International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

A Review on Sustainable Soil Stabilization Incorporating Recycled Concrete Aggregate and Ground Granulated Blast Furnace Slag

Sourav Kumar Nanda[1] and Jyoti Prakash Giri[2]

[1]PG Student, Centurion University of Technology and Management, Bhubaneswar, Odisha, India, 752050. Email: 220303230002@cutm.ac.in
[2]Assistant Professor, Centurion University of Technology and Management, Bhubaneswar, Odisha, India, 752050.
Email: jyotiprakash.giri@cutm.ac.in

ABSTRACT

Soil stabilization is a fundamental characteristic of civil engineering, crucial for ensuring the stability and longevity of pavement infrastructure projects. Traditional stabilization methods often rely on non-renewable resources and may carriage environmental challenges. In response, this review study explores the potential of utilizing construction & demolition wastes (C&D) and ground granulated blast furnace slag (GGBS) as alternative materials for soil stabilization. The extensive overview of soil stabilization techniques, highlighting the importance of sustainable construction practices in addressing environmental concerns. It then delves into the properties and applications of recycled concrete aggregate (RCA), derived from the crushing and processing of concrete waste. RCA's physical and mechanical properties, such as particle size distribution and shape, are discussed together with its role in enhancing soil stability. Past research studies and experimental data demonstrate RCA's effectiveness in improving soil strength, durability, and permeability. Subsequently, the use of GGBS, a by-product of the iron and steel industry, famous for its pozzolanic and hydraulic properties. The production process, chemical composition, and unique characteristics of GGBS are explored in detail, emphasizing its potential as a soil stabilizer. Past research also demonstrates GGBS's ability to enhance soil properties, reduce carbon emissions, and minimize waste generation. Furthermore, the review investigates the combined application of RCA and GGBS in soil stabilization, highlighting their synergistic effects and potential benefits. In conclusion, this review underscores the importance of adopting alternative materials such as RCA and GGBS in soil stabilization to promote environmental sustainability and resilience in civil engineering projects.

Keywords: Soil stabilization, C & D wastes, GGBS, sustainable construction

1. Introduction

Soil stabilization plays a crucial role in civil engineering and construction projects to improve the engineering properties of soil, such as strength, durability, and workability. Traditional soil stabilization methods often involve the use of cement, lime, or chemical additives. However, these methods may have limitations in terms of cost, environmental impact, and sustainability. In recent years, there has been growing interest in utilizing waste materials, such as plastic and GGBS, for soil stabilization, offering an alternative approach that addresses both engineering and environmental concerns. Soil stabilization techniques have evolved significantly in recent years, driven by the need for sustainable and cost-effective solutions in civil engineering projects. Among the innovative approaches gaining traction are the utilization of waste plastic and ground granulated blast furnace slag (GGBS) as stabilizing agents. This literature review aims to summarize recent findings, advancements, and applications in soil stabilization using waste plastic and GGBS. Expansive soils contribute to billions of dollars in damages annually worldwide, complicating geotechnical design and analyses. Traditional chemical stabilization methods involve additives like lime, fly ash, or cement, while physical techniques aim to reduce soil swell without altering its chemistry. Several reinforcement methods exist, including chemical additives, rewetting, and compaction control, but they may entail drawbacks such as ineffectiveness and high cost. (Carraro et al., 2008; Akbulut et al., 2007).

