



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 Issue: V Month of publication: May 2026

DOI: <https://doi.org/10.22214/ijraset.2026.83034>

www.ijraset.com

Call:  08813907089

E-mail ID: ijraset@gmail.com

A Laboratory Study on the Performance of Mill Scale Dust on Improving the Properties of the Marine Clay as Subgrade for Flexible Pavements

Sajida Sulthana Mohammed¹, Harish Gangaraju², Dr. D. Koteswara Rao³

¹Assistant Professor(C), Department of Civil Engineering, University College of Engineering Kakinada(A), JNTUK, Kakinada, Andhra Pradesh, India

²Ph.D. Scholar, Department of Civil Engineering, Mahindra University, Hyderabad, Telangana, India

³Professor of Civil Engineering & OSD to Hon'ble Vice Chancellor, JNTUK, Kakinada, Andhra Pradesh, India

Abstract: Globally, the Marine Clay is found in coastal areas. It is a problematic soil due to its varying moisture content and compressibility characteristics. In marine clays, the swelling and shrinkage behaviour is due to the clay mineral montmorillonite. Hence the constructions on the Marine Clay have become a challenging task for civil engineers. The Pavements on marine soils have low strength and highly compressible, resulting in poor performance and increased maintenance costs. Soil stabilization helps a lot in improving the strength characteristics of marine soil. Mill scale dust is a by-product from lathe machine workshops, which contains ferrous (Fe) predominantly, supports in improving the strength characteristics. In this investigation, the efficacy of mill scale dust has been studied for improving the strength parameters of the Marine Clay to suit it as subgrade for flexible pavements under cyclic pressures. In view of the recent developments in the coastal area, a great number of ports and industries are being created. The availability of land for the development of commercial, housing, industries and infrastructure etc., is limited. The scarcity of land become big task for civil engineers in civil engineering application and also become a challenged task for constructions of various structures in problematic soils. The Marine Clay is a kind of micro crystalline clay. It comprises clay minerals such as chlorite, illite, kaolinite, and montmorillonite, as well as non clay minerals such as quartz and feldspar. Because of the unpredictability associated with the performance of the Marine Clay, it provides significant challenges in pavement and foundation construction.

Due to its poor technical qualities, employing the Marine Clay (locally accessible soils) as a sub grade in a coastal zone will not give appropriate results. Several corrective measures, such as soil replacement, will be implemented, in which weak soil particles will be removed and replaced with rich soil particles. However, this is not economically possible, because it raises the project's budget. So, to avoid this problem and to improve soft soils, there are several solutions available, one of which is soil stabilization using admixtures (industrial by-products) and certain chemical additions. In the present study an attempt has been taken to improve the properties of Marine Clay with the percentage variation of Mill Scale Dust. The Marine Clay exhibited suitable on addition of 25 % Mill Scale Dust as optimum. The treated Marine Clay as exhibited suitable CBR value as per codes of practice [IRC 37:2012] and this treated Marine Clay can be used as subgrade for flexible pavements. The cyclic plate load test were conducted on treated and untreated Marine Clay model flexible pavements in the laboratory. It is observed from the laboratory test results that the treated Marine Clay is more effective as subgrade for flexible pavements under cyclic pressures.

Keywords: The Marine Clay, Mill Scale Dust, Subgrade, Stabilization, Flexible Pavements.

I. INTRODUCTION

Engineers have been essential to build earth constructions such as embankments and major highways over the Marine Clay deposits with inadequate bearing capacities and excessive settlement characteristics due to rapid development methods and related urbanization in certain parts of India. Construction on the Marine Clay deposits has proven difficult because of the high natural moisture content. Low permeability and high compressibility characterize this clay soil.

The Marine Clay is a kind of soil that can be found both on the ocean floor and on the coast. India, as a peninsular country, has a wide coastal region with a length of 7,517 kilometers. West Bengal, Orissa, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, and some portions of Gujarat are home to the Marine Clay.

These soils are often had low density, poor shear strength, and are very compressible in nature. The characteristics of saturated Marine Clay differ markedly from those of damp and dry soil. The Marine Clay is microcrystalline in nature, and it contains clay minerals such as chlorite, kaolinite, and illite, as well as non-clay minerals such as quartz and feldspar. The soils include a higher percentage of organic matter, which works as a cementing agent. Because of the unpredictability associated with their performance, the Marine Clay, in particular, can cause significant challenges in pavement design. They are frequently unstable beneath the pavement and are prone to a variety of difficulties with minor variations in moisture content. These soils are often compacted, very saturated, soft, and sensitive. These are often of low density, poor shear strength, and expansive in character. When wet, the Marine Clays expand and become soft, but when dry, they shrink and become hard.

