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

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Abstract
BC soil or extensive soil is otherwise called swelling soil. This kind of Black soils will found in Central states and a few areas of south India. The presence of this sort of soil is Black, subsequently they are called as Black cotton soils. This BCS are particularly helpful for developing Cotton. Generally expansive soils have unacceptable engineering properties like low bearing capacity and high compressibility. Thus the improvement of soil at a site is needed. There are so many stabilizers to stabilise the strength of expansive soil like Jute, gypsum, fly ash, rise- husk ash, cement, lime, used rubber tyres etc. In this thesis the Jute Fibre inserted as a stabilizer and Molasses as additive to improve the properties of Expansive soil. The objectives of this study are to improve shear strength of the expansive soil by mixing Jute Fibre and Molasses mixture. Addition stabiliser of Jute Fibre different lengths are using i.e 1cm, 2cm, 3cm, 4cm and different percentages of 0.5%, 1%, 1.5% and 2%. Another stabiliser is Molasses of varying percentage of 5%, 8%, 12%, 15%.

It is noticed from the laboratory investigations that the liquid limit, plastic limit and plasticity index of the Expansive soil has been decreased and maximum dry density and CBR by on addition of 12% Molasses and 1.5% Jute Fibre as an optimum when compared with untreated Expansive Soil. It was observed from laboratory cyclic load test results that the load carrying capacity of the treated Expansive soil sub grade flexible pavement has been Improved 62% when compared with untreated Expansive soil flexible pavement.The utilization of Construction wastes like Molasses is an alternative to reduce the construction cost of roads particularly in the rural areas of developing countries and also Jute Fibre will give good Reinforcement to Expansive soils.

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INTRODUCTION

A land based structure of any type is only as strong as its foundation. For that reason, soil is a critical element influencing the success of a construction project. Soil is either part of the foundation or one of the raw materials used in the construction process. Therefore, understanding the engineering properties of soil is critical to obtain strength and economic performance. Soil stabilization is the process of maximizing the suitability of soil for a given construction purpose.

Defining Soil Stabilization

What is Soil Stabilization?

Improving an on-site (in situ) soil's engineering properties is referred to as either "soil modification" or "soil stabilization." The term "modification" implies a minor change in the properties of a soil, while stabilization means that the engineering properties of the soil have been changed enough to allow field construction to take place.

Soil is one of nature's most abundant construction materials. Almost all constructions is built with or upon soil. When unsuitable construction condition are encountered, a contractor has 4 options

(1)Find a new construction site

(2)Redesign the structure so it can be constructed on the poor soil

(3)Remove the poor soil and replace it with good soil

(4)Improve the engineering properties of the site soils

In general, Options (1) and (2) tend to be impractical today, while in the past,

Option (3) has been the most commonly used method. However, due to improvement in technology coupled with increased transportation costs, Option (4) is being used more often today and is expected to dramatically increase in the future.

Why and when is it used?

Traditionally, stable sub-grades, sub-bases and/or bases have been constructed by using selected, well-graded aggregates, making it fairly easy to predict the load- bearing capacity of the constructed layers. By using select material, the engineer knows that the foundation will be able to support the design loading.

Gradation is an important soil characteristic to understand. A soil is considered either "well-graded" or "uniformly-graded" (also referred to as "poorly-graded"). This is a reference to the sizes of the particles in the materials. Uniformly-graded materials are made up of individual particles of roughly the same size. Well-graded materials are made up of an optimal range of different sized particles. The addition of lime slurry is a form of chemical soil.

It is desirable from an engineering standpoint to build upon a foundation stabilization of ideal and consistent density. Thus, the goal of soil stabilization is to provide a solid, stable foundation. "Density" is the measure of weight by volume of a material, and is one of the relied-upon measures of the suitability of a material for construction purposes. The more density a material possesses, the fewer voids are present. Voids are the enemy of road construction; voids provide a place for moisture to go, and make the material less stable by allowing it to shift under changing pressure temperature and moisture conditions.

Uniformly-graded materials, because of their uniform size, are much less dense than well-graded materials. The high proportion of voids per volume of uniformly- graded material makes it unsuitable for construction purposes. In well-graded materials, smaller particles pack in to the voids between the larger particles, enabling the material to achieve high degrees of density. Therefore, well-graded materials offer higher stability, and are in high demand for construction.

With the increased global demand for energy and increasing local demand for aggregates, it has become expensive from a material cost and energy use standpoint to remove inferior soils and replace them with choice, well-graded aggregates. One way to reduce the amount of select material needed for base construction is to improve the existing soil enough to provide strength and conform to engineering standards.

