A Laboratory Investigation on The Efficacy of Calcium Chloride on Improving The Properties of Vitrified Polish Waste Treated Marine Clay For Flexible Pavement Subgrades Under Cyclic Pressures

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Abstract- *Weak marine soil deposits have been found both on the coast and in several offshore areas spread over many parts of the world. When clay particles precipitate in salt water, there is a tendency for the clay particles to flocculate and stick together giving rise to some sort of edge-to-face arrangement. As a result, clay, silt and fine sand particles settle almost at the same rate and the final sediment formed consists of particles with a very loose card house-like structure.. In addition to these, the problems arising out of high compressibility and strength of these weak marine deposits expose geotechnical engineers to considerable changes in the construction of various coastal and offshore structures.*

Keeping in view the research finding outlined above ,in the present work, experimentation was carried out to investigate the efficiency of vitrified polish waste in stabilizing the marine clay ,there by ,improving the strength ,swell characteristics of the marine clay . A systematic methodical process was followed involving experimentation in the laboratory under controlled conditions. The present study deals with the engineering properties of the marine clay collected from Kakinada sea ports Ltd, Kakinada, AP., India. The physical & chemical properties, the strength characteristics and also the load carrying capacity of the Marine clay have been determined in this study before and after stabilization with vitrified polish waste(VPW) and $Cacl_2$

Keywords- Marine clay, chemical additives, sub grade, flexible pavement

I. INTRODUCTION

Transportation and Communication facilities are necessary for any developing countries like India. The technology of road construction depends mainly upon the vehicular pattern, construction materials and sub grade condition. Sub grade is an integral part of the road pavement structure as it provides the support to the pavement from beneath. The main function of the sub grade is to provide adequate support to the pavement and for this the sub grade should possess sufficient stability under any adverse climate, loading and deformation loading conditions.

In order to improve the engineering behaviour of these soils, several improvement techniques are available in geotechnical engineering practice. The selection of any of these methods to overcome any problem can be proved to be efficient only after the comparison of that with other techniques, then it can be said that the particular method is well suited for a specific system. In general, the soils which are existing in the coastal corridors are Soft Marine Clays formed by the deposits and generally weak and possesses high deformation values in nature. It is essential to study the various techniques for the improvement of marine clays, especially in case of infra-structure development.

The present study deals with the engineering properties of the marine clay collected from Kakinada sea ports Ltd ,Kakinada, AP., India. The physical & chemical properties, the strength characteristics and also the load carrying capacity of the Marine clay have been determined in this study before and after stabilization with vitrified polish waste(VPW) and $Cacl_2$. the detailed test results are also discussed.

DAMAGES TO THE PAVEMENT SUB GRADES

Majority of the pavement failures could be attributed to the poor sub grade conditions and marine clay is one such problematic situation (Evans and McManus, 1999). Roads running through marine clays regions are subjected to severe unevenness with or without cracking, longitudinal cracking parallel to pavement centre line, rutting of pavement surface and localized failure of pavement associated with disintegration of the surface. The extensive damage to highways running over expansive and high compressible soil sub-grades (Plate 2.5) is estimated to be in billions of dollars all over the world. Even railway tracks are no exception and are affected by appreciable movements due to the nature of high compressibility of the marine clay soils.

Plate 2.5 Pavement cracks Due to Sub grade Failure

Compressibility of the clayey soils.

(a) Rutting:-

The rutting is mainly due to consolidation of one or more layers of pavement and also due to repeated application of the load along the same wheel path resulting in deformation of pavements.

(b) Longitudinal Cracks

This is due to differential volume changes that occur in marine soils. The deformation characteristics of the marine clay soils results in cracking through the full pavement thickness (Plate 2.6). The visual which is represented below is an example for the pavements cracks which are developed longitudinally.

II. REVIEW OF LITERATURE

Marine clay is a type of clay and normally possesses soft consistency (Plate 2.2).Marine clay deposits from Kakinada sea ports limited, Kakinada were used for the testing with the aim to investigate its Engineering properties (Penner and Bum(1978); Tan(1983); NarasimhaRao and Swamy(1984); Sridharan et al.(1989); Chong (1991); BuddhimaIndraratna et al.,(1991); Anandarajah and Chu (1997) ; Chong et al.,(1998); Thiam-Soon Tan et al.,(2002); Chu et al.,(2002); SupakijNontananandh et al.,(2004); Oh and Chai (2006); MatchalaSuneel et al.,(2008); Basak and Purkayastha (2009); Gang Ren (2010)) and further, made suitable for construction of foundations over it and also for the flexible pavement sub grades.