The Marine Clays expand when they come into contact with moisture and shrink when that moisture is removed. These volume variations in swelling soils generate a slew of issues in structures that come into touch with them or are built on top of them. The liquid limit values of the Marine Clays in India range from 50 to 100 percent, the plasticity index ranges from 20 to 65 percent, and the shrinkage limit is from 9 to 14 percent.

A considerable literature has determined the severity and amount of damage produced by swelling soil deposits on various constructions across the world. The loss caused by damaged buildings demonstrated the necessity for more reliable analysis of such soil, as well as the essential ways to eliminate or limit the effect of soil volume change.

When blended in the right quantities with problematic soils, additives such as lime, fly ash, Portland cement, saw dust, and, more recently, synthetics can improve these issues. These extracts can be used alone or in blend, and each has creation difficulties that affect their performance.

II. MATERIALS AND METHODOLOGY

A. Materials

1) Marine Clay

The Marine Clay was collected at a depth of 0.3m-1.0m from Kakinada Sea Ports Limited in Kakinada. The port of Kakinada is located on India's east coast. Changes in the stress system, moisture content, and pore fluid chemistry are all very sensitive to soft the Marine Clays. Geotechnical engineers believe that any of the existing ground improvement techniques must be used to improve the behaviour of these deposits.

2) Mill Scale Dust

Mill Scale Dust is a by-product in lath Machine during smoothening of rusted cast iron. The flaky surface of hot rolled steel that consists of the mixed iron oxides iron (II) oxide (FeO), iron (III) oxide (Fe₂O₃), and iron (II,III) oxide (Fe₃O₄) is known as mill scale (Fe₃O₄, magnetite).

When red hot iron or steel billets are rolled in rolling mills, mill scale accumulates on the exterior surfaces of plates, sheets, and profiles. Mill scale has a bluish-black appearance. It is typically less than 0.1 mm (0.0039 in) thick and initially clings to the steel surface, protecting it from air corrosion if there is no break in the coating.

Because it is electro chemically cathodic to steel, any break in the mill scale coating will result in rapid corrosion of the steel exposed at the crack. Mill scale is therefore a benefit for a time until its coating cracks owing to handling of the steel product or any other mechanical reason.

When the steel needs to be treated, mill scale becomes an annoyance. Any paint that is placed over it is useless because it will be washed away with the scale when moisture-laden air passes beneath it. Thus, mill scale can be removed from steel surfaces by flame cleaning, pickling, or abrasive blasting, all of which are time-consuming and energy-intensive processes. This is why shipbuilders and steel fixers used to leave freshly rolled steel and rebar brought from mills out in the open to 'weather' until much of the scale came off due to atmospheric action. Nowadays, most steel mills can offer their product with mill scale removed and steel coated with shop primers, allowing for safe welding or painting. Mill scale produced in rolling mills will be collected and recycled at a sinter plant.

For this investigation, Mill Scale Dust was collected from the Jaggampeta East Godavari district of Andhra Pradesh, India.

B. Methodology

The Marine Clay is treated with various percentages of Mill Scale Dust to test the suitability of mix proportion as subgrade of the flexible pavement as given in the below table.

TABLE 1
METHODOLOGY

SI No	Trail Mix	Marine Clay (%)	Mill Scale Dust (%)
1	Trail Mix 1	100	0
2	Trail Mix 2	85	15
3	Trail Mix 3	80	20
4	Trail Mix 4	75	25

III. LABORATORY EXPERIMENTS

A series of laboratory tests were conducted on natural soil and stabilized mixes to evaluate improvements in engineering behavior, with all procedures performed in accordance with Indian Standard (IS) code regulations. The soil’s expansiveness was first determined via the Differential Free Swell (DFS) test (IS 2720 – Part 40) using distilled water and kerosene, where the reduction in DFS values for treated samples helped assess the effectiveness of stabilization in controlling swelling. The specific gravity of the soil solids was measured using a pycnometer (IS 2720 – Part 3) to provide insight into mineralogical composition and support compaction and classification studies. To evaluate workability and swelling potential, the liquid limit, plastic limit, and plasticity index were determined for both untreated and treated soils following IS 2720 – Part 5. Compaction characteristics, specifically the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), were obtained via the Standard Proctor compaction test (IS 2720 – Part 7) to study the influence of Mill Scale Dust combinations. Finally, soaked and unsoaked California Bearing Ratio (CBR) values (IS 2720 – Part 16) were determined to evaluate the potential use of the stabilized soil in pavement subgrades.

IV. RESULTS AND DISCUSSIONS

A. Untreated Marine Clay

The properties of the untreated Marine Clay are given in the table below.

