International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 10 Issue: 02 | Feb 2023 www.irjet.net p-ISSN: 2395-0072

A Laboratory Study on the Stabilization of Marine Clay using Copper Slag

Dowleswarapu Manikanta[1], Ch. Chaitanya Kumar~~Sat~~[2], M. Harsha ~~Satya Sai~~ Kiran[3], K.B.S.K.V Sai Ram ~~Satya S~~[4]

[1]Post Graduation Student, Department of Civil Engineering, UCEK-JNTUK Kakinada.
[2]Post Graduation Student, Department of Civil Engineering, UCEK-JNTUK Kakinada.
[3]Post Graduation Student, Department of Civil Engineering, UCEK-JNTUK Kakinada.
[4]Post Graduation Student, Department of Civil Engineering, UCEK-JNTUK Kakinada.

---***---

Abstract - *Marine clay refers to clays that are prevalent around the coast. The majority of the clays in the coastal areas are marine clays. Numerous ports and pavements are being constructed in these coastal districts as a result of ongoing industrialization. The soil subgrade on which the pavement was constructed has a major impact on how well it performs. The pavement will fail before it reaches the end of its life span if the subgrade is subjected to severe swell and shrinkage and low CBR value. Marine Clay contains minerals like illite, chlorite, and kaolinite are sensitive to significant swelling and shrinkage with a variation of moisture content and it has a lower CBR value. In order to enhance its engineering properties, marine clay is to be stabilized. industrial wastes like fly ash, steel slag, copper slag, etc can be utilized for soil stabilization. These industrial wastes require a lot of space to be disposed of, which poses serious environmental issues. These wastes can be used to stabilize soil while reducing environmental pollutants and enhancing the soil's Engineering Properties. The Engineering Properties of the Marine Clay obtained from Kakinada Seaports Pvt ltd are being improved in this study using Copper Slag (CS). Laboratory experiments like Atterberg's Limits and Modified Proctor Test and CBR tests are conducted with Various Percentages of Copper Slag and its Optimum Dosage was Identified.*

***Key Words*: Marine Clay, Copper Slag, MDD, OMC, CBR.**

1. Introduction

Clays that are found in the coastal regions are called Marine clay. Marine clays predominate all over the coastal regions. Due to rapid industrialization, a large number of ports and pavements are being built in these coastal regions. The performance of the pavement mainly depends upon the soil subgrade on which it is laid. When the soil subgrade is subjected to a high swell and shrinkage cycle then the pavement will fail before the end of its life period. Marine clay is subjected to high swell and shrinkage with varying moisture content, and also has a low CBR value. Due to its poor properties, marine clay has to be pre-treated to be used as a subgrade in highways. Soil Stabilization is one of the most popular and widely used ground improvement techniques. Soil stabilization can be done by adding admixtures to the soil. These admixtures react with the soil and improve its properties. Lime, ~~fly~~and fly ash are the most commonly used admixtures.

Industrial by-Products like copper slag, steel slag, ferrochrome slag, and zinc slag require more space to dispose as millions of tons of these waste are produced from the industries and also create environmental problems when they are not properly disposed. The usage of this waste as an admixture in soil stabilization helps in improving the soil properties in an economical manner as well as leads to a solution for disposing and minimizing environmental degradation.

In this present study, Copper Slag was added to Marine Clay to evaluate its performance through laboratory tests such as the standard proctor test and California Bearing Ratio test.

2. Objectives of The Study

The objectives of the present Laboratory study are

- To identify the Index and Engineering Properties of Marine Clay.
- To evaluate the performance of Marine Clay when treated with Copper Slag as an admixture and to identify its optimum dosage.

3. Materials Used

3.1 Marine Clay (MC)

Marine Clay used in this study was collected from the Kakinada Seaports Private Limited at a depth of 1.2 m below the ground level, it was air-dried and pulverized to the required size to and its geotechnical properties are determined as per IS codes of practice.

