The Influence of Lime And Quarry Dust on Improving The Properties of Marine Clay For Foundation Beds

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Abstract- *Vast areas, particularly along the coast, are covered with thick soft marine clay deposits having very low shear strength and high compressibility. India has large coastline exceeding 6000kms.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. Soft soils are generally labeled as 'problematic' because they have poor resistance to deformation, low permeability and limited bearing capacity. The properties of marine soil depend significantly on its initial conditions. The properties of saturated marine soil differ significantly from moist soil and dry soil. Due to the poor engineering characteristics of these deposits, they pose several foundation problems to various coastal structures.*

Majority of the population in India depends on road-based transport. There are many deposits of fine clays on coastal corridor and those soils are suffering from high saturation, low density, low shear strength, sensitivity, and deformation problems and are normally consolidated. The marine clays, because of the specific physico-chemical make-up, are subjected to volume change with the changes in their ambient environment. These soils are widely occupied in costal corridor and not easy to avoid marine clay regions for the construction of pavements and foundations due to the population density.

In any developing country infrastructure, transportation and communication facilities play a major role for the development. Majority of the population in India depends on road-based transport. The stability and performance of a pavement is reflected by the soil sub grade. Roads constructed on Marine Soils, have poor strength and high deformation character, are bound to fail resulting in poor pavement performance and increased maintenance costs. Problematic soils are unstable for any civil engineering construction including for construction of the pavements and foundation soil beds. Such soils have been treated with different kinds of additives to produce new materials, which impart stability and durability to the pavements and foundation soil beds.

On the other hand, accumulation of various waste materials is now becoming a major concern to the environmentalists. The situation of environmental pollution has become alarming and it is the foremost task to think regarding the disposal of waste materials. The generation, handling and disposal of solid wastes are now a severe concern in the country. In these circumstances, there is a need to explore the possibility of utilization of these waste materials in bulk. Highway construction is one such field where waste materials can be used in abundance, reducing the total cost of construction in addition to providing a solution to an environmental problem

A substantial literature has concluded the severity and extent of damage inflicted by soil deposits of soft soils in the nature, to various structures, throughout the world (Ganapathy, 1977; Jones.D.E, 1982; Shridharan et.al, 1989; Abduljauwad, 1995; Osama and Ahmed, 2002; Supakij Nontananandh et.al, 2004; Zhuge et.al, 2007; Ameta, N.K, 2007; Basack et. al,2009; Kamruzzaman et.al, 2009 and Fairfax Country, Virginia,2010). The loss caused due to the damaged structures proved the need for more reliable investigation of such soils and necessitates methods to eliminate, or reduce, the effect of settlements.

Keeping in view the research findings outlined above, in the present work, experimentation was carried out to investigate the efficacy of different additives, viz., lime and Quarry Dust, in stabilizing the marine clay, thereby, improving the strength, swell characteristics of the marine clay. A systematic methodical process was followed, involving experimentation in the laboratory under controlled conditions.

It was observed that ***7.5% lime*** *treatment as individually and with the combination of* ***25% Quarry Dust*** *with marine clay has effectively improved the laboratory CBR value.*

Keywords- Vast areas, particularly along the coast, are covered with thick soft marine clay deposits having very low shear strength and high compressibility. India has large coastline exceeding 6000kms.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. The properties of saturated marine soil differ significantly from moist soil and dry soil. Due to the poor engineering characteristics of these deposits, they pose several foundation problems to various coastal structures.

I. INTRODUCTION

Vast areas, particularly along the coast, are covered with thick soft marine clay deposits having very low shear strength and high compressibility. India has large coastline exceeding 6000kms. In view of the developments on coastal areas in the recent past, large number of ports and industries are being built. In addition, the availability of land for the development of commercial, housing, industrial and transportation, infrastructure etc. are scarce particularly in urban areas. This necessitated the use of land, which has weak strata, wherein the geotechnical engineers are challenged by presence of different problematic soils with varied engineering characteristics. Many of these areas are covered with thick soft marine clay deposit, with very low shear strength and high compressibility.

Majority of the population in India depends on road-based transport. There are many deposits of fine clays on coastal corridor and those soils are suffering from high saturation, low density, low shear strength, sensitivity, and deformation problems and are normally consolidated. The marine clays, because of the specific physico-chemical make-up, are subjected to volume change with the changes in their ambient environment. These soils are widely occupied in costal corridor and not easy to avoid marine clay regions for the construction of pavements and foundations due to the population density.

The marine clays are not suitable as pavement sub grade & foundation soil beds and pose problems due to their inability of strength criteria. More and more construction projects are encountering soft clays and hence there is a need to better quantifying the properties of marine clays.

These soils are generally found in the states of West Bengal, Orissa, Andhra Pradesh, Tamilnadu, Kerala, Karnataka, Maharashtra and some parts of Gujarat in India. So there is need to improve transportation and also the construction facilities in these coastal regions for easy access. Marine clays exist in these regions are weak and highly compressible in nature.

Continued efforts have been made all over the world to devise ways to means to solve the problems of marine clays. Placement of adequate surcharge load, chemical stabilization and using various reinforcement techniques are some of the tried and tested remedial measures to avoid problems posed by the marine clays.

A comprehensive review of literature indicates that considerable amount of work related to determination of engineering behavior of marine soils has been carried out worldwide since last 50 years. 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). The loss caused due to the damaged structures proved the need for more reliable investigation of such soils and necessitates methods to eliminate, or reduce, the effect of settlements. To overcome these problems, there is no other alternative, except to improve the sub-soil or sub grade for expected loads with suitable treatment to the in-situ soil.

In this work it is attempted to study the effect of LIME and QUARRY DUST on the properties of marine clay.

II. IDENTIFY, RESEARCH AND COLLECT IDEA

For any developing nation like India transportation and communication facilities are vital. The technology of road construction is subjected to changes to cope up with the vehicular pattern, construction materials and sub grade condition.

Sub grade soil 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 give adequate support to the pavement and for this the sub grade should possess sufficient stability under adverse climate and loading conditions. The formation of waves, corrugations, rutting and the phenomena of pumping, blowing and consequent cracking of cement concrete pavements are generally attributed due to the poor sub grade conditions.

All over the world, problems of marine clay have appeared as cracking and break-up of pavements, railway and highway embankments, roadways, building foundations, irrigation systems, water lines, canal and reservoir linings. The estimated damage was very expensive to the pavements running over the marine clay sub grades.

In addition to these, the problems arising out of high compressibility and low shear strength of these weak marine deposits expose geotechnical engineers to considerable changes in the construction of various coastal and offshore structures. The performance of these soft fine grained deposits under different conditions of environment varies over wide limits. In order to improve the engineering behavior of soils, several improvement techniques are available in geotechnical engineering practice. The fact that the selection of anyone 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.

