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Geotechnical Enhancement of Marine Clay using Optimized Blends of Lime and Ferrochrome Slag

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Abstract: This study investigates the feasibility of enhancing the geotechnical properties of problematic marine clay using a binary blend of lime and ferrochrome slag. Marine clay is a type of clay found in coastal regions typically exhibit poor engineering properties such as low shear strength, high compressibility, and high plasticity, making them unsuitable for infrastructure like roads and foundations with prior treatment. The main problem of marine clay is settlement and heave of house footings that are three feet more or less. This study involves preparing marine clay specimens mixed with various proportions of lime and ferrochrome slag. The mechanical and geotechnical properties of stabilized soil were evaluated through series of tests.

Keywords: Soil Stabilization, Marine Clay (MC), Lime, Ferrochrome Slag (FCS).

I. INTRODUCTION

The rapid expansion of coastal infrastructure, including highways, port facilities, and urban developments, frequently encounters vast deposits of marine clay. These soils are notoriously problematic due to their poor geotechnical properties, which stem from a high natural water content, low shear strength, high compressibility, and high plasticity. As a result, structures built on untreated marine clay are highly susceptible to excessive settlement, bearing capacity failure, and instability, necessitating significant and costly ground improvement measures. Soil stabilization is a crucial and widely adopted technique for chemically or physically improving the engineering performance of these soft soils, making them suitable for construction subgrades and embankments.

The most common and effective chemical stabilization technique involves adding a calcium-based binder like lime or cement. Lime, in particular, is an established stabilizer for clayey soils, initiating immediate property modification through cation exchange and flocculation, followed by long-term strength gain via slow reactions with the silica and alumina content of the clay.

However, the pursuit of sustainable and economical engineering solutions has motivated research into replacing or supplementing traditional stabilizers with industrial by-products. The production of conventional binders like cement and lime is energy-intensive and contributes significantly to global emissions. Simultaneously, industries worldwide generate voluminous quantities of waste materials, which pose major environmental and disposal challenges. The innovative use of these by-products in construction, known as waste valorisations, offers a dual benefit: reducing environmental footprint and lowering construction costs.

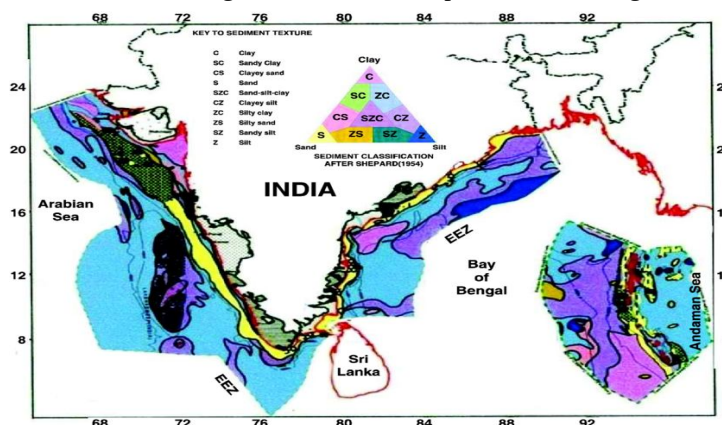


Figure 1 Map Showing Regional Seabed Sediment Types in Indian off Shore Territory

II. MATERIALS AND METHODS

A. Marine Clay

Source: Typically collected from coastal areas or port sites at a certain depth below the ground level.

Preparation: Air-dried, pulverized, and sieved to remove large organic matter or debris before testing and mixing.

Purpose: The soil to be stabilized, characterized by high contents of clay minerals (like illite and kaolinite) that make it highly sensitive to moisture variation.



Figure 2 sample of Marine Clay

B. Lime

Source: Commercial-grade hydrated lime, also known as calcium hydroxide.

Chemical Role: The main stabilizer. Its calcium ions react with the clay minerals, causing cation exchange and flocculation-agglomeration. This initial reaction immediately reduces the soil's plasticity, liquid limit, and swelling potential.



Figure 3 sample of Lime

C. Ferrochrome Slag

Source: A granular industrial by-product from the production of ferrochrome alloy.

Chemical Role: Typically serves as a pozzolanic material and filler. When combined with the free lime and water, it facilitates a long-term pozzolanic reaction. This process is responsible for the delayed but significant increase in the treated soil's strength and durability.