Essentially, soil stabilization allows engineers to distribute a larger load with less material over a longer life cycle. There are many advantages to soil stabilization:

•Stabilized soil functions as a working platform for the project
•Stabilization waterproofs the soil
•Stabilization improves soil strength and durability
•Stabilization helps reduce soil volume change due to temperature or moisture
•Stabilization improves soil workability
•Stabilization reduces dust in work environment
•Stabilization conserves aggregate materials
•Stabilization reduces cost and conserves energy

Applications

Soil stabilization is used in many sectors of the construction industry. Roads parking lots, airport runways, building sites, landfills, back fills, embankments and soil remediation all use some form of soil stabilization. Other applications include waterway management, mining, and agriculture

Advantages:

It improves the strength of the soil, thus, increasing the soil bearing capacity.

It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation.

It is also used to provide more stability to the soil in slopes or other such places.

Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.

Stabilization is also done for soil water-proofing; this prevents water from entering into the soil and hence helps the soil from losing its strength.

It helps in reducing the soil volume change due to change in temperature or moisture content.

Stabilization improves the workability and the durability of the soil.

METHODOLOGY

Laboratory investigations were conducted on the soil specimens in order to study the properties of soil and soil mixed with varying percentage of Jute fiber and varying percentage of molasses. The tests were conducted according to Indian standards IS: 2720. Different soil properties were listed as below.

Experimental Study

A brief literature on various problems posed by Expansive soil for the civil engineering structures have been discussed in the previous chapter. An outline of soil investigation and the test procedure adopted in the course of investigation are discussed in this chapter. This chapter also present the results obtained from various laboratory tests.

Variables taken for study

The study is carried out on Expansive soil, Expansive soil blended with molasses and Expansive Soil with optimum percentage of molasses Reinforced with jute fiber in the following percentages.
Molasses was varied in percentages of 5%, 8%, 12% and 15% by weight of

Expansive soil throughout the experiments.

To increase the CBR of molasses treated Expansive soil, jute Fiber was added in percentages of 0.5%, 1%, 1.5% and 2%.

Flow Chart Representing the Materials Used in the Project

RESULTS AND DISCUSSIONS

Introduction

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.

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

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

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

Jute Fibre Properties:

- 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 .
- Jute fibre is 100% bio-degradable and recyclable and thus environmentally friendly.
- Jute is a **natural fibre** with golden and silky shine and hence called The Golden Fibre.
- It has high tensile strength, low extensibility, and ensures better breathability of fabrics.
- jute Fibre will give good Reinforcement to Expansive soils.
- Abundant availability
- Superior durability, Jute Fibre can perfectly shape itself to ground contours.
- High moisture/water absorbing capacity. Jute Fibre can absorb moisture/water up to about 5 times its dry weight.
- High initial strength
- 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

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

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

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

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

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

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

Discussion-2

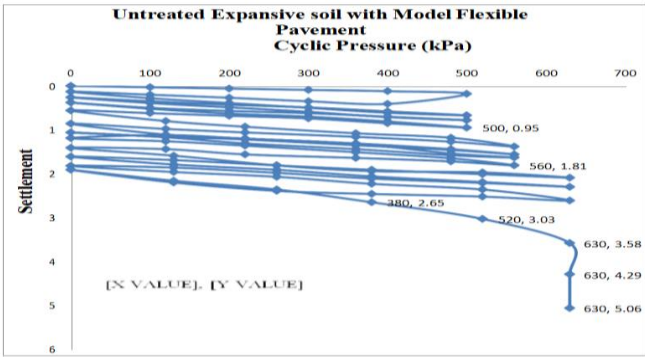
From the above study, 12% Molasses treated Expansive soil has exhibited the CBR value of 6.11% on addition of 1.5% Jute Fibre as an optimum. Hence this treated Expansive soil is suitable as sub grade for flexible pavements as per IRC 37-2001 and 37- 2012 codes of practice.

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.

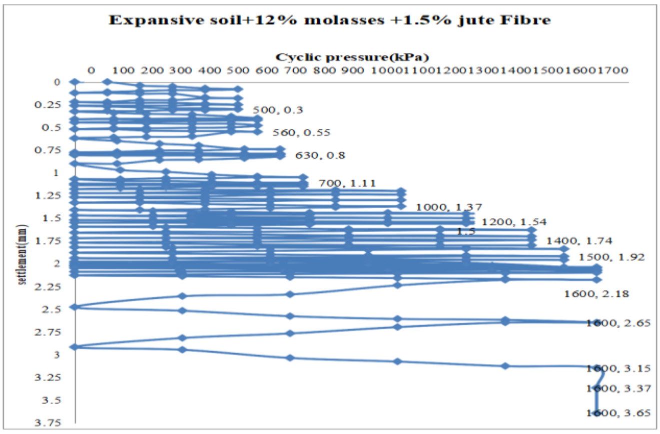


Figure Laboratory Cyclic Plate Load Test results of Expansive soil treated with 12% molasses + 1.5% Jute Fibre