Sustained efforts are being made all over the world on highway research field to evolve more promising treatment methods for proper design and construction of pavements running over the soft clay sub grade. In the present work, the efficacy of Lime and Quarry Dust, as stabilizing agents, was extensively studied in the laboratory, for improving the properties of marine clay.

Silvestri, V (1979) and Law, K.T (1979), reported that the undrained cohesion of the marine clay was determined using Triaxial, vane shear test and presented the effect of the consolidation pressure on the undrained shear strength of a soft clay.

Shridharan A et.al (1989), reported the Engineering properties of Cochin and Mangalore Marine Clays. A research has been done on the Physico-Chemical effects on the engineering behavior of Indian marine clays by Rao, M.S et.al (1992).

Hyde AL et.al (1993), presented the Engineering properties and stability criteria for marine clay under cyclic loading.

Paul K.Mathew et al.(1996) recommended the use of lime column technique to improve the permeability of a marine clay. And the result shows an enormous improvement in permeability values and the K values were 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, J et.al (2002), reported the consolidation and permeability properties of the Singapore marine clay based on the laboratory and field investigations.

Balasubramaniam, A.S et.al (2003), proved the effects of additives on Soft Clay behavior and concluded that the strength characteristics of the soft clays are improved by using various additives.

Supakij Nontananandh, Sanupong Boonyong et al.(2004) studied the efficiency of Cement and Fly ash with marine clay and the test results shows that strengths are markedly increased when mixed with OPC and OPC with 10% fly ash replacement.

Oh, E.Y.N et.al (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. W.L. 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.

Basack,S et.al (2009), reported that the Engineering characteristics of marine clay collected form Visakhapatnam, India and the physical, chemical and mineralogical properties were presented and the strength, stiffness of the soil water matrix were established

John E. Sevee (2010) compare a glacial marine clay deposit’s effective and total porosities and the result shows the effective porosity was found to be approximately equal to the total porosity within an error of less than 10%.

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

D. Koteswara Rao et al.(2012) studied the efficiency of Rice Husk Ash & Lime with marine clay and the test results concluded that load carrying capacity of the marine clay foundation soil bed has been improved.

III. STUDIES AND FINDINGS

Materials Used and Their Properties

The details of the various materials and chemicals used in the laboratory experimentation are reported in the following sections.

Marine clay

The marine clay used as sub grade and foundation soil in this study and was typical soft clay. The marine clay was collected at a depth of 0.30m to 1.00m from ground level from Kakinada Sea Ports limited, Kakinada, and Andhra Pradesh State, India. The properties of soil are presented in the Table 3.1. All the tests carried on the soil are as per IS specifications.

Lime

Commercial grade lime mainly consisting of 58.67% of Cao and 7.4% Silica was used in the study. The quantity of lime was varied from 0% to 10% by dry weight of soil.

Quarry Dust

The quarry dust used in this study was brought from Padmavathi crusher unit situated at Yeleswaram around 40 Km away from Kakinada.

Geo-textile

PP woven Geo-textile-GWF-40-220, manufactured by GARWARE –WALL ROPES LTD, Pune, India, was used in this investigation. The tensile strength of woven geo-textile is 60.00kN/m for warp and 45.00 kN/m for weft and was used in this investigation as a separator between sub-grade and sub-base.

Gravel

For the present investigation, the gravel was brought from Surampalem, East Godavari District, A.P, and India. The gravel was classified as well graded gravel and was used in this investigation as a sub-base course in all model flexible pavements.

Aggregates

Road aggregate of size between 40-20 mm, confirming WBM-III standards was used for the preparation of the base course in the investigation of the model flexible pavements

Table 3.1 Properties of Marine clay

S.No	Property	Value
1.	**Grain size distribution** Sand (%) Silt (%) Clay (%)	 **10** **29** **61**
2.	**Atterberg limits** Liquid limit (%) Plastic limit (%) Plasticity index (%) Shrinkage limit (%)	 **78.8** **27.16** **51.64** **9.5**
3.	**Compaction properties** Optimum Moisture Content, (%) Maximum Dry Density, (g/cc)	 **33.79** **1.364**
4.	**Specific Gravity (G)**	**2.440**
5.	**IS Classification**	**CH**
6.	**C.B.R (%)**	**0.895**
7.	**Differential free swell (%)**	**60**
8.	**Shear Strength Parameters** Cohesion (t/m²) Angle of internal friction (⁰)	 **11.25** **2**

Table 3.2 Properties of Quarry dust

S.No	Property	Value
1.	**Grain size distribution** Gravel(%) Sand (%) Fines (%)	 **14.6** **84.94** **0.46**
2.	**Atterberg limits** Liquid limit (%) Plastic limit (%) Plasticity index (%) Shrinkage limit (%)	 **19.072** **NP** **NP** **NP**
3.	**Compaction properties** Optimum Moisture Content, (%) Maximum Dry Density, (g/cc)	 **12.40** **2.04**
4.	**Specific Gravity (G)**	**2.906**
5	**IS Classification**	**SW**
6.	**C.B.R (%)**	**9.26**
7.	**Shear Strength Parameters** Cohesion (t/m²) Angle of internal friction (⁰)	 **0.5** **22**

Table 3.3 Properties of Gravel

S.No	Property	Value
1.	**Grain size distribution** Gravel(%) Sand (%) Fines (%)	 **60** **30** **10**
2.	**Atterberg limits** Liquid limit (%) Plastic limit (%) Plasticity index (%)	 **23** **17** **6**
3.	**Compaction properties** Optimum Moisture Content,(%) Maximum Dry Density, (g/cc)	 **11.55** **1.992**
4.	**Specific Gravity (G)**	**2.67**
5	**IS Classification**	**GW**
6.	**C.B.R (%)**	**15**

LABORATORY EXPERIMENTATION

Properties of Untreated and Treated Marine Clay

General

The soil was initially air dried prior to the testing. The tests were conducted in the laboratory on the marine clay to study the behavior of marine clay, when it was untreated and treated for the modal flexible pavements.

The following tests were conducted as per IS Codes of practice.

i. The grain size distribution
ii. Index properties –Liquid Limit, Plastic Limit, Shrinkage Limit
iii. Swell Tests- Differential Free swell
iv. Strength tests- Triaxial Compression tests
v. Penetration tests- California bearing ratio tests.
vi. Bearing tests- Cyclic plate load tests on model flexible pavements.

Grain Size Distribution

The grain size distribution of the treated and untreated marine clay was determined according to the Indian Standard Codes of practice I.S: 1498-1970.

Index Properties

Standard procedures recommended in the respective I.S Codes of practice (I.S.2720 (Part-V) -1985; IS: 2720 (Part-VI) -1972) were followed while finding the index properties of the untreated and treated marine clay.

Compaction Properties

Optimum moisture content and maximum dry density of untreated and treated marine clay and Quarry dust were determined according to I.S heavy compaction test (IS: 2720 (Part-VIII), 1983).

Differential Free Swell (DFS)

The DFS values of the untreated and treated marine clay were determined as per IS: 2720 (Part-XL)-1977.