A research has been done on the Physio-Chemical effects on the engineering behaviour of Indian marine clays by Rao, M.S et al., (1992). Sridharan et al., (1989) reported the engineering properties of Cochin and Mangalore Marine Clays. Hyde et al., (1993) presented the engineering properties and stability criteria for marine clay under cyclic loading. Narasimha Rao et al., (1996) stated that the Permeability (k) values shows an enormous improvement by using lime column technique and the permeability value was improved up to 23 times. This shows good promise for improving the soft coastal deposits and the offshore deposits. Thiam-Soon et al (2002) reported on improving the strength of the marine clay by the stabilization technique. Chu et al., (2002) reported the consolidation and permeability properties of the Singapore marine clay based on the laboratory and field investigation. Plate 2.3 shows the general patterns of cracks develop on pavement.

Plate 2.3 Marine Clay Showing Cracks

Balasubramaniam et al., (2003) proved the effects of additives on Soft Clay behaviour and concluded that the strength characteristics of the soft clays are improved by using various additives. Supakij Nontananandh et al., (2004) reported the efficacy of the stabilization techniques on strength characteristics of the marine clay. Oh and Chai (2006) presented the engineering properties and the characterization of marine clay for road embankment design in coastal area and the engineering properties of the marine clay were improved using various stabilization techniques. Matchala Suneel et al., (2008) represented the compressibility characteristics of Korean marine clay. Sing et al., (2008) reported an improvement in the engineering properties of peat soils stabilizing with cement and ground granulated blast furnace slag and proved a remarkable increase in the pH and unconfined compressive strength, significant reduction in linear shrinkage, compressibility and permeability of the stabilized peat soils.

Dr.D.Koteswara Rao (2011) studied the efficiency of CaCl2,KCL,GBFS with marine clay and the test results concluded that load carrying capacity of marine clay John foundation soil bed has been improved.

Dr.D.Koteswara Rao (2012) studied the efficiency of rice husk ash and ferric chloride with the marine clay and the test results concluded that load carrying capacity of marine clay foundation soil bed has been improved.

Dr.D.Koteswara Rao (2013) studied the efficiency of Vitrified Polish Waste (VPW) with marine clay and the test results concluded that marine clay can be used as pavement sub-grade if this VPW treated marine soil is used along with optimum chemical or by reinforcing the pavement.
performance. Stabilization can increase the shear strength of

III. METHODOLOGY

MECHANICS OF SOIL STABILIZATION

Stabilization is the process of blending and mixing materials with a soil to improve the soil's strength and durability. Soil Stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Soils stabilized by additives often provide an all-weather working platform for construction operations

CHEMICAL STABILIZATION:-

Chemical stabilization includes the use of chemicals and emulsions as compaction aids to soils, as binders and water repellents, and as a means of modifying the behavior of clay. It also includes deep mixing and grouting. Chemical stabilization can aid in dust control on roads and highways, particularly unpaved roads, in water erosion control, and in fixation and leaching control of waste and recycled materials. Under this category, soil stabilization depends mainly on chemical reactions between stabilizer (cementitious material) and soil minerals (pozzolanic materials) to achieve the desired effect. A chemical stabilization method is the fundamental of this review and, therefore, throughout the rest of this report, the term soil stabilization will mean chemical stabilization.
The following chemicals have been successfully used:

- Calcium Chloride
- Sodium Chloride
- Sodium Silicate
- Polymers
- Chrome Lignin
- Other chemicals

MATERIALS USED

Properties of soil sample

The marine clay used in this study was obtained from Kakinada Seaports Limited, Kakinada, collected at a depth of 1.0m from ground level. The Index & Engineering properties of marine clay are determined as per IS code of practice and presented in table
.

Table shows Physical Properties of Marine Clay

S NO	Property		Symbol	Value
1	Gravel (%)		—	0
2	Sand (%)		—	4
3	Fines	Silt (%)	—	29
		Clay (%)	—	67
4	Liquid limit (%)		W_L	81.50
5	Plastic limit (%)		W_P	35.49
6	Plasticity index (%)		Ip	46.01
7	Soil classification		—	CH
8	Specific gravity		G	2.63
9	Optimum moisture content (%)		OMC	26.32
10	Maximum dry density (%)		MDD	1.53
11	Cohesion t/m^2		C	10
12	Angle of internal friction (°)		Cp	0
13	CBR value soaked (%)		—	1.50

Vitrified Polish Waste (VPW)

Vitrified tiles manufacturing units are the largest growing industry to meet the requirement of tiles across the globe. Vitrified tiles have far superior properties compared to natural stones and other man made tiles. Available Vitrified Polish Waste from the RAK Ceramics, Samarlakot, East Godavari Dist., A.P., India.

Calcium chloride ($CaCl_2$)

Commercial grade calcium chloride (consisting of 58% of calcium chloride+42% magnesium chlorides) was used in this investigation. The quantity of calcium chloride was varied from0.5% to 1.5% by dry weight of soil.

