International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 5, Issue 10, October-2019

A LABORATORY STUDY ON IMPROVING THE PROPERTIES OF THE MARINE CLAY USING SEASHELL POWDER AND FERRIC CHLORIDE TO SUITE IT AS A SUBGRADE FOR FLEXIBLE PAVEMENTS

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Abstract— Transportation is the artery through which Indian economy grows. For the sake of Transportation, roads play vital role, for this there is a need of well-prepared pavements to bare all moving vehicular loads. In India, The available costal corridor is of 7516.6 km. This coastal region mostly consists of marine clay deposits. Using locally available soils and materials for the construction of roads is more economical. But in coastal region, using marine clay (locally available soil) as sub grade will not yield desirable results due to its poor engineering properties. Replacement of the soil is not economically feasible as it increases the cost of the project. As the coastal region consists of huge quantity of sea shells which are having high percentage of CaO, hence, grinded sea shells (Seashell Powder) can be used as stabilizing material. In the present study, under controlled conditions, sea shell powder as an admixture and ferric chloride as an additive are used to enhance the engineering properties of marine clay to suit it as the sub grade for flexible pavements.

Keywords— Marine Clay, Seashell Powder, Ferric Chloride ($Fecl_3$), Maximum Dry Density (MDD), Optimum Moisture Content (OMC), California Bearing Ratio (CBR).

1. INTRODUCTION

The pavement service depends upon the subgrade of the pavement. Sub grade is the main constituent of the pavement for caring the loads. So, it is necessary to check the required properties of the sub grade to bear the designed traffic. Otherwise, the service of the pavement gets gradually decreased. To resolve this problem, different methods have been developed to minimize the variability in sub grade characteristics. Marine clay is one of the problematic soils which can be found on coastal region. Marine clays are microcrystalline in nature and it has clay minerals like illite, chlorite and kaolinite. Marine clay tends to become stiff on drying, but it becomes very soft on wetting. Naturally the marine clay suffers from High compressibility and low shear strength. Due to the poor properties the marine clay, it has to be pre-treated to suit it as the sub grade in pavements. In general, for improving soft soils, various technics may be used viz remove and replace the soil, stabilizing the base materials using various by-products & chemicals and also by using reinforcement technical to suit it as foundation beds and subgrade for flexible pavements. Replacement of soil increases cost of the project. It is well known fact that the economy of the project should be consider.

In present study, sea shell powder and ferric chloride are added to marine clay to evaluate its performances through laboratory tests such as standard proctor test and California bearing ratio strength test.

2. REVIEW OF LITERATURE

Dr.D.Koteswara Rao et al., (2011) studied the properties of marine clay before and after the treatment with GGBS. The effect of rice husk ash & lime on the properties of Marine Clay has been studied by Dr.D.Koteswara Rao (2012). Dr.D.Koteswara Rao (2013) stated that the vitrified polish waste improves the properties of marine clay. The effect of sea shell powder on black cotton soil was investigated by K. Mounika et al., (2014). S.Siva Gowri Prasad, Y.Harish (2015**)** studied the stabilization of marine clay with geotextile reinforced stone columns using silica-manganese slag as a stone column material. G.Bisanal et al., (2015) stated that addition of Sea Shell powder to the black cotton soil, reduces its plastic indices significantly. DSV Prasad et al., (2016) reported that the deformation and load carrying capacity of treated marine clay improved greatly when the Marine Clay was treated with quarry dust as an admixture and Ferric chloride as an additive.

3. OBJECTIVES OF STUDY

The objectives of present experimental study are as follows

- To determine the properties of the Marine Clay
- To evaluate the performance of the marine clay when stabilized with sea shell powder as an admixture.
- To study the impact of Sea shell powder as an admixture and Ferric Chloride as an additive on the properties of marine clays through laboratory experimentations to suit it as a subgrade for flexible pavements.

4. MATERIAL USED

A. Marine clay (MC)

Marine clay was collected from a dredging site, where dredging was carried out at a depth of 2-4 m below the Sea water level in Kakinada Sea Ports ltd, Kakinada. The collected samples were black in color. The presence of sea shells in the marine clay indicated the presence of organic content.