Strength Characteristics

Strength characteristics of the treated and untreated marine clay were found as per I. S. (9143-1979) Codes of practice.

California Bearing Ratio (CBR) Tests

The CBR tests were conducted as per I.S. Codes (IS: 2720(Part XVI) - 1979) of practice on all combinations, and a set of two samples for each combination were tested and the average value was reported.

was placed on the loading as shown in the plate 3.1.

IV. RESULTS

Laboratory Test Results

General

In the laboratory, index tests, swell tests, strength tests were conducted by using different percentages of Lime and Quarry Dust(QD) with a view to determine the optimum percentages of Lime and Quarry Dust.

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

The effect of addition of Lime and Quarry Dust to the marine clay, on compaction, CBR properties, Atterberg limits, swell properties, and strength properties, were discussed in detail in the following sections.

Effect of Lime and Quarry Dust on Compaction and CBR Properties of the 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.

The individual influence of Lime and combination with Quarry Dust on the compaction and CBR properties of marine clay as observed in the laboratory testing as presented in Table 4.9,4.10 & 4.16,4.17 respectively.

It was observed that 7.5% lime treatment as individually and with the combination of 25% Quarry Dust with marine clay has effectively improved the laboratory CBR value as given in the Table4.10 & 4.17.

The optimum percentages of different individual additives observed during the laboratory experimentation were summarized and presented in the following table.

Additives	Optimum Percentage
$Ca(OH)_2$ Quarry Dust	7.5% 25%

Compaction test results of Lime treated marine clay

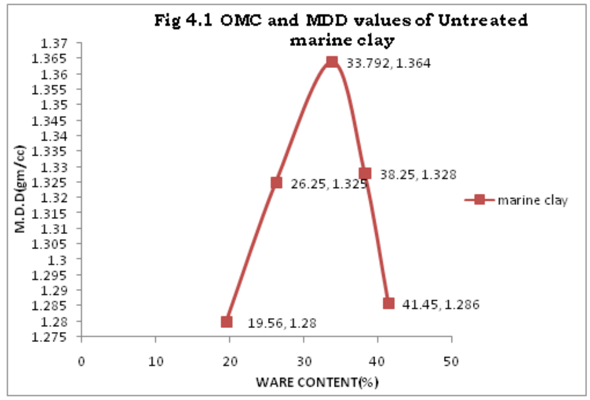
Compaction tests were conducted to get the Optimum moisture content and Maximum dry density of different proportions of marine clay and Lime using modified proctor compaction apparatus.

Compaction test results for untreated marine clay

Table 4.1 and Fig 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	19.56	1.28
	26.25	1.325
	33.792	**1.364**
	38.25	1.328
	41.45	1.286



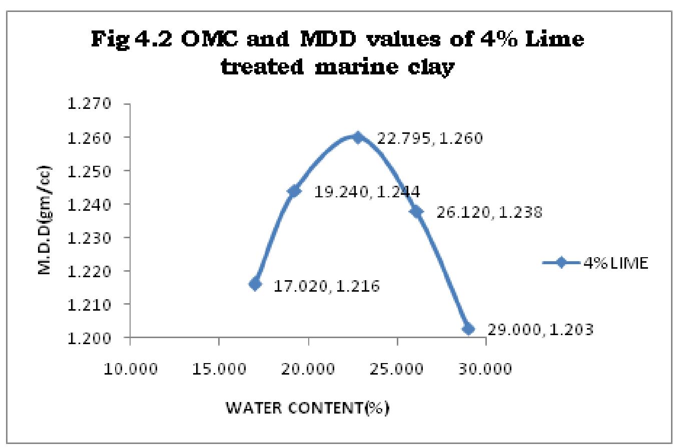
Optimum moisture content = 33.79%
Maximum dry density = 1.364 gm/cc

Compaction test results for marine clay treated with 4% Lime

Table 4.2 and Fig 4.2 present the OMC and MDD values of the 4% Lime treated marine clay.

Table 4.2 Compaction Properties of 4% Lime treated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
96%Marine Clay+4% Lime	17.02	1.216
	19.24	1.244
	22.795	**1.260**
	26.12	1.238
	29.00	1.203



Optimum moisture content = 22.795 %
Maximum dry density = 1.260 gm/cc

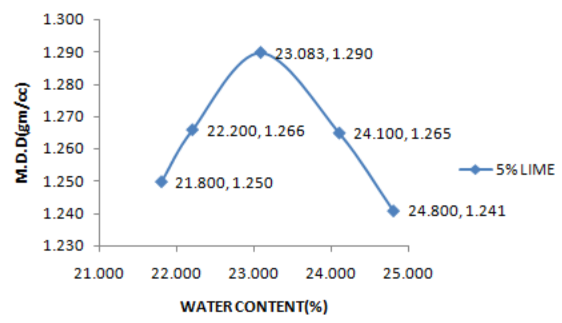
Compaction test results for marine clay treated with 5% Lime

Table 4.3 and Fig 4.3 present the OMC and MDD values of the 5% Lime treated marine clay.

Table 4.3 Compaction Properties of 5% Lime treated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
95%Marine Clay+5% Lime	21.800	1.250
	22.200	1.266
	23.083	**1.290**
	24.100	1.265
	24.800	1.241

Fig 4.3 OMC and MDD values of 5% Lime treated marine clay



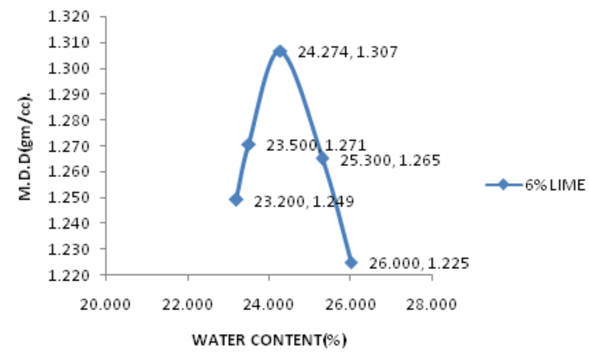
Optimum moisture content = 23.083 %
Maximum dry density = 1.290 gm/cc
Compaction test results for marine clay treated with 6% Lime

Table 4.4 and Fig 4.4 present the OMC and MDD values of the 6% Lime treated marine clay

Table 4.4 Compaction Properties of 6% Lime treated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
94%Marine Clay+6% Lime	23.200	1.249
	23.500	1.271
	24.274	**1.307**
	25.300	1.265
	26.000	1.225

Fig 4.4 OMC and MDD values of 6% Lime treated marine clay



Optimum moisture content = 24.274 %
Maximum dry density = 1.307gm/cc

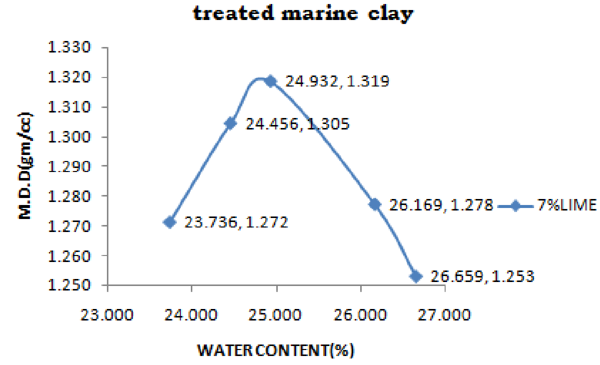
Compaction test results for marine clay treated with 7% Lime

Table 4.5 and Fig 4.5 present the OMC and MDD values of the 7% Lime treated marine clay.