TABLE 2
PROPERTIES OF UNTREATED MARINE CLAY

S. No	Property	Symbol	Untreated The Marine Clay
1.	Differential Free Swell (%)		40
2.	Specific Gravity	G	2.57
3.	Liquid Limit (%)	WL	79.2
4.	Plastic Limit (%)	WP	30.4
5.	Plasticity Index (%)	IP	48.8
6.	Soil Classification	-	CH
7.	Maximum Dry Density(g/cc)	MDD	1.601
8.	Optimum Moisture Content (%)	OMC	19.54
9.	CBR (%)		1.344

B. Differential Free Swell

TABLE 3
VARIATION OF DFS VALUES OF THE MARINE CLAY BLENDED WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	MIX PROPORTIONS	DFS (%)
1.	M.C+0% MSD	40
2.	M.C+15% MSD	35
3.	M.C+20% MSD	30
4.	M.C+25% MSD	25

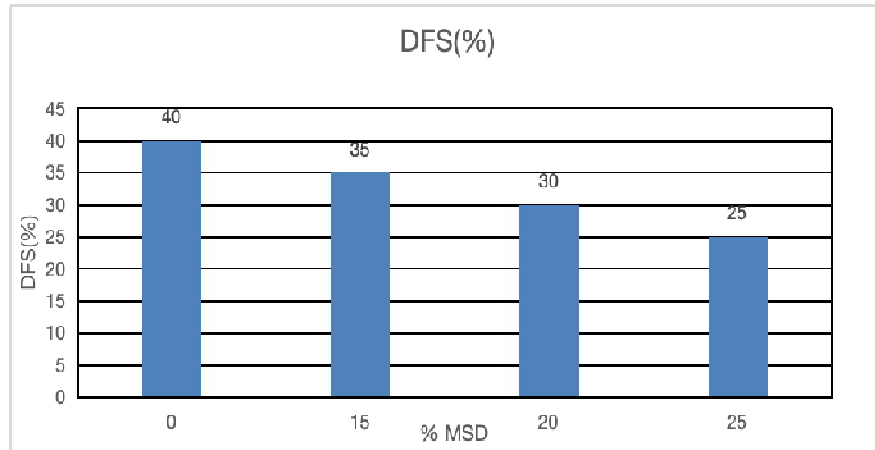


Fig 1 Variation of DFS of the Marine Clay blended with Different percentages of Mill Scale Dust

C. Atterberg Limits

TABLE 4

VARIATION OF LL, PL AND PI OF THE MARINE CLAY BLENDED WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	MIX PROPORTIONS	LL (%)	PL (%)	PI (%)
1.	M.C+0% MSD	57.09	25.62	31.47
2.	M.C+15% MSD	51.23	27.83	23.4
3.	M.C+20% MSD	47.93	29.27	18.66
4.	M.C+25% MSD	42.79	30.59	12.2

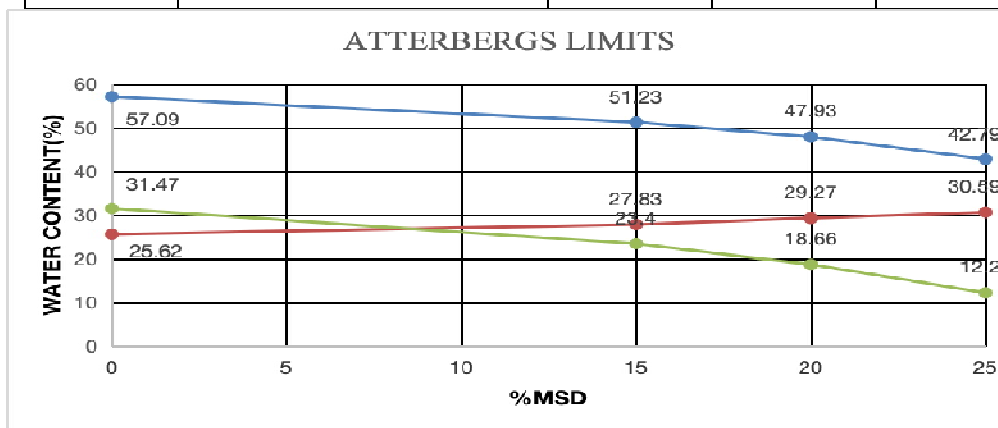


Fig 2 Variation of LL, PL and PI of The Marine Clay blended with Different Percentages of Mill Scale Dust

