International Journal for Innovative Engineering and Management Research

A Peer Revieved Open Access International Journal

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IJIEMR Transactions, online available on 4th Dec 2018. Link

:http://www.ijiemr.org/downloads.php?vol=Volume-07&issue=ISSUE-12

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Volume 07, Issue 12, Pages: 915–922.

Paper Authors

POTHULASARATH KUMAR, P.MEHER LAVANYA

Kakinada institute of engineering & Technology-II

International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
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A LABORATORY STUDY ON EXPANSIVE SOIL USING SOIL STABILIZATION TECHNOLOGY WITH NATURAL PLANT FIBER AND FERRIC CHLORIDE FOR PAVEMENT SUBGRADE

POTHULASARATH KUMAR[1], P. MEHER LAVANYA[2]
[1]PG scholar, Department of civil engineering, Kakinada institute of engineering & Technology-II
[2]Assistant Professor, Head of the Department Civil engineering, Kakinada institute of engineering & Technology-II

ABSTRACT
Expansive soils are a worldwide problem especially in the regions where climate is arid or semi-arid. These soils swell when they are exposed to water and shrink when they dry. Cyclic swelling and shrinkage of clays and associated movements of foundations may result in cracking of structures. Several methods are used to decrease or prevent the swelling potential of such soils like pre-wetting, surcharge loading, chemical stabilization etc. Among these, one of the most widely used methods is using chemical admixtures (chemical stabilization). Cyclic wetting and drying affects the swell – shrink behaviour of expansive soils. Banana fibre is natural biodegradable material abundantly available in some parts of south and coastal regions of India. In present work, experimentation was carried out to investigate the efficiency banana fibre and ferric chloride in stabilizing the marine clay. There by improving the swelling characteristics of expansive soil. A systematic methodical process was followed involving experimentation in the laboratory under controlled conditions. The physical & chemical properties, the strength characteristics and also the load carrying capacity of expansive soil have been determined in this study before and after stabilization with banana fibre and ferric chloride. The main objective of this study is to investigate use of materials such as banana fibre and ferric chloride in geotechnical applications. Various tests such as Proctor Compaction test (OMC & MDD), California Bearing Ratio (CBR), unconfined compression test (UCC) and Cyclic Plate Load test were carried out and the results are analysed. From the test results a considerable improvement was observed for the treated Marine Clay with 0.75% Banana Fiber + 1% ferricChloride as reinforcement to compare with all other treatments tried in this investigation.

INTRODUCTION
The soils which show volumetric changes due to changes in their moisture content are referred to as swelling soils. Some partially saturated soils are very sensitive to variations in water content and showexcessive volume changes. Such soils, when they increase in volume because of an increase in their water contents, are classified as expansive soils.Problem of expansive soils has appeared as cracking and break-up of pavements, railways, highway

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embankments, roadways, building foundations, slab on-grade members and, channel and reservoir linings, irrigation systems, water lines, sewer lines. (Gromko, 1974; Wayne et al. 1984; Mowafy et al. 1985; Kehew, 1995)It is reported that damage to the structures due to expansive soils has been the most costly natural hazard in some countries. In the United States damage caused by expansive clays exceeds the combined average annual damage from floods, hurricanes, earthquakes, and tornadoes (Jones and Holtz, 1973). Documented evidence of the problems associated with expansive clays is worldwide, having occurred in such countries as the United States, China, Australia, India, Canada, and regions in Europe. (Popescu, 1986) It is reasonable that studies on the problem of expansive soils become more important day by day if the durative deficit of world resources and economy is taken into consideration. (Cited in Ipek, 1998) When geotechnical engineers are faced with expansive soils, the engineering properties of those soils may need to be improved to make them suitable for construction. (Muntohar and Hantoro, 2002) A substantial literature has concluded this severity an extent of damage inflicted by soil deposits of swelling nature, to various structures, throughout the world (Ganapathy, Joneqs and Jones, Abduljauwad, Osama and Ahmed, Zhang).

TABLE:1 PROPERTIES OF EXPANSIVE SOILS (Katti, 1979)

