute fiber and molasses on the properties of the expansive soil. Key parameters such as liquid limit, plastic limit, plasticity index, maximum dry density, and California Bearing Ratio (CBR) were analyzed to assess the performance of the treated expansive soil. The findings of this research provide valuable insights into the optimal percentages of jute fiber and molasses for treating expansive soil in flexible pavements. The study focuses on the changes in soil properties and the resulting improvements in load-carrying capacity and deformation characteristics observed in the treated soil through cyclic load tests. The implications of these findings for road construction, particularly in rural areas of developing countries, are discussed, highlighting the potential cost-effectiveness and sustainability of utilizing jute fiber and molasses as additives.

Overall, this research contributes to the understanding of the benefits and practical applications of jute fiber and molasses in stabilizing expansive soils for the construction of high-quality and durable flexible pavements..

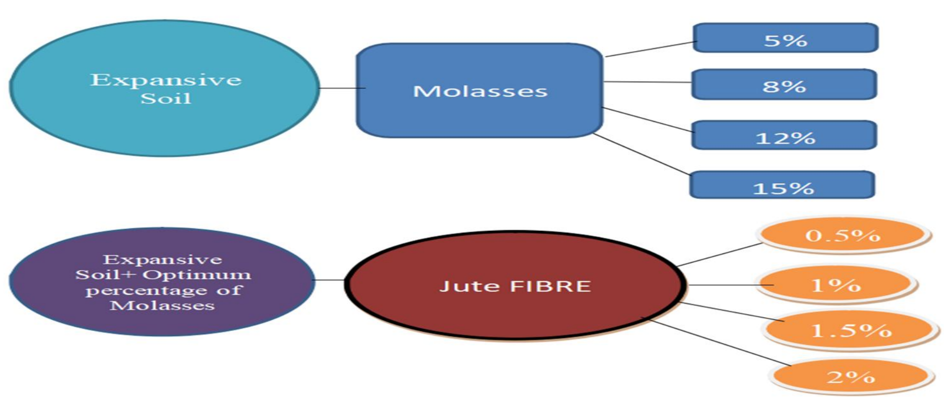
II. METHODOLOGY

1) *Soil Sample Collection:* Expansive soil samples were collected from the target region where Black cotton soils (BCS) are prevalent. Samples were collected at representative locations to ensure a comprehensive analysis of the soil characteristics.
2) *Soil Characterization:* The collected soil samples underwent a series of laboratory tests to determine their physical and engineering properties. Tests such as particle size analysis, Atterberg limits (liquid limit, plastic limit, and plasticity index), and compaction tests (maximum dry density) were conducted following standard procedures.
3) *Selection of Jute Fiber Length and Percentage:* Different lengths of jute fiber (1cm, 2cm, 3cm, and 4cm) were chosen as potential stabilizers. The percentages of jute fiber (0.5%, 1%, 1.5%, and 2%) were determined based on previous research and initial trials to identify the most effective range.
4) *Preparation of Molasses Solution:* Molasses was obtained from the sugar industry and prepared as a solution with varying percentages (5%, 8%, 12%, and 15%) to be added to the expansive soil. The solution was thoroughly mixed to ensure uniform distribution.
5) *Laboratory Testing:* The laboratory testing phase involved the following steps:

a) *Stabilization Procedure:* Expansive soil samples were mixed with different percentages of jute fiber and molasses solution in a controlled environment. The jute fiber was added at the chosen lengths and percentages, while the molasses solution was added gradually to achieve the desired percentage.
b) *Test Specimen Preparation:* The stabilized soil samples were compacted using standard compaction procedures to obtain specimens of uniform density and moisture content. Special care was taken to ensure consistent compaction energy throughout the process.
c) *Testing Parameters:* The treated soil specimens were subjected to various tests, including California Bearing Ratio (CBR) tests, cyclic load tests, and deformation analysis. CBR tests were performed to determine the load-bearing capacity of the treated expansive soil. Cyclic load tests were conducted to evaluate the behavior of the treated soil under repeated loading, simulating real-world conditions.

