Green Solutions to Clayey Soil Stabilization: Harnessing Ground Granulated Blast Furnace Slag and Bagasse Ash for Sustainable Geotechnics

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Abstract: *Soil enhancement constitutes a procedure directed at fortifying the durability and potency of soil. This encompasses altering the features of less steadfast soil to amplify its compressive strength or adjusting the qualities of foundational soil to secure their appropriateness. Through bolstering shear strength and regulating soil shrink-swell tendencies, it heightens the capacity of a subgrade to support pavements and foundations. The strengthened soil improves tensile strength, bearing capacity, and overall soil functionality. The process of soil fortification encompasses the application of diverse chemicals. Among the notable strategies for amplifying the engineering characteristics of problematic soil is chemical fortification. In the present context of diminishing resources and energy usage, there is an increasing inclination towards employing discarded materials as soil fortifiers. Sugarcane bagasse ash, a silica-enriched byproduct derived from the combustion of sugarcane bagasse, stands out as one such substance. This investigation aims to contrast the fortifying efficacy of lime and sugarcane bagasse ash. Laboratory analyses were executed to evaluate the influence of different proportions of GBFS and bagasse ash on the fortification of clayey soil. The results suggest that the GBFS fortification technique can significantly augment the geotechnical features of clayey soil, providing pragmatic and enduring resolutions for construction initiatives.*

Key Words: Soil Stabilisation, Bagasse Ash, GBFS, Liquid Limit, Plastic Limit, etc.

1.Introduction:

The earth's uppermost layer, known as soil, comprises air, water, and solid particles formed through the breakdown of rocks. It serves as a widely available and cost-effective construction material, with varying properties, particularly in clayey soil across different locations. Engineering challenges arise due to low strength, limited water-holding capacity, high compressibility, and low bearing capacity in clay, making it unsuitable for various constructions like paving and embankments. Consequently, there is a pressing need to address these issues through soil treatment. Stabilization proves beneficial in enhancing clay properties, employing diverse stabilizing agents. This process is crucial for rendering unsuitable soil suitable for construction, maintaining or improving its strength during the soil stabilization process. Stabilizing agents, such as those enhancing California Bearing Ratio (CBR), play a key role in achieving necessary construction requirements. Soil stabilization, often used in road construction globally, relies on different technologies, considering soil types, site conditions, and cost factors. Shear strength is a vital characteristic for any soil-based structure, and in wet conditions, clayey soils exhibit low shear strength, leading to undesirable engineering properties. Treating clayey soil with methods like chemical stabilization, densification, reinforcement, and pore water pressure reduction becomes essential before construction to prevent potential harm or damage. Utilizing sugarcane steel slag and marble dust powder for clayey soil treatment proves economical and pollution-controlling, contributing to its desired properties for construction. The ongoing focus on waste product utilization, particularly from the sugarcane industry, highlights the potential of Sugarcane Bagasse Ash (SBA) enriched with silica, alongside lime, as effective stabilizing agents in recent times.

2. Literature Review

To undertake a comprehensive investigation, the following referenced works were meticulously examined, and the resulting conclusions and recommendations are outlined below.

Amit S. Kharade, et al. examined through laboratory experiments on black cotton soil, the incorporation of bagasse ash at varying percentages (3%, 6%, 9%, and 12%) revealed notable effects. The compressive strength exhibited a substantial increase of 43.58%. The study's outcomes suggest that the addition of bagasse ash enhances both compressive strength and California Bearing Ratio (CBR) by nearly 40%, with a significant impact on density. As per the study's recommendation, the optimal mixture comprises black cotton soil with a 6% replacement of bagasse.

Ayesha Rehman et al. (2014) utilized marble dust to evaluate brick strength, this research focused on the incorporation of mechanical waste, specifically marble dust (MD), along with other materials. Steel slag (SS) was employed for producing unfired and environmentally friendly blocks. The study explored various mixtures involving gypsum, lime, MD, and SS, with unique ratios prepared in the laboratory. Parameters such as water content, compressive strength, setting time, and absorption coefficient for the test blocks were systematically examined. The resulting blocks exhibited enhanced compressive strength, approximately seven times superior to traditional fired clay blocks. However, it is noteworthy that despite the improved quality, each block still exhibited water absorption properties.