D. Compaction Characteristics

1) Maximum Dry Density

TABLE 5

VARIATION OF MDD FOR THE MARINE CLAY TREATED WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	MIX PROPORTIONS	MDD(g/cc)
1.	M.C+0% MSD	1.601
2.	M.C+15% MSD	1.712
3.	M.C+20% MSD	1.879
4.	M.C+25% MSD	1.986

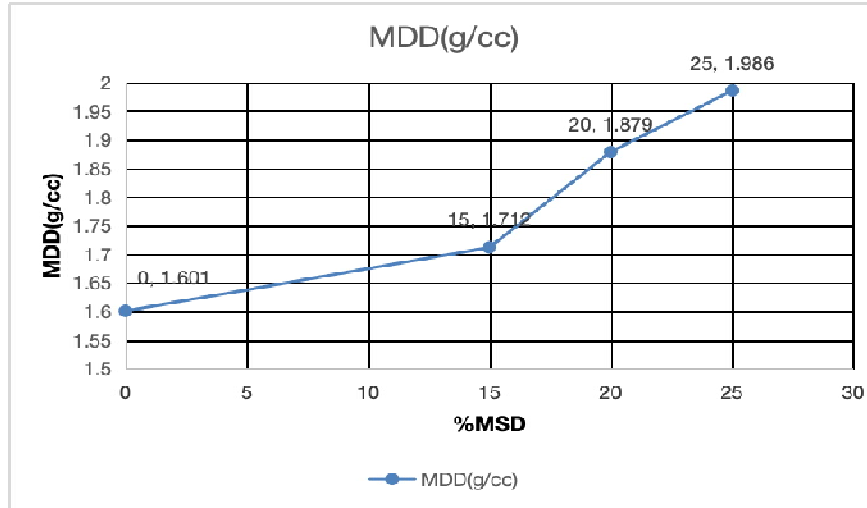


Fig 3 Variation of MDD for The Marine Clay Treated with Different Percentages of Mill Scale Dust

2) *Optimum Moisture Content*

TABLE 6

VARIATION OF OMC FOR THE MARINE CLAY TREATED WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	MIX PROPORTIONS	OMC (%)
1.	M.C+0% MSD	19.54
2.	M.C+15% MSD	15.59
3.	M.C+20% MSD	14.96
4.	M.C+25% MSD	13.012

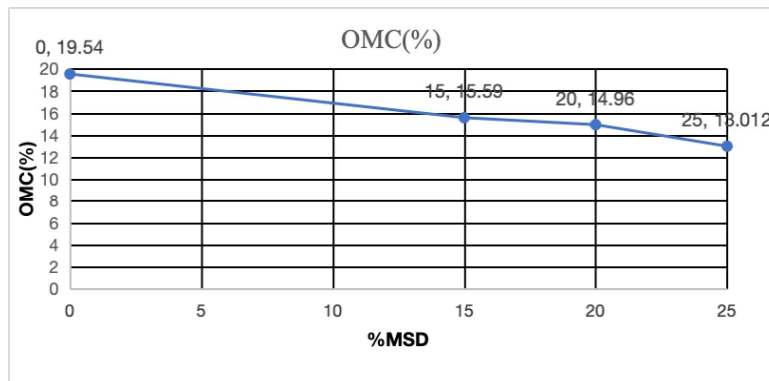


Fig 4 Variation of OMC for The Marine Clay Treated with Different Percentages of Mill Scale Dust

E. *California Bearing Ratio*

TABLE 7

VARIATION OF CBR VALUES FOR THE MARINE CLAY WITH DIFFERENT PERCENTAGES OF MILL SCALE DUST

S.no	MIX PROPORTIONS	CBR (%)
1.	M.C+0% MSD	1.344
2.	M.C+15% MSD	6.722
3.	M.C+20% MSD	7.618
4.	M.C+25% MSD	8.963

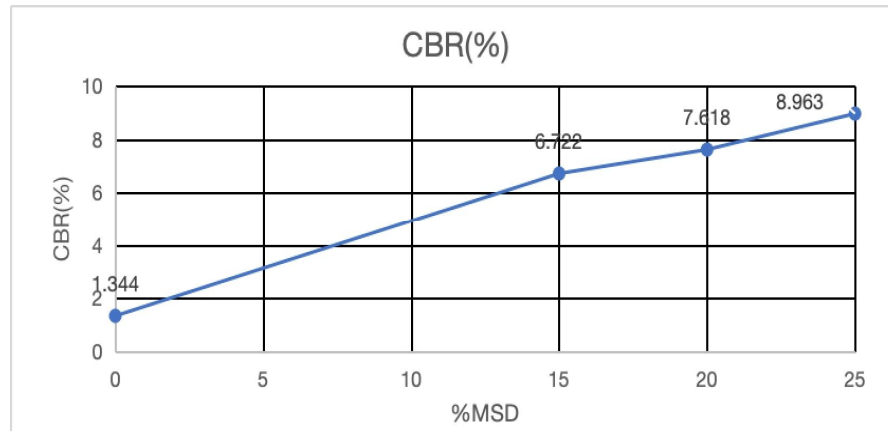


Fig 5 Variation of CBR values for the Marine Clay with Different Percentages of Mill Scale Dusts