TABLE-1
GEOTECHNICAL PROPERTIES OF THE UNTREATED MARINE CLAY

S.No	Properties		Marine clay
1	Soil classification	Gravel (%)	0
		Sand (%)	8.50
		Silt (%)	16.80
		Clay (%)	74.70
2	Liquid limit (%)		78.10
3	Plastic limit (%)		28.66
4	Plasticity index (%)		49.44
5	Soil classification		CH
6	Specific gravity		2.33
7	Differential free swell (%)		95
8	MDD(g/cc)		1.393
9	OMC (%)		32.20
10	CBR (%)		1.360
11	Cohesion (kN/m^2)		90
12	Angle of internal friction (^{0}), Φ		3.42

B. Sea shell powder

The sea shells were collected from local seafood vendor in Kakinada. The shells were cleaned, dried, burnt in brick furnace, crushed into small pieces using Los Angeles machine, then grounded with a blender, and sieved using 150 micron sieve to produce seashell powder. The shells were burnt at high temperature of 500^0C for a period of 3 days. The sea shell powder mainly consists of 51.56% CaO and 1.60% SiO2.

TABLE 2
CHEMICAL COMPOSITION OF SEA SHELL POWDER

S.No	Oxide	Percentage
1	SiO_2	1.60
2	Al_2O_3	0.92
3	CaO	51.56
4	MgO	1.43
5	Na_2O	0.08
6	K_2O	0.06
7	H_2O	0.31
8	LOI	41.84

Courtesy to Monita Oliviaa, Annisa Arifandita Mifshella, Lita Universities Riau, Kampus Bina Widya Simpang Baru, Pekanbaru Riau 28293, Indonesia

C. Ferric Chloride

Ferric chloride is the inorganic compound with the formula. It is also called as Iron (III) chloride, it is a common compound of iron in the +3 oxidation state. Ferric chloride is used as coagulants or flocculants for odour control, phosphorus removal and hydrogen sulphide minimization. The commercial product is available in powder form.

5. LABORATORY STUDIES

The laboratory investigation was carried out on the Marine clay, Marine clay treated with various percentages of sea shell powder and Marine clay treated with optimum percentage of seashell powder on percentage variation of ferric chloride for obtaining the mix of marine clay with the optimum percentage of sea shell powder & ferric chloride.

Liquid limit

Liquid limit test was performed on the untreated Marine clay, Marine clay treated with an optimum of 18% seashell powder, and Marine clay treated with an optimum of 18% seashell powder on addition of 1.50% of ferric chloride as an optimum, using Casagrande's liquid limit apparatus as per the procedures presented in IS: 2720 part 4 (1970).

Plastic limit

Plastic limit test was performed on the untreated Marine clay, Marine clay treated with an optimum of 18% seashell powder, and Marine clay treated with an optimum of 18% seashell powder on addition of 1.50% of ferric chloride as an optimum, as per the procedures presented in IS: 2720 part 4 (1970).

Differential free swell

Differential free swell was performed on the untreated Marine clay, Marine clay treated with an optimum of 18% seashell powder, and Marine clay treated with an optimum of 18% seashell powder on addition of 1.50% of ferric chloride as an optimum, as per the procedures presented in IS: 2720 part 40 (1979).

Modified proctor compaction Test

The optimum moisture content and maximum dry density have an important role in changing the strength properties of clay. Preparation of soil sample for proctor's compaction test was done as per IS: 2720 part-6 (1974).

Specific Gravity Test

Specific gravity is the ratio of the mass of unit volume of soil at a stated temperature to the mass of the same volume of gas free distilled water at a stated temperature. The specific gravity of a soil is used in the phase relationship of air, water, and solids in a given volume of the soil. Specific gravity test was carried out by Pycnometer as per IS 2720 Part 3 (1980).