Elizabeth Siby.K. and Betsypaul K. (2014) Eggshell powder has been infrequently utilized as a stabilizing agent in much of the world. Marble dust, a byproduct of cutting and polishing marble, is known for its fine particles. This study aims to investigate the geotechnical properties of clay stabilized with a combination of eggshell powder and marble dust, comparing it to traditional lime-stabilized clay. The primary objective of the project is to assess the stabilizing capabilities of readily available waste materials, such as eggshell powder and marble dust, in comparison to synthetic lime. Traditional lime production involves environmentally detrimental processes like burning limestone in kilns, which is not only harmful but also costlier. Given that both eggshell powder and marble dust contain lime, they present a potential alternative to industrial lime for stabilization, offering a more sustainable and cost-effective solution.

3.Objectives:

This study aims to investigate the effectiveness of bagasse ash and GBFS in stabilizing clayey soil and determine the optimal mix proportions for achieving improved engineering performance. The main objectives of the study are to:

1. Examine the distinct and combined impacts of bagasse ash and GBFS on the consolidation of clayey soil.
2. Ascertain the optimum blending ratios of bagasse ash, and GBFS to achieve maximum soil consolidation and robustness.
3. Evaluate the extended performance and endurance of the fortified clayey soil under different ecological circumstances.
4. Contrast the geotechnical characteristics of the solidified clayey soil with those of untreated soil and conventionally strengthened soil.
5. Gauge the cost-effectiveness of the suggested consolidation technique compared to traditional procedures for soil reinforcement.
6. Establish the repercussions of consolidation on the plasticity index and other crucial soil traits.

4. Materials and Testing

The clay under investigation was sourced from Baramulla, Srinagar, Jammu & Kashmir, while the stabilizing agents—Lime, Bagasse Ash, and Granulated Blast Furnace Slag—were procured from Batamaloo market in Srinagar, Jammu & Kashmir.

The empirical design of this research aims to scrutinize the efficacy of bagasse ash and pulverized granulated blast furnace slag (GBFS) as stabilizing agents for clay-rich soil. The research design involves a series of laboratory examinations to evaluate the technical characteristics of the fortified soil and determine the optimal blend ratios to achieve enhanced functionality.

1. Grain Size Analysis
2. Natural Moisture Content
3. Compaction Test
4. Unconfined Compressive Strength

5.Results

The results obtained during the experimental program are mentioned below in detail.

5.1 Sieve Analysis

Fig.1 illustrates the results of the particle size distribution analysis, presenting the percentages retained in and passed through each sieve.

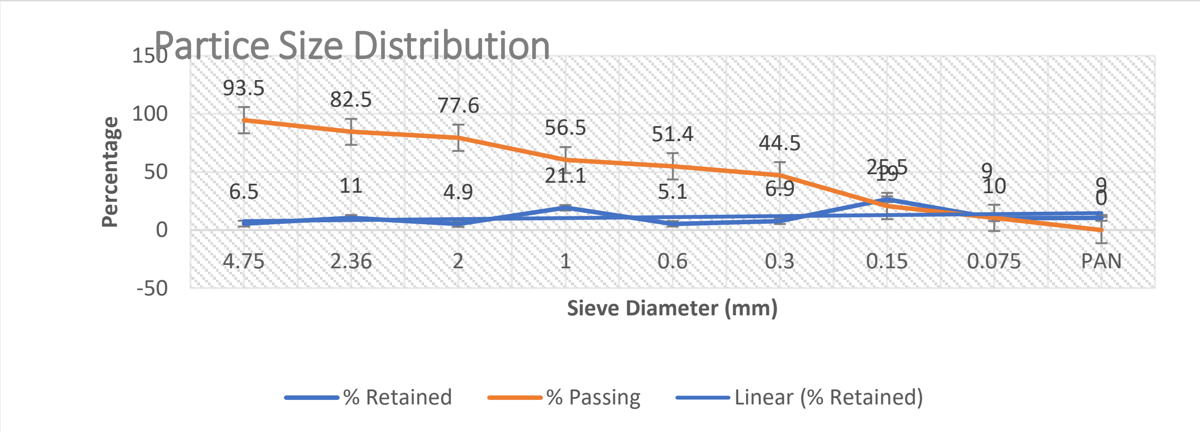


Fig.1 Particle Size Distribution Analysis

5.2 Natural Moisture Content

The clay sample used had natural moisture content 7.29% as given in Table 1

Test Sample	M1	M2	M3	MC (%)	Moisture (g)
1 2 3	45.00 46.00 47.50	96.00 98.13 99.25	94.00 93.30 95.60	4.08 10.21 7.58	2.08 5.32 3.92
Average				**7.29**	**3.77**