Fig-1: Marine Clay

S. No	Description		Value
1	Natural Moisture Content (%)		94.36
2	Particle Size Distribution	Gravel (%)	0
		Sand (%)	8.2
		Silt (%)	32.4
		Clay (%)	59.6
3	Specific Gravity		2.43
4	Free Swell Index (%)		79.0
5	Liquid Limit (%)		69.62
6	Plastic Limit (%)		31.22
7	Plasticity Index (%)		38.40
8	Soil Classification		CH
9	Maximum Dry Density (g/cc)		1.390
10	Optimum Moisture Content (%)		33.12
11	CBR (%)		0.80

Table 1: Geotechnical Properties of Marine Clay

3.2 Copper Slag (CS)

Copper slag is an industrial by-product of the Copper industry. It is formed during the extraction of copper metal from its ore. During this process impurities floating on the metal are known as copper slag, which is present in the molten state and is removed and then air-cooled. Production of one tone of copper approximately produces 2.2 tons of copper slag. The appearance of Copper Slag is black in color and its particle size distribution is similar to sand which possesses a high angle of internal friction. Due to this when it is mixed with soil, it increases its stability.

Fig-2: Copper Slag

S. No	Property		Value
1	Colosur		Black
2	Particle shape		Irregular
3	Natural Moisture content (%)		0.18
4	Specific Gravity		3.07
5	Differential Swell index (%)		0
6	Atterberg's limits		Non-Plastic
7	Particle Size Distribution	Gravel (%)	0
		Sand (%)	98.6
		Silt (%)	1.40
		Clay (%)	0
8	Maximum Dry Density (g/cc)		2.233
9	Optimum Moisture content (%)		3.52
10	CBR (%)		10.66

Table 2: Properties of Copper Slag

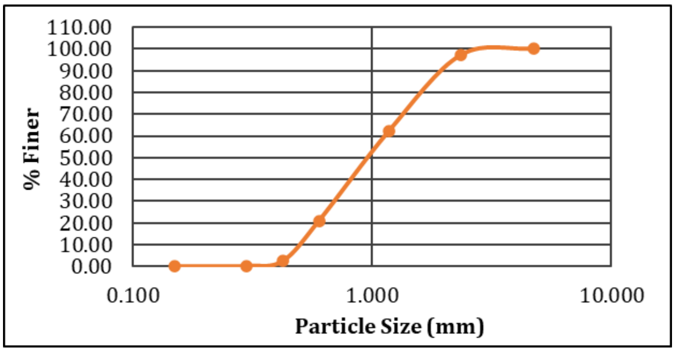

Chart-1: Particle size distribution of Copper Slag

S. No	Chemical Composition	Percentage by weight
1	Iron oxide (Fe_2O_3)	51.65
2	Silica (SiO_2)	36.60
3	Aluminium Oxide (Al_2O_3)	8.45
4	Calcium oxide (CaO)	1.50
5	Magnesium oxide (MgO)	1.00
6	Sodium Oxide (Na_2O)	0.58
7	Potassium Oxide (K_2O)	0.23
8	Copper Oxide (CuO)	0.08
9	Manganese Oxide (Mn_2O_3)	0.22

Table 3: Chemical Composition of Copper Slag

4. Laboratory Experiments

4.1 Differential Free Swell Index

The Free Swell Index is the increase in the volume of soil without any external constraint when subjected to submergence in water for 24 hours. it is conducted as per IS 2720 (Part XL)-1977. The free swell index of the soil helps in identifying the swelling potential of the soil.

$$\text{Free swell index (\%)} = \frac{V_d - V_k}{V_k} * 100$$

V_d = Volume of soil specimen after submerging 24 hours in distilled water.

V_k = Volume of soil specimen after submerging 24 hours in Kerosene.

4.2 Atterberg's Limits

The Liquid Limit, Plastic Limit, and thereby the Plasticity Index were determined using Casagrande's apparatus as per the procedures laid down in IS: 2720 part 5 (1985).