SL.NO	DESCRIPTION	RANGE OF VALUE (%)
1	Specific Gravity	2.7-2.9
2	Sand fraction (%) (0.075-4.5mm)	1-26
3	Silt fraction (%) (0.002-0.075mm)	17-43
4	Clay fraction (%) (<0.02mm)	32-70
5	Liquid limit (%)	40-100
6	Plastic limit (%)	20-50
7	Shrinkage limit (%)	8-18
8	Plasticity index (%)	20-50
9	Maximum dry density(t/m^3)	1.3-1.7
10	Optimum moisture content (%)	18-30
11	Soil group symbol (I.S)	CH
12	Colour	Dark grey to Black
13	Degree of shrinkage (wet volume)	40-50
14	Volumetric shrinkage (dry volume)	200-300
15	Size of shrinkage cracks (%) (In summer)	10cm (wide), 3m (deep)
16	Volumetric expansion (Rainy season)	60% (In horizontal) 30% (In vertical)
17	Free Swell Index (%)	70-300
18	Swell Potential (%)	1-15
19	Swelling Pressure (%)	0.5-1.0
20	Safe Bearing Capacity (t/m3)	5-7.5
21	SiO2 (%)	45-58
22	Al2O3	13-18
23	CaO (%) &MgO (%)	1-8 & 2-5 respectively
24	pH Value	8-8.5

LABORATORY IDENTIFICATION

Laboratory identification tests for expansive soils includes grain size analysis, Atterberg limits, swelling pressure, free swell index test etc as per IS codes. The range of N physical properties of swelling soils is as follows:

Liquid Limit 40 – 100% (exceptionally high for Bentonite)

Plastic Limit 20-60%

Shrinkage Limit 6-18%

Free swell Index 20-150%

Montmorillonite is the prime mineral, which causes the problem of swelling and shrinking. Further, the swelling characteristics depend upon the structure of the clay mass and the cation change capacity of the mineral. Hence it is necessary to evaluate the swelling

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potential of clay mineral. In order to estimate the swelling potential of expansive soils, the following laboratory tests are conducted.Free swell test to determine the volume change of the soil.Swelling pressure test to evaluate the development of swelling pressure if no volume change of soil is allowed.

PINCIPLES OF SOIL STABILIZATION

Evaluating the soil properties of the area under consideration.

Deciding the property of soil which needs to be altered to get the design value and choose the effective and economical method for stabilization

Designing the stabilized soil mix sample and testing it in the lab for intended stability and durability values.

METHODS OF STABILIZATION

The basic methods of soil stabilization are

a. Mechanical stabilization
b. Cement stabilization
c. Lime stabilization
d. Bituminous stabilization
e. Chemical stabilization
f. Thermal stabilization

EXPERIMENTAL STUDY

In this chapter, a brief description of the experimental procedures adopted in this investigation and the methodology adopted during the course of study are briefly presented.

- The experimental work consisted of the characterization of the soils and the evaluation of the effect of various percentages of banana fibre and Ferric chloride.
- The Geotechnical properties of soil such as Atterberg limits, Free Swell Index, Compaction test, California Bearing Ratio, Tri-axial test and Unconfined compressive strength tests were conducted to determine the properties of expansive soil.
- It can be observed that specific Gravity of soil is very low due to the presence of organic matter.
- Compaction Test and California Bearing Ratio were conducted for stabilized soils and results were analyzed.

BANANA FIBRE: It is a natural fibre obtained from banana plant. This fibre is obtained mainly from pseudo stem which acts as a strong fibre after dried properly. It is a fibre with appropriate stiffness and good mechanical properties

TABLE:2 Properties of Banana Fibre

S.No	Properties	Values
1.	Colour	Light Brown
2.	Average diameter(mm)	0.75
3.	Average length (mm)	15
4.	Average tensile strength (N/mm^2)	11
5.	Fiber Density (g/cc)	0.62

Ferric Chloride ($FeCl_3$): Ferric chloride is an orange to brown-black solid. Ferric chloride is completely soluble in water. Ferric chloride is non-combustible. Ferric chloride is corrosive to aluminium and most metals when it is wet. From earlier studies it was found that $FeCl_3$ was quite effective in minimizing swelling of expansive soils.

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Table 3: Properties of Ferric Chloride

Property	Value
Molar Mass	162.2 g/mol (anhydrous)
Crystal structure	hexagonal
Appearance	Orange-brown black by reflected light and purple-red by transmitted light
Odor	Slight HCL
Density	2.898 g/cm^3 (anhydrous), 1.82 g/cm^3 (hexahydrate)
Melting Point	306 ^{0}C anhydrous 37 ^{0}C hexahydrate
Boiling Point	315 ^{0}C (anhydrous) 280 ^{0}C (hexahydrate)
Viscosity	40% solution

Gravel:For The gravel was classified as well graded gravel and was used in this investigation as a gravel cushion on untreated, treated & reinforced marine clay foundation soil bed and also as a subbase course in all model flexible pavements. the properties of gravel were presented and it was used as subbase in foundation beds and as a cushion in foundation soil beds.

