An Investigation on Improving The Properties of The Marine Clay Using Air Cooled Slag And Potassium Chloride As Subgrade For Flexible Pavement

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Abstract- *Vast areas particularly the coastal regions are covered with thick soft marine clay deposits. India has a large coastline exceeding 6000kms.In general; Soft Marine Clays are generally weak and possesses high deformation values in nature. Soft soils are generally labeled as 'problematic' because of their poor resistance to deformation, low permeability and limited bearing capacity natures.Its properties differ significantly in moist and dry conditions. Due to the poor engineering characteristics of these deposits, they pose several foundation problems to various coastal structures. Keeping in view the research findings outlined above, in the present work, experimentation was carried out to investigate the efficacy of different additives viz., potassium Chloride and Air Cooled Slag, in stabilizing the marine clay thereby improving its strength, swell characteristics. Systematic and methodological process was followed involving experimentation in the laboratory under controlled conditions .*

Keywords- KCL,MDD, Air Cooled Slag, OMC, Load carrying capacity.

I. INTRODUCTION

Marine clays suffer from the problems of high saturation, low density, low shear strength, sensitivity and deformation, normally consolidated and possess specific physic -chemical make-up which are subjected to volume changes with the environment accordingly. Irrespective of the problems in view of the population density it is not possible to avoid the construction of pavements and foundations on them. Amongst various contributions, the investigations on physical, chemical and mineralogical properties of marine clay conducted by Eden et al. (1957), Noorani (1984), Shridharan et al.(1989), Mathew et al. (1997) and Chew et al. (2004) are worthy of note. Significant research on strength and stiffness characteristics was performed by Koutsoftas et al.(1987) and Zhou et al. (2005). ; Zhuge et.al, 2007; Ameta, 2007; Basack et. Al, 2009; Kamruzzaman et.al, 2009 and Fairfax Country, Virginia, 2010). Marine clay deposits of yetimoga were used for testing with the aim to investigation its properties of marine clay and load carrying capacity and further make suitable for foundation construction over it. The soil was collected at 1.00m to 2.00m depth from the Yetimoga of Kakinada Sea, A.P, and India.

1.2 OBJECTIVES OF THE STUDY

The objectives of present experimental study are as follows.

- To identify the strategy of techniques to overcome the problems posed by marine clays with a view to adopt suitable methodology through critical review of literature.
- To study the impact of proposed additives and admixtures on the properties of marine clays through laboratory experimentations.
- To evaluate the performance of marine clay when stabilized with proposed additives and admixtures and their suitability for pavement sub grade.

II. STUDY OF METHODOLOGY

methodology for both laboratory and field experimentation will be presented along with the properties of different types of materials used during the laboratory experimentation. The cyclic plate load tests were conducted on untreated, treated & reinforced model flexible pavements and a brief description of the experimental procedures adopted in this investigation and the methodology adopted during the course of study is presented.

Properties of Marine clay

Table 3.1 Properties of Marine clay

S.No	Property	Value
1.	**Grain size distribution**	
	Sand (%)	6
	Silt (%)	27.5
	Clay (%)	66.5
2.	**Atterberg limits**	
	Liquid limit (%)	76.4
	Plastic limit (%)	25.16
	Plasticity index (%)	51.24
	Shrinkage limit (%)	9
3.	**Compaction properties**	
	Optimum Moisture Content, (%)	33.79
	Maximum Dry Density, (g/cc)	1.443
4.	**Specific Gravity (G)**	2.42
5.	**IS Classification**	CH
6.	**C.B.R (%)**	0.87
7.	**Differential free swell (%)**	70
8.	**Shear Strength Parameters**	
	Cohesion (t/m²)	12.25
	Angle of internal friction (°)	3

2.1.POTASSIUM CHLORIDE

The chemical compound potassium chloride (KCl) is a metal halide salt composed of potassium and chlorine. In its pure state, it is odorless and has a white or colorless vitreous crystal appearance, with a crystal structure that cleaves easily in three directions. In this Study it is brought from Nargarjuna Fertilisers and Chemicals Limited in Kakinada of East Godavari. Potassium chloride crystals are face-centered cubic. Potassium chloride was historically known as "muriate of potash".

Plate 3.1 Potassium Chloride

2.2 AIR COOLED SLAG

Air cooled slag is a waste material generated in steel plants. In this study it is brought from Visakhapatnam Steel plant, Visakhapatnam.