4.3 Modified Proctor Compaction Test

The Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were determined by using for proctor's compaction test as per IS: 2720 part-10 (1983).

4.4 California Bearing Ratio Test

The California Bearing Ratio test is mainly used in assessing the suitability of the subgrade and materials used in the flexible pavements sub-base and base.

The Specimen was prepared by compacting it to its Maximum Dry Density value at its Optimum Moisture Content as per IS 2720 part 16 (1987).

In this CBR test, the plunger penetrates the mould specimen at a rate of 1.25mm per minute. The loads necessary for 2.5mm and 5.0mm penetration were noted.

$$\text{CBR (\%)} = \frac{\text{Penetration load}}{\text{Standard load}} * 100$$

The CBR Value is Calculated for both penetration levels. The higher Value is Considered as CBR Value of that Specimen.

5. Results and Discussion

5.1 Free Swell Index

S. No	Mix Proportion	DFS (%)
1	100 % Marine Clay	79
2	95 % MC + 5 % CS	76
3	90 % MC + 10 % CS	72
4	85 % MC + 15 % CS	69
5	80 % MC + 20 % CS	66

Table 4: DFS value of Marine Clay treated with various percentages of Copper Slag

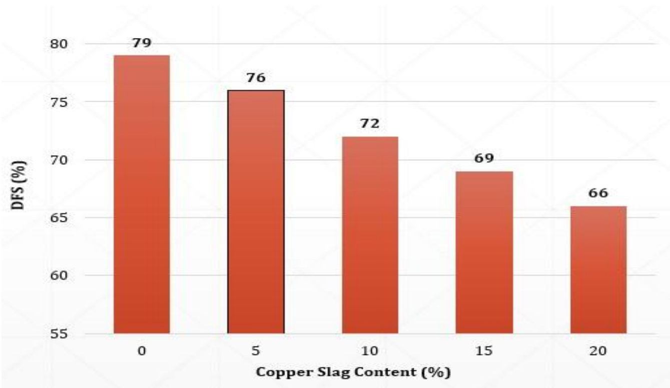

Chart-2: DFS Values of MC treated with various percentages of CS

- From the above table and chart, it was observed that the differential free swell index of the Marine Clay decreases with increasing the percentage of copper slag. The DFS value decreases from 79 % to 66 % when the Copper Slag content is increased from 0 % to 20 %.

5.2 Atterberg's Limits

S. No	Mix	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
1	100 % MC	69.62	31.22	38.4
2	95 % MC+5 % CS	66.13	31.41	34.72
3	90 % MC+10 % CS	62.59	31.48	31.11
4	85 % MC+15 % CS	56.33	31.59	24.74
5	80 % MC+20 % CS	51.52	31.64	19.88

Table 5: Atterberg's Limits values of Marine Clay treated with various percentages of Copper Slag

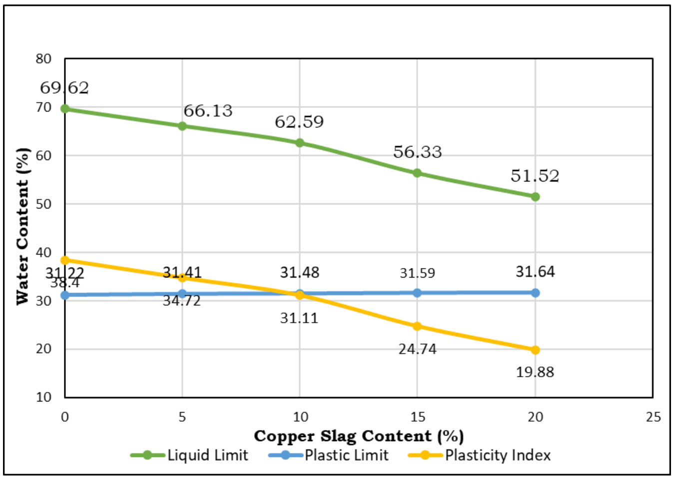

Chart-3: Atterberg's Limits of MC treated with various percentages of CS

- The Liquid Limit of the Marine Clay decreases with increasing the percentage of Copper Slag. The Liquid Limit value decreases from 69.22 % to 51.52 % when Copper Slag content is increased from 0 % to 20 %.

