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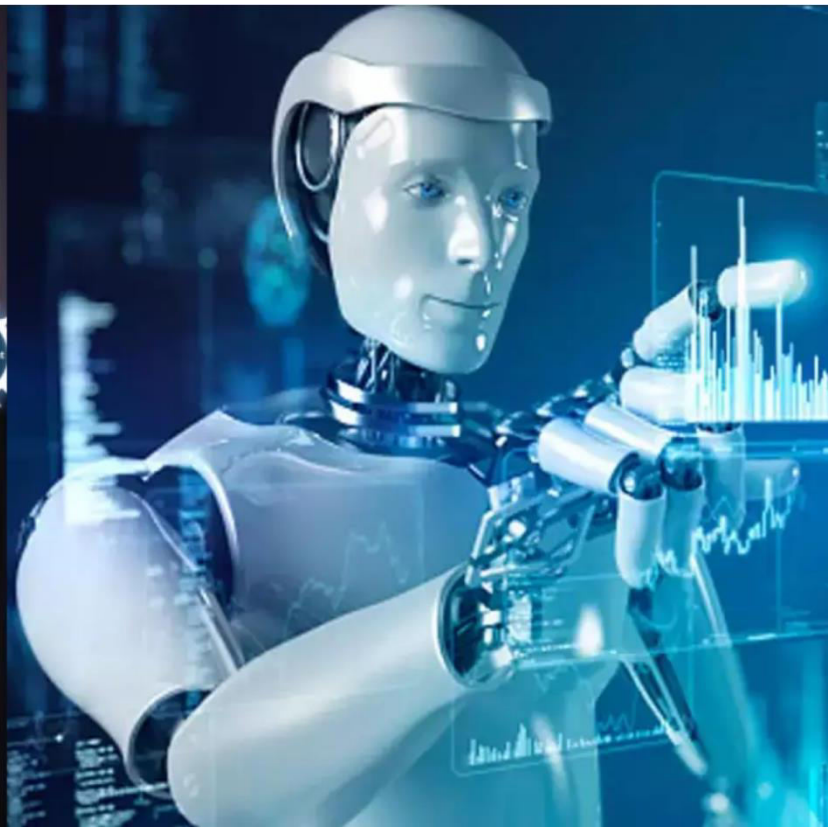

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Sustainable Stabilization of BC Soil by using GGBS & Mining Waste

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ABSTRACT: Black Cotton Soil (BCS), widely found in India, is highly expansive and causes pavement failures, foundation cracks, and structural instability due to its swelling–shrinkage behavior. Traditional stabilization methods using cement or lime improve soil performance but are costly, energy-intensive, and environmentally unsustainable. This study explores the sustainable stabilization of BCS using Ground Granulated Blast Furnace Slag (GGBS) and Mining Waste, both industrial by-products. Laboratory tests including Atterberg limits, Standard Proctor Compaction, Unconfined Compressive Strength (UCS), California Bearing Ratio (CBR), and Free Swell Index were performed. Results showed that GGBS reduced soil plasticity and promoted cementatious bonding, while mining waste acted as filler, reducing voids and enhancing density. The optimum mix of 10% GGBS and 20% mining waste significantly improved UCS and CBR values while reducing swelling. Thus, this approach provides an eco-friendly, cost-effective method for stabilizing expansive soils, supporting sustainable construction and industrial waste utilization.

KEYWORDS: GGBS, Mining waste,Water, Black cotton Soil, Basic Tests (Specific gravity, Liquid limit, Plastic limit, Standard proctor test, fineness)

I. INTRODUCTION

building design include dead load, live load, wind load, and seismic load. These loads must be calculated according to relevant codal provisions to ensure structural stability.

In recent years, structural engineering has increasingly relied on advanced software tools to perform accurate and efficient analysis. Programs such as AutoCAD, STAAD.Pro, and RCDC allow engineers to model complex structures, analyze load combinations, and design reinforced concrete members in accordance with Indian Standard codes.

Black cotton soil is a type of expansive clay soil predominantly found in tropical and subtropical regions, especially in India. It is characterized by its dark color, high clay content, and significant shrink-swell behavior due to moisture variations. During the rainy season, it swells excessively, and in dry conditions, it shrinks and develops deep cracks. These properties make it problematic for construction activities, as it leads to instability and structural damage. Despite its fertility for agriculture, its engineering behavior is poor. Therefore, stabilization techniques are essential to enhance its load-bearing capacity and make it suitable for construction and infrastructure development.