Plate.3.2 Air Cooled Slag

Table 3.4 Properties of Air Cooled Slag

S.No	Property	Value
1.	**Grain size distribution**	
	Gravel (%)	14.6
	Sand (%)	84.94
	Fines (%)	0.46
2.	**Atterberg limits**	
	Liquid limit (%)	19.072
	Plastic limit (%)	NP
	Plasticity index (%)	NP
	Shrinkage limit (%)	NP
3.	**Compaction properties**	
	Optimum Moisture Content, (%)	12.40
	Maximum Dry Density, (g/cc)	2.04
4.	**Specific Gravity (G)**	2.906
5	**IS Classification**	SW
6.	**C.B.R (%)**	9.26
7.	**Shear Strength Parameters**	
	Cohesion (kN/m²)	5
	Angle of internal friction (°)	22

III. CALIFORNIA BEARING RATIO (CBR) TESTS

The CBR tests were conducted as per I.S. Codes (IS: 2720(Part XVI) - 1979) .

Plate 3.3. CBR test

The steel tank was placed at centre of the loading frame. Marine clay which used as a sub-grade is pulverized and the material passing through 4.75mm is used for this study. The marine clay was compacted in layers of 2cm thickness, at its OMC and MDD, to a total compacted thickness of 20cm. For 'marine clay+KCl+Air cooled slag' mix, the water content corresponding to OMC of same mix was taken and the required quantity of chemical was dissolved or mixed in it. For the "marine clay + KCl + air cooled slag" mixes, the weights of the dry mixes corresponding to the MDD of same mix were taken and compacted at OMC of the 'marine clay + KCl + Air cooled slag' mix. On the prepared marine clay sub-grade, Gravel subsoil used as a sub-base, of thickness 5cm is compacted in two layers. These layers are also compacted to OMC and MDD. Then, two layers of each 2.5cm thick compacted. WBM-III layers were laid over the sub-base, to the total thickness of 5cm,as shown in the Fig.3.1.On the prepared sub-grade or sub-base, a sand layer of 1.0cm thickness is provided .

3.1. CYCLIC PLATE LOAD TEST

This flexible pavement has exhibited the ultimate cyclic load of 619.84kN/m^2 with the deformation of 2.63mm at OMC.

3.1.Prepared model tank for conducting Cyclic Plate Load test

In the laboratory, index tests, swell tests, strength tests were conducted by using different percentages of KCl and Air Cooled Slag(ACS) with a view to determine the optimum percentages of KCl and ACS.

The cyclic plate load tests were conducted on untreated and treated marine clay sub grade model flexible pavements.

The effect of addition of KCl and ACS to the marine clay, on compaction, CBR properties, Atterberg limits, swell properties, and strength properties, were discussed in detail in the following sections.The Graph 4.24 and 4.17 show the laboratory cyclic plate load test results of 1%KCl+20%ACS treated marine clay sub grade flexible pavement. This treated marine clay subgrade flexible p averment has exhibited the ultimate cyclic load of 999.7kN/m^2 with the deformation of 1.87mm at OMC.

IV. DISCUSSION ON TEST RESULTS

4.1. EFFECT OF KCL AND ACS ON COMPACTION AND CBR PROPERTIES OF MARINE CLAY

The influence of different materials on the compaction and CBR properties were discussed in this article. The CBR values of the untreated and treated marine clay were determined at the respective OMC of the various mixes obtained from IS modified compaction test.

It was observed that 1.0% KCL treatment as individually and with the combination of 20% ACS with marine clay has effectively improved the laboratory CBR value.

Additives	Optimum Percentage
KCL	1.0%
ACS	20%

Plate 4.1 Preparing sample for modified Proctor Compaction test

4.2COMPACTION TEST RESULTS OF KCL TREATED MARINE CLAY

Compaction tests were conducted to get the Optimum moisture content and Maximum dry density by adding different proportions of KCL to marine clay using modified proctor compaction apparatus.

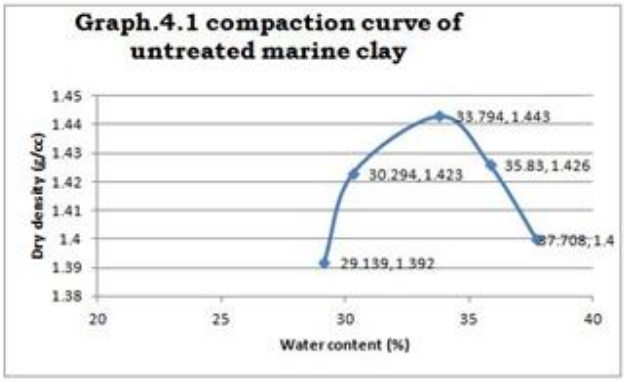
Plate 4.2 Conducting Modified Proctor Compaction test

4.2.3.1 COMPACTION TEST RESULTS FOR UNTREATED MARINE CLAY

Table 4.1 and graph 4.1present the OMC and MDD values of the untreated marine clay