IV. RESULTS AND DISCUSSIONS

The laboratory studies were carried out on the samples of marine clay; vitrified polish waste treated marine clay and marine clay treated with an optimum of vitrified polish waste and $cacl_2$. Details of the laboratory experimentation carried-out with different combinations of different chemical additives have been discussed in the previous chapter. In this chapter a detailed discussion on the results obtained from various laboratory tests done on untreated and treated marine clay are presented.

4.1 Modified proctor compaction and CBR test results of Untreated Marine Clay and Clay Treated with Vitrified Polish Waste

The optimum moisture content and maximum dry density of untreated marine clay and the marine clay treated with % variation of vitrified polish waste are presented in the following figs and tables

Table 4.1 OMC and MDD of untreated marine clay and marine clay treated with percentage variation of VPW

Mix Proportions	Water content (%)	Dry density(g/cc)
100% soil	24.32	1.53
MC+10% VPW	23.8	1.557
MC+14% VPW	25.4	1.583
MC+15% VPW	**23.2**	**1.595**
MC+16% VPW	28.36	1.584
MC+17% VPW	29	1.574
MC+20% VPW	30.52	1.563

Fig 4.1 OMC&MDD values of marine clay with percentage variation VPW

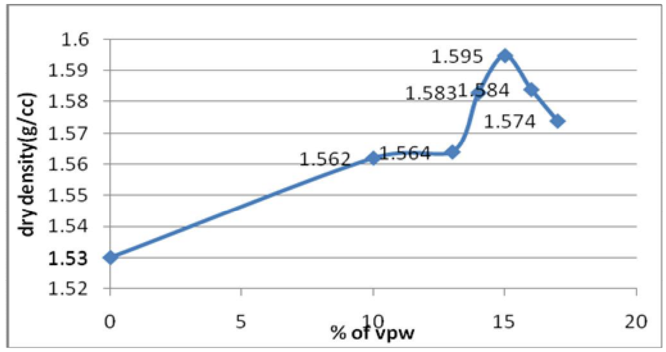


FIG 4.2 CBR VALUES OF MARINE CLAY WITH PERCENTAGE VARIATION OF VPW

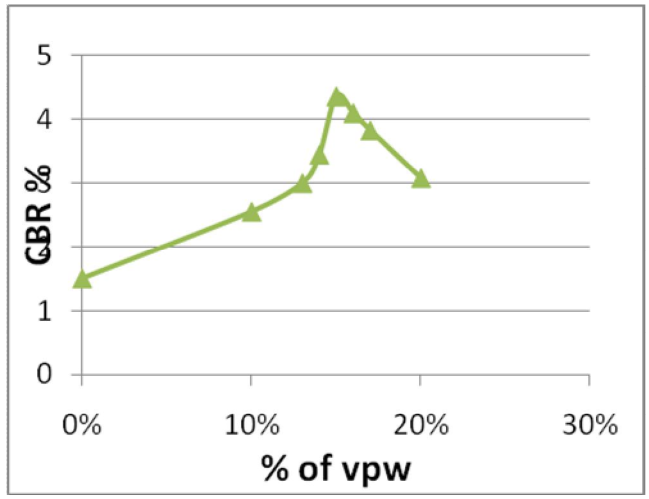


Table 4.2 Properties of Marine Clay treated with an optimum of Vitrified Polish Waste

S. NO	PROPERTY	SYMBOL	MARINE CLAY	MARINE CLAY TREATED
1	Specific gravity	G	2.63	2.72
2	Liquid limit (%)	W_L	81.50	72.56
3	Plastic limit (%)	W_P	35.49	39.58
4	Plasticity index (%)	I_P	46.01	32.98
5	Optimum moisture content (%)	OMC	26.32	31
6	MAXIMUM DRY DENSITY(g/cc)	MDD	1.53	1.59
7	Cbr(soaked)%		1.66	4.36
8	Soil classification	-----	CH	CH
9	COHESION t/m² ANGLE OF INTERNAL FRICTION (°)	C □	10 0	7.5 4.3

The CBR value of the soil on stabilizing with VPW is found to be 4.36%, but according to the IRC 2001, the CBR value should be in between 5-6 %, to be used as sub grade in pavements. Hence further improvement in CBR value is required for VPW treated marine clay to full fill the requirement of CBR value as per IRC -2001 to utilize it as sub-grade material.