LABORATORY EXPERIMENTATION

TABLE:4 Properties of gravel

S.NO	Property	Values
1	Specific gravity	2.82
2	**Grain size Distribution**	
	Gravel (%)	62
	Sand (%)	28
	Silt & clay (%)	10
3	**Compaction properties**	
	Maximum dry density (g/cc)	1.98
	OMC (%)	12.90
4	**Atterberg limits**	
	Liquid limit (%)	24
	Plastic limit (%)	17
	Plasticity index (%)	7
5	Soaked CBR (%)	7.80

Different tests were conducted in the laboratory on the expansive soil to study the behaviour of expansive soil, when it is treated with Banana fibre along with Ferric chloride. The following tests were conducted as per IS code of practice.

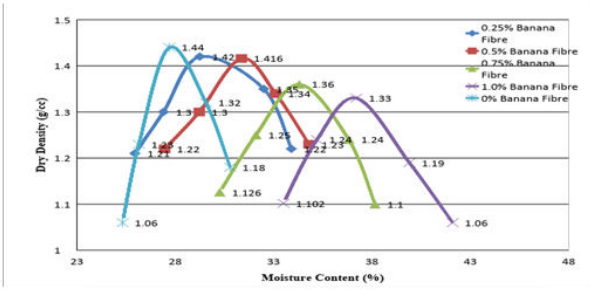
1. Specific Gravity
2. Grain Size Analysis
3. Differential Free swell
4. Atterberg's Limits (LL, PL & PI)
5. Compaction Parameters (OMD & MDD)
6. California Bearing Ratio (CBR)
7. Unconfined Compressive Strength (UCS)
8. Plate load test

CYCLIC PLATE LOAD TESTCONSTRUCTION DETAILS OF DIFFERENT MODEL FLEXIBLE TABLE:5 PAVEMENTS IN LABORATORY

S.No	Type of Sub-grade	Sub-base	Base Course
1	Expansive soil	----	------
2	Untreated Expansive soil	Gravel	WBM-III
3	Expansive soil + 1% BF + 1% $FeCl_3$	Gravel	WBM-III

TABLE:6 OMC and MDD values of expansive soil treated with percentage variation of Banana fibre

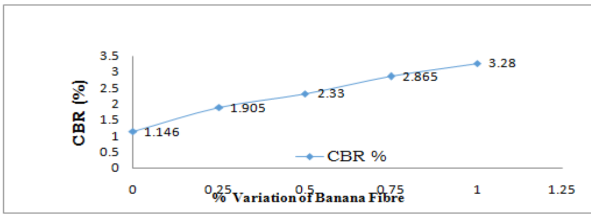
S.No	Mix Proportion	OMC (%)	MDD (g/cc)
1	100% soil + 0 % BF	27.69	1.445
2	99.75% soil + 0.25% BF	29.24	1.42
3	99.5% soil + 0.5% BF	31.36	1.416
4	**99.25% soil + 0.75% BF**	**34.3**	**1.36**
5	99.0% soil + 1.0% BF	37.21	1.33



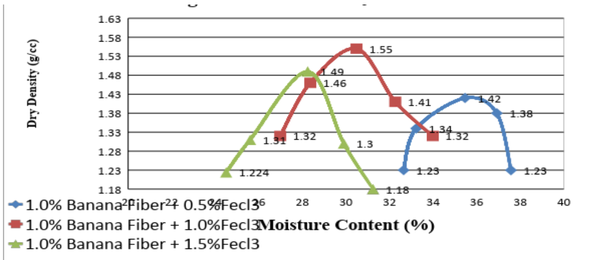
OMC and MDD values of expansive soil treated with percentage variation of Banana fibre

TABLE:7 CBR values of expansive soil treated with percentage variation of BF

S.No	Mix proportion	OMC (%)	Soaked CBR (%)
1	100 % soil	27.69	1.146
2	99.75 % soil + 0.25% BF	31.24	1.905
3	99.50% soil + 0.5% BF	34.36	2.330
4	99.25 % soil + 0.75 % BF	39.30	2.865
5	**99.0 % soil + 1.0 % BF**	**43.21**	**3.280**



CBR values of expansive soil treated with percentage variation of BF



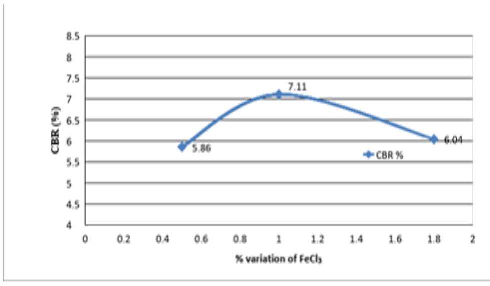
OMC and MDD values of BF treated expansive soil with percentage variation of $FeCl_3$.

TABLE8 OMC and MDD values of BF treated expansive soil with percentage variation of $FeCl_3$.