Table 4.1 Compaction Properties of Untreated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
Marine Clay	29.139	1.392
	30.294	1.423
	33.792	**1.443**
	35.830	1.426
	37.708	1.400



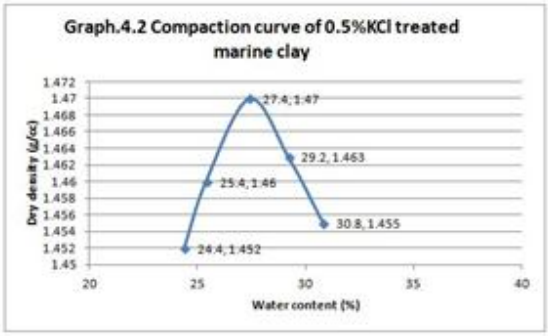
Optimum moisture content = 33.792%
Maximum dry density = 1.443 g/cc

4.2.3.2 Compaction test results for marine clay treated with 0.5% KCl

Table 4.2 and graph 4.2 present the OMC and MDD values of the 0.5% KCl treated marine clay.

Table 4.2 Compaction Properties of 0.5% KCl treated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
99.5%Marine Clay+0.5% KCl	24.40	1.452
	25.40	1.460
	27.40	**1.47**
	29.20	1.463
	30.80	1.455



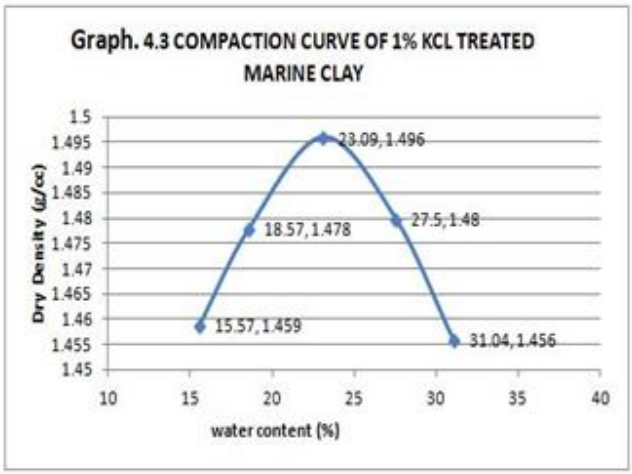
Optimum moisture content = 27.4 %
Maximum dry density = 1.47 gm/cc

4.2.3.3 Compaction test results for marine clay treated with 1% KCl

Table 4.3 and graph 4.3 present the OMC and MDD values of 1% KCl treated marine clay

Table 4.3 Compaction Properties of 1%KCl treated Marine Clay

Mix Proportion	water content (%)	DD (g/cc)
99%Marine Clay+1% KCl	15.57	1.459
	18.57	1.478
	23.09 (OMC)	**1.496 (MDD)**
	27.50	1.480
	31.04	1.456



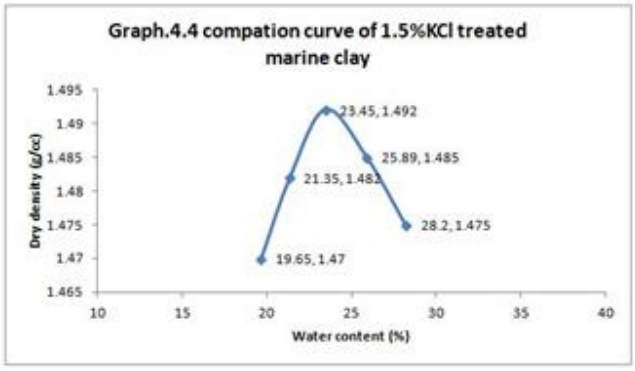
Optimum moisture content = 23.09%
Maximum dry density = 1.496 g/cc

4.2.3.4 Compaction test results for marine clay treated with 1.5% KCl

Table 4.4 and graph 4.4 present the OMC and MDD values of the 1.5% KCl treated marine clay

Table 4.4 Compaction Properties of 1.5% KCl treated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
98.5%Marine Clay+1.5 % KCl	19.65	1.470
	21.35	1.482
	23.45 (OMC)	**1.492 (MDD)**
	25.89	1.485
	28.20	1.475



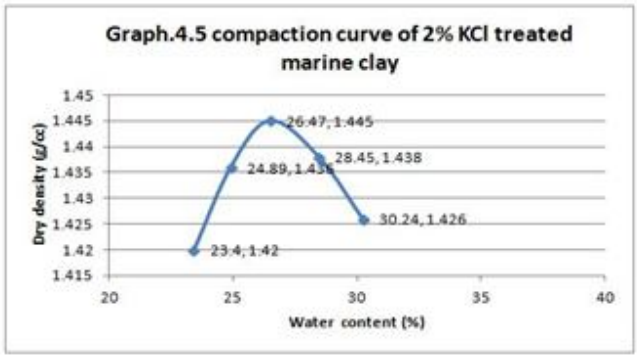
Optimum moisture content = 23.45 %
Maximum dry density = 1.492g/cc

4.2.3.5 Compaction test results for marine clay treated with 2% KCl

Table 4.5 and graph 4.5 present the OMC and MDD values of the 2% KCl treated marine clay.