Table 4.5 Compaction Properties of 7% Lime treated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
93%Marine Clay+7% Lime	23.736	1.272
	24.456	1.305
	24.932	**1.319**
	26.169	1.278
	26.659	1.253

Fig 4.5 OMC and MDD values of 7% Lime treated marine clay



Optimum moisture content = 24.800%.
Maximum dry density = 1.320gm/cc.

Compaction test results for marine clay treated with 7.5% Lime

Table 4.6 and Fig 4.6 present the OMC and MDD values of the 7.5% lime treated marine clay.

Table 4.6 Compaction Properties of 7.5% Lime treated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
92.5%Marine Clay+7.5% Lime	24.500	1.290
	24.900	1.306
	25.830	**1.330**
	27.205	1.295
	27.900	1.273

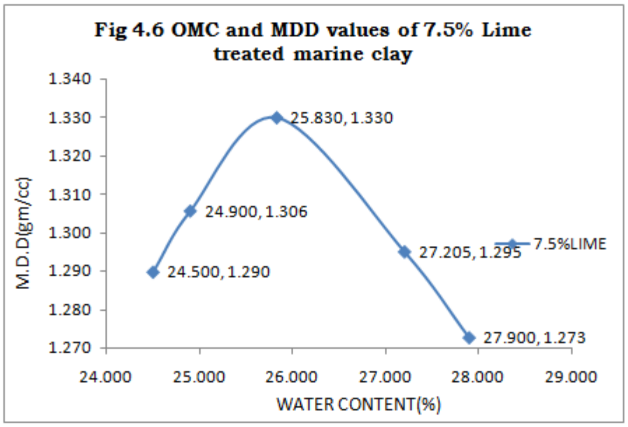


Fig 4.6 OMC and MDD values of 7.5% Lime treated marine clay

Optimum moisture content = 25.830%.
Maximum dry density = 1.330gm/cc.

Compaction Test Results for Marine Clay Treated with 8% Lime

Table 4.7 and Fig 4.7 present the OMC and MDD values of the 8% lime treated marine clay.

Table 4.7 Compaction Properties of 8%Lime treated Marine Clay

Mix Proportion	OMC (%)	MDD (g/cc)
92%Marine Clay+8% Lime	25.400	1.282
	25.841	1.294
	26.836	**1.320**
	27.800	1.302
	28.500	1.275

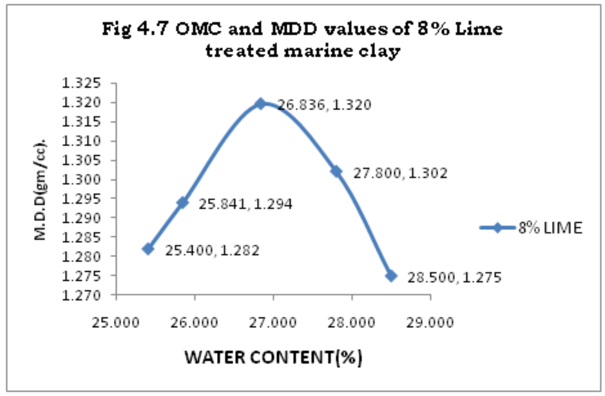


Fig 4.7 OMC and MDD values of 8% Lime treated marine clay

Optimum moisture content = 26.836%.
Maximum dry density = 1.320gm/cc.

Compaction test results for marine clay treated with 9% Lime

Table 4.8 and Fig 4.8 present the OMC and MDD values of the 9% lime treated marine clay.

Mix Proportion	OMC (%)	MDD (g/cc)
91%Marine Clay+9% Lime	26.174	1.277
	26.342	1.285
	27.209	**1.305**
	28.000	1.279
	28.366	1.265

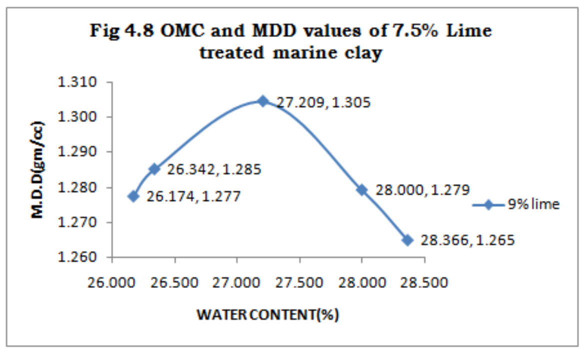


Fig 4.8 OMC and MDD values of 7.5% Lime treated marine clay

Optimum moisture content = 27.209%.
Maximum dry density = 1.305gm/cc.

Compaction test results for marine clay treated with % Variation of Lime.

Table 4.9 and Fig 4.9 present the OMC and MDD values of the marine clay treated with % Variation of Lime.

Table 4.9 Compaction Properties of Marine Clay treated with % Variation of Lime

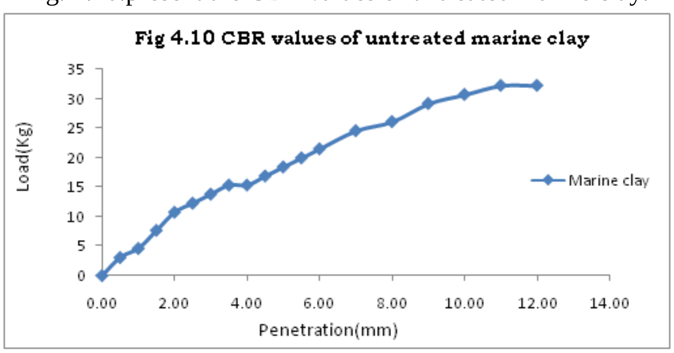
Mix Proportion	OMC (%)	MDD (g/cc)
100% Marine clay	33.792	1.364
96%Marine clay +4%Lime	22.795	1.260
95%Marine clay +5%Lime	23.083	1.290
94%Marine clay +6%Lime	24.274	1.307
93%Marine clay +7%Lime	24.800	1.320
92.5%Marine clay+ 7.5%Lime	**25.830**	**1.330**
92%Marine clay +8%Lime	26.836	1.320
91%Marine clay +9%Lime	27.209	1.305

C.B.R Test Results of Lime treated Marine Clay

The soaked and un-soaked CBR values of various mixes of marine clay and Lime using OMC obtained from compaction tests are determined. The soaked CBR after immersing in water for four days , that is when full saturation is likely to occur, is also determined. Variation of CBR with % variation in Lime is presented.