- *Data Analysis:* The test results, including changes in soil properties, load-carrying capacity, and deformation characteristics, were recorded and analyzed. The obtained data were compared with the properties of untreated expansive soil to assess the effectiveness of jute fiber and molasses as stabilizers.
- *Statistical Analysis:* Statistical techniques were employed to analyze the data, including calculations of means, standard deviations, and correlations. The significance of the results was determined using appropriate statistical tests.
- *Interpretation and Conclusion:* The data obtained from the laboratory testing and analysis were interpreted to draw conclusions regarding the optimal percentages of jute fiber and molasses for stabilizing expansive soil. The findings were discussed in terms of their implications for the performance and design of flexible pavements.

The methodology outlined above provides a systematic approach for investigating the effects of jute fiber and molasses on the properties of expansive soil. The combination of laboratory testing, statistical analysis, and interpretation of results ensures a comprehensive understanding of the stabilizing potential of these additives for flexible pavement applications.



Flow Chart Representing the Materials Used in the Project

III. RESULTS AND DISCUSSIONS

This chapter presents the results of the tests conducted on soil by addition of varying percentage of molasses and varying percentage of jute fiber. The tests were conducted in order to determine the following properties.

1) Index properties and classify the soil according to Indian Standards
2) Proctor compaction (MDD&OMC) characteristics of the soil.
3) California Bearing Ratio (CBR) characteristics of the soil.
4) Variation of compaction values (MDD&OMC) with varying in percentage of molasses Content.
5) Variation of California Bearing Ratio (CBR) with varying in percentage of molasses content.
6) Variation of compaction values (MDD&OMC) with Optimum percentage of molasses content along with varying in percentage of jute Fibre content.
7) Variation of California Bearing Ratio (CBR) with Optimum percentage of molasses content along with varying in percentage of jute Fibre content.
8) Index properties at optimum values of maximum dry density and optimum moisture content, California bearing ratio.
9) Variation of Ultimate Cyclic Pressure and Settlement for Untreated Expansive soil subgrade with Model Flexible pavement.
10) Variation of Ultimate Cyclic Pressure and Settlement for Expansive soil subgrade treated with optimum percentages of molasses and jute Fibre for Model Flexible pavement.

A. *Soil Properties*

The soil used for current study has been taken from MUMMIDIVARAM near Amalapuram area of East Godavari district, AP, India. It is collected from a depth of 2 m. Tests are conducted to determine the Index properties, Engineering properties as per Indian standard (IS 2720). The Soil properties are given in Table

Table : Grain size Distribution of the Expansive soil

S.No	Property		Percentage
1.	Gravel (%)		1.0
2.	Sand (%)		4.0
3.	Fines	Silt (%)	10.0
		Clay (%)	85.0

Table :Physical Properties of Untreated Expansive soil

S.No	Property	Symbol	Untreated Expansive soil
1.	Liquid Limit (%)	W_L	80
2	Plastic Limit (%)	W_P	35
3.	Plasticity Index (%)	I_P	45
4.	Soil Classification	--	CH
5.	Specific Gravity	G	2.60
6.	Free Swell (%)	FS	126
7.	Optimum Moisture Content (%)	OMC	26.66
8.	Maximum Dry Density (g/cc)	MDD	1.399
9.	CBR (%)	--	1.98

B. *Molasses Properties*

The Molasses collected from the sugar industry, the molasses waste we used in the Present study. Molasses is a very thick, dark brown, syrupy liquid obtained as a by-product in processing cane sugar. It is also called treacle. It contains resinous and some inorganic constituents that render it unfit for human consumption. The molasses are collected from the sugar industry near erode.