Table 4.5 Compaction Properties of 2% KCl treated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
98.%Marine Clay+2% KCl	23.4	1.42
	24.89	1.436
	26.47	**1.445**
	28.45	1.438
	30.24	1.426



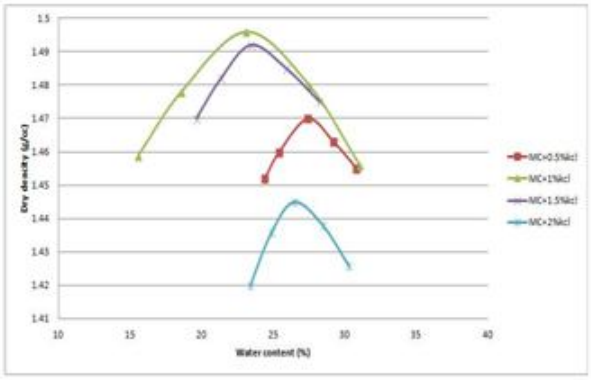
Optimum moisture content = 26.47%.
Maximum dry density = 1.445g/cc.

4.2.3.6 Compaction test results for marine clay treated with percentage Variation of KCl

Table 4.6 and graph 4.6 present the OMC and MDD values of the marine clay treated with % Variation of KCl.

Table 4.6 Compaction Properties of Marine Clay treated with percentage Variation of KCl

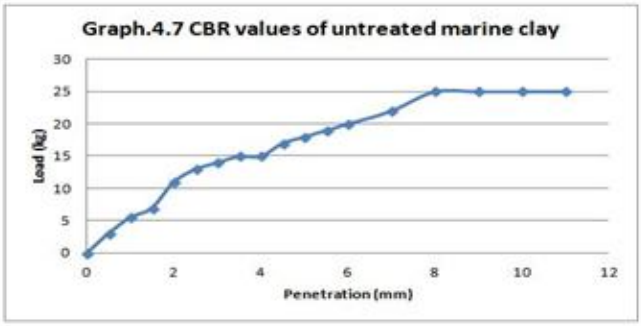
Mix Proportion	OMC (%)	MDD (g/cc)
100% Marine clay+0% KCl	33.792	1.443
99.5%Marine clay +0.5% KCl	27.40	1.470
99%Marine clay +1% KCl	23..09	1.496
98.5%Marine clay +1.5% KCl	23.45	1.492
98%Marineclay+2% KCl	26.47	1.445



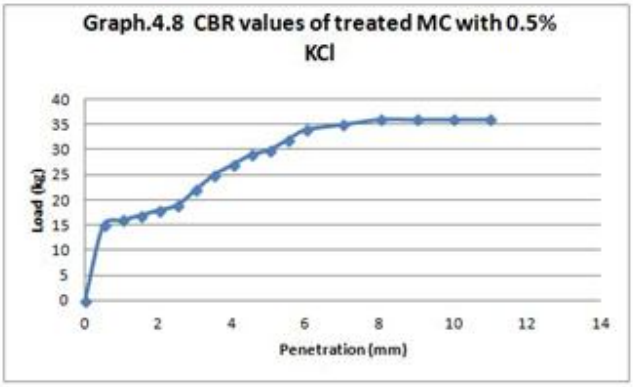
Graph.4.6 Compaction Curves for different percentages of KCl treated Marine clay

4.2.4. C.B.R Test Results of Untreated Marine Clay

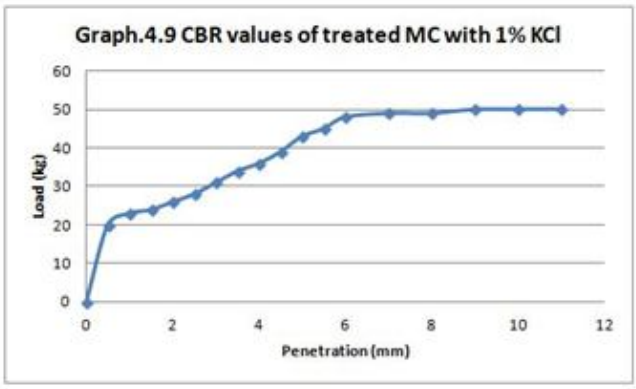
Graph. 4.7.present the CBR values of untreated marine clay.