- The Plastic Limit of the Marine Clay increases with increasing the percentage of Copper Slag. The Plastic Limit value increases from 31.22 % to 31.64 % when Copper Slag content is increased from 0 % to 20 %.

- The Plasticity Index of Marine Clay decreases with increasing the percentage of Copper Slag. The Plasticity Index value decreases from 38.40 % to 19.88 % when Copper Slag content is increased from 0 % to 20 %.

5.3 Compaction Properties

S. No	Mix Proportion	Optimum Moisture Content (%)	Maximum Dry Density (g/cc)
1	100 % MC	33.12	1.390
2	95 % MC + 5 % CS	27.91	1.519
3	90 % MC + 10 % CS	25.91	1.607
4	85 % MC + 15 % CS	23.38	1.693
5	80 % MC + 20 % CS	21.40	1.791

Table 6: OMC-MDD values of Marine Clay treated with various percentages of Copper Slag

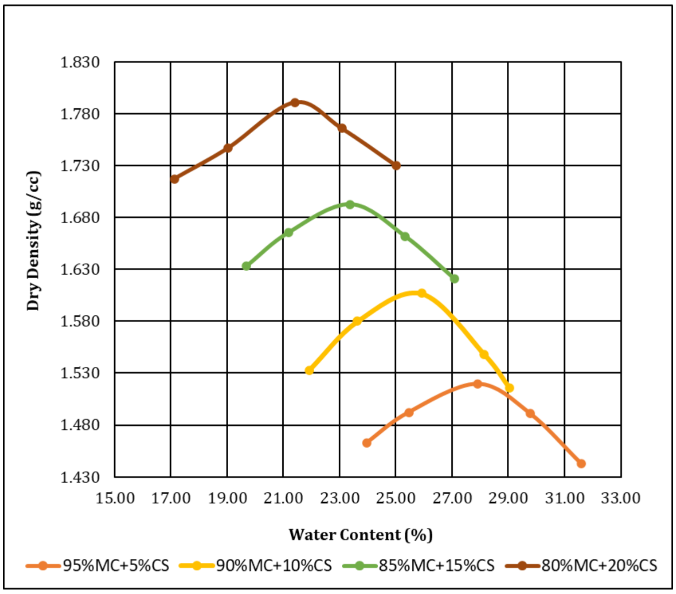

Chart-4: OMC-MDD values of MC treated with various percentages of CS

- From the above table and chart, it was observed that the Maximum Dry Density of the Marine Clay increases with an increase in the amount of Copper Slag. The MDD value increases from 1.39 g/cc to 1.791 g/cc when Copper Slag content is increased from 0 % to 20 %.

- The Optimum Moisture Content of the Marine Clay has decreased with an increase in the amount of Copper Slag. The OMC decreases from 33.12 % to

21.48 % when Copper Slag content is increased from 0 % to 20 %.

5.4 California Bearing Ratio

S. No	Mix Proportion	CBR (%)
1	100 % MC	0.80
2	95 % MC + 5 % CS	2.241
3	90 % MC + 10 % CS	2.510
4	85 % MC + 15 % CS	2.779
5	80 % MC + 20 % CS	3.048

Table 7: CBR values of Marine Clay treated with various percentages of Copper Slag