Table:Physical Properties of molasses

Constituent	Cane molasses %
Water	20
Organic Constituent	
Sugar: fructose	16
Saccharose	32
Glucose	14
Non sugar nitrogenous materials, soluble gummy materials, free and bound acids	10
Constituent	Cane molasses %
In Organic Constituent (ash)	
Silicon-Di-Oxide	0.5
Potassium Oxide	3.5
Calcium Oxide	1.5
Magnesium Oxide	0.1
Phosphors Oxide	0.2
Sodium Oxide	0.2
Iron Oxide	
Aluminium oxide	
Sulphate residue (as SO_2)	1.6
Chlorides	1.4
Total	100

C. Jute Fibre Properties

1) The Jute fibers are off-white to brown, and 1–4 metres (3–13 feet) long. Jute fibre is also called the *golden fiber* for its color .
2) Jute fibre is 100% bio-degradable and recyclable and thus environmentally friendly.
3) Jute is a **natural fibre** with golden and silky shine and hence called The
4) Golden Fibre.
5) It has high tensile strength, low extensibility, and ensures better breathability of fabrics.
6) jute Fibre will give good Reinforcement to Expansive soils.
7) Abundant availability
8) Superior durability, Jute Fibre can perfectly shape itself to ground contours.
9) High moisture/water absorbing capacity. Jute Fibre can absorb moisture/water up to about 5 times its dry weight.
10) High initial strength
11) Jute Fibres possess good pliancy and render a high degree of flexibility, High initial modulus, high torsional rigidity and low percentage of elongation-at- break make Jute a suitable fibre for geosynthetics.

The Fiber properties are given in table .

Table:Physical Properties of jute Fibre

Property	Range/Value
Fibre Length, mm	20mm
Fibre Diameter, mm	0.3-0.45
Specific Gravity	1.3
Bulk Density, Kg/,m3	1300
Ultimate tensile strength N/mm2	3400
Modulus of Elasticity, N/mm2	72
Elongation at Break, (%)	2-3

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Table :Chemical Composition of jute Fibre

Properties	Range/Value
Cellulose (%)	64.4
Hemi-cellulose (%)	12
Ligin (%)	11.8
Pectin (%)	0.2
Waxes (%)	0.5
Moisture Content (%)	1.1
Density (g/cm3)	1.46
Micro-fibrillar angle (0)	8
Price (EUR/kg)	0.3

D. Test Results

Optimum Moisture Content and Maximum Dry Density of Expansive Soil Treated with Various Percentages of molasses.

Table: Compaction Characteristics of Expansive soil treated with percentage of molasses.

Mix Proportion	Water Content (%)	Dry Density(g/cc)
100% Expansive soil	26.66	1.399
100% ES + 5% molasses	24.86	1.411
100% ES + 8% molasses	22.96	1.423
100%ES + 12% molasses	20.42	1.435
100%ES + 15% molasses	19.29	1.430

Variation of Atterberg limits with percentage variation of molasses

Table: Variation of LL, PL, PI for Expansive soil treated with different percentage of molasses.

% molasses	LiquidLimit (%)	Plastic Limit (%)	Plasticity Index(PI)
100% Expansive soil	80	35	45
100% ES + 5% molasses	76	33	43
100% ES + 8% molasses	72	31	41
100%ES + 12% molasses	68	29	39
100%ES + 15% molasses	65	28	37

Soaked CBR Test Results of Expansive soil treated with different percentages of molasses

Table : CBR Values of Expansive soil treated with Percentage Variations of molasses

Mix Proportions	CBR (%)
100% Expansive soil	1.98
100% ES + 5% molasses	2.465
100% ES + 8% molasses	3.826
100%ES + 12% molasses	4.09
100%ES + 15% molasses	3.95

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Table:Properties of Expansive soil treated with an optimum of 12% molasses

S.No	Property	Symbol	Expansive soil	ES+12% molasses
1	Liquid Limit (%)	W_L	80	68
2	Plastic Limit (%)	W_P	35	29
3	Plasticity Index (%)	I_P	45	39
4	Soil Classification	---	CH	CH
5	Free Swell (%)	F.S	126	82
6	Optimum Moisture Content (%)	O.M.C	26.66	20.42
7	Maximum DryDensity (g/cc)	M.D.D	1.399	1.435
8	CBR (%)	---	1.98	4.09

E. Discussion-1

As per IRC 37-2001 and 37-2012 the sub grade soil should possess the minimum CBR value of 6%. In the present study molasses treated Expansive soil has exhibited the CBR value of 4.09% which is less as per codes of practice. To achieve required CBR value as per codes of practice, an attempt has been taken to improve the CBR value of molasses treated Expansive soil reinforced with the percentage variation of jute Fibre to suite it as sub grade for flexible pavements.