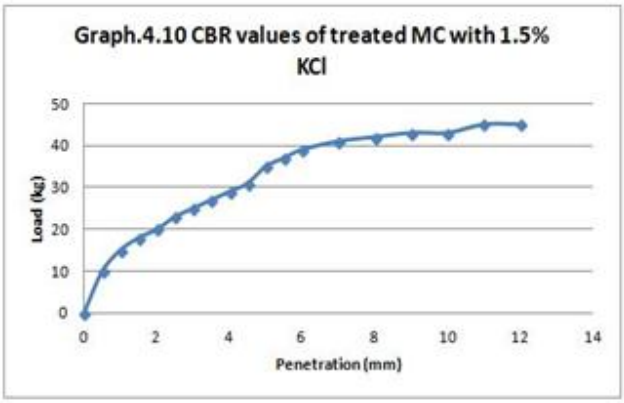
CBR (soaked) value: 0.87 %



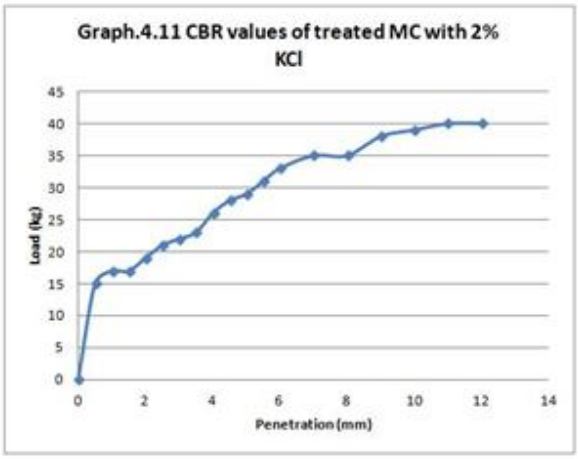
CBR (soaked) value: 1.38 %



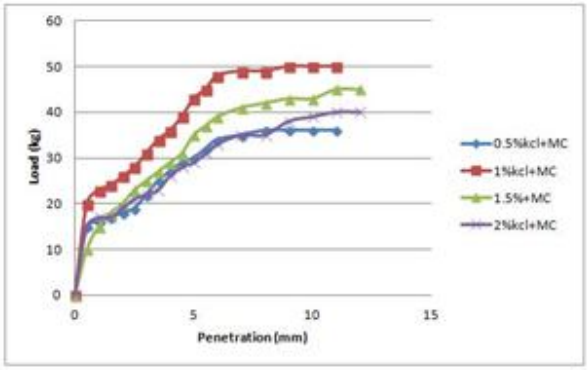
CBR (soaked) value: 2.04%



CBR (soaked) value: 1.67%



CBR (soaked) value: 1.41 %



Graph.4.12 CBR Curves for different percentages of KCl treated Marine clay

Table 4.7 CBR Values of Marine Clay treated with % Variation of KClz

Mix proportion	% variation of KCl	Soaked CBR
Marine clay	0	0.87
99.5% Marine clay	0.5	1.38
99% Marine clay	**1.0**	**2.04**
98.5% Marine clay	1.5	1.67
98% Marine clay	2.0	1.41

Discussion:

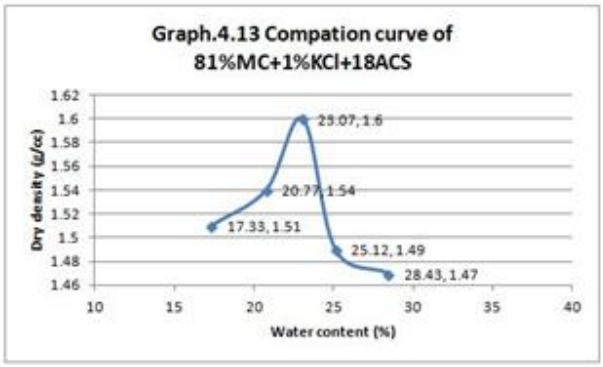
It can be observed from Table 4.7 that 1.0% KCl treatment with marine clay has effectively improved the laboratory CBR value. However, beyond the addition of 1.0% KCl required improvement in CBR values of the marine clay was not observed. As per IRC Codes 37-2001&2012 the minimum CBR value of sub grade is 6%.In this present study an attempt has been made to improve the CBR value of the KCL treated Marine Clay with percentage variation of air cooled slag as an admixture to suit it as sub grade for flexible pavements as per IRC 37-2001.

