Stabilization of Marine Clay by Using Copper Slag

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Abstract- **Marine clay is a type of clay found in coastal regions around the world. The most common problem in marine clay areas is the settlement and heave of house footings that are three feet deep or less. During dry periods, the soil loses moisture and shrinks which causing a gap under the footings. The house then settles resulting in cracked masonry walls, interior cracks in plaster, and warped door and window frames. Foundations that have settled during dry periods will often return to near the original position after rainfall replenishes the soil moisture causing the soils to swell again. After several cycles, the rebound of the foundation may become progressively less resulting in larger cracks. The main aim of this paper to improve the engineering characteristics of marine clay. Marine clay can be densified by mixing it with cement or similar binding material in specific proportions. In this paper Marine clay can be stabilized using copper slag. This method is usually adopted in highways where marine clay is used as a sub grade soil.**

Key words— Marine clay, copper slag, stabilization.

I. INTRODUCTION

Site feasibility study for geotechnical projects is of far most beneficial before a project can take off. Site survey usually takes place before the design process begins in order to understand the characteristics of subsoil upon which the decision on location of the project can be made. The following geotechnical design criteria have to be considered during site selection.

- Design load and function of the structure.
- Type of foundation to be used.
- Bearing capacity of subsoil.

In the past, the third bullet played a major in decision making on site selection. Once the bearing capacity of the soil was poor, the following were options:

- Change the design to suit site condition.
- Remove and replace the in situ soil.
- Abandon the site

The current practice is to modify the engineering properties of the native problematic soils to meet the design specifications. Nowadays, soils such as, soft clays and organic soils can be improved to the civil engineering requirements. This state of the art review focuses on soil stabilization method which is one of the several methods of soil improvement.

Soil stabilization is to improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two (Sherwood, 1993). Usually, the technology provides an alternative provision structural solution to a practical problem. The simplest stabilization processes are compaction and drainage (if water drains out of wet soil it becomes stronger). The other process is by improving gradation of particle size and further improvement can be achieved by adding binders to the weak soils (Rogers et al, 1996). Soil stabilization can be accomplished by several methods.

Copper slag

- Copper slag is a by-product obtained during the production of copper metal, which can be used as pozzolana in the production of cementing materials.

A) PHYSICAL AND CHEMICAL PROPERTIES OF COPPER SLAG

Table: Physical properties copper slag

Physical properties	**Copper slag**
Particle shape	Irregular
Appearance	Black & glassy
Type	Air cooled
Specific gravity	3.91
Percentage of voids	43.20%
Bulk density	2.08 g/cc
Fineness modulus	3.47
Angle of internal friction	51° 20’
Hardness	6-7 mohs
Water absorption	0.3 to 0.4%
Moisture content	0.1%
Fineness	125 m2 /kg

B) CHEMICAL COMPOSITION OF COPPER SLAG

Copper slag samples were analyzed for constituent oxides including minor oxides and heavy elements besides mineral phases.

Table: Chemical properties copper slag

Chemical Component	% of Chemical Component
SiO2	25.84
Fe2O3	68.29
Al2O3	0.22
CaO	0.15
Na2O	0.58
K2O	0.23
LoI	6.59
Mn2O3	0.22
TiO2	0.41
SO3	0.11
CuO	1.20
Sulphidesulphur	0.25
Insoluble residue	14.88
Chloride	0.018

II. MATERIALS AND METHODOLOGY

The marine clay soil copper slag is mixed on different proportions and a series of laboratory tests were conducted on samples containing various percentages of copper slag, i.e., 0%, 5%, 10%, 15%, 20%, by weight of the dry soil. The following tests were conducted on marine clay soil and copper slag mixes as per relevant IS codes of practice.

The Experiments Conducted are:

- Grain-size Distribution
- Liquid Limit
- Plastic Limit
- Plasticity Index
- Procter compaction
- Direct shear
- Differential Free Swell (DFS) Test.
- CBR Test

III. TEST RESULTS

The Various tests are conducted on marine clay soil mixed with copper slag in different proportions as per relevant IS Code of practice.

IV. RESULTS AND DISCUSSION

A) SPECIFIC GRAVITY

Table: Specific gravity of soil sample (IS: 2386 Part3)

Soil location	Specific gravity (G)	Soil classification
Vadakadu	2.38	Organic soil Both soil is same
Mandapam	2.10	

B) ATTERBERG LIMITS

Table: Atterberg limits

V+C.S %	0	5	10	15
Wl	28	26	25	23.5
Wp	14.7	18	18.70	17.9
w	19.30	19.30	19.30	19.30
Ip	13.30	8	6.3	5.6
Il	34.58	16.25	9.52	25
Ic	65.40	83.75	90.47	75

Where,

V+ C.S – vadakadu + copper slag
Wl- liquid limit
Wp- plastic limit
Ip- plasticity index
Il- liquidity index
Ic- consistency index

Consistency	Consistency index (%)	Unconfined compressive strength(q_u) (KN/m^2)	Characteristics of soil
Very soft	0-25	<25	First can be pressed in to soil
Soft	25-50	25-50	Thumb can be pressed in to pressure
Medium (firm)	50-75	50-100	Thumb can be pressed with pressure
Stiff	75-100	100-200	Thumb can be pressed with great difficulty
Very stiff	>100	200-400	The soil can be readily indended with thumb nail
Hard	>100	>400	The soil can be readily indended with thumb nail

Table: Consistency in terms of consistency index and unconfined compressive strength (q_u)

Compare the above table with atterberg limits value the unconfined compressive strength (q_u) of clay

Table: unconfined compressive strength (q_u)

(q_u)	0	5	10	15
V+C.S	50-100	100-200	100-200	100-200

C) PROCTER COMPACTION

Table: max.dry density of soil

r_{max} (KN/m^3)	0	5	10	15
V+C.S	2	2	2.1	2.2

D) CBR TEST

CBR	0	5	10	15
V+C.S	5	8	11	7

Table: CBR value

CBR Value	Sub grade& Strength	Comments
3% and less	poor	Capping is required
3%-5%	Normal	Widely encountered CBR range capping considered according to road category
5% - 15%	Good	Capping" normally unnecessary except on very heavily trafficked roads.

Table: CBR For Commonly Found Sub-Grade Conditions

Compare the CBR value with Sub-Grade Conditions 10%, of copper slag got more than 5% of CBR value,

V. CONCLUSION

Based on extensive laboratory tests conducted on marine clay mixed with copper slag from 0% to 15% by weight of dry clay. The following conclusions can be drawn:

1. The liquid limit values of the samples are decreasing with the inclusion of copper slag into the marine clay soils. It has been found that the liquid limit decreased from 31% to 22% on adding of 0% to 20% copper slag in it.
2. There is significant increasing in CBR value by the % of 10 & 15 mixed with copper slag.
3. From the above laboratory investigation it can be concluded that the industrial waste like copper slag has a potential to modify the characteristics of expansive clay like marine clay soil and to make it suitable in sub graded soil by addition of 10%, 15% of copper slag.

VI. SCOPE OF THE FUTURE WORK

1. The tests are conducted to improve the properties in pavement.
2. The further tests like ,
   i. Direct shear test is used to calculate shear parameter cohesion and frictional resistance of soil.
   ii. Plate load test is used to calculate the differential settlement.
   iii. Standard penetration test is used to calculate the safe bearing capacity of soil.
3. It helps to make a strong foundation in structures present in the marine clay.

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