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Resource Utilization Evaluation of Water Treatment Sludge and Ground Granulated Blast Furnace Slag

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ABSTRACT

This study explores the resource utilization of water treatment sludge and reservoir sediment as raw materials, combined with furnace slag powder. Adjusting the composition ratio enables the production of low-temperature sintered blocks, reducing the sintering temperature and enhancing process efficiency. This study evaluates how different mix designs affect product density and engineering performance, demonstrating feasibility through relevant tests. The expected results indicate that this technology can minimize landfill waste, lower carbon emissions, and promote a circular economy and green buildings. Additionally, this method reduces production costs, enhances environmental benefits for enterprises, and facilitates technology commercialization. It also offers scientific evidence for government environmental policies, contributing to green infrastructure and sustainable development.

Key word: resource utilization, low-temperature sintering, blocks, sustainable development

1. INTRODUCTION

Amid trends of energy conservation, carbon reduction, and sustainable resource development, effectively managing and reusing water treatment sludge has become a critical issue in today's environmental and engineering fields. With Taiwan's limited land,

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high population density, and substantial sludge output, improper disposal would impose considerable burdens on both land and the environment. This study focuses on combining water treatment sludge with ground granulated blast furnace slag (GGBS) through low-temperature sintering to produce eco-friendly recycled bricks, exploring its feasibility.

2. LITERATURE REVIEW

Most studies (Table 1.) indicate that water treatment sludge and reservoir sediment possess certain sinterability and solidification potential. Notably, when combined with materials such as clay, waste glass, or ground granulated blast furnace slag (GGBS), their physical and mechanical properties can be improved (Wang et al., 2021; Al-Fakih et al., 2019). GGBS, rich in calcium, silicon, and aluminum oxides, exhibits excellent alkali activation capability, making it a suitable substitute for cement in inorganic binder materials, thus achieving both energy savings and reductions in carbon emissions (Cheah et al., 2021; Silva et al., 2023).

2.1 Properties and Current Applications of Water Treatment Sludge

Water treatment sludge is a byproduct of the tap water treatment process, mainly composed of metallic hydroxides formed by coagulants, inorganic suspended solids, and a small amount of organic matter. In the past, its disposal methods primarily included landfilling or incineration. However, due to limited land resources and increasing environmental awareness, resource recycling and reuse have gradually gained attention. Recent studies have explored the utilization of sludge in brick making, pellet production, cement manufacturing, or as a soil amendment, emphasizing its feasibility and safety (Wang et al., 2021; Lin, 2020). Notably, after sintering treatment, the leaching concentrations of heavy metals are significantly reduced, demonstrating excellent stabilization effects (Zhao et al., 2022).

2.2 Properties and Current Applications of Reservoir Sediment

Reservoir silt, rich in fine clay minerals, organic matter, and iron oxides, possesses certain sintering potential. However, its high moisture content and insufficient mechanical properties limit its direct application as a structural material, necessitating combination with auxiliary cementing agents to enhance performance. According to Lin et al. (2012), when the content of reservoir silt is controlled below 50% and fluxing agents are added, sintering at 1000°C can produce lightweight eco-bricks with compressive strength exceeding 10 MPa. Wu and Lin (2003) also confirmed that with appropriate moisture content and sintering treatment, silt bricks can meet building material standards, demonstrating their reuse potential.

Additionally, Chi and Huang (2014) proposed a non-sintered alkali-activated process, in which sodium hydroxide and sodium silicate activate reservoir silt and ground granulated blast furnace slag. Under low-temperature curing, C-(A)-S-H geopolymer gels are formed, resulting in a 28-day compressive strength exceeding 20 MPa, offering both excellent mechanical properties and carbon reduction advantages.

2.3 Characteristics of Ground Granulated Blast Furnace Slag and Alkali Activated Effects

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of ironmaking in blast furnaces and possesses latent hydraulic activity. It can be alkali-activated by materials such as NaOH and Na_2SiO_3 to form C-S-H gel, resulting in solidification. Alkali-activated slag materials can significantly reduce carbon emissions compared to traditional cement manufacturing processes, offering environmental benefits (Silva et al., 2021). In addition, the incorporation of GGBS helps improve material density and resistance to sulfate attack, while also shortening the hardening time (Lee & Kim, 2024).

2.4 Research on Recycled Bricks

The production of recycled bricks typically combines various waste resources (such as water treatment sludge, ground granulated blast furnace slag, fly ash, etc.) and achieves structural stability and desired properties through appropriate mix proportions and sintering conditions. Studies have shown that the compressive strength and water absorption rate of sludge bricks are closely related to sintering temperature and admixture ratios (Abbas et al., 2023; Dosho, 2021). Al-Fakih et al. (2019) used sodium hydroxide and waste aluminum additives to produce lightweight geopolymer bricks, demonstrating excellent thermal insulation and lightweight properties. Additionally, Maaze et al. (2023), from a sustainability perspective, evaluated both sintered and non-sintered bricks, noting that while the former offers higher strength, it also imposes a greater environmental burden. Therefore, low-temperature sintering techniques and thoughtful material selection have become key research areas in recent years (Zhao et al., 2022).

Table 1. Consolidated Classification Table

Classification	References	Research Focus
Water Treatment Sludge Application	Peng & Chen (2018), Chen et al. (2022), Wang et al. (2019, 2021), Kamizela & Kowalczyk (2023), Lin (2020), Zhao et al. (2022)	Preparation of lightweight aggregates, analysis of water purification and metal adsorption performance
Reservoir Sediment Application	Lin et al. (2012), Wu & Lin (2003), Chi & Huang (2014)	Reducing the use of natural clay, low-carbon and low-energy processes
GGBS and Alkali Activation Systems	Cheah et al. (2021), Silva et al. (2021, 2023), Dosho (2021), El-Naggar et al. (2019), Lee & Kim (2024)	Cementing properties of GGBS, geopolymer bricks, effects of mineral admixtures
Waste Brick Applications	Al-Fakih et al. (2019), Abbas et al. (2023), Maaze & Shrivastava (2023)	Integration of waste-based bricks, performance and environmental assessment, a feasibility comparison
Energy and Sustainability Benefits	Lee et al. (2024)	Analysis of energy consumption in water treatment plants and sustainable sludge treatment strategies

3. CONCLUSIONS

This study demonstrates the feasibility of using water treatment sludge and ground granulated blast furnace slag (GGBS) to produce regenerated bricks via sintering or alkali-activation. Adding other by-products can improve material performance and resource efficiency. Combining reservoir sediment with GGBS helps reduce sediment and develop eco-friendly building materials. Future research should focus on raw material reactivity, durability, and the industrialization potential of non-sintered methods for Taiwan's conditions.

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