C.B.R Test Results of Untreated Marine Clay

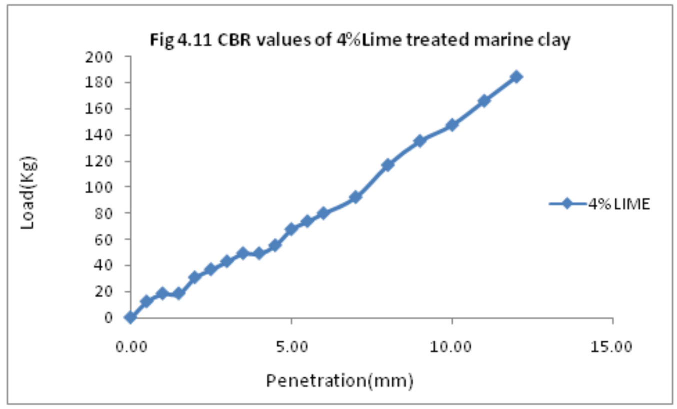
Fig. 4.10.present the CBR values of untreated marine clay.



CBR (soaked) value: 0.896%

C.B.R Test Results of Marine Clay Treated with 4% Lime

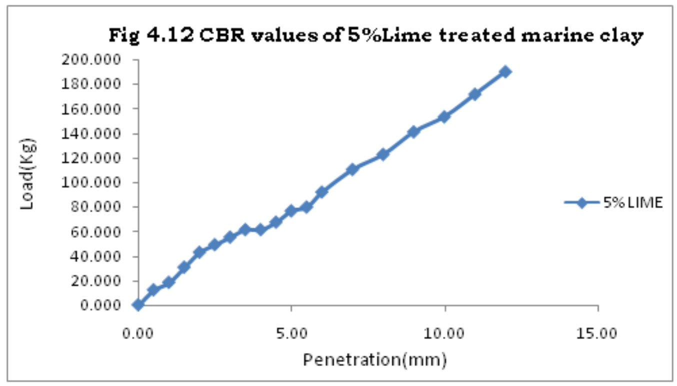
Fig. 4.11present the CBR values of 4% Lime treated marine clay.



CBR (soaked) value: 3.287 %

C.B.R Test Results of Marine Clay Treated with 5% Lime

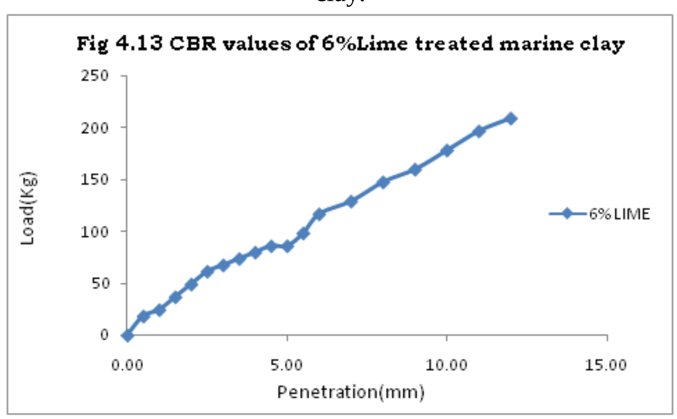
Fig. 4.12.present the CBR values of 5% Lime treated marine clay.



CBR (soaked) value: 3.735 %

C.B.R Test Results of Marine Clay Treated with 6% Lime

Fig. 4.13.present the CBR values of 6% Lime treated marine clay.



CBR (soaked) value: 4.482 %.

C.B.R Test Results of Marine Clay Treated with 7% Lime

Fig. 4.14.present the CBR values of 7% Lime treated marine clay.

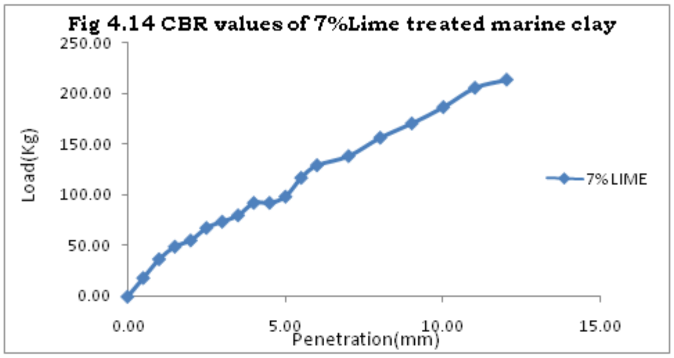


Fig 4.14 CBR values of 7%Lime treated marine clay

CBR (soaked) value: 4.930 %.

C.B.R Test Results of Marine Clay Treated with 7.5% Lime

Fig. 4.15 present the CBR values of 7.5% Lime treated marine clay.

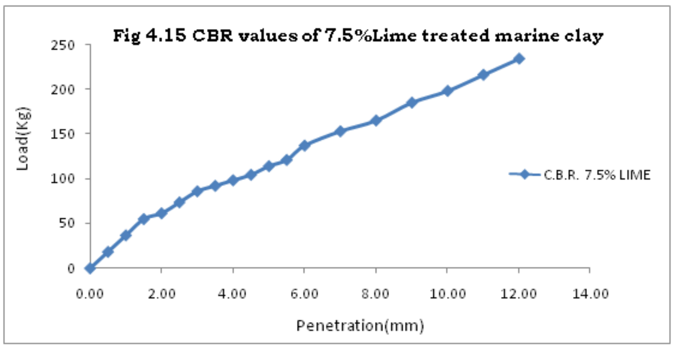


Fig 4.15 CBR values of 7.5%Lime treated marine clay

CBR (soaked) value: 5.378 %.

C.B.R Test Results of Marine Clay Treated with 8% Lime

Fig. 4.16.present the CBR values of 8% Lime treated marine clay.

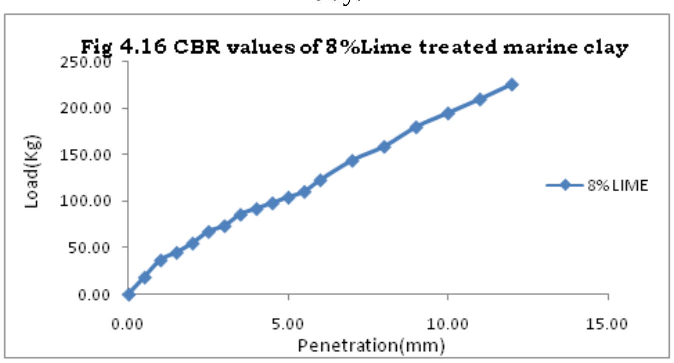


Fig 4.16 CBR values of 8%Lime treated marine clay

CBR (soaked) value: 5.079 %.