California Bearing Ratio Test

The California bearing ratio tests are conducted on the untreated Marine clay, Marine clay treated with an optimum of 18% seashell powder, and Marine clay treated with an optimum of 18% seashell powder on addition of 1.50% of ferric chloride as an optimum, as per IS 2720 part 16 (1979).

6. Results and discussion

1. Modified proctor test and CBR test values of the Marine clay treated with various percentages of Sea Shell Powder

(A) Modified proctor test results of marine clay when treated with various percentage of Sea Shell Powder are given in table 3 and figure 1 & 2 present the OMC and MDD values of the untreated and treated marine clay.

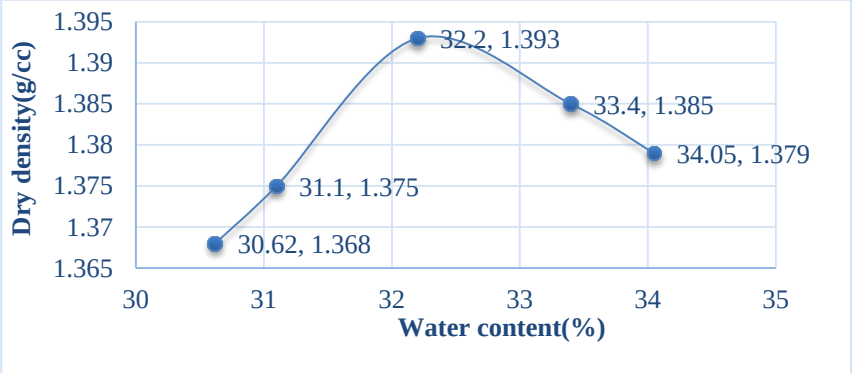

Fig.1 OMC and MDD Values of the Untreated Marine Clay

TABLE. 3
OMC AND MDD VALUES OF UNTREATED AND TREATED MARINE CLAY

Mix	OMC (%)	MDD(g/cc)
100% MC	31.97	1.382
MC +5% SSP	31.20	1.486
MC +10% SSP	28.06	1.533
MC +15% SSP	24.12	1.565
MC +18% SSP	23.46	1.567
MC +20% SSP	25.65	1.552