Figure 4 Sample of Ferrochrome Slag

D. Objectives of Study

The objectives of the present experimental study are

- 1) To determine the geotechnical properties of untreated marine clay.
- 2) To access the effect of adding several percentages of ferrochrome slag (5%, 10%, 15%, 20% to dry weight of the soil) on the strength characteristics of marine clay and finalizing the optimum percentage of ferrochrome slag.
- 3) To access the effect of adding several percentages of lime (0.5%, 1%, 1.5% and 2% by dry weight of the soil) on the strength properties of the marine clay treated with optimum percentage addition of lime to the treated marine clay.
- 4) To perform the cyclic plate load tests on both the untreated and treated marine clay subgrade model flexible pavements in the laboratory.

III.METHODOLOGY

This study was carried out at several stages to evaluate the performance of lime and ferrochrome slag on improving the strength properties of marine clay. This procedure includes collection of soil, preparation of materials, laboratory testing and analysing the results.

A. Materials Collection

For the present investigation the marine clay was collected from the special economic zone (SEZ) in Bheemili region at a depth of 1.0-1.5 m below the ground surface to avoid the marine mixing with impurities at the ground level. The soil samples were carefully excavated and transported to the laboratory, and then air-dried. The air dried marine clay was pulverized thoroughly lumps and then sieved through 4.75 mm IS sieve to obtain a uniform soil sample for testing.

- 1) Marine Clay: The collected material was used as base material for the stabilization. Its index and engineering properties of the marine clay were determined as per IS 1498, IS 2720 and IS 1888 codes of practice.
- 2) Ferrochrome Slag (FCS): The ferrochrome used in the present investigation was collected from the Jharana ferroalloys industry, Rasulgarh, Bhubaneswar, India. It is a by-product of ferrochrome production that can be used as sustainable construction material. It contains high percentages of silica, alumina, magnesia and chromium and aluminium compounds. A typical composition includes 27-33% of SiO_2 , 15-25% of Al_2O_3 , 20-35% of MgO and 10-15% of iron-chromium compounds.
- 3) Lime: Lime is collected from the Andhra scientific agency. Lime stabilization is a ground improvement technique that mixes lime with soil, typically fine-grained clay, to increase its strength, stiffness, and durability. This process involves several chemical reactions that permanently transform the soil into a stronger, more stable material by creating cementitious bond through a long-term pozzolanic reaction. The technique improves properties like load-bearing capacity and reduces plasticity, swelling, and shrinkage, making the soil suitable for construction purposes like roadways.

B. Mix Proportions

This stabilization process includes adding different percentages of lime and ferrochrome slag. Several percentages of ferrochrome slag were considered, viz., 5%, 10%, 15% and 20% and then the marine clay treated with several percentages of lime was stabilized on percentages (0.5%, 1%, 1.5%, and 2%) of lime.

Table -1: Mix Proportions for testing soil

S. NO	Stabilizing Agent	% Content
1	ferrochrome	5,10,15,20
2	lime	0.5,1,1.5,2

C. Laboratory Testing

To evaluate the influence of ferrochrome slag in improving the properties of marine clay. A series of laboratory tests conducted were carried out with several IS codes of practice. The tests were conducted are as follows:

- 1) Differential Free Swell (DFS) Test (IS 2720 – Part 40): The free swell behavior of the untreated and treated marine clay was studied to evaluate the reduction in expansiveness after stabilization. The DFS value was obtained by immersing oven- dried soil samples in kerosene and distilled water separately, and calculating the difference in swell percentage. This test was particularly important in determining the effectiveness of stabilization in controlling volumetric changes of marine clay.

- 2) Specific Gravity Test (IS: 2720 Part 3 – 1980): The specific gravity of soil solids was determined using a pycnometer method as per IS: 2720 (Part 3). Oven-dried soil passing through a 4.75 mm sieve was used. The soil sample was mixed with distilled water in the pycnometer, and weights were recorded for different stages. The specific gravity was calculated based on the ratio of the weight of soil solids to the weight of an equal volume of water. This property helps assess soil composition and its suitability for stabilization.
- 3) Atterberg Limits Test (IS 2720 – Part 5): This test was performed to determine the liquid limit, plastic limit, and plasticity index of both untreated and stabilized soil samples. The variation in plasticity characteristics helped in assessing the reduction in swelling tendency and workability of the soil.
- 4) Standard Proctor Compaction Test (IS 2720 – Part 7): Compaction tests were conducted to establish the maximum dry density (MDD) and optimum moisture content (OMC) for each mix proportion. The effect of foundry sand and Zycobond on soil densification and water requirement was examined.
- 5) California Bearing Ratio (CBR) Test (IS 2720 – Part 16): Both soaked and unsoaked CBR tests were conducted to determine the load-bearing capacity of the stabilized soil. The results provided a measure of the potential application of the stabilized marine clay in pavement subgrade construction.

