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REINFORCEMENT OF WEAK SOIL BY USING GGBS, PHOSPHOGYPSUM AND COPPER SLAG

Mr. Sunil Kumar Birkur, Assistant Professor, Guru Nanak Dev Engineering College Bidar, Karnataka and India, Email: birkursuneal@gmail.com

Abstract: **This research paper investigates the reinforcement aspect of Black Cotton (BC) soil using industrial by-products: Ground Granulated Blast Furnace Slag (GGBS), Phosphogypsum, and Copper Slag. BC soil, known for its abject engineering properties such as high swelling, shrinkage, and low bearing capacity, poses significant challenges in construction. This study aims to augment the mechanical properties of BC soil by incorporating GGBS, Phosphogypsum, and Copper Slag. Series of lab exams were conducted to evaluate the changes in densification characteristics, UCS and CBR of the stabilized soil. The results indicate a significant improvement in the soil properties, making it appropriate for construction uses.**

Keywords —Soil Stabilization, Phosphogypsum, Copper Slag, GGBS, UCS, Index properties

I. INTRODUCTION

We are forced to make extensive use of rich soil in developing countries like India where industry and civilization are expanding due to a lack of available land. The majority of geotechnical projects are unable to locate sites that meet the plan specifications, which is said to be tolerable of the weight of the superstructure delivered as load to the soil without experiencing shear failure. Hard soils are not appropriate for geotechnical work because of their high compressibility, poor capacity to bear, and excessive swelling/shrinking. Huge expanses are covered in "complex" or "extensive" soil. The most erratic clay mineral, montmorillonite, located in remnant deposits of rip rocks. It fluctuates in size as reaction to changes in saturation changes. In case of precipitation dominated by evaporation, negative leaching and porosity will become inefficient to sufficiently support the formation of expansive soils in dry and semiarid areas. Soil shrinkage and settlement are decreased via soil stabilization. Compaction and draining for soil up gradation are as fundamental as switching the particle length gradation and adding blinders to hazardous soils. Soil stabilization techniques are numerous.[1,6]

MECHANICAL STABILIZATION

Under this category, soil stabilization can be achieved through physical process by altering the physical nature of native soil particles by either induced vibration or compaction or by incorporating other physical properties such as barriers and nailing. This process aims to address the geotechnical properties in certain areas of the various mixtures of soil. It is made with the intention of reducing the void ratio by providing adequate space between soil particles and improved soil. A soil combination of the approximate proportions have changed because of stabilizing effect of compaction is referred to as coarse equilibrium. The densification procedure ensures that the void ratio is compressed, which improves the cohesion (C), aspect of inner friction, and soil strength factors.. [12]

CHEMICAL STABILIZATION

Stabilizer-soil mineral interaction is necessary for chemical stabilization. Whereas stabilizing agent pertaining to minerals, cementitious material relates to chemicals. The process of stabilizing soil involves utilizing cementitious mixtures, such as lime, bitumen, fly ash, etc., to bind loose elements together. Stabilized soil exhibits higher permeability, higher strength, and lower compressibility in comparison to un stabilized soil. The variables that may be examining the issue include durability, quantity stability, permeability, and compressibility. A strategy's system wall depends on the resources, location, and kind of soil. When it comes to geotechnical development, chemical stabilizers are among the cheapest techniques to manipulate expanding soil. These approaches can be applied on highways, railroads, and runways to improve sub-bases and sub grades that target ridges by soil modification in non-stable grades, such as backfill for bridges and retaining walls. [12]

MINERAL ADMIXTURES USED IN THE PROJECT

Stabilizing agents can be either primary or second hand agents that react with moisture to form cemented merging materials or that come into contact with water through pozzolanic material reactions. In this work, GGBS, copper slag, and phosphogypsum are the cast-off files.

A) Phosphogypsum: The process of producing phosphogypsum (PG) phosphate fertilizers yields. It is

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produced by phosphoric acid and phosphate rock. The kind of ore and how it is processed affect how dispersed it is. Due to the discovery of radioactive elements in the earth's bedrock the amount of material covered depends on environmental factors. Evaluation of PG characteristics in different countries and the various applications of PG which include cement industry, ceramic and brick production, agricultural applications, and rare element recovery conversion are reported in this study. [4,7]

B) Copper Slag: As a byproduct of the copper smelting process, copper slag produces large amounts of waste that should be properly disposed of to avoid harming the environment. Nonetheless, scientists and engineers have found that Copper slag is a useful resource that may be used to soil. Because of its pozzolanic qualities, which improve stability, when mixed with cement, the soil's binding strength. Cement and copper slag together create a special chance to accomplish successful soil stabilization, as both materials that accentuate each other's advantages.[2,3]