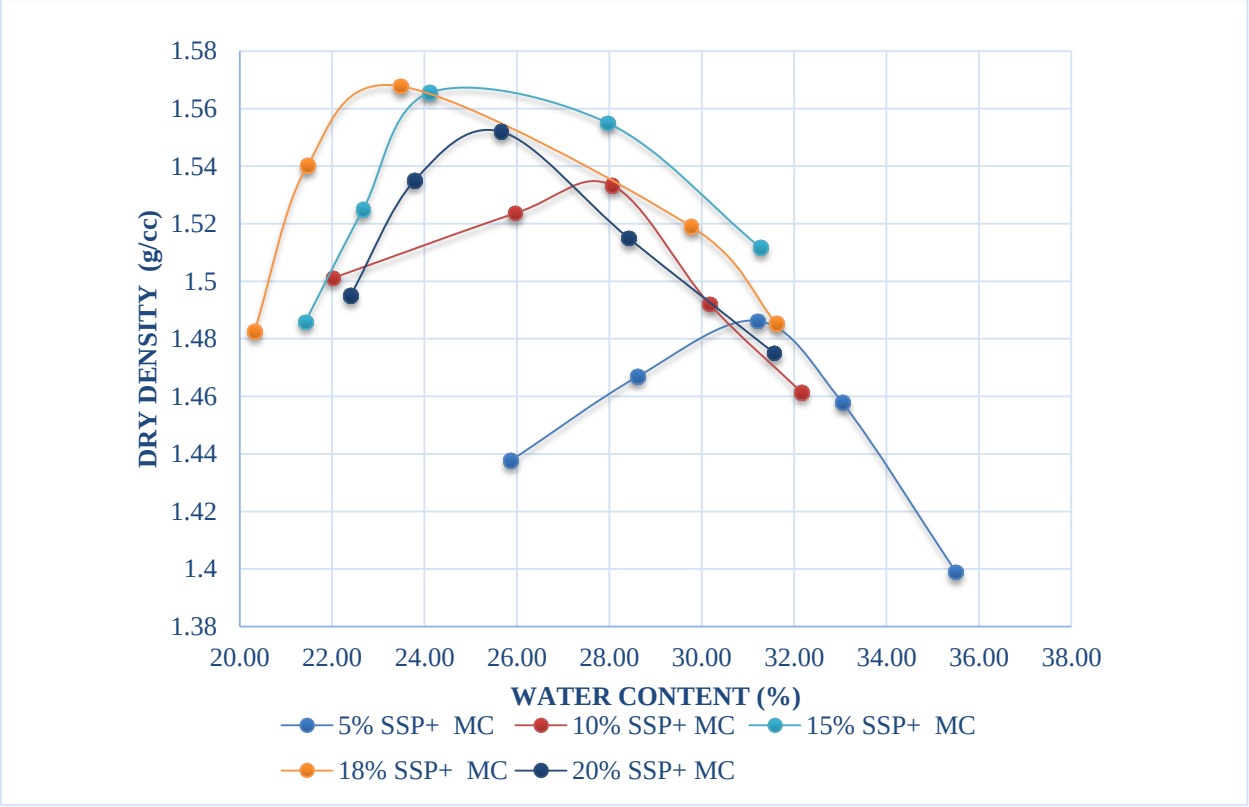

Fig.2 OMC and MDD values of the marine clay treated with various percentages of SSP

B) CBR Values

Table 4 and fig. 6 present the CBR values of the marine clay treated with various percentages of the Sea Shell Powder.