Table 2: Properties of Marine clay

S. No	Property	Percentage
1	Gravel	0
2	Sand	11
3	Silt	43
4	Clay	46

Table 3: Engineering properties of Marine clay

S.No	Property	Untreated Marine Clay
1	Differential Free Swell (%)	82
2	Specific Gravity (G)	2.44
3	Liquid Limit (%)	67.04
4	Plastic Limit (%) W_p	32.60
5	Plasticity Index (%) I_p	34.44
6	Soil Classification	CH
7	Maximum Dry Density (g/cc) MDD	1.364
8	Optimum Moisture Content (%) OMC	32.40

IV. RESULTS AND DISCUSSIONS

A. Differential Free Swell

Table 4: Results of free swell index test

S. No	Mix Proportions	DFS (%)
1	M.C + 15% FCS	54
2	MC + 15% FCS + 1.0% Cao	48
3	MC + 15% FCS + 1.5% Cao	39
4	MC + 15% FCS + 2.0% Cao	7.0
5	MC + 15% FCS + 2.5% Cao	2.0

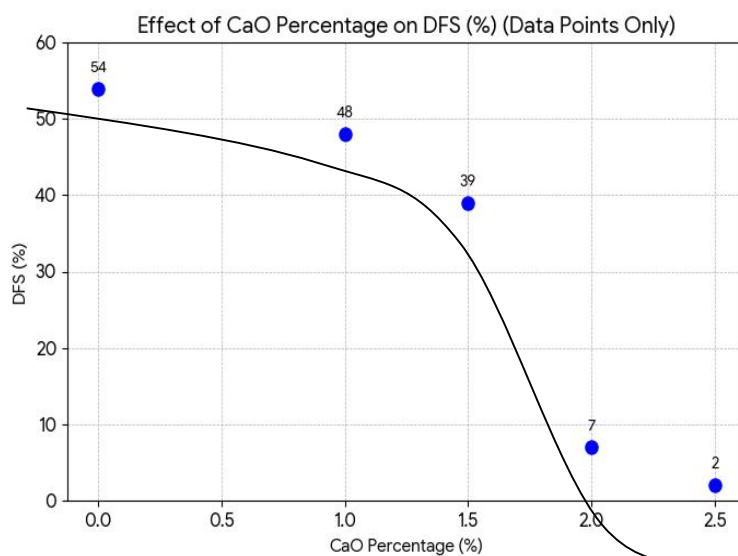


Figure 5 Variation in marine clay and ferrochrome treated with different percentages of lime

B. Atterberg's Limit

Table 5: Results for atterberg's limit

S.No	MIX PROPORTIONS	LL (%)	PL (%)	PI (%)
1	MC+15% FCS	56.50	36.30	21.30
2	MC+15% FCS+ 1% CaO	56.14	38.50	18.10
3	MC+15% FCS+1.5% CaO	55.29	40.14	16.12
4	MC+15% FCS+2.0% CaO	48.14	38.34	9.80
5	MC+15% FCS+2.5% CaO	53.94	44.16	11.36

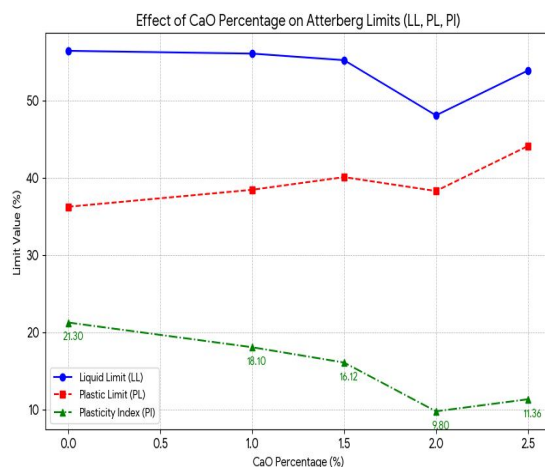


Figure 6 Variation in PL, LL, PI of marine clay and ferrochrome treated with different percentages of lime

C. Standard Proctor Compaction test

Table 5: Results for Modified Compaction Test

S. No	MIX PROPORTIONS	OMC (%)	MDD (g/cc)
1	M.C+15% FCS	14.12	1.880
2	MC+15% FCS+1.0% CaO	13.24	1.898
3	MC+15% FCS+1.5% CaO	12.23	1.914
4	MC+15% FCS+2.0% CaO	10.96	1.929
5	MC+15% FCS+2.5% CaO	9.36	1.912