4.2.6.1Compaction test results for 1.0% KCl treated marine clay with 18% ACS T

Table 4.9 and Graph 4.13 present the OMC and MDD values of 1.0% KCl treated marine clay with 18% ACS.

Table 4.9 Compaction Properties of 1.0%KCl treated Marine Clay with 18%ACS

Mix Proportion	OMC (%)	MDD (g/cc)
MC+1.0%KCl+18%ACS	17.33	1.51
	22.77	1.54
	23.07	**1.60**
	28.12	1.49
	28.43	1.47



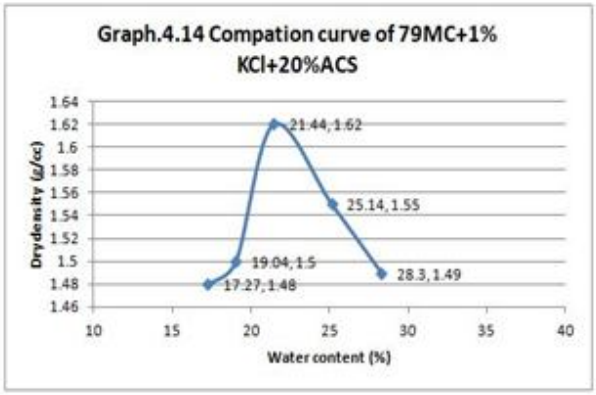
Optimum moisture content = 23.07 %
Maximum dry density = 1.60 g/cc

4.2.6.2 Compaction test results for 1.0% KCl treated marine clay with 20% ACS T

Table 4.10 and Graph 4.14 present the OMC and MDD values of 1.0% KCl treated marine clay with 20% ACS.

Table 4.10 Compaction values of 1.0% KCl treated Marine Clay with 20%ACS

Mix Proportion	OMC (%)	MDD (g/cc)
MC+1.0%KCl +20%ACS	17.27	1.48
	19.04	1.50
	21.44	**1.62**
	25.14	1.55
	28.30	1.49



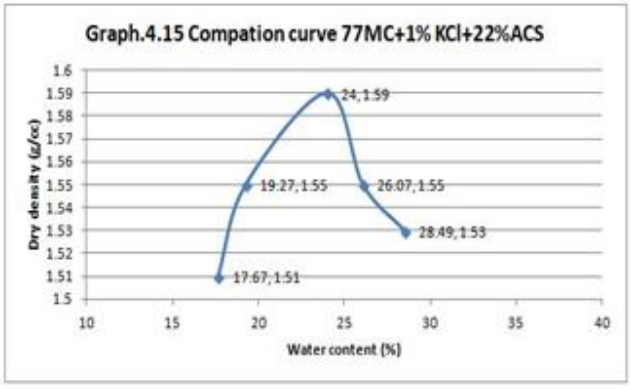
Optimum moisture content = 21.44 %
Maximum dry density = 1.62 g/cc

4.2.6.3 Compaction test results for 1.0% KCl treated marine clay with 22% ACS T

Table 4.11 and Graph 4.15 present the OMC and MDD values of 1.0% KCl treated marine clay with 22% ACS.

Table 4.11 Compaction Properties of 1.0% KCl treated Marine Clay with 22%ACS

Mix Proportion	OMC (%)	MDD (g/cc)
MC+1.0%KCl +22%ACS	17.67	1.51
	19.27	1.55
	24.00	**1.59**
	26.07	1.55
	28.49	1.53



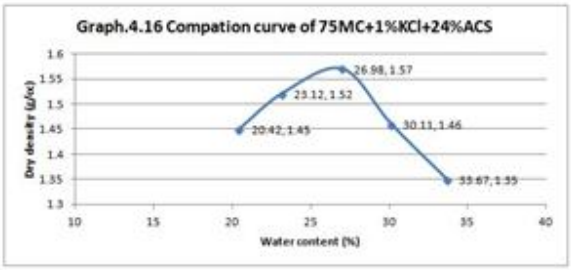
Optimum moisture content = 24%
Maximum dry density = 1.59 g/cc.

4.2.6.4 Compaction test results for 1.0% KCl treated marine clay with 24% ACS T

Table 4.12 and Graph 4.16 present the OMC and MDD values of 1.0% KCl treated marine clay with 24 % ACS.

Table 4.12 Compaction Properties of 1.0% KCl treated Marine Clay with 24%ACS

Mix Proportion	OMC (%)	MDD (g/cc)
MC+1.0%KCl +24%ACS	20.42	1.45
	23.12	1.52
	26.98	**1.57**
	30.11	1.46



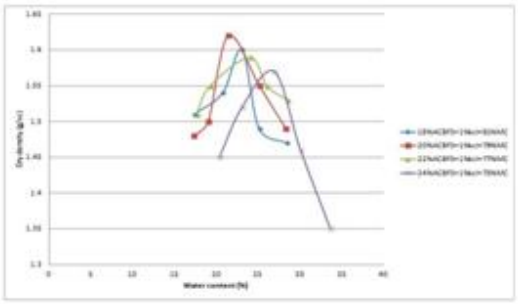
Optimum moisture content = 26.98%
Maximum dry density = 1.57 g/cc.