Index and Engineering Properties for Test Results of Expansive Soil Combined with 12 % of molasses (Optimum) is Reinforced with various percentages of jute Fibre

From above results Table 5 the Soaked CBR value obtained is 4.09%. It is not sufficient for Flexible pavement subgrade is for Low volume Roads as Per IRC37:2012. So the Optimum combination of Expansive soil with 12 % of molasses with different percentages of jute Fibre.

The jute Fibre material was reinforced with the Expansive soil and 12% molasses by hand till uniform mixing was obtained. The jute Fibre was mixed in varying proportions of 0.5%, 1%, 1.5% and 2% of dry weight of the soil.

Optimum Moisture Content and Maximum Dry Density of Expansive Soil with 12% of molasses with Various Percentages of jute Fibre

Table:OMC and MDD Values of the Expansive soil with 12% of molasses with different percentages of jute Fibre.

S.No	Mix proportion	Optimum Moisture Content (%)	Maximum Dry Density (g/cc)
1	Expansive soil	26.66	1.399
2	100% Expansive soil+12% molasses	20.42	1.435
3	100% Expansive soil+12% molasses + 0.5% jute Fiber	18.32	1.521
4	100% Expansive soil+12% molasses + 1.0% jute Fiber	16.65	1.57
5	100% Expansive soil+12% molasses + 1.5% jute Fiber	15.05	1.596
6	100% Expansive soil+12% molasses + 2.0% Jute Fiber	13.25	1.580

Variation of Atterberg Limits with Percentage of Jute Fibre of Expansive soil with 12% Molasses

Table :Variation of LL, PL, PI for Combination of Expansive soil with 12% molasses with different percentages of Jute Fibre.

Mix Proportions	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
100%Expansive soil	80	35	45
100%Expansive soil+12% molasses	68	29	39
100% Expansive soil+12% molasses + 0.5% jute Fiber	65	25.03	39.97
100% Expansive soil+12% molasses + 1.0% jute Fiber	62	23.25	38.75
100% Expansive soil+12% molasses + 1.5% jute Fiber	59	21.22	37.89
100% Expansive soil+12% molasses + 2.0% Jute Fiber	57	19.95	37.05

Soaked CBR Test Results of combination of Expansive soil with 12 % molasses with different percentages of Jute Fibre

Table 4.12 CBR Values of 12% molasses Treated Expansive soil with Various Percentages of Jute Fibre

S.No	Mix Proportions	CBR (%)
1	100%Expansive soil	1.98
2	100%Expansive soil+12% molasses	4.09
3	100% Expansive soil+12% molasses + 0.5% jute Fiber	4.86
4	100% Expansive soil+12% molasses + 1.0% jute Fiber	5.788
5	100% Expansive soil+12% molasses + 1.5% jute Fiber	6.11
6	100% Expansive soil+12% molasses + 2.0% Jute Fiber	6.10

Table :Properties of Treated and Untreated Expansive soil

S.No	Property	Symbol	Expansive soil	100%ES+ 12% Molasses	100% ES + 12% molasses+ 1.5% Jute Fiber
1	Liquid limit (%)	WL	80	68	59
2	Plastic Limit (%)	WP	35	29	21.22
3	Plasticity Index (%)	IP	45	39	37.89
4	Soil classification	----	CH	CH	CH
5	Optimum Moisture Content (%)	O.M.C	26.66	20.42	15.05
6	Maximum Dry Density (g/cc)	M.D.D	1.399	1.435	1.596
7	CBR Value (%)	-----	1.98	4.09	6.11
8	Differential Free Swell (%)	DFSI	126	82	65