4.2 MODIFIED PROCTOR COMPACTION AND CBR TEST RESULTS OF VPW TREATED MARINE CLAY WITH PERCENTAGE VARIATION Of $Cacl_2$

Fig 4.3 OMC & MDD VALUES OF VPW TREATED MARINE CLAY WITH VARIATION OF $Cacl_2$

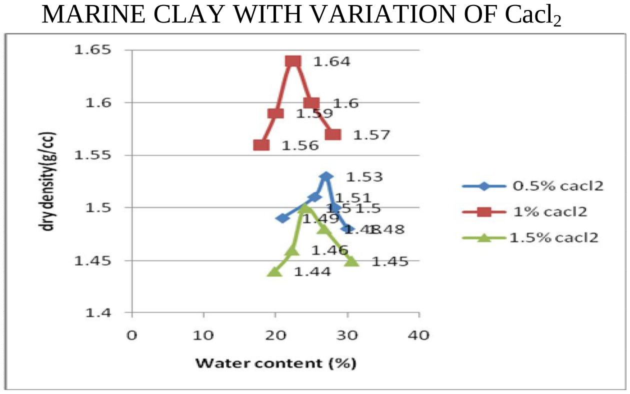
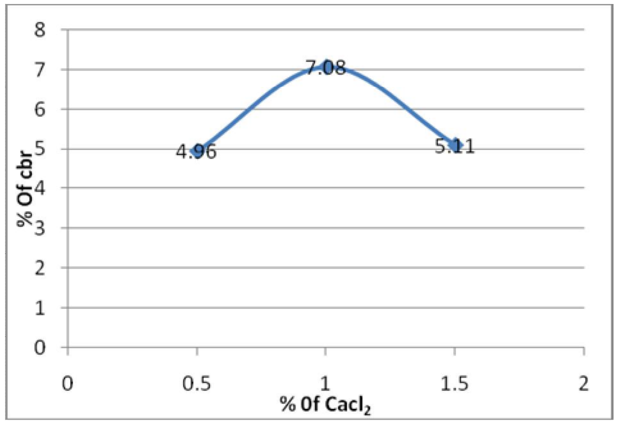


FIG 4.4 CBR VARIATION OF VPW TREATED MARINE CLAY WITH $Cacl_2$



4.3 LABORATORY CYCLIC PLATE LOAD TEST ON UNTREATED MARINE CLAY AND TREATED MARINE CLAY FLEXIBLE PAVEMENTS USING MODEL TANKS

Table 4.3 Laboratory Cyclic Plate Load Test Results Of Treated And Untreated Marine Clay Flexible Pavement At OMC

S. NO	Type of sub grade	Sub base	Base course	Pressure (kpa)	Settelement (mm)
1	Marine clay	----	-----	63.63	2.92
2	Untreated marine clay	Gravel	WBM-III	1000	2.45
3	Marine clay+15% VPW+1%Cacl2	Gravel	WBM-III	1400	2.35
4	Marine clay +15%vpw +1% cacl2 and geotextile provided as reinforcement &seperator	Gravel	WBM-III	2200	1.69

V. CONCLUSIONS

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

- It is observed from the laboratory test results that the liquid limit of the marine clay has been decreased by10.96 % on the addition of 15% vitrified polish waste and further the liquid limit of 15% VPW treated marine clay has been decreased by 23.56% with an addition of 1% $Cacl_2$ when compared with the untreated marine clay.
- It is noticed from the test results that the plasticity index of the marine clay has been decreased by 28.32% on addition of 15% Vitrified Polish Waste and further the plasticity index of 15% VPW treated marine clay has been decreased by 56.75% with an addition of 1% $Cacl_2$ when compared with the untreated marine clay.
- It is observed from the test results that the C.B.R. value of the marine clay has been increased by 61.92% on addition of 15% Vitrified Polish Waste and further the CBR value of 15% VPW treated marine clay has been improved by 38.41% with an addition of 1% $Cacl_2$ when compared with the untreated marine clay.
- From the cyclic plate load test results of the untreated and treated marine clay model flexible pavements, the total and elastic deformation values were determined.
- From the laboratory observations, the total and elastic deformation values of the treated marine clay flexible pavement, at 560kPa (standard tyre pressure as per IRC Codes), has been reduced by 50% and 64% respectively at OMC, when compared with the untreated marine clay flexible pavement.
- It was observed from laboratory cyclic load test results that the load carrying capacity of the treated marine clay sub grade flexible pavement has been Improved 54.54% when compared with untreated marine clay flexible pavement.
- It was noticed from the laboratory result that, the total deformations at ultimate load carrying capacity of the treated marine clay model flexible pavement has been decreased by 37.40% at OMC, when compared with the untreated marine clay model flexible pavement.
- It was observed, in case of the cyclic plate load test, highest reduction in the values of total deformation was observed for the treated marine clay flexible pavement with 1% $Cacl_2$+ 15% VPW and geotextile as reinforcement and separator at OMC.

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