4.2.6.5 Compaction test results for 1.0%KCl treated marine clay with %Variation of ACS.

Table 4.13and Graph 4.17 presents the OMC and MDD values of the KCl treated marine clay with % Variation of ACS.

Table 4.13 Compaction Properties of KCl treated marine clay with % Variation of ACS.

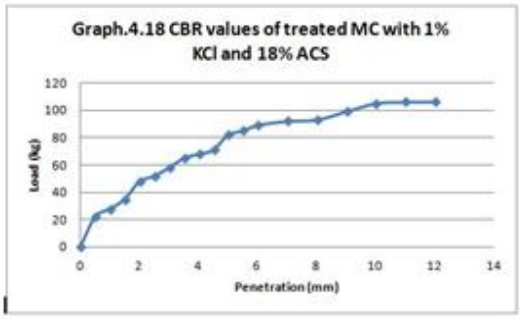
Mix proportion	OMC(%)	MDD(g/cc)
1.0%KCl treated Marine clay with 18%ACS	23.07	1.60
1.0%KCl treated Marine clay with 20%ACS	21.44	1.62
1.0%KCl treated Marine clay with 22%ACS	24.00	1.59
1.0%KCl treated Marine clay with 24%ACS	26.98	1.57



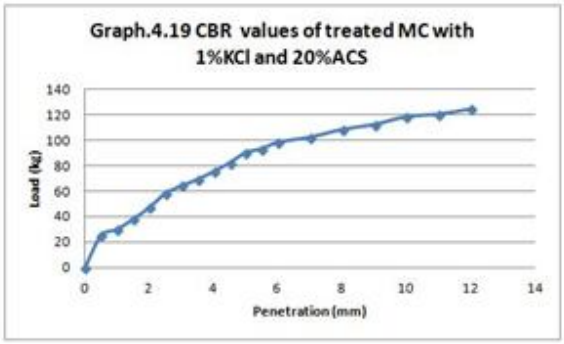
Graph: 4.17 Compaction curves for 1.0% KCl and varying percentages of ACS treated Marine Clay

4.2.7. C.B.R Test Results of 1.0% KCl Treated Marine Clay with percentage variation Of ACS

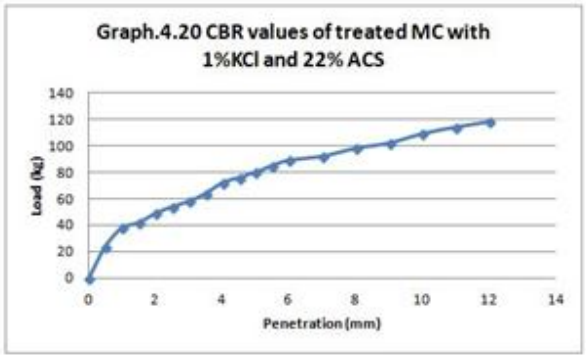
CBR values of various mixes of 1.0% KCl treated marine clay and Air Cooled Slag using OMC obtained from compaction tests are determined. Variation of CBR with % variation of Air cooled slag is presented in table 4.14 and Graph.4.18 to Graph.22



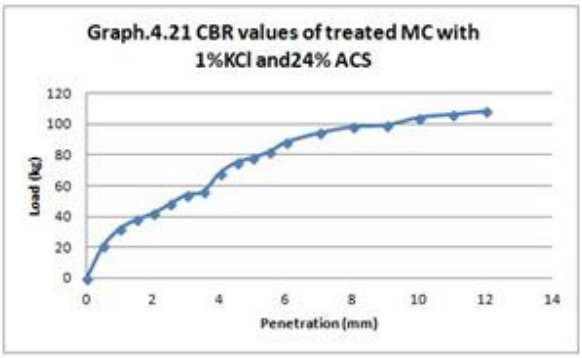
CBR(soaked) value: 3.79%



CBR (soaked) value: 6.23%



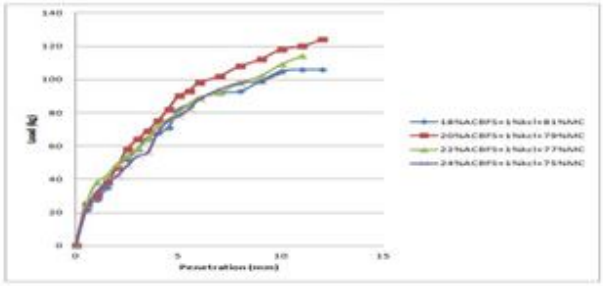
CBR (soaked) value: 5.89%



CBR (soaked) value: 3.50%

Table 4.14 CBR Values of 1.0% KCl treated Marine Clay with Percentage Variation of ACS