Table.1 Moisture content results

Where,
M1= Mass of Empty Can (g)
M2= Mass of Can + Wet Soil (g)
M3= Mass of Can + Dry Soil (g)

MC= $\frac{M2-M3}{M3-M1}$ x 100

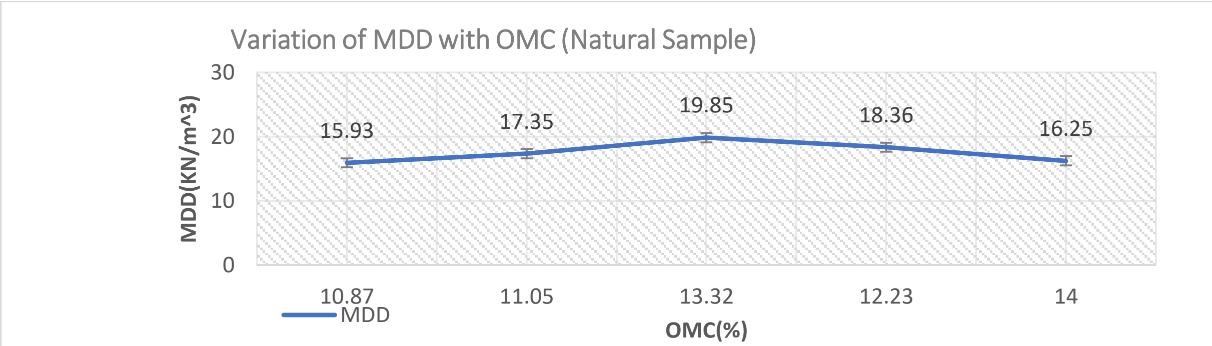
Moisture= $\frac{MC\ x\ (M2-M1)}{100}$

5.3 Compaction Test

The compaction test results are tabulated in table 2.

S. No.	MDD (KN/m³)	OMC (%)
1	15.93	10.87
2	17.35	11.05
3	19.85	13.32
4	18.36	12.23
5	16.25	14.00
Average	**17.55**	**12.29**

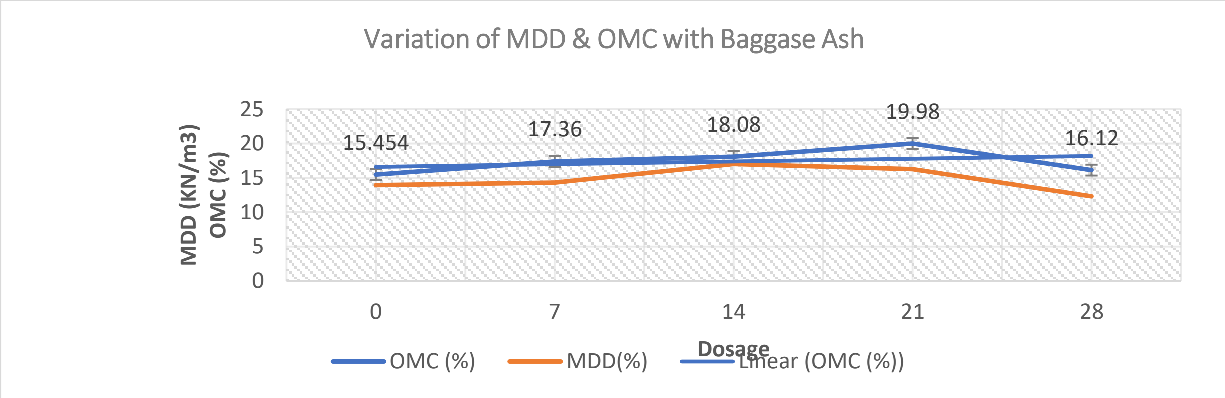
Table 2: MDD and OMC Values of virgin clay samples



Results of Maximum dry density and Optimum moisture content against different dosages of Bagasse Ash are shown in table 3.