TABLE. 4
CBR VALUES OF THE UNTREATED AND TREATED MARINE CLAY ON PERCENTAGE VARIATION OF SEA SHELL POWDER

Mix	CBR (%)
100% MC	1.344
MC +5% SSP	1.792
MC +10% SSP	2.913
MC +15% SSP	3.809
MC +18% SSP	**4.257**
MC +20% SSP	3.585

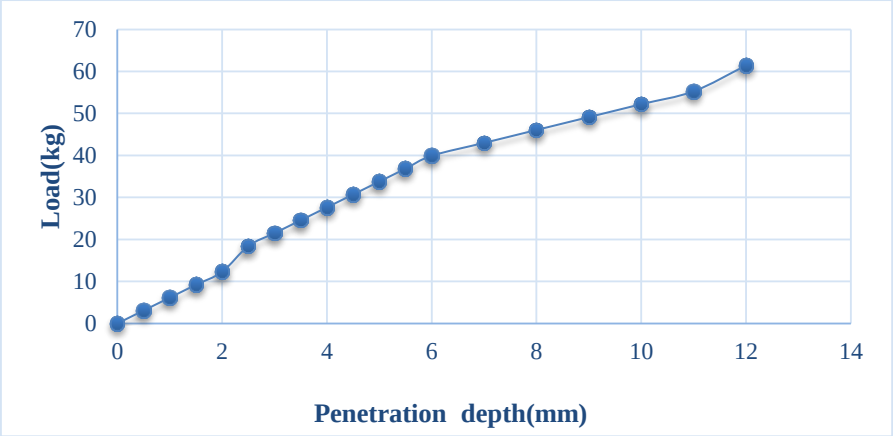

Fig.3 CBR values of the untreated marine clay

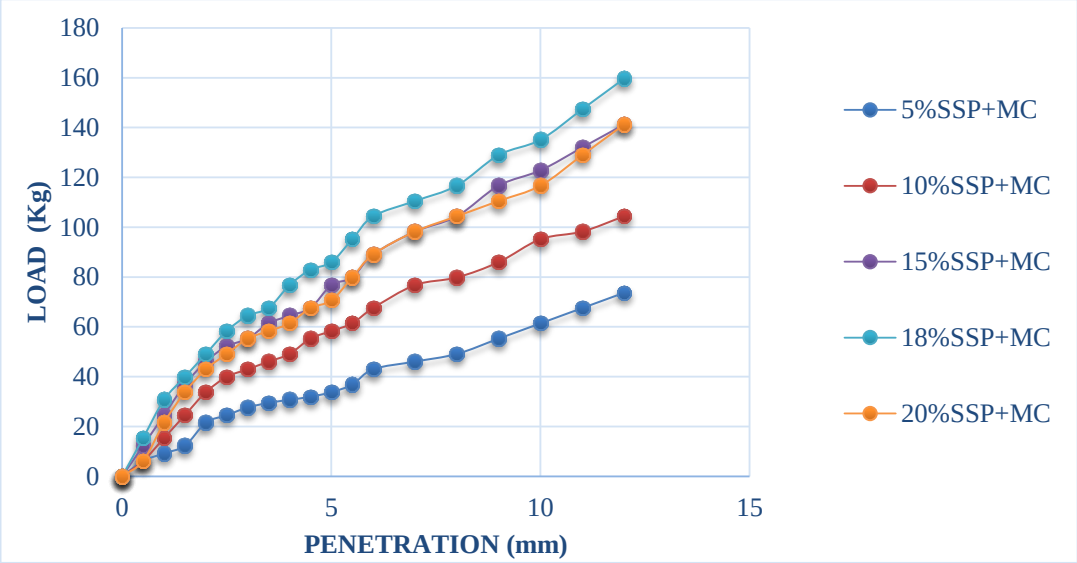

Fig.4 CBR values of the treated marine clay on percentage variation of SSP

DISCUSSION-1

It was observed from the above laboratory test results that the CBR value of the marine clay has been improved effectively from 1.36% to 4.257% on addition of 18% of Sea sell powder as an optimum. But as per IRC Code 37- 2012 the minimum required CBR value of the sub grade soil should be 8%.

Further, an attempt has been taken to improve the CBR value of this treated marine clay by addition of percentage variation of ferric chloride as an additive.

2. OMC, MDD and CBR values of the marine clay treated with an optimum of 18% Sea Shell Powder on percentages variation of the Ferric Chloride.

A. Table. 5 and fig. 5 present the OMC & MDD values of the marine clay treated with an optimum of 18% Sea Shell Powder on percentages variation of the Ferric Chloride.

TABLE. 5
OMC & MDD VALUES OF THE MARINE CLAY TREATED WITH AN OPTIMUM OF 18% SEA SHELL POWDER ON PERCENTAGES VARIATION OF THE FERRIC CHLORIDE.

Mix	OMC (%)	MDD(g/cc)
MC + 18% SSP + 0.50 $FeCl_2$	23.43	1.572
MC + 18% SSP + 1.00 $FeCl_2$	23.20	1.589
MC + 18% SSP + 1.50 $FeCl_2$	**22.99**	**1.622**
MC + 18% SSP + 2.00 $FeCl_2$	23.04	1.596