C) GGBS: Granulated Blast Furnace Slag on the Ground (GGBS) When iron is manufactured in a blast furnace, slag from the furnace is created as a byproduct. Slag from a molten blast furnace is quickly cooled to avoid crystallization, with a temperature range of 1300–1600 degrees Celsius. The process of putting liquid iron slag from a shot furnace out in water or steam yields ground-granulated impact furnace slag, which is further dried and ground into a fine powder. The result is a polished, granular product. Granulated blast furnace slag is the term for the granulated material that is so created. The cementing effect is produced by the glassy, disordered, crystalline structure of blast furnace slag, which is visible under a microscope.[11]

STABILIZATION MECHANISM

To alter and stabilize soil, traditional stabilizers usually rely on pozzolanic processes and cation exchange. At normal temperatures, pozzolanic reactions take place when siliceous and aluminous minerals chemically react with calcium hydroxide to generate cementitious compounds. Conversely, a cation exchange takes place when the soil may swap out free cations that are present in the exchange sites. Compounds having a high PH are formed by alumina and silica oxides dissolved in clay and calcium.Strength improvement (expended) is mostly determined by cement gel generation and chemical consumption, aside from the requirement that the total amount of chemicals computed be related to the inorganic clay content of the soil.[2,6,8,9,11]

AIM OF THE PROJECT

The aim of the present study is:

To look at how the concentrations of GGBS, phosphogypsum, and copper slag affect the expansive soil's index and geotechnical properties.

II. MATERIALS AND METHODOLOGY

The following materials are used in the current research are BC soil, GGBS, PS, CS

Soil:

The process of chemical stability impassively stabilizes clayey soil, particularly fat clays like expanding clay. Therefore, the soil that belongs to the clay group of stronger minerals was chosen. In the present study, the soil cast-off stayed distinct. The Bidar district of Karnataka's Aurad is where the soil was gathered. One kilogram of soil sample was required from a specific location where road building was planned. The sample was administered and kept in steel trays for the purpose of conducting experiments. Considering the low geotechnical reactivity of expanding soil. One element that significantly affects the soil's chemical stability response is the process utilized to create model samples for different types of research. A standard operating procedure was put in place to prevent deviation based on the same testing.

Ground Granulated Blast Furnace Slag (GGBS)

GGBS is obtained from quenching of molten iron slag. It is a highly cementitious product. It can also improve the strength and durability of concrete. It was procured from Sagar cements Hyderabad

Phosphogypsum:

Phosphogypsum:(PG) is the calcium sulfate hydrate formed as a by-product of the production of fertilizer, particularly phosphoric acid, from phosphate rock. It is mainly composed of gypsum ($CaSO_4 \cdot 2H_2O$). The main ingredient of phosphogypsum is calcium sulfate, while it also contains certain other particles. It was procured from Skanda chemical technologies Bangalore

Copper Slag:

Recovery of copper at high temperature takes place by the process of smelting followed by converting. Major constituents of a smelting charge are sulphides and oxides of iron and copper. The charge also contains oxides such as Al_2O_3, CaO, MgO and principally SiO_2 which are either present in the original concentrate or added as flux. It is the iron, copper, sulphur, oxygen and these oxides which largely control the chemistry and physical constitution of the smelting system. It was procured from Sarda industrial enterprises Hyderabad.

Index property Test:

The testing included a variety of admixtures and the virgin soil's index qualities as follows:

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a. SG (IS 2720 Part III -1980)
b. GSA (IS 2720 Part IV - 1985)
c. LL (IS 2720 Par V - 1985)

d. EL (IS 2720 Par V - 1985)

e. SL (IS 2720 Par VI - 1972)

f. FSI (IS 2720 Part XL -1977)

Physical and Geotechnical Properties Test:

Numerous tests were carried out on both virgin and stabilized soil to ascertain the underlying geotechnical engineering assets.

1. Standard Proctor compaction Test (IS 2720 Part VII - 1980)

2. Unconfined compressive strength Test (IS 2720 Part X - 1970)

Sample Preparation:

The following mix plan and method for creating soil samples with various chemicals have been planned in order to examine the behavior of untreated and chemically treted soil samples.

a. The soil sample was added with GGBS (starting from 10 to 30 %), Phosphogypsum (starting from 10 to 30 %), copper slag (starting from 10 to 30 %), until the soil sample attained the liquid limit.

b. The soil is housed in a humidity chamber and sealed in an airtight container. After it has been appropriately modified with chemicals and the appropriate amount of water. Following 7, 14, and 28 days of curing, the samples underwent index quality analysis.

c. The concept of custom modes revolves around the individual user. Establish your vocal expression using a singular term or unleash your creative prowess without restraint.

d. After aging, soil samples were classified for UCS testing according to mix percentage and dry unit weight.