2. Literature Review

2.1 Recycled Concrete Aggregate (RCA) in Soil Stabilization

The composition and properties of RCA, such as particle size distribution, shape, and density, will be discussed comprehensively, with reference to relevant research studies and literature. Examples of successful applications of RCA in soil stabilization projects will be provided, along with case studies demonstrating the benefits and limitations of its use. The mechanisms by which RCA improves soil properties, such as mechanical interlocking and pozzolanic reactions, will be explored in depth, drawing on scientific principles and experimental data. Shourijeh (2022) conducted experiments to assess the efficacy of recycled concrete aggregates (RCA) as a cementitious reagent for stabilizing clay reinforced with recycled tire polymer fibers (RTPFs) and glass fibers (GFs). Their findings indicated that both RTPFs and GFs exhibited an optimal fiber content, resulting in the highest unconfined compressive strength (UCS) for fiber-reinforced clay. Additionally, the introduction of RCA to the clay-fiber mixture, particularly at the optimal fiber content, further enhanced its performance. Kianimehr et al. (2019) also supported these findings, noting that the addition of RCA to clay soils led to lower dry density but higher UCS, especially with moist curing. Clay soils mixed with RCA exhibited increased dilative behavior during shear and enhanced shear strengths compared to untreated clay. These mixtures yielded stronger, stiffer, and less compressible blends, ideal for construction applications like road pavements' subbase/subgrade. Similarly, Ali and Tobeia (2022) reported that incorporating RCA at values of 5%, 10%, and 15% increased bearing capacity by 33%, 67%, and 80%, respectively, when the soil-concrete aggregate mixture was at a depth equal to half the footing diameter. Moreover, they observed no significant decrease in settlement beyond a depth equivalent to the footing diameter, particularly at RCA contents of 10% and 15%. The correlation between experimental and analytical data demonstrated a high R2 value of 0.933 (Figure 1), indicating a strong relationship.

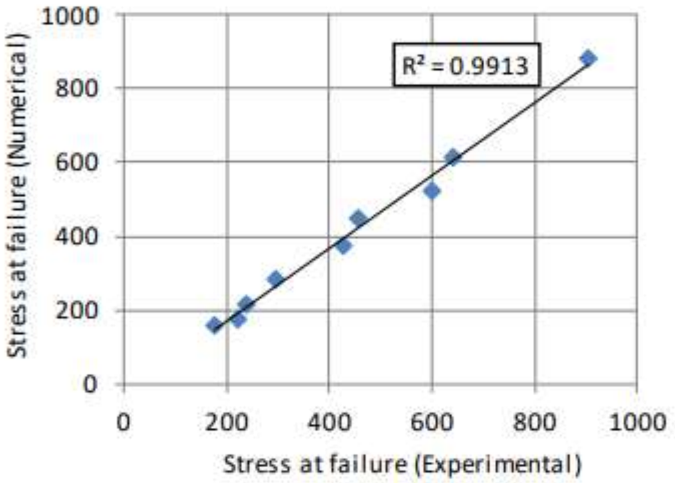

Figure 1 Relationship between the experimental and numerical test results [Ali and Tobeia (2022)]

2.2 Ground Granulated Blast Furnace Slag (GGBS) in Soil Stabilization

This section will provide a comprehensive overview of ground granulated blast furnace slag (GGBS), including its production process, chemical composition, and physical properties. The unique characteristics of GGBS that make it suitable for soil stabilization will be discussed in detail, highlighting its pozzolanic and latent hydraulic properties. Case studies and experimental data demonstrating the effectiveness of GGBS in improving soil strength, durability, and stability will be presented, along with comparisons to other traditional stabilizers. The environmental benefits of using GGBS, such as reduced carbon emissions and waste generation, will also be discussed, drawing on relevant research and industry reports. Pathak et al. (2014) observed that as the percentage of ground granulated blast furnace slag (GGBS) increased, the optimum moisture content decreased (see Figure 2), while the maximum dry density increased, leading to improved soil compactibility and increased density and hardness. Similarly, Mumtaz and Bhatia (2022) investigated the effect of adding GGBS to soft soil at various percentages (0%, 3%, 6%, 9%, and 12%). Their results demonstrated enhancements in both the physical and strength properties of the soil. The incorporation of GGBS resulted in a decrease in the Plasticity Index, while the Maximum Dry Density (MDD) increased and the Optimum Moisture Content (OMC) decreased. According to unconfined compressive strength (UCS) tests, the optimal GGBS content was found to be 6%, leading to an approximately 80% increase in strength compared to untreated soft soil (see Figure 3). However, despite the improvements observed, the increase was not as substantial as expected, as GGBS is considered a latent hydraulic material requiring an activator to break its glassy phase.