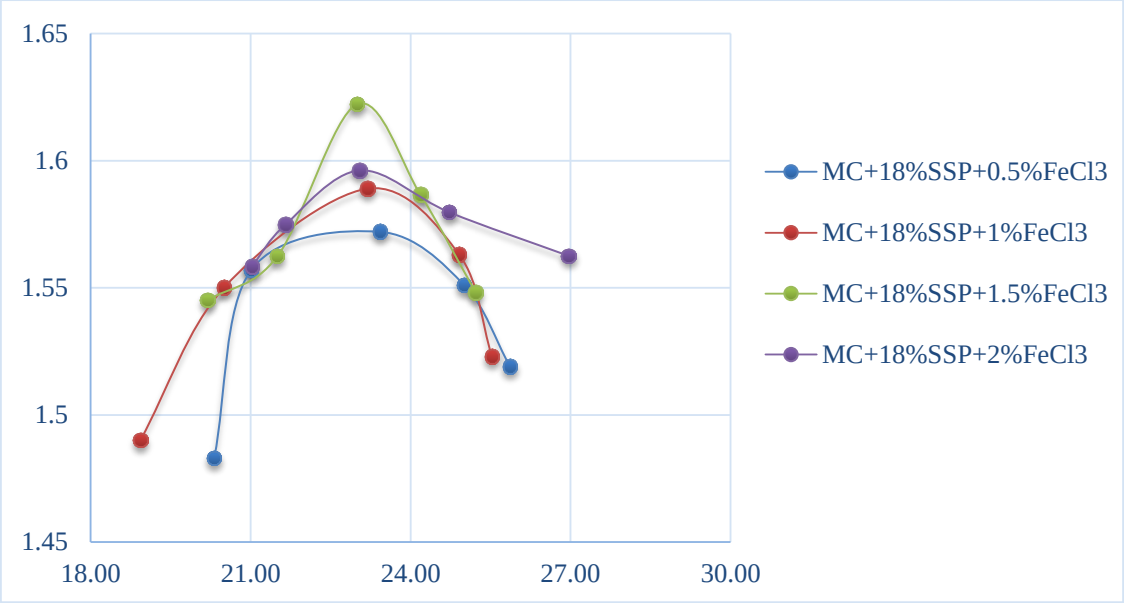

Fig .5 OMC & MDD values of the marine clay treated with an optimum of 18% Sea Shell Powder on percentages variation of the Ferric Chloride.

B. CBR test results

Table 5 and fig. 6 present the CBR values of the marine clay treated with an optimum of 18% Sea Shell Powder on percentages variation of the Ferric Chloride.

TABLE 6
CBR VALUES OF THE MARINE CLAY TREATED WITH AN OPTIMUM OF 18% SEA SHELL POWDER ON PERCENTAGES VARIATION OF THE FERRIC CHLORIDE.

Mix	CBR (%)
MC + 18% SSP + 0.50 $FeCl_2$	6.274
MC + 18% SSP + 1.00 $FeCl_2$	7.170
MC + 18% SSP + 1.50 $FeCl_2$	**8.067**
MC + 18% SSP + 2.00 $FeCl_2$	6.946