S. No.	Dosage of Bagasse Ash (%)	MDD (KN/m³)	OMC (%)
1	0	13.92	15.45
2	7	14.29	17.36
3	14	17.01	18.08
4	21	16.26	19.98
5	28	12.30	16.12

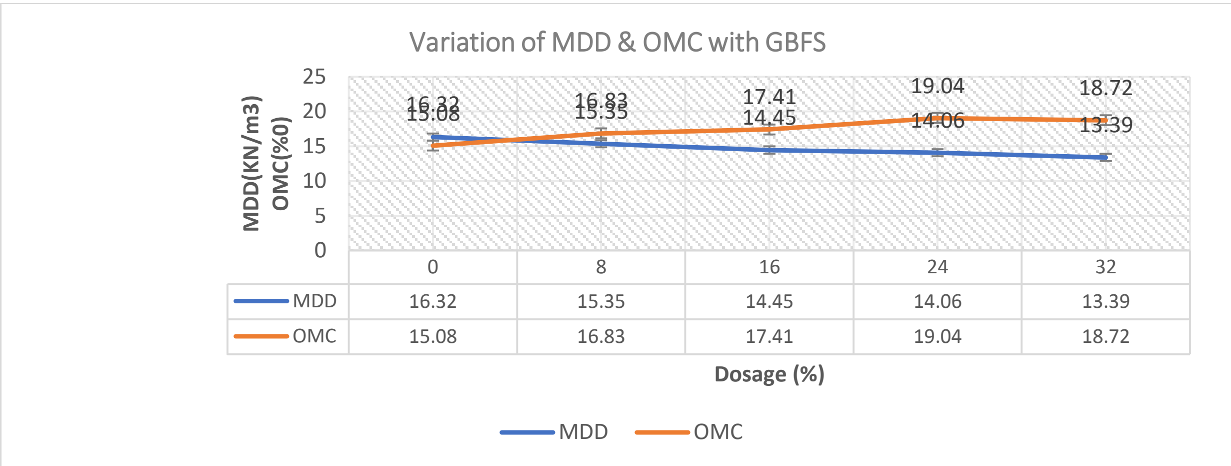
Table:3 Results of MDD & OMC against different Bagasse Ash dosages.



Results of Maximum dry density and Optimum moisture content against different dosages of GBFS are shown in table 3.

Table 3: MDD and OMC against different dosages of GBFS

S. No.	Dosage of GBFS (%)	MDD (KN/m³)	OMC (%)
1	0	16.32	15.08
2	8	15.35	16.83
3	16	14.45	17.41
4	24	14.06	19.04
5	32	13.39	18.72



5.4 Unconfined Compressive Strength

Unconfined Compressive Strength results obtained from Bagasse Ash blending is depicted hereunder in table 4.

Table 4: UCS results obtained from Bagasse Ash blending

S. No.	Dosage of Bagasse Ash (%)	Curing Period (days)	UCS (KN/m²)
1	0	28	66
2	7	28	77
3	14	28	94
4	21	28	111
5	35	28	69

Unconfined Compressive Strength results obtained from GBFS blending is depicted hereunder in table 5.

Table 5: UCS results obtained from GBFS Stabilization

S. No.	Dosage of GBFS (%)	Curing Period (days)	UCS (KN/m2)
1	0	28	61
2	8	28	87
3	16	28	93
4	24	28	127
5	32	28	77

6. Conclusions

Based on the observational inferences and calculations, the following deductions can be made:

1) The natural moisture content of the Clay obtained from Baramulla, Srinagar is 7.29%.

2) The highest density without moisture and the perfect moisture level were identified as 17.55 KN/m3 and 12.29% respectively.

3) The maximum dry density decreased due to the incorporation of GBFS, initially rising and then declining with Bagasse Ash, reaching a peak of 17.01 KN/m3 at a 14% dosage.