D. California Bearing Ratio (CBR) test

Table 6: Results of CBR test

S. No	Mix Proportions	CBR %
1	M.C+15% FCS	5.90
2	MC+15% FCS+1.0% CaO	6.06
3	MC+15% FCS+1.5% CaO	6.96
4	MC+15% FCS+2.0% CaO	8.12
5	MC+15% FCS+2.5% CaO	7.62

Table 7: Properties of Treated and Untreated Marine Clay

S.NO	PROPERTIES	MARINE CLAY	M.C+15% FCS	M.C+15% FCS+2.0% Cao
1	Specific Gravity (G)	2.43	2.65	2.63
2	Differential Free Swell (%)	82	54	7.0
3	Liquid Limit (%)	67.04	56.50	48.14
4	Plastic Limit (%) W_p	32.60	36.30	38.34
5	Plasticity Index (%) IP	37.60	20.20	9.80
6	Soil Classification	CH	CH	CI
7	Optimum Moisture Content (%) OMC	32.40	14.12	16.56
8	Maximum Dry Density (g/cc) MDD	1.364	1.88	1.72
9	CBR (%)	1.12	5.90	8.12

V. CONCLUSIONS

The following conclusions were drawn based on the laboratory studies carried out for stabilizing the marine clay with an optimum of 15% Ferrochrome slag and further, the foundry sand treated marine clay was stabilized further with an optimum 2.0% of Lime.

Table 8: Optimum Percentages of FCS and Lime observed in the Geotechnical Laboratory Investigations

S. No	Additive	Optimum Percentage of Additives
1	Ferrochrome Slag	15%
2	Lime	2.0%

- 1) It is noticed from the laboratory test results that the Differential Free Swell of the Marine Clay has been reduced 54% on the addition of 15% FCS and it has been further reduced 27% with an addition of 2.0% of lime.
- 2) It is observed from the laboratory test results that the Liquid limit of Marine Clay has been decreased to 56.50% on the addition of 15% FCS and it has been further decreased to 48.14% with an addition of 2.0% Lime.

- 3) It is observed from the laboratory test results that the Plastic limit has been increased to 36.30% in addition of 15% FCS and it has been further increased 38.34% with an addition of 2.0% Lime.
- 4) It is noticed that the Plasticity Index has been decreased to 21.30% in addition of 10% FCS and it has been further decreased to 9.80% with addition of 2.0% Lime.
- 5) It is observed from the laboratory tests that the OMC of the Marine Clay has been decreased to 14.00% on the addition of 15% FCS and it has been further decreased to 32.64% in addition of 2.0% Lime.
- 6) It is observed from the laboratory tests that the MDD of the Marine Clay has been increased to 1.880g/cc on addition of 15% FCS and it has been further increased to 1.929g/cc with addition of 2.0% of Lime.
- 7) It is observed that the CBR of the Marine Clay has been increased to 5.90% on addition of 15% FCS and it has been further increased to 8.12% with addition of 2.0% Lime.

Applicability

- The treated marine clay can be used as a sub grade for flexible pavements as it exhibited this CBR value of 8.12% and this CBR value is suitable as IRC 37-2018.
- As per IRC 37-2018 codes of practice, any sub grade material should possess a minimum CBR value of 8%.
- In the present study the treated marine clay as exhibited a CBR value of 8.12%. Hence this treated marine clay is suitable to use as sub grade for flexible pavement.

REFERENCES

- [1] Dr. D. Koteswara Rao et al. (2011) "Laboratory Studies on the Properties of Stabilized Marine Clay from Kakinada Sea Coast, India" International Journal of Engineering and Technology, Vol. 3 No. 1 Jan 2011.
- [2] Dr. D. Koteswara Rao et al. (2011) "The Effect of Reinforcement on the GBFS and Lime treated Marine Clay for Foundation Soil Beds" International Journal of Engineering and Technology, Vol. 3 No. 3 March 2011.
- [3] Izabel K J et al. (2016) "Stabilization of Marine Clay Using Jerofix" International Journal of Scientific Engineering and Research (IJSER), Volume 4, Issue 3, March 2016.
- [4] Nandan A. Patel et al. (2015) "Subgrade soil stabilization using Chemical additives" International Journal of Science, Engineering and Technology Research (IJSETR), Volume 4, Issue 10.
- [5] Mustafa yasin et al. (2024) "Improvement of Geotechnical Properties of clayey Soil Using Biopolymer and Ferrochromium Slag Additives.
- [6] Manchikanti Srinivas et al. (2020) "A Study on the Performance of Marine Clay Stabilized with Waste Materials" Indian Geotechnical Society.
- [7] Youdeowei et al. (2020) "Soil Stabilization and Improvement of Marine Clay using Cement and Lime in a Marshland" Engineering Heritage Journal (GWK).
- [8] CH Ajay et al. "Ferrochrome Slag Characterization and its compatibility with Quarry in Flexible Pavement" IOP Conference Series (2020).
- [9] Venkateswarlu Dumpa et al (2014). "A study on the Lime-Cement Stabilized Marine Clay "Asian Journal of Microbiology Biotechnology and Environmental Sciences.
- [10] Fatin Amirah Kamaruddin et al (2020). "Improvement of Marine Clay Soil using Lime and Alkaline Activation Stabilized with Inclusion of Treated Coir Fibre" Applied Sciences.