C.B.R Test Results of Marine Clay Treated with 9% Lime

Fig. 4.17.present the CBR values of 9% Lime treated marine clay.

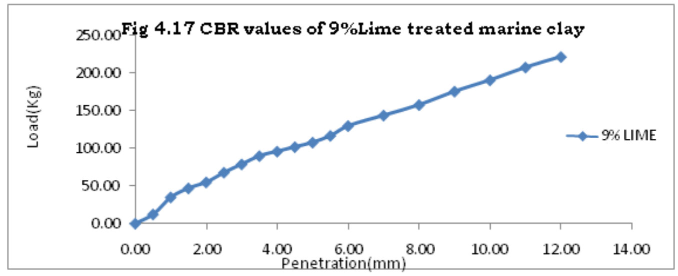


Fig 4.17 CBR values of 9%Lime treated marine clay

CBR (soaked) value: 4.930 %.

CBR test results for marine clay treated with %Variation of Lime.

Table 4.10 and Fig 4.18 present the CBR values of the marine clay treated with % Variation of Lime.

Table 4.10 CBR Values of Marine Clay treated with % Variation of Lime

Mix proportion	% variation of Lime	Soaked CBR
Marine clay	0	0.896
96% Marine clay	4	3.287
95% Marine clay	5	3.735
94% Marine clay	6	4.482
93% Marine clay	7	4.930
92.5% Marine clay	**7.5**	**5.378**
92% Marine clay	8	5.079
91% Marine clay	9	4.930

It was observed that 7.5% lime treatment as individually with marine clay has effectively improved the laboratory CBR value as given in the Table4.11 and Figs 4.9 & 4.18. However, beyond the addition of 7.5% Lime no significant improvement in CBR values of the marine clay were observed as depicted in the Fig.4.18.

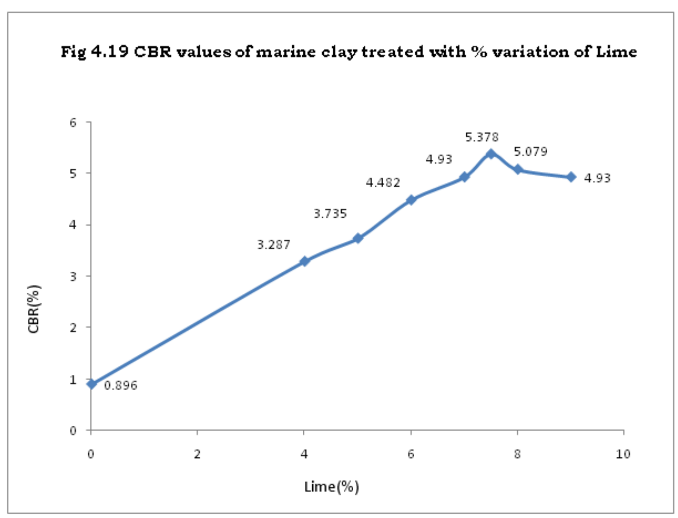


Fig 4.19 CBR values of marine clay treated with % variation of Lime

Table 4.11 Properties of Untreated and Lime Treated Marine clay

S.No	Property	Untreated Marine Clay	7.5% Lime Treated Marine Clay
1.	**Atterberg limits**		
	Liquid limit (%)	**78.8**	**65.20**
	Plastic limit (%)	**27.16**	**30.50**
	Plasticity index (%)	**51.64**	**34.70**
	Shrinkage limit (%)	**9.5**	**12**
2.	**Compaction properties**		
	Optimum Moisture Content, (%)	**33.79**	**25.83**
	Maximum Dry Density, (g/cc)	**1.364**	**1.330**
3	**Specific Gravity (G)**	**2.44**	**2.503**
4.	**IS Classification**	**CH**	**CH**
5.	**C.B.R (%)**	**0.895**	**5.378**
6.	**Differential free swell (%)**	**60**	**40**
7	**Shear Strength Parameters**		
	Cohesion (t/m²)	**11.25**	**8.5**
	Angle of internal friction(⁰)	**2**	**7**

Compaction test results of Lime treated marine clay with %variation of Quarry Dust

Compaction tests were conducted to get the Optimum moisture content and Maximum dry density of different proportions of Quarry Dust and Lime treated marine clay using modified proctor compaction apparatus.

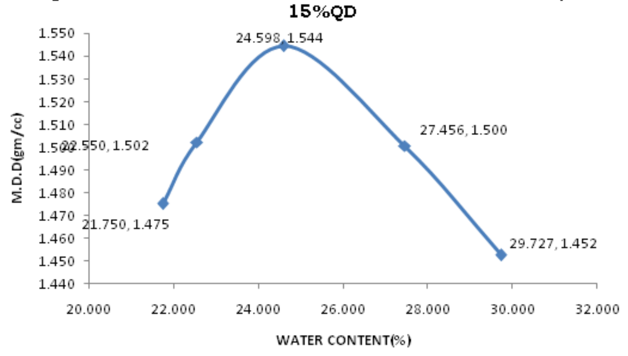
Compaction test results for Lime treated marine clay with 15% QD

Table 4.12 and Fig 4.20 present the OMC and MDD values of the Lime treated marine clay with 15% QD.

Table 4.12 Compaction Properties of Lime treated Marine Clay with 15%QD

Mix Proportion	OMC (%)	MDD (g/cc)
85%Lime treated marine clay +15%QD	21.750	1.475
	22.550	1.502
	24.598	**1.544**
	27.456	1.500
	29.727	1.452

Fig 4.20 OMC and MDD values of Lime treated Marine Clay with 15%QD



Optimum moisture content = 24.598 %
Maximum dry density = 1.544 gm/cc

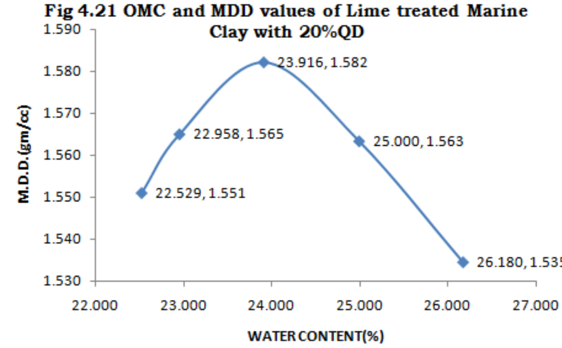
Compaction test results for Lime treated marine clay with 20% QD

Table 4.13 and Fig 4.21 present the OMC and MDD values of the Lime treated marine clay with 20% QD.

Table 4.13 Compaction Properties of Lime treated Marine Clay with 20%QD

Mix Proportion	OMC (%)	MDD (g/cc)
80%Lime treated marine clay +20%QD	22.529	1.551
	22.958	1.565
	23.916	**1.582**
	25.000	1.563
	26.180	1.535

Fig 4.21 OMC and MDD values of Lime treated Marine Clay with 20%QD



Optimum moisture content = 23.916 %
Maximum dry density = 1.582 gm/cc

Compaction test results for Lime treated marine clay with 25% QD

Table 4.14 and Fig 4.22 present the OMC and MDD values of the Lime treated marine clay with 25% QD.