F. Discussion-2

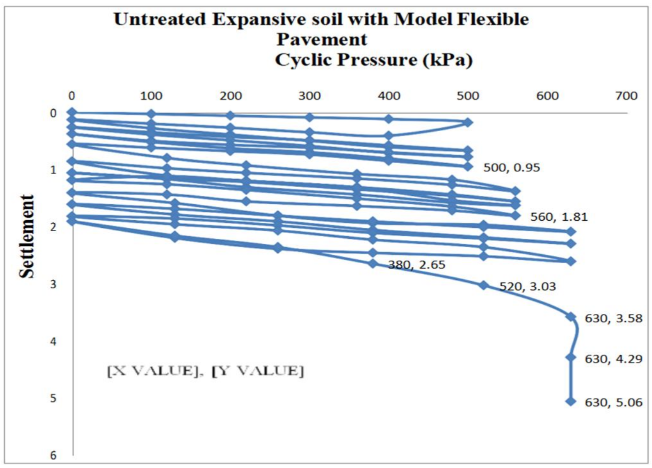
From the above study, 12% Molasses treated Expansive soil has exhibited the CBR value of 6.11% on addition of 1.5% Jute Fibre as an optimum. Hence this treated Expansive soil is suitable as sub grade for flexible pavements as per IRC 37-2001 and 37- 2012 codes of practice.

Laboratory Cyclic Plate Load tests on Untreated and Treated Expansive soil Flexible Pavements Using Model Tanks

Cyclic plate load tests were carried out on untreated and treated Expansive soil flexible pavements in separate model tanks under cyclic pressures 500kPa, 560kPa, 630kPa, 700kPa, 1000kPa,1400kPa,2000kPa. The tests were conducted until the failure of the Expansive soil model flexible pavements at OMC conditions.

Laboratory Cyclic Plate Load Test Results of Untreated Expansive Soil with Model Flexible Pavement at OMC

Figure shows the laboratory cyclic plate load test results of untreated Expansive soil with model flexible pavement at OMC. The Untreated Expansive soil with model flexible pavement has exhibited the ultimate cyclic pressure of 630kN/m^2 with the deformation of 2.61mm at OMC.



Laboratory Cyclic Plate Load Test

Results of Untreated Expansive soil with model Flexible pavement at OMC

Fig Laboratory Cyclic Plate Load Test Results of Expansive Soil treated with 12% molasses and 1.5% Jute Fibre with Model Flexible pavement at OMC. Figure show the laboratory cyclic plate load test results of Expansive soil treated with 12% molasses + 1.5% jute Fibre. This treated Expansive soil model flexible pavement has exhibited the ultimate cyclic load of 1600kN/m^2 with the deformation of 2.10mm at OMC.

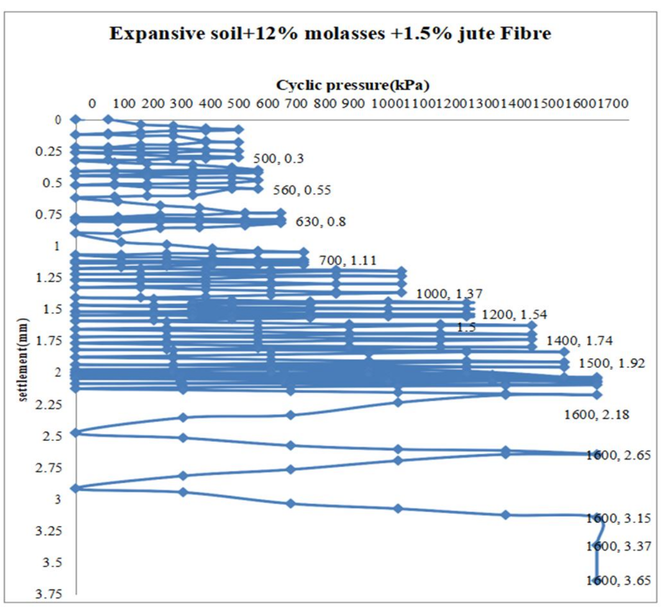


Figure Laboratory Cyclic Plate Load Test results of Expansive soil treated with 12% molasses + 1.5% Jute Fibre