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

Conclusions:

Modern pavements are expected to provide a high level of safety and comfort for their users. Pavements are commonly designed using a combination of mechanistic and empirical approaches. These methods involve selecting the appropriate soil and pavement parameters and then calculating layer thickness for the sub base, base and the concrete pavement as appropriate. With any method, a strength parameter is used to describe the sub grade or native material beneath the pavement layers. Sub grade materials vary from soft soils to rock. Variations in the sub grade, even over short distances, are inevitable and can occur abruptly or gradually, depending on the geological history of the surface soils. A high variability in sub grade soil characteristics may dictate the use of conservative estimates that may lead to thicker pavements with higher construction costs or poor performance and higher maintenance costs. In order to alleviate these problems, methods have been developed to try and minimize the variability in sub grade characteristics.

In order to improve the engineering behavior of soils, several improvement techniques are available in geotechnical engineering practice. The fact that the selection of any one of these methods for any problem can be made only after a comparison with other techniques proves that the method is well suited for a particular system. In fine -grained soils chemical stabilization methods and reinforcement techniques are well suited to improve their engineering behaviour and to make them less sensitive to environmental factors.

However, these and many other techniques were successful only to a partial extent and hence the attempts to devise better techniques are still on. In addition, majority of these works have been confined to laboratory, under controlled conditions on re-moulded samples and hence fail to simulate many of the field conditions. Despite years of practice and research, an economical and satisfactory solution to the problems posed by the expansive soil, continues to elude researchers and practicing engineers.

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%

➢ It is noticed from the laboratory investigations that the liquid limit of the Expansive soil has been decreased by 17.64% on addition of 12% molasses and further the liquid limit of molasses treated Expansive soil has been decreased by 35.59% with the addition of 1.5% jute Fibre as an optimum when compared with untreated Expansive Soil.

- It is observed from the laboratory investigations that the plastic limit of the Expansive soil has been decreased by 20.68% on addition of 12% molasses and further the plastic limit of molasses treated Expansive soil has been decreased by 64.93% with the addition of 1.5% jute Fibre as an optimum when compared with untreated Expansive Soil.
- It is observed from the laboratory investigations that the plasticity index of the Expansive soil has been decreased by 15.38% on addition of 12% molasses and further the plasticity index of molasses treated Expansive soil has been decreased by 18.76% with the addition of 1.5% jute Fibre as an optimum when compared with untreated Expansive soil.
- It is found from the laboratory investigations that the optimum moisture content of the Expansive soil has been decreased by 30.55% on addition of 12% molasses and further the optimum moisture content of molasses treated Expansive soil has been decreased by 77.14% with the addition of 1.5% jute Fibre as an optimum when compared with untreated Expansive soil.
- It is found from the laboratory investigations that the maximum dry density of the Expansive soil has been increased by 2.57% on addition of 12% molasses and further the maximum dry density of molasses treated Expansive soil has been increased by 14.08% with the addition of 1.5% Jute Fibre as an optimum when compared with untreated Expansive soil.
- It is observed from the laboratory investigations that the Soaked C.B.R. value of the Expansive soil has been increased by 106% on addition of 12% molasses and further the Soaked C.B.R of jute fibre treated Expansive soil
has been increased by 208% with the addition of 1.5% Jute Fibre as an optimum when compared with untreated Expansive soil.
- It is noticed from the laboratory investigations of the cyclic plate load test results that, the ultimate cyclic pressure of treated Expansive soil subgrade flexible pavement has been improved by 620kPa to 1000Pa when compared with untreated Expansive soil.
- It is noticed from the laboratory investigations of the cyclic plate load test results that, the total deformations of treated marine clay subgrade flexible pavement with has been improved by 24.30% when compared with Expansive soil.
- It was observed from laboratory cyclic load test results that the load carrying capacity of the treated Expansive soil sub grade flexible pavement has been Improved 154% when compared with untreated Expansive soil flexible pavement.
- The soaked CBR values of Expansive soil on stabilizing treated with molasses and jute Fibre was found to be 208% and it is satisfying standard specifications. So finally it is concluded from the above results that molasses and jute Fibre can potentially stabilize the Expansive soil.
- The utilization of Construction wastes like molasses is an alternative to reduce the construction cost of roads particularly in the rural areas of developing countries and also jute Fibre will give good Reinforcement to Expansive soils.

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.

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.

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

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