Table 4.14 Compaction Properties of Lime treated Marine Clay with 25%QD

Mix Proportion	OMC (%)	MDD (g/cc)
75%Lime treated marine clay +25%QD	21.800	1.580
	22.246	1.594
	23.275	**1.623**
	24.205	1.590
	24.631	1.573

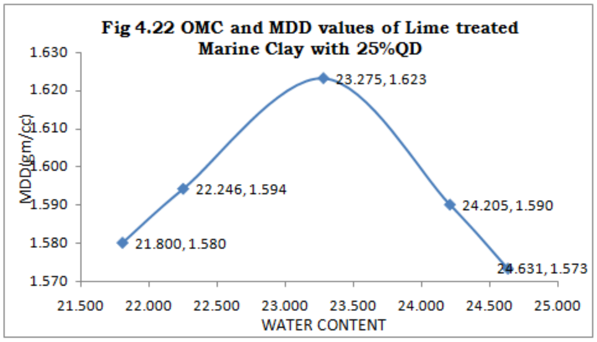


Fig 4.22 OMC and MDD values of Lime treated Marine Clay with 25%QD

Optimum moisture content = 23.275%
Maximum dry density = 1.623 gm/cc.

Compaction test results for Lime treated marine clay with 30% QD

Table 4.15 and Fig 4.23 present the OMC and MDD values of the Lime treated marine clay with 30% QD.

Table 4.15 Compaction Properties of Lime treated Marine Clay with 30%QD

Mix Proportion	OMC (%)	MDD (g/cc)
70%Lime treated marine clay +30%QD	16.240	1.573
	17.850	1.601
	20.650	**1.641**
	23.250	1.599
	24.650	1.539

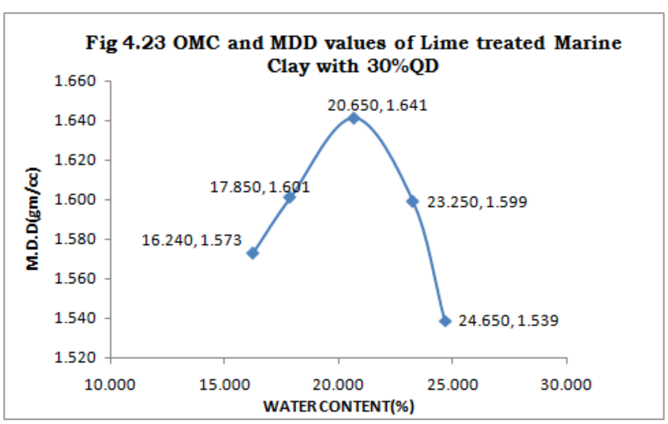


Fig 4.23 OMC and MDD values of Lime treated Marine Clay with 30%QD

Optimum moisture content = 20.307%
Maximum dry density = 1.641 gm/cc.

Compaction test results for Lime treated marine clay with %Variation of Quarry Dust.

Table 4.16and Fig 4.24 present the OMC and MDD values of the treated marine clay with % Variation of QD.

Table 4.16 Compaction Properties of Lime treated marine clay with % Variation of QD.

Mix Proportion	OMC (%)	MDD (g/cc)
85%Lime treated Marine clay +15%QD	24.598	1.544
80%Lime treated Marine clay +20%QD	23.916	1.582
75%Lime treated Marine clay +25%QD	23.275	1.623
70%Lime treated Marine clay +30%QD	20.650	1.641

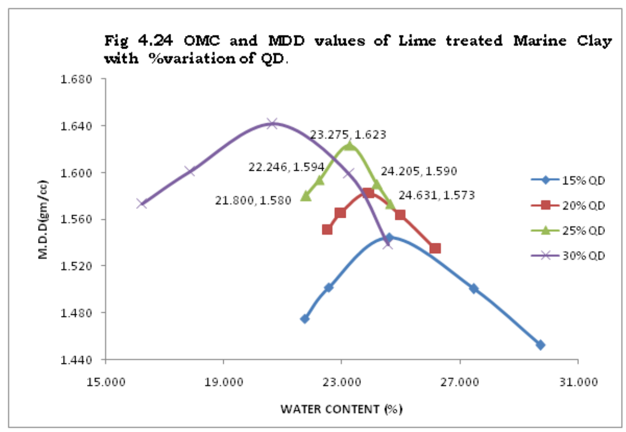


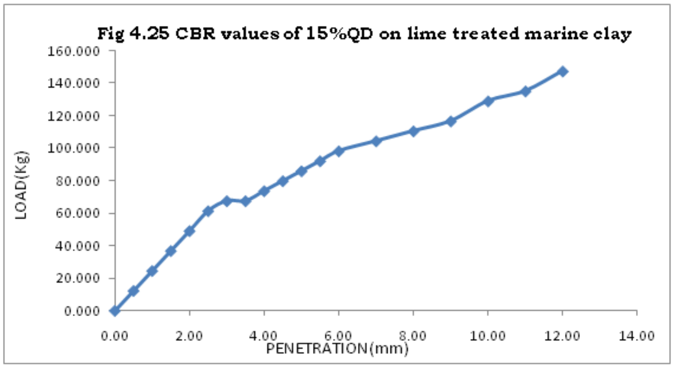
Fig 4.24 OMC and MDD values of Lime treated Marine Clay with %variation of QD.

C.B.R Test Results of Lime Treated Marine Clay with % Variation of Quarry Dust

The soaked and unsoaked CBR values of various mixes of lime treated marine clay and Quarry Dust using OMC obtained from compaction tests are determined. The soaked CBR after immersing in water for four days , that is when full saturation is likely to occur, is also determined. Variation of CBR with % variation of Quarry Dust is presented.

C.B.R Test Results of Lime Treated Marine Clay With 15% of Quarry Dust

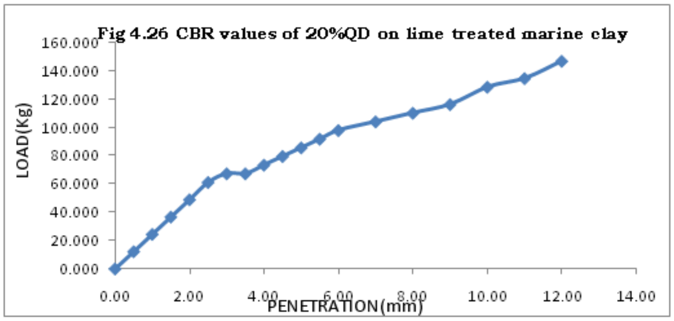
Fig. 4.25 present the CBR values of Lime Treated Marine Clay With 15% Of Quarry Dust.



CBR (soaked) value: 4.482%.