Table :Laboratory Cyclic Plate Load Test Results of Treated and Untreated Expansive Soil with Model Flexible Pavements at OMC

S.No	Sub-grade soil	Sub-base	Base Course	Pressure (kPa)	Settlements (mm)
1	Untreated Expansive soil subgrade with Model flexible pavement	Gravel	WBM-III	630	2.61
2	12% molasses and 1.5% jute Fibre treated Expansive soil subgrade with model flexible pavement	Gravel	WBM-III	1600	2.10

IV. CONCLUSIONS

Optimum percentage of fibres and molasses observed during the laboratory investigations are summarized and presented in the following table.

Table :Optimum percentage of molasses and jute Fibre observed during the laboratory investigations

S.No	Additives	Optimum percentage addition
1	Molasses	12%
2	Jute Fibre	1.5%

Based on the laboratory studies conducted in this research, the following conclusions were drawn:

1) The optimum percentages of molasses and jute fiber were found to be 12% and 1.5%, respectively, for treating expansive soil.
2) The addition of 1.5% jute fiber to molasses-treated expansive soil resulted in a 35.59% decrease in liquid limit compared to untreated expansive soil. Similarly, the addition of 12% molasses decreased the liquid limit of untreated expansive soil by 17.64%.
3) The plastic limit of molasses-treated expansive soil decreased by 64.93% with the addition of 1.5% jute fiber, while the plastic limit of untreated expansive soil decreased by 20.68% with the addition of 12% molasses.
4) The plasticity index of molasses-treated expansive soil decreased by 18.76% with the addition of 1.5% jute fiber, compared to a decrease of 15.38% with the addition of 12% molasses in untreated expansive soil.
5) The ideal moisture content of molasses-treated expansive soil was reduced by 30.55% with the addition of 12% molasses, and further reduced by 77.14% with the addition of 1.5% jute fiber, compared to untreated expansive soil.
6) The maximum dry density of molasses-treated expansive soil increased by 14.08% with the addition of 1.5% jute fiber, while the maximum dry density of untreated expansive soil increased by 2.57% with the addition of 12% molasses.
7) The soaked C.B.R. (California Bearing Ratio) value of expansive soil increased by 106% with the addition of 12% molasses, and by 208% with the addition of 1.5% jute fiber, compared to untreated expansive soil.
8) The cyclic plate load test results showed that the ultimate cyclic stress of treated expansive soil subgrade flexible pavement improved by 620kPa to 1000Pa, compared to untreated expansive soil.
9) The total deformations of treated marine clay subgrade flexible pavement improved by 24.30% compared to expansive soil, as observed from the cyclic plate load test results.
10) The load-carrying capacity of treated expansive soil subgrade flexible pavement increased by 154% compared to untreated pavement, as determined from the laboratory cyclic load test.
11) The soaked C.B.R. values of expansive soil stabilized with molasses and jute fiber met standard specifications, exhibiting a 208% improvement.
12) The use of molasses and jute fiber as additives provides effective reinforcement to expansive soils, offering cost-effective solutions for road construction, particularly in rural areas of developing countries.

V. DISCUSSION

Hence, from the present laboratory investigations, it was concluded that the expansive soil treated with 12% molasses and 1.5% jute Fibre as an optimum exhibits satisfactory results as per IRC 37-2001 & 2012 Codes of practice.

VI. SCOPE FOR FURTHER WORK

The following areas are identified as the scope of further research in this direction, based on the experience of the present work.

1) Further laboratory investigations can be carried out with the addition of various additives with the expansive soil along with molasses to improve strength characteristics.
2) Field tests are to be conducted to confirm the laboratory test results in the field.
3) Further laboratory Cyclic Plate Load tests can be conducted by using Geotextile as Reinforcement and Separator.