BIOGRAPHIES



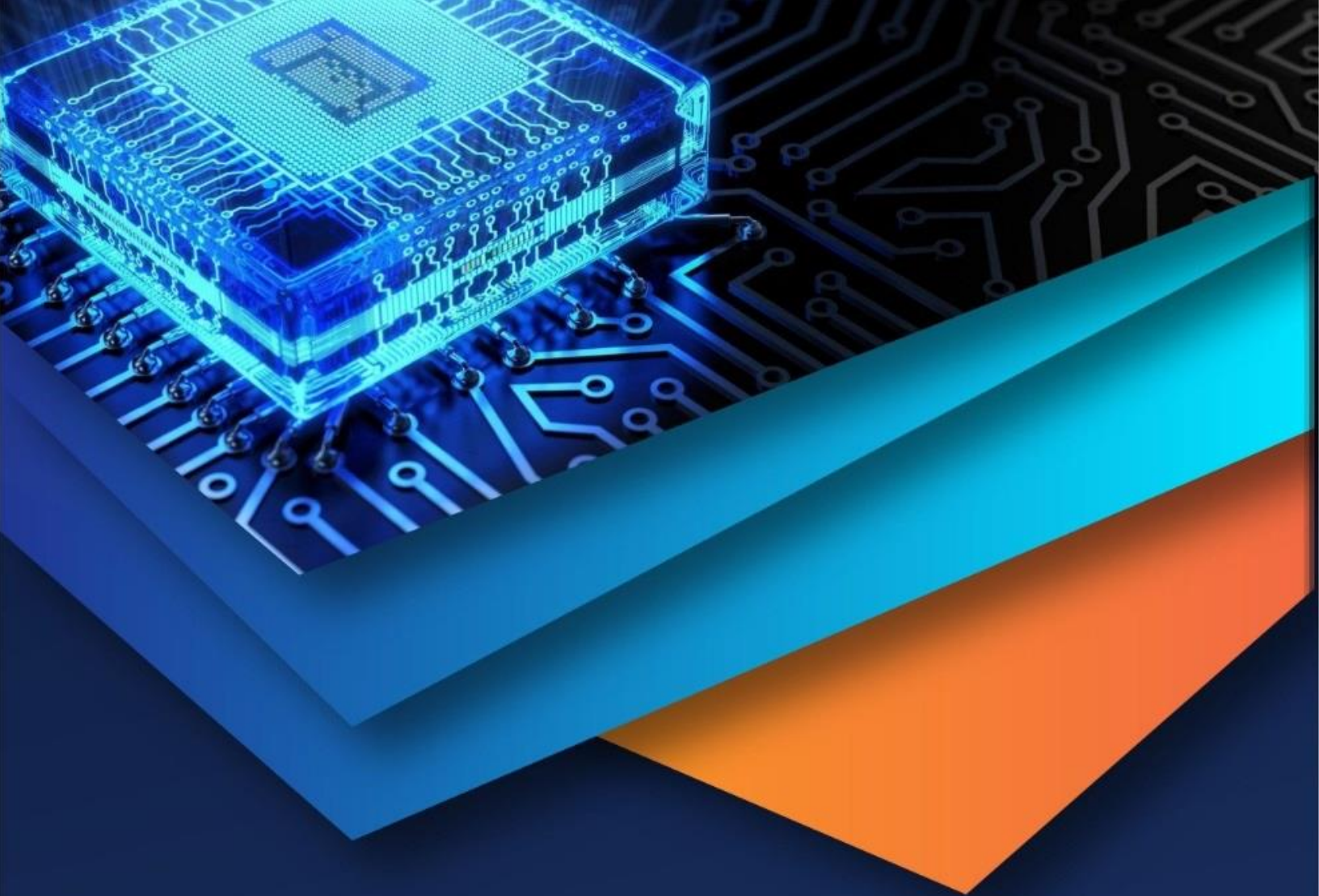
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