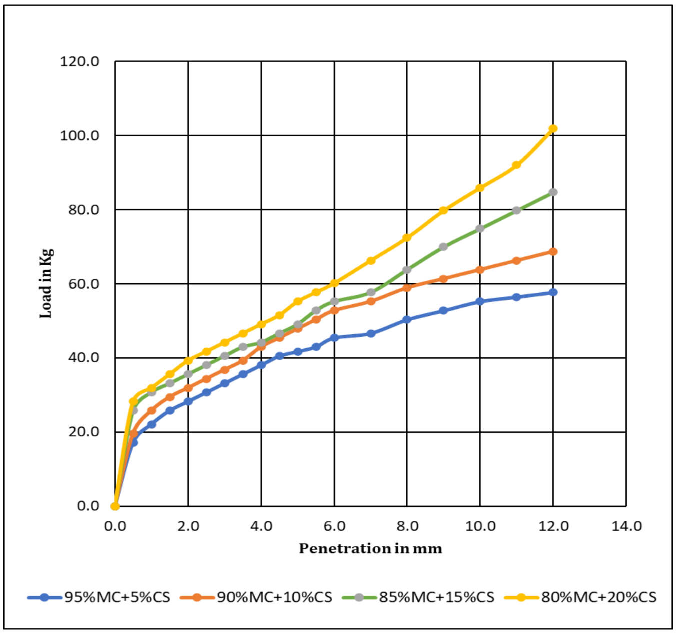

Chart-5: CBR values of MC treated with various percentages of CS

- From the above table and chart, it was clearly observed that the CBR Value of the Marine Clay increases with increasing the amount of Copper Slag. The CBR value increases from 0.80 % to 3.048 % when Copper Slag content is increased from 0 % to 20 %.

5. Conclusions

With the addition of 20 % Copper Slag the following conclusions were made:

- ❖ It was observed that the Liquid Limit of the Marine Clay has decreased by 25.99 %, with the addition of 20 % Copper Slag.
- ❖ It was observed that the Plasticity Index of the Marine Clay has decreased by 48.22 %, with the addition of 20 % Copper Slag.
- ❖ It was noticed that the Maximum Dry Density of the Marine Clay has increased by 28.84 %, with the addition of 20 % Copper Slag.
- ❖ It was noticed that the Optimum Moisture Content of the Marine Clay has decreased by 35.38 %, with the addition of 20 % Copper Slag.
- ❖ It was found that the CBR value of the Marine Clay has been improved by 281 % with the addition of 20 % Copper Slag.

REFERENCES

[1] P. Bharath Goud, D. Sruthi Laya. "Stabilization of Black Cotton Soil with Copper Slag and Rice Husk Ash – An Environmental Approach" IJSR, Volume 7 Issue 5, ISSN (Online): 2319-7064, May 2018.

[2] D.Koteswara Rao, Stabilization of expansive soil with rice husk ash, lime and gypsum – an experimental study, IJEST, Vol.3, No.11, November 2011.

[3] Prof. Jinka Chandrasekhar, Timir A chokshi and Dharsha V Chauhan. "A review on utilization of waste material "copper slag" in geotechnical applications." International journal of innovative research in science and technology (IJIRST), vol. 1, pp. 246250, May 2015.

[4] M. Adams Joe "Soil Stabilization Using Industrial waste and Lime" International Journal of Scientific Research Engineering & Technology (IJSRET), ISSN 2278 – 0882 Volume 4, Issue 7, July 2015.

[5] Prof. M.A. Qureshi, H.M. Mistry and Patel V.D. "Improvement in Soil properties of Expansive Soil by using Copper Slag." International Journal of Advance Research in Engineering, Science & Technology (IJAREST), vol. 2(7), pp.125-130, 2015.

[6] IS: 2720 Part - 5 (1970): Determination of Liquid Limit and Plastic Limit.

[7] IS: 2720 Part - 4 (1975): Grain size analysis.

[8] IS: 2720 Part - 6 (1974): Determination of Dry Density and Optimum Moisture Content.

[9] IS: 2720 Part -16 (1979): Determination of California Bearing Ratio.