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct obtained during the manufacturing of iron in a blast furnace. It is formed when molten slag is rapidly cooled with water, resulting in a glassy, granular material that is then dried and ground into a fine powder. GGBS is widely used in construction due to its cementitious properties and ability to enhance the durability and strength of concrete and soil. As a sustainable alternative to Ordinary Portland Cement, it reduces carbon emissions and improves resistance to chemical attacks. Its application in soil stabilization contributes to eco-friendly and long- lasting infrastructure development.

Mining waste, also known as mine tailings or spoil, is the byproduct generated during the extraction and processing of minerals from the earth. It includes overburden, rock fragments, and residues left after oreextraction. Traditionally considered an environmental burden, mining waste is now being explored for sustainable engineering applications. Its reuse in construction and soil stabilization offers a cost-effective and eco-friendly solution to reduce environmental

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degradation. When processed and combined with binders like GGBS, mining waste can improve the strength and stability of weak soils such as black cotton soil, promoting sustainable construction practices and efficient waste management. Black cotton soil, known for its high clay content and extreme shrink-swell behavior, poses serious challenges to construction due to its poor engineering properties.

II. LITERATURE SURVEY

- **Rehana Rasool et al. (2017)** that the primary benefits of using GGBS for soil stabilization are Cost Savings: because slag is typically cheaper than cement and lime; and Availability: because slag sources are easily available across the country from nearby steel plants. Waste management of one of the industrial wastes can be done economically. Use of slag as an admixture for improving engineering properties of the soils is an economical solution to use the locally available poor soil.
- RajeshJain etal. (2017) :states that -The lowest dry density was observed to be about 1.84g/cc for 90% soil and 10% GBFS mixture and maximum density was about 2.05 g/cc for 50% soil and 50% GBFS mixture. The lowest CBR value was observed to be about 3.26% for 90% soil and 10% GBFS mixture and maximum CBR value was about 8.74% for 50% soil and 50% GBFS mixture. [3]
- FaisalI.Shalabietal. (2017) :from Saudi Arabia says that- Unconfined compressive strength of the treated clay soils with GGBS depends on the initial compaction conditions of the soil. While the zero GGBS compactedsoil,showsadecreaseinUCSwiththeincreasein GGBScontent,thecompacted soil at different GGBS content shows almost a slight change in UCS with GGBS content. In addition, CBR value of the treated clay soil was found to increase with the increase inGGBS content, and it is in a reverse relation with the free swell value.
- MukulDhakeet al. (2017):suggests that from UCS test results the addition of GGBS up to 40%, it increases the strength of the test specimen. However, after 30% there is very little increase in UCS strength. The UCS strength increased from 230.1KPa for 100% black cotton soil (0% GGBS) to 443.3 for 70% black cotton soil (30%GGBS). Therefore, they have concludedthat 30% is the optimum dosage of GGBS in soil. [4]

III. METHODOLOGY

1) Start

↓

2) SoilSampleCollection(BlackCottonSoil)

↓

3) Initial Soil Characterization(Atterberglimits,CBR,compaction,etc.)

↓

4) Selection and Collection of Stabilizers(GGBSandMiningWastee.g.,flyash,redmud)

↓

5) MaterialCharacterization (ChemicalandphysicalanalysisofGGBSandwaste)

↓

6) MixDesignPreparation (Variousproportionsofsoil,GGBS,andminingwaste)

↓

7) LaboratoryTesting (CBR,UCS,durability,pH,permeability)

↓

8) AnalysisofResults (Comparewithstandardlimitsand requirements)

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↓

9) OptimizationofMixDesign (Selectmosteffectiveandsustainableblend)

↓

10) FieldTrial(optionalforlarge-scaleapplication)

↓

11) ConclusionandRecommendation

↓

End

IV. RESULTS AND ANALYSIS

MixProportion	UCS(%)	CBR(%)	FSIReduction (%)
G5M10	80	200	50
G10M20	180	500	72
G15M30	120	300	60

12) Discussion:

This chart shows the relative performance gain. The UCS increased by nearly **180%**, CBR by **500%**, while the swelling potential reduced by **>70%** at G10M20. This proves that the combined effect of GGBS and mining waste is highly beneficial compared to control soil.