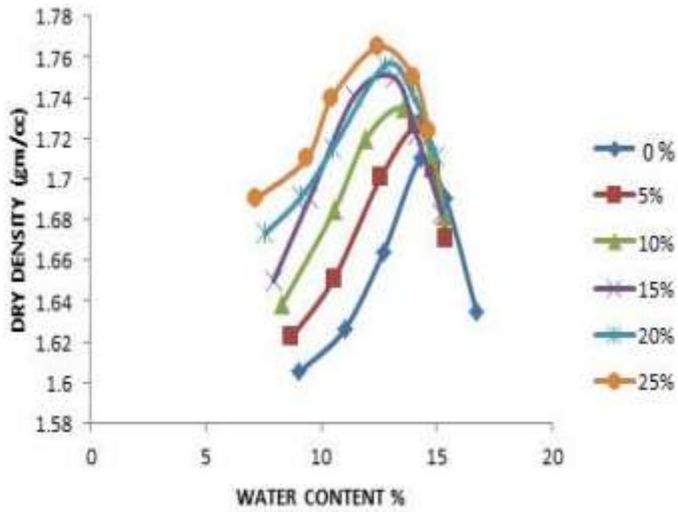

Figure 2 OMC and MDD from 0% to 25 % [Pathak et al. (2014)]

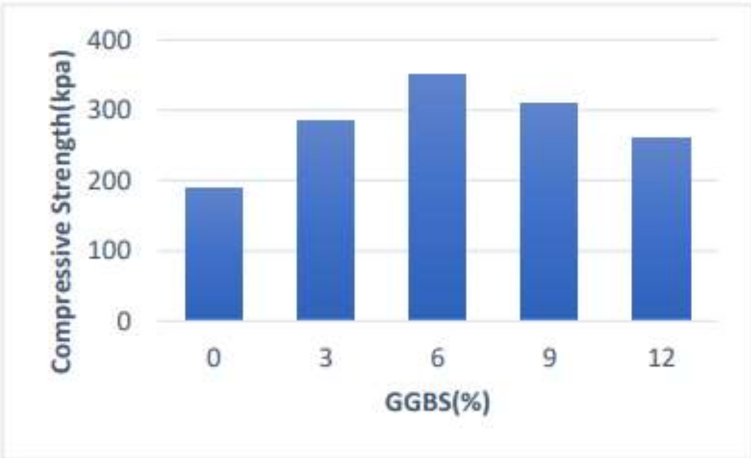

Figure 3 Relationship between UCS and GGBS percentages in 7 days curing [Mumtaz and Bhatia (2022)]

However, Sheikh et al. (2023) the increase of Fly ash and GGBFS percentage, optimum moisture content goes on decreasing, while maximum dry density goes in increasing. The addition of 15% of Fly ash and 10% of GGBFS and 3% of Silica Fume changes the soil group from CH to ML group according to IS1498:1970 (figure 4). The shear stress increases with addition of 15% Fly ash and 10% GGBFS and 3% Silica Fume tends to decrease beyond this limit.

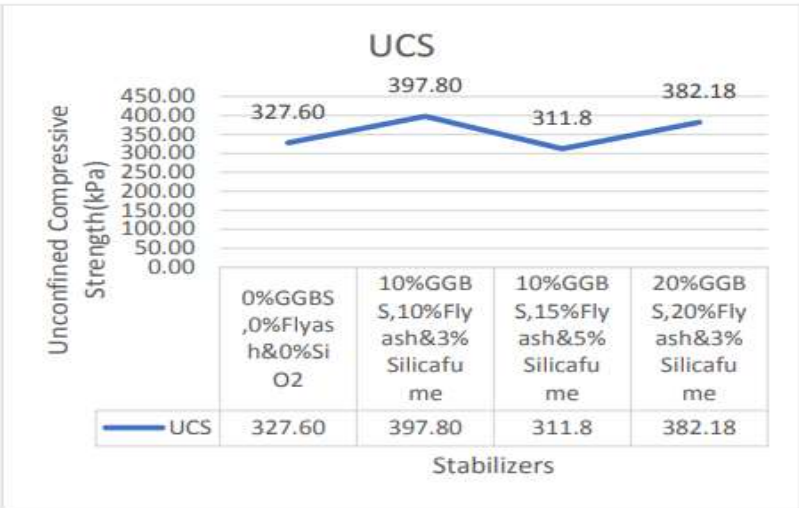

Figure 4 Compressive strength varying with %of Fly ash, GGBS and Silica Fume [Sheikh et al. (2023)]

3. Mechanisms of Soil Stabilization

Soil stabilization mechanisms involving waste plastic and GGBS are multifaceted. Waste plastic, owing to its fibrous or granular nature, enhances soil properties through mechanical interlocking and reinforcement. Studies by Kogbara et al. (2020) demonstrated that the inclusion of waste plastic fibers in soil improved its tensile strength and reduced moisture susceptibility, attributed to increased interparticle friction and reduced pore connectivity. On the other hand, GGBS acts as a pozzolanic material, undergoing chemical reactions with soil constituents to form stable hydration products. Research by Wang et al. (2019) elucidated the role of GGBS in enhancing soil stability by promoting cementitious bonding and reducing void spaces within the soil matrix.