C.B.R Test Results of Lime Treated Marine Clay With 20% of Quarry Dust

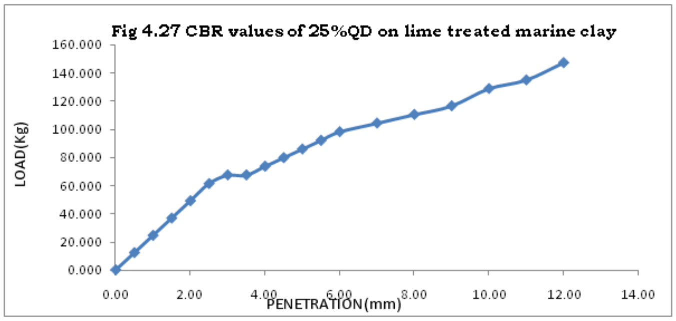
Fig. 4.26 present the CBR values of Lime Treated Marine Clay With 20% Of QD.



CBR (soaked) value: 5.677%.

C.B.R Test Results of Lime Treated Marine Clay With 25% Of Quarry Dust

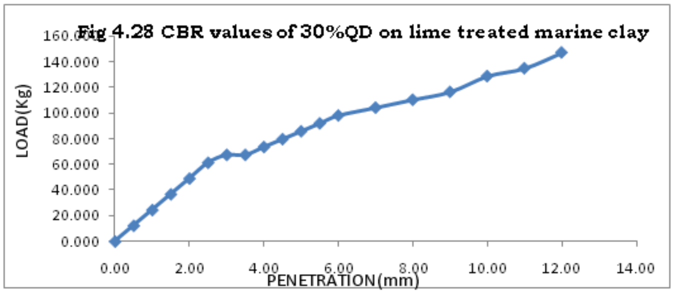
Fig. 4.27 present the CBR values of Lime Treated Marine Clay With 25% Of QD.



CBR (soaked) value: 6.573%.

C.B.R Test Results of Lime Treated Marine Clay With 30% of Quarry Dust

Fig. 4.28 present the CBR values of Lime Treated Marine Clay With 30% Of QD.



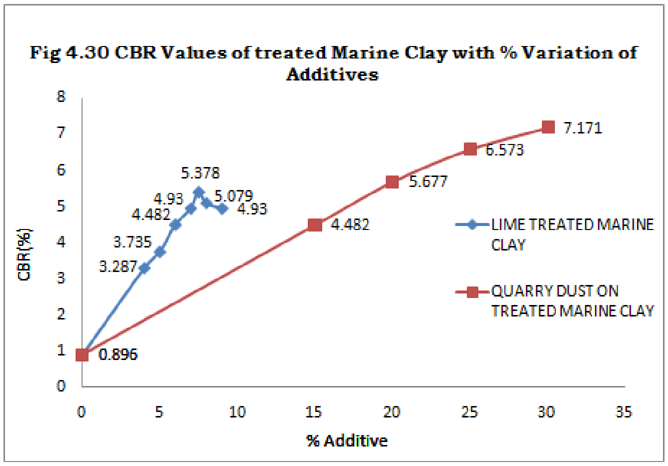
CBR (soaked) value: 7.171%.

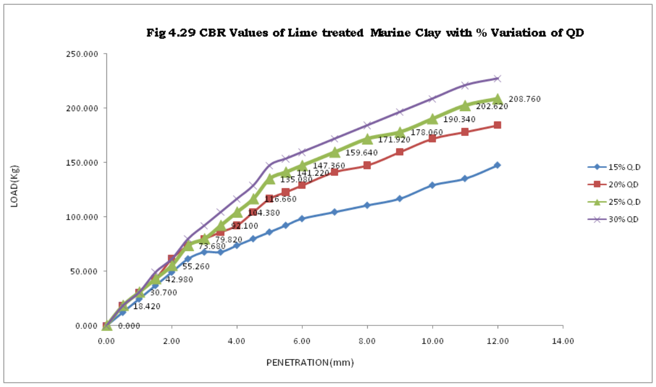
CBR test results for Lime Treated Marine Clay with %Variation of Quarry Dust.

Table 4.17 and Fig 4.29 present the CBR values of the Lime treated marine clay with % Variation of Quarry Dust.

Table 4.17 CBR Values of Lime treated Marine Clay with % Variation of QD

Mix proportion	%variation of Quarry Dust	Soaked CBR
Marine clay	0	0.896
Lime treated Marine clay	15	4.482
Lime treated Marine clay	20	5.677
Lime treated Marine clay	**25**	**6.573**
Lime treated Marine clay	30	7.171





It was observed that 7.5% lime treatment as individually and with the combination of 25% Quarry Dust with marine clay has effectively improved the laboratory CBR value as given in the Table4.11 & 4.17.

Properties of Untreated and Treated Marine Clay

Table 4.18 present the properties of untreated and treated marine clay with an optimum of 7.5% Lime and 25% Quarry Dust.

Table 4.18 Properties of Untreated and Treated Marine clay

S.No	Property	Untreated Marine Clay	25% Quarry Dust Treated Marine Clay	25% Quarry Dust +7.5% Lime + treated M.C
1.	**Atterberg limits** Liquid limit (%) Plastic limit (%) Plasticity index (%) Shrinkage limit (%)	 78.8 27.16 51.64 9.5	 65.20 30.50 34.70 12.00	 49.50 32.65 16.85 15.5
2.	**Compaction properties** Optimum Moisture Content, (%) Maximum Dry Density (g/cc)	 33.79 1.364	 25.83 1.330	 23.275 1.623
3	**Specific Gravity (G)**	2.44	2.503	2.669
4.	**IS Classification**	CH	CH	MI
5.	**C.B.R (%)**	0.895	5.378	6.574
6.	**Differential free swell (%)**	60	40	20
7	**Shear Strength Parameters** Cohesion (t/m²) Angle of internal friction (⁰)	 11.25 2	 8.5 7	 5.55 11

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 values are decreased by 17% and 37% on addition of 7.5% lime and 7.5% lime+25% Quarry dust respectively with respect to the untreated marine clay.
2. It was observed that the Plasticity index values are decreased by 33% and 67% on addition of 7.5% lime and 7.5% lime+25% Quarry dust respectively with respect to the untreated marine clay.
3. It was observed that 7.5% lime treatment as individually and with the combination of 25% Quarry Dust with marine clay has effectively improved the laboratory CBR value.
4. It was noticed from the laboratory investigations of the cyclic plate load test results that, the load carrying capacity of the treated marine clay model flexible pavement has been increased by 254% at OMC and 225% at FSC when compared with untreated marine clay subgrade model flexible pavement.
5. It was noticed from the laboratory results that, the total deformation at ultimate load carrying capacity of the treated marine clay model flexible pavement have been decreased by 40% at OMC and 38% at FSC when compared with the untreated marine clay subgrade model flexible pavement.

VI. ACKNOWLEDGMENT

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