Mix Proportion	OMC (%)	MDD (g/cc)
98.50% ES +1.0% BF +0.50% $FeCl_3$	35.46	1.42
98.00% ES +1.0% BF +1.00% $FeCl_3$	**30.48**	**1.55**
97.50% ES +1.0% BF +1.50% $FeCl_3$	28.24	1.49

TABLE:9 CBR values of Banana fibre treated expansive soil with percentage variation of Ferric chloride.

Mix Proportion	CBR value (%)
98.50% ES + 1.0% BF + 0.50% $FeCl_3$	5.86
98.0% ES + 1.0% BF + 1.00% $FeCl_3$	**7.11**
97.50% ES + 1.0% BF + 1.50% $FeCl_3$	6.04



CBR values of Banana fibre treated expansive soil with percentage variation of Ferric chloride.

TABLE:10 Expansive soil with optimum % of Banana Fibre and $FeCl_3$

S.No	Property	Expansive soil	99.0 ES +1.0% BF	98.0 ES+1.0% BF + 1.00% $FeCl_3$
1.	Atterberg limits			
	Liquid limit (%)	74	65.35	61.0
	Plastic limit (%)	36	39.35	41.26
	Plasticity index (%)	38	26.0	19.74
2.	Compaction properties			
	O.M.C (%)	27.69	37.21	30.48
	M.D.D (g/cc)	1.445	1.33	1.55
3.	Specific Gravity (G)	2.68	2.72	2.789
4.	IS Classification	CH	CH	CH
5.	**Soaked C.B.R (%)**	1.146	3.28	7.11
6.	Free swell (%)	140	92	48
7.	Cohesion (C) (Kg/cm²)	0.58	0.94	0.98
8.	Angle of internal friction (ø)	2°	4°2'	5°08'

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LABORATORY CYCLIC PLATE LOAD TEST RESULTS OF TREATED AND UNTREATED TABLE:11 EXPANSIVE SOIL FOR FLEXIBLE PAVEMENTS AT OMC.

S.NO	Sub-grade soil	Gravel Cushion	Sub- Base	Ultimate cyclic load (kN/m²)	Settlements (mm)
1	Untreated Expansive soil	Gravel	WBM III	67.12	3.02
2	Treated expansive soil with 1% BF	Gravel	WBM III	160.72	2.53
3	Expansive soil treated with 1% BF and 1%$FeCl_3$	Gravel	WBM III	1016	2.23

CONCLUSIONS

1. From the laboratory studies, it was observed that the Free Swell Index of the expansive clay has been **decreased** by 34% with the addition of 1% BF when compared with the untreated expansive soil.
2. It was also observed that the Free Swell Index of the expansive clay has been further **decreased** by 47.8% with addition of Ferric Chloride to the BF treated expansive soil.
3. From the laboratory studies, it was observed that the liquid limit of the expansive soil has been **decreased** by 11.68% with the addition of 1% BF when compared with the untreated expansive soil.
4. It was also observed that the liquid limit of the expansive soil has been **decreased** by 6.65% with the addition of Ferric Chloride to the 1% BF treated expansive soil.
5. From the laboratory studies, it was observed that the plastic limit of the expansive clay has been **increased** by 9.35% with the addition of 1% BF when compared with the untreated expansive soil.
6. It was also observed that the plastic limit of the expansive clay has been further **increased** by 4.8% with the addition of Ferric Chloride to the 1% BF treated expansive soil.
7. It was observed that the CBR value **increased** by 186.2% on addition of 1% BF and further improvement was observed that 116.4% increased when treated with optimum values of Ferric Chloride when compared with untreated expansive soil.
8. It was observed from the laboratory results that the shear strength parameters of expansive soil are **improved** with the addition of Banana Fibre along with optimum percentages of Ferric Chloride.
9. It was concluded from the laboratory investigation that the CBR values of expansive soil treated with 1% BF + 1% Ferric Chloride exhibits better results.
10. It was observed from the laboratory Static Plate Load Test results, that the ultimate load carrying capacity of the 1% BF treated expansive soil foundation bed has been **improved** by 82% when compared with the untreated expansive soil foundation bed.
11. It was observed from the laboratory Cyclic Plate Load Test results, that the ultimate load carrying capacity was further **improved** by 175% with 1% BF + 1% $FeCl_3$treated expansive soil foundation bed when compared with the untreated expansive soil foundation bed.
12. Hence, from all the above observations, it was concluded that the 1% Ferric Chloride along with 1% BF treated expansive soil

exhibits better and satisfactory results.

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Author Details

Pothula Sharath[1],
Prince.sarath.kumar@gmail.com
1 PG scholar, Department of civil engineering, Kakinada institute of Engineering & Technology-II,
P. Mehar Lavanya[2]
Lavanyacivil19@gmail.com
2 Assistant Professor, Head of the Department Civil engineering, Kakinada institute of Engineering & Technology-II