F. Discussion

It was observed from the laboratory test results that the Marine Clay treated with an optimum of 25 % of Mill Scale Dust, has exhibited the CBR value is 8.96%. As per codes of practice IRC 37:2012 the CBR value of subgrade for flexible pavements is greater than or equal to 8%.

V. CONCLUSIONS

- 1) It is noticed from the laboratory test results the Differential Free Swell of Marine Clay has been improved by 37.5 % when compared with untreated Marine Clay.
- 2) It is noticed from the laboratory test results the liquid limit of Marine Clay has been decreased by 85.04 % when compared with untreated Marine Clay.
- 3) It is also observed from laboratory test results that the plasticity index of the treated Marine Clay has been enhanced by 75.03 % on addition of 25% Mill Scale Dust.
- 4) It is noticed from the laboratory test results the O.M.C of Marine Clay has been improved by 33.41 % when compared with untreated Marine Clay.
- 5) It is noticed from the laboratory test results the M.D.D of Marine Clay has been improved by 41.75 % when compared with untreated Marine Clay.
- 6) It is noticed from the laboratory test results the C.B.R of Marine Clay has been improved by 8.96 % when compared with untreated Marine Clay.

REFERENCES

- [1] D. Koteswara Rao, B. Satyanarayana, B. Rudrayya Chowdary "A Laboratory Investigation on the Influence of Calcium Chloride on Silica Fume Treated the Marine Clay as Sub-Grade for Flexible Pavements under Cyclic Pressures" International Interdisciplinary Research Journal Volume-08, Dec 2018 Special Issue (02).
- [2] Juliana Idrus et al. (2020) studied "Bearing capacity of soft the Marine Clay stabilization with Cockle Shell Powder (CSP)." ISSN: 2249 – 8958, Volume-9 Issue (2).
- [3] D. Koteswara Rao, Ch. Srikanth (2019) studied "An experimental study on the performance of the Marine Clay stabilized with seashell powder and sodium silicate as a sub-grade for the flexible pavements."
- [4] G.R. Ashwin Kumar, T. Thivakar, M. Pradeep Kumar, J. Raj (2018) studied "Stabilization of The Marine Clay by Using Copper Slag." ISSN: 2278-0181, Special Issue – 2015.
- [5] Samaila Saleh, Nur Zurairahetty Mohd Yunus, Kamarudin Ahmad and Nazri Ali (2018) studied "Stabilization of The Marine Clay Soil Using Polyurethane." SEPKA-ISEED 2018.
- [6] Aminaton Marto et al. (2016) studied "Stabilization of the Marine Clay using biomass silica-rubber chips mixture." doi:10.1088/1757-899X/160/1/012084.
- [7] B. Satyanarayana et al. (2018) studied "The effect of Silica Fume and lime in the stabilisation of the Marine Clay for the pavement sub-grade under Cyclic Pressure."
- [8] MatchalaSuneel et al. (2008) represented the compressibility characteristics of Korean Marine Clay.
- [9] 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.



- [10] Basak and purkayastha (2009), reported that the Engineering characteristics of Marine Clay collected from Visakhapatnam, India and the physical, chemical and mineralogical properties were presented and the strength, stiffness of the soil water matrix were established.
- [11] R. Pourebrahim et al (2010) presented the paper on effect of geogrids on compressive strength and elasticity modulus of lime and cement treated soils.
- [12] Mir sohail Ali et al (2011) represented that performance analysis of expansive soil treated with stone dust and fly ash.
- [13] Dr. D. Koteswara Rao et al (2012) presented the paper on the affect of Rice Husk Ash and Lime on the properties of Marine Clay.
- [14] Barends, F. (2011) introduction to soft soil geotechnique, content, context and application, Amsterdam, Netherlands:IOS Press.
- [15] G.V.R. Prasada Raju (2001), Elevation of Flexible Pavement Performance with Reinforcement and Chemical Stabilization of Expansive soil subgrade, a Ph.D. Thesis, Kakatiya University, Warangal.(A.P,India).



10.22214/IJRASET



45.98



IMPACT FACTOR:
7.129



IMPACT FACTOR:
7.429



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089  (24*7 Support on Whatsapp)