Table I: Mix Design

MixID	GGBS(%bydry wt. of soil)	MiningWaste (MW)(%by drywt.ofsoil)	RemainingSoil(%by dry wt.)
Control	0	0	100
G5M0	5	0	95
G10M0	10	0	90
G15M0	15	0	85
G0M10	0	10	90
G0M20	0	20	80
G5M10	5	10	85
G10M20	**10**	**20**	**70**
G15M30	15	30	55

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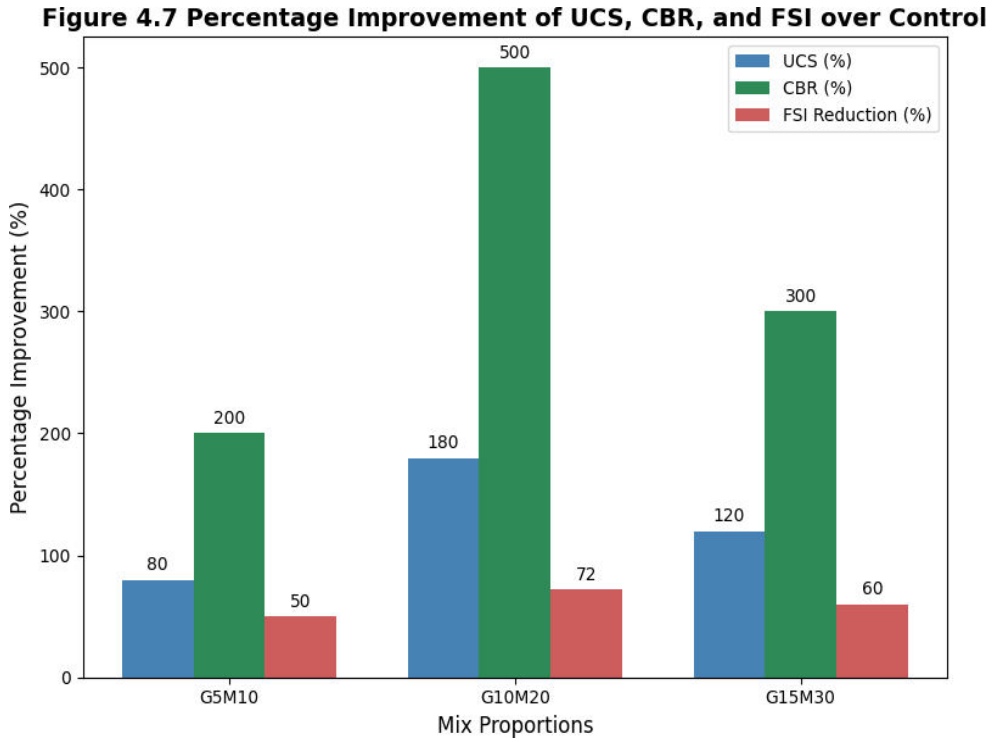

(c)

Fig 1(a)**design output** table, showing the final reinforcement design for all columns(b)**design output** table, showing the final reinforcement design for all beams (c) **design output** table, showing the final reinforcement design for all footings

V. CONCLUSION

This study investigated the potential of Ground Granulated Blast Furnace Slag (GGBS) and Mining Waste (MW) as sustainable stabilizers for expansive Black Cotton Soil (BCS), which poses serious challenges in civil engineering due to its high plasticity, swelling, and low strength. Laboratory tests including Atterberg Limits, Compaction, Free Swell Index, Unconfined Compressive Strength (UCS), and California Bearing Ratio (CBR) provided clear insights into the performance improvements achieved with different proportions of GGBS and MW.

The results demonstrated that the **optimum blend of 10% GGBS and 20% MW (G10M20)** provided maximum benefits across all geotechnical parameters. Specifically:

- The**PlasticityIndexreducedby43%**,loweringswelling potential.
- The**MaximumDryDensityincreasedby15%**,reflectingimprovedcompaction.
- The**FreeSwellIndexdroppedbymorethan70%**,confirmingreduced expansiveness.
- The**UCSincreasedmorethan3.5times(from120 kPato420kPa)** after28days curing.
- The**CBRimprovedsixfold(from2%to12%)**,makingthesoilsuitablefor subgrade applications.

These findings prove that the combined action of GGBS (as a pozzolanic binder) and MW (as a filler material) enhances soil strength, density, and dimensional stability. Beyond technicalperformance,thisapproachis**eco-friendly,cost-effective,andpromotes circular economy practices** by reusing industrial by-products that would otherwise contribute to waste management issues.

In conclusion, the stabilization of Black Cotton Soil using GGBS and Mining Waste is a **viable and sustainable solution** forroad subgrades,embankments,and shallow foundations in expansive soil regions. The technique notonly addresses geotechnical challenges but also supports green construction and sustainable infrastructure development.

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