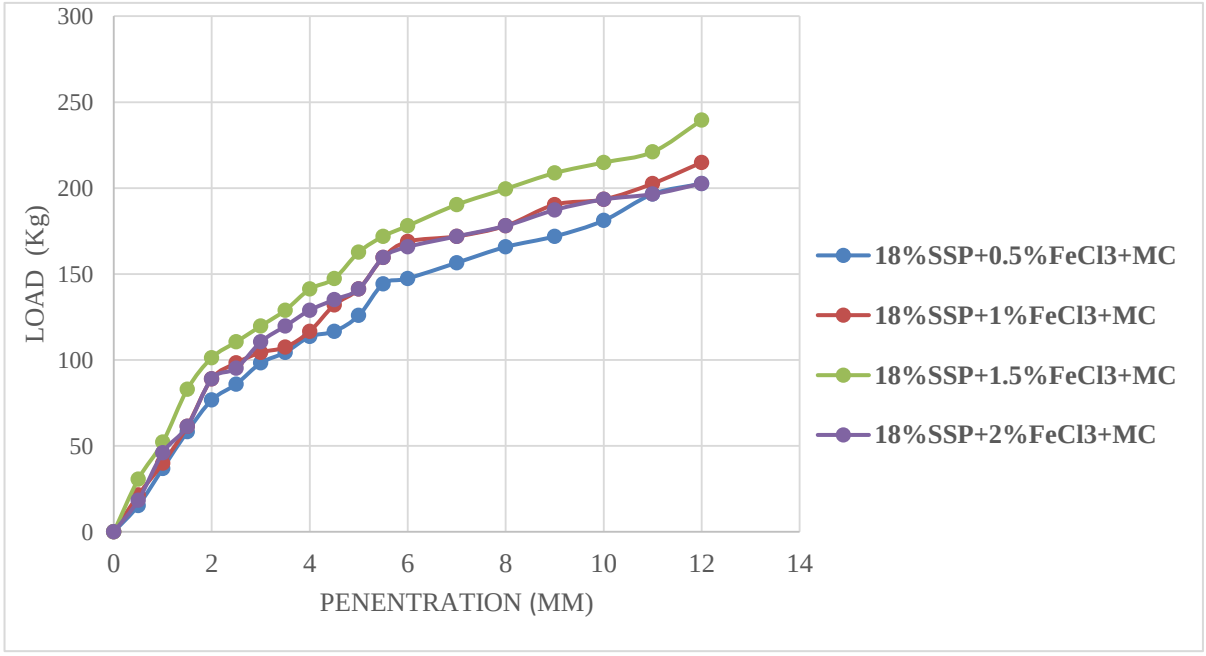

Fig.6 CBR values of the marine clay treated with an optimum of 18% sea shell powder on percentages variation of the ferric chloride.

3. Laboratory tests results of Index properties, Strength properties, Specific gravity and Differential Free Swell of the marine clay when treated with an optimum of 18% SSP and 1.50% of ferric chloride are presented in the table. 7.

TABLE. 7
LABORATORY TEST RESULTS OF THE UNTREATED AND TREATED MARINE CLAY

S.No	Properties	Symbol	Marine clay	Marine clay +18%ssp	Marine clay +18% SSP +1.5%ferric chloride
1	Liquid limit (%)	W_l	78.10	64.00	57.78
2	Plastic limit (%)	W_p	28.66	29.94	30.22
3	Plasticity index (%)	I_p	49.44	34.06	28.88
4	Specific gravity	G	2.33	2.48	2.72
5	Differential free swell (%)	D_f	95	60	40
6	MDD(g/cc)	Y_d	1.382	1.567	1.622
7	OMC (%)	W	31.97	23.46	22.99
8	CBR (%)		1.36	4.257	8.067
9	Cohesion(kN/m^2)	C	90	74	55
10	Angle of internal friction	Φ	3.12^0	6^0	10^0

DISCUSSION-2

It is observed from the above test results the CBR value of the treated marine clay is 8.067%, which is sufficient as per IRC-37-2012. Hence, the treated marine clay can be used as sub grade for flexible pavements.

7. CONCLUSIONS

1. It is noticed from the laboratory test results that the differential free swell of the marine clay has been improved by 36.84 % on addition of 18% Sea Shell Powder as an optimum and further, the differential free swell of this treated marine clay has been improved by 57.89% on addition of 1.50% Ferric Chloride also as an optimum when compared with untreated marine clay.
2. It is observed from the laboratory test results that the liquid limit value of marine clay has been improved by 18.04% on addition of 18% Sea Shell Powder as an optimum and further, the liquid limit value of this treated marine clay has been improved by 26.01% on addition of 1.50% Ferric Chloride also as an optimum when compared with untreated marine clay.
3. It is observed from the laboratory test results that the plasticity index of marine clay has been improved by 31.01% on addition of 18% Sea Shell Powder as an optimum and further, the plasticity index of this treated marine clay has been improved by 41.58% on addition of 1.50% Ferric Chloride also an optimum when compared with untreated marine clay.
4. It is noticed from the laboratory test results that the OMC value of marine clay has been improved by 26.61% on addition of 18% Sea Shell Powder as an optimum and further, the OMC value of this treated marine clay has been improved by 28.01% by addition of 1.50% Ferric Chloride also an optimum when compared with untreated marine clay.
5. It is perceived from the laboratory test results that the Maximum Dry Density (MDD) of marine clay has been improved by 13.38% on addition of 18% Sea Shell Powder as an optimum and further, the Maximum Dry Density (MDD) of this treated marine clay has been improved by 17.36% on addition of 1.50% Ferric Chloride also an optimum when compared with untreated marine clay.
6. It is noticed from the laboratory test results that the CBR value of marine clay has been improved by 213.01% on addition of 18% Sea Shell Powder as an optimum and further, the CBR value of this treated marine clay has been improved by 493.16% on addition of 1.50% Ferric Chloride also an optimum when compared with untreated marine clay.

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