4) The optimal moisture content exhibited a similar pattern of increase followed by decrease with all three stabilizing agents, with peak values noted as 19.98% at a 21% dosage of Bagasse Ash and 18.72% at a 32% dosage of GBFS.

5) The Unconfined Compressive Strength of the native clay soil, starting at 64 KN/m3, rose to a peak and then declined after stabilization with all three agents. The highest values achieved were

111 KN/m3 at a 21% dosage of Bagasse Ash and 127 KN/m3 at a 24% dosage of Ground Granulated Blast Furnace Slag.

7) Bagasse Ash was identified as the costliest among the trio, procured from Srinagar at a retail cost of Rs. 300/ Quintal for lime, Rs. 300/ Quintal for GBFS, and Rs. 500/ Quintal for Bagasse Ash.

In conclusion, the most efficient soil stabilizer for the Baramulla clay is Ground Granulated Blast Furnace Slag, providing optimal results at a 24% dosage and being economically feasible as well.

6.References

1 Amit S. Kharade, Vishal V. Suryavanshi, Bhikaji S. Gujar, Rohankit R. Deshmukh, (2014) Waste product bagasse ash from sugar industry can be used as stabilizing material for expansive soils, IJRET.

2 Ankit Singh Negi, Mohammed Faizan, Devashish Pandey and Rehanjot Singh (2013), Soil stabilization using lime, Environmental Science.

3 Bowles J.E. 1984. Physical and Geotechnical Properties of Soils. Second Edition, McGraw-Hill, Singapore.

4 Butt W.A., Gupta K. and Jha J.N. 2016. "Strength behavior of clayey soil stabilized with saw dust ash", International Journal of GeoEngineering, 7(1): 18.

5 Chen F.H. 1975. Foundation on Expansive Soils, Developments in Geotechnical Engineering 12, ElseVier Scientific Publishing Company, New York.

6 Edeh J.E., Agbede I.O. and Tyoyila A. 2013. "Evaluation Lateritic of Soil Sawdust as Ash–Stabilized Highway Pavement Material", Journal of Materials in Civil Engineering, 26(2): 367-373.

7 Elinwa A.U. and Mahmood Y.A. 2002. "Ash from timber waste as cement replacement material", Cement Composites, 24(2):219-222.

8 Hary Christady, Hardiyatmo. 2010. Soil Stabilization for Highway Pavement, Yogyakarta: Gadjah Mada University Press.

9 Ingles O.G dan, Metcalf J.B. 1972. Soil Stabilization Principles and Practice. Butterworths Pty. Limited, Melbourne.

10 Jafar Abubakar Sadeeq, Joshua Ochepo, A.B. Salahudeen and ST Tijjani (2015), Effect of bagasse ash on lime stabilized lateritic soil, Jordan journal of civil engineering.

11 Jagmohan Mishra, R K Yadav and A K Singhai, 'Effect of granite dust on index Properties of lime stabilized black cotton soil', International journal of Engineering Science and Research & Technology, Vol. 3, No. 1, pp. 19-23, (2014).

12 Kezdi. A. 1979. Stabilized Earth Roads. Elsevier Science Publishing Company, New York.

13 Khan S. and Khan H. 2016. "Improvement of Mechanical Properties by Waste Sawdust Ash Addition into Soil", Jordan Journal of Civil Engineering, 10(1).

14 K.J. Osinubi, V. Bafyau, A, O. Eberemu, and O. Adrian (2009), Bagasse ash stabilization of lateritic soil, Appropriate Technologies for Environmental Protection.

15 Kumar.K A., Narayanan P. and Chiranthana N. 2014. "Stability of Red Clay and Laterite Soil with Sawdust Ash as an Amendment", International Journal of Combined Research & Development IJCRD- eISSN:2321225X;p ISSN:2321-2241 Volume: 2; Issue: 2

16 Meron Wubshet and Samuel Tadesse (2014), Stabilization of expansive soil using bagasse ash and lime, Journal of EEA.

17 Ogunribido T.H.T. 2012. "Geotechnical Properties of Saw Dust Ash Stabilized Southwestern Nigeria Lateritic Soils", Environmental Research, Engineering and Management, 60(2): 29-33.