4. Challenges and Future Directions

Despite the promising benefits of waste plastic and GGBS in soil stabilization, several challenges remain. Optimal dosage, compatibility with different soil types, and long-term performance evaluation are critical considerations that require further investigation. Moreover, the environmental implications of utilizing waste materials in soil stabilization must be carefully assessed. Future research should focus on exploring innovative stabilization techniques, optimizing material properties, and developing sustainable practices for widespread adoption. Collaboration between researchers, practitioners, and policymakers is essential to address these challenges and promote the adoption of eco-friendly soil stabilization methods.

5. Conclusion

In conclusion, soil stabilization stands as a fundamental aspect of civil engineering, ensuring the reliability and resilience of infrastructure projects. However, traditional methods often rely on non-renewable resources, posing potential environmental risks. The vulnerability of soil under heavy loads necessitates reinforcement or stabilization, demanding a comprehensive understanding of deformation, stress, and strain analysis. Expansive soils further complicate this scenario, contributing to significant damages globally. While conventional chemical and physical stabilization methods exist, they may incur drawbacks such as ineffectiveness and high costs. Nevertheless, innovative approaches like incorporating recycled concrete aggregate (RCA) and ground granulated blast furnace slag (GGBS) showcase promising results. These materials not only enhance soil properties but also offer environmental benefits, indicating a sustainable path forward for soil stabilization in civil engineering. Through continued research and implementation of advanced techniques, we can strive towards more resilient and eco-friendly infrastructure systems.

References

1. Akbulut, S., S. Arasan and E. Kalkan, 2007. Modification of clayey soils using scrap tire rubber and synthetic fibers. Applied Clay Science, 38: 23-32.
2. Carraro, J.A.H., J. Dunham-Friel and M. Smidt, 2008. Beneficial Use of Scrap Tire Rubber in Low Volume Road and Bridge Construction with Expansive Soils. (USDOT-MPC/274 INTERIM REPORT), Department of Civil and Environmental Engineering, Colorado State University.
3. Shourijeh, P.T., Rad, A.M., Bigloo, F.H.B. and Binesh, S.M., 2022. Application of recycled concrete aggregates for stabilization of clay reinforced with recycled tire polymer fibers and glass fibers. Construction and Building Materials, 355, p.129172.
4. Kianimehr, M., Shourijeh, P.T., Binesh, S.M., Mohammadinia, A. and Arulrajah, A., 2019. Utilization of recycled concrete aggregates for light-stabilization of clay soils. Construction and Building Materials, 227, p.116792.
5. Ali, A.M. and Tobeia, S.B., 2022. Mechanical Stabilization of Weak Sand Subgrade Using Recycled Concrete Aggregate. Journal of Engineering Science and Technology, 17(1), pp.0239-0256.
6. Pathak, A.K., Pandey, V., Murari, K. and Singh, J.P., 2014. Soil stabilization using ground granulated blast furnace slag. Int. J. Eng. Res. Appl, 4, pp.164-171.
7. Mumtaz, A. and Bhatia, E.S., 2022. Potential of Soil Stabilization Using Ground Granulated Blast Furnace Slag (GGBS). International Journal of Innovative Research in Computer Science & Technology, 10(6), pp.10-16.
8. Kogbara, R. B., Akpila, S. B., & Onuh, H. C. (2020). Utilization of Waste Plastic Fiber in Soil Stabilization: A Review. Journal of Materials in Civil Engineering, 32(11), 04020337.
9. Wang, Y., Li, Z., & Xing, Y. (2019). Mechanical and microstructural properties of cement stabilized soil with different curing conditions. Construction and Building Materials, 209, 277-285