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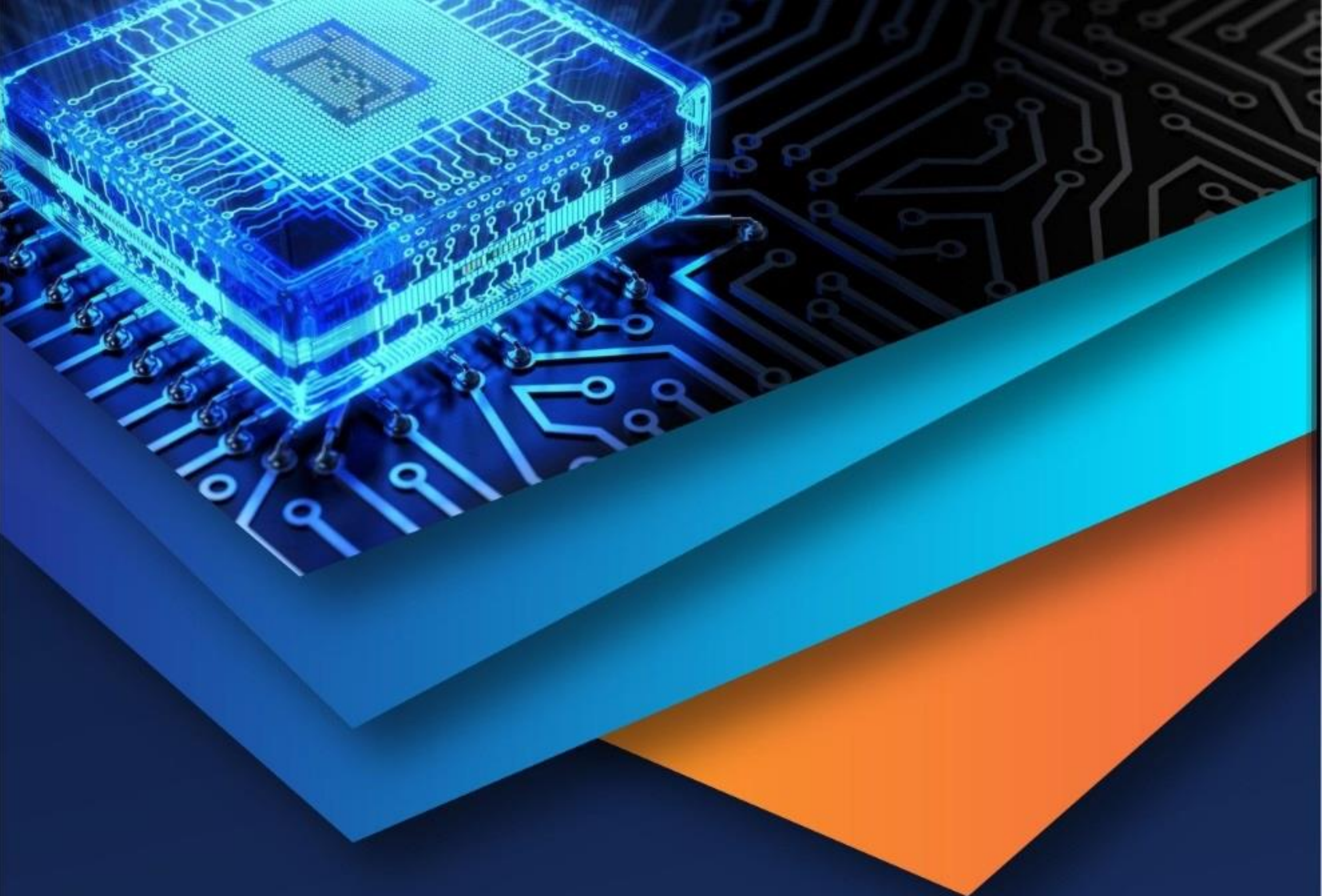

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