III. RESULTS

EFFECT OF GGBS

Effect of GGBS after 7 days curing time period

Percentage of GGBS	Virgin soil	10%	20%	30%
LL (%)	32.1	38.0	37.50	35.70
PL (%)	18.7	20.0	25.17	26.32
PI (%)	16.75	18	12.33	9.38
SL (%)	17.2	15.53	13.59	12.15
Ucs(KN/m^2)	129.21	140	220	330

Effect of GGBS after 14 days curing time period

Percentage of GGBS	Virgin soil	10%	20%	30%
LL (%)	32.1	38.0	37.50	35.70
PL (%)	18.7	20.0	25.17	26.32
PI (%)	16.75	18	12.33	9.38
SL (%)	17.2	15.53	13.59	12.15
Ucs(KN/m^2)	129.21	151	237	342

Effect of GGBS after 28 days curing time period

Percentage of GGBS	Virgin soil	10%	20%	30%
LL (%)	32.1	38.0	37.50	35.70
PL (%)	18.7	20.0	25.17	26.32
PI (%)	16.75	18	12.33	9.38
SL (%)	17.2	15.53	13.59	12.15
Ucs(KN/m^2)	129.21	168	242	356

EFFECT OF PHOSPHOGYPSUM

Effect of PG after 7 days curing time period

Percentage of Phosphogypsum	Virgin soil	10%	20%	30%
LL (%)	72	67	66.5	64
PL (%)	31	28	22	23
PI (%)	42	42	45	40
SL (%)	13	11	19	20.7
UCS (KN/m^2)	172.66	194	250	390

Effect of PG after 14 days curing time period

Percentage of Phosphogypsum	Virgin soil	10%	20%	30%
LL (%)	72	67	66.5	64
PL (%)	31	28	22	23
PI (%)	42	42	45	40
SL (%)	13	11	19	20.7
UCS (KN/m^2)	172.7	194	330	395

Effect of PG after 28 days curing time period

Percentage of Phosphogypsum	Virgin soil	10%	20%	30%
LL (%)	72	67	61	57.5
PL (%)	31	28	20.8	23.5
PI (%)	42	42	39.5	35.5
SL (%)	13	11	16	17.5
UCS (KN/m^2)	172.6	194	350	450

EFFECT OF COPPER SLAG

Effect of CS after 7 days curing time period

Percentage of Copper slag	Virgin soil	1 0%	20%	30%
LL (%)	65.50	57.44	48.32	43.39
PL (%)	34.10	30.72	23.98	18.74
PI (%)	31.70	26.32	24.53	23.85
SL (%)	12.91	15.68	16.68	18.90
UCS (KN/m^2)	172.66	181.54	184.8	230.1

Effect of CS after 14 days curing time period

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Percentage of Copper slag	Virgin soil	1 0%	20%	30%
LL (%)	65.50	57.44	48.32	43.39
PL (%)	34.10	30.72	23.98	18.74
PI (%)	31.70	26.32	24.53	23.85
SL (%)	12.91	15.68	16.68	18.90
UCS (KN/m^2)	172.66	192.04	197.67	242

Effect of CS after 28 days curing time period

Percentage of Copper slag	Virgin soil	10%	20%	30%
LL (%)	65.50	57.44	48.32	43.39
PL (%)	34.10	30.72	23.98	18.74
PI (%)	31.70	26.32	24.53	23.85
SL (%)	12.91	15.68	16.68	18.90
UCS (KN/m^2)	172.66	201	210.94	252

IV. CONCLUSION

GGBS, phosphogypsum, and copper slag addition decreases the LL, raises the elastic limit, and lowers the soil's PI standards in the process. The addition of GGBS, phosphogypsum, and copper slag no longer shows a significant variation in moisture and elastic restrictions with an increase in percent and curing period. Phosphogypsum, however, denotes the full-size form. Due to mass transfer in excessive valence, the limitation of dual bulk density has been connected to the fall in elasticity features components, whereas the elasticity features of soil treated with lime climbed considerably throughout a prolonged curing period.

➢ The chemical's capacity to reduce soil flexibility in an ideal percentage when combined with GGBS, phosphogypsum, and copper slag. The decrement in plasticity behaviour lessens the soil's capacity to enlarge.

➢ The chemical's capacity to reduce soil flexibility in an ideal percentage when combined with GGBS, phosphogypsum, and copper slag. The decrease in plasticity behavior lessens the soil's capacity to enlarge.

➢ When comparing the UCC test results to virgin soil, the addition of 30% GGBS, 30% phosphogysum, and 30% copper slag results in an increase in UCC values of 175%, 160%, and 46%, respectively.

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