Mix proportion	% variation of ACS	Soaked CBR
Untreated Marine clay	0	0.87
1.0%KCltreatedMarine clay +ACS	18	3.79
1.0%KCltreatedMarine clay +ACS	**20**	**6.23**
1.0%KCltreatedMarine clay +ACS	22	5.89
1.0%KCltreatedMarine clay +ACS	24	3.50

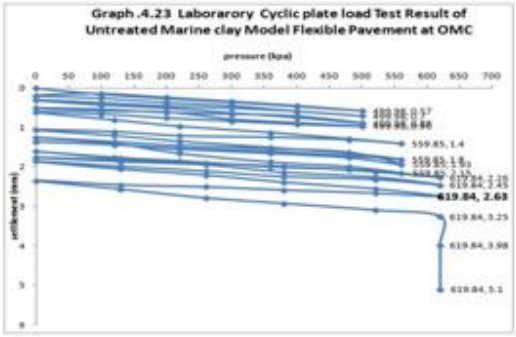


Graph.4.22 CBR Values of 1.0% KCl treated Marine Clay with Percentage Variation of ACS

It was observed that 1.0% KCl treatment as individually and with the combination of 20% Air Cooled Slag with marine clay has effectively improved the laboratory CBR value.

Discussion:

In this present study, the marine clay treated with 1%KCL and 20% Air cooled slag has exhibited the CBR value of 6.23%, which suitable value for using this material as sub grade for flexible pavements as per IRC 37-2001 & 2012



The Graph 4.27 and 4.28 show the laboratory cyclic plate load test results of 1%KCl+20%ACS treated marine clay sub grade flexible pavement. This treated marine clay subgrade flexible p averment has exhibited the ultimate cyclic load of 999.7kN/m2 with the deformation of 1.87mm at OMC.

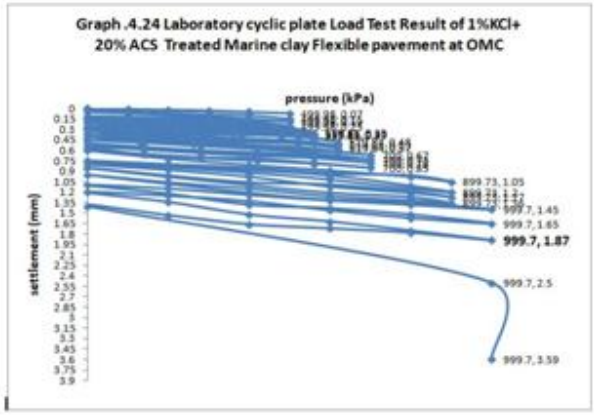


Table 4.20 Laboratory Cyclic Plate Load Test Results of Untreated and Treated Marine Clay Model Flexible Pavement at OMC & FSC.

S.No	Sub grade	Sub base	Base course	Ultimate cyclic Pressure (KN/m^2)	settlements(mm)
				OMC	OMC
1.	Untreated marine clay	Gravel	WBM-III	**619.84**	**2.63**
2.	Treated marine clay (1%KCl +20%ACBFS)	Gravel	WBM-III	**999.97**	**1.87**

V. CONCLUSION

The following conclusions are made based on the laboratory experiments carried out in this investigation.

1. It was observed that the **liquid limit** of treated Marine Clay has been improved by 9.03% with the addition of 1.0% KCl and 38.71% on the addition of 1.0% KCl+20% Air Cooled Slag respectively when compared with the untreated marine clay.
2. It was observed that the **Plasticity index** of the treated Marine clay has been improved by 17.93% with the addition of 1.0% KCl and 63.36% with addition of 1.0% KCl+20% Air Cooled Slag respectively when compared with respect to the untreated marine clay.
3. It was observed that **1.0% KCl** treatment as individually and with the combination of **20%ACS** with marine clay has improved the laboratory CBR value.
4. It was observed from laboratory cyclic plate load test results that the **load carrying capacity** of the treated marine clay sub grade flexible pavement has been improved by 61.32% at OMC when compared with the untreated marine clay sub grade flexible pavement.
5. It was noticed from the result of cyclic load test that the deformation of treated marine clay sub grade flexible pavement has been decreased by 28.89% at OMC when compared with the untreated marine clay sub grade flexible pavement.

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