

Light Weight Concrete Block Substituting GGBS with Foaming Agent

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<p>Peer Review Information</p> <p><i>Type: Article</i> <i>Received: 3 February 2026</i> <i>Revised: 2 March 2026</i> <i>Accepted: 1 April 2026</i> <i>Published: 23 May 2026</i></p>	<p style="text-align: center;">Abstract</p> <p>The review article looks at how Ground Granulated Blast Furnace Slag (GGBS) is used in foamed concrete blocks. Understanding how GGBS influences the strength, density, thermal characteristics, and durability of lightweight concrete blocks is the major objective. A byproduct of the steel industry, GGBS is frequently used as a partial substitute for cement to enhance concrete qualities and lower environmental effect. He reports examines prior studies on varying GGBS cement replacement ratios, foam producing techniques, and curing conditions. These variables influence foamed concrete's pore structure, dry density, compressive strength, water absorption, and thermal insulation. The research also looks at how well the blocks hold up when exposed to chloride and sulphates. The literature search reveals that using GGBS can lower CO2 emissions and cement use while simultaneously enhancing long-term strength and durability. For modern construction, this review helps in finding appropriate mix ratios for creating lightweight, strong, and environmentally friendly concrete blocks.</p> <p>Keywords: Lightweight Concrete Block, GGBS, Foaming Agent, Cellular Concrete, Sustainable Construction, Green Building Material.</p>
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Introduction

The building sector is always working toward using materials that are both strong and good for the environment. Lightweight concrete is very important because it can make buildings stronger, keep them cooler in the summer, and make them easier to build. Foamed concrete has shown to be a great option among several lightweight materials because it is easy to make, it is not heavy, and it has a cellular structure. A homogenous and extremely porous material is produced when stable air voids are added into a cementitious matrix by means of foaming agents. Usually, foamed concrete has a density between 400 and 1200 kg/m³. This makes it good for semi-structural and non-load-bearing jobs like insulation layers, partition walls, and low-rise building. Still, its mechanical and durability qualities are significantly influenced by the amount of entrained air present. The linked pore structure usually results in lower compressive strength, greater permeability, more water absorption, and vulnerability to chemical assault. Its widespread use in structural applications is limited by these drawbacks, hence its composition has to be changed to improve performance.

To solve these difficulties, much study has gone into adding extra cementitious materials (SCMs). Ground Granulated Blast Furnace Slag (GGBS), among them, has shown to be among the most efficient and environmentally friendly substitute for standard Portland cement. Derived from the iron-making process, GGBS results from quickly cooling liquid slag and grinding it into a fine powder. It has both pozzolanic and latent hydraulic properties that allow it to take part in secondary hydration processes that lead to the formation of more calcium silicate hydrate (C-S-H) gel. This gel is mostly responsible for the strength of cement-based materials. Adding GGBS to foamed concrete changes its microstructure drastically. The better particle packing of GGBS results in a decrease in void connectivity and therefore pore structure refinement. This leads to a thicker matrix, better bonding between the paste and entrained air voids, and a better interfacial transition zone (ITZ). As a result, the mechanical characteristics, especially compressive strength and long-term strength increase, are significantly better. Furthermore, the slower hydration rate of GGBS lowers the heat of hydration, therefore lowering thermal cracking and enhancing dimensional stability.

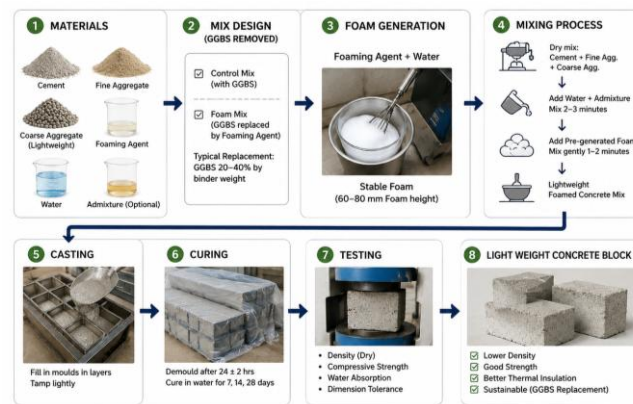


Fig 1. Methodology for Development of Lightweight Concrete Blocks Using Foaming Agent as a Substitute for GGBS

The impact of GGBS addition on durability performance is yet another crucial consideration. The improved pore structure and lower permeability increase resistance to hostile surroundings including chloride and sulfate attack. This means that GGBS-based foamed concrete is better for places where it is very hot or cold, or where it is very wet, because normal concrete mixes can break down over time. Additionally, GGBS increases alkali-silica reaction (ASR) resistance and minimizes reinforcement corrosion risk in reinforced applications.

The current review article offers a thorough assessment of the body of knowledge on GGBS application in foamed concrete. It thoroughly examines how the general performance of the substance is affected by several variables including foam content, water-to-binder ratio, GGBS replacement level, and curing circumstances. Since foamed concrete systems' parameters of density, strength, and durability are somewhat correlated, special attention is given to knowing how they interact. The research also looks at how different ways of making foam (like pre-formed foam and mixed foam) affect how the pores are spread out and how stable they are past studies show that foamed concrete's performance may be much improved with an ideal substitution of cement with GGBS, usually between 20% and 50%

Higher GGBS levels could enhance durability and long-term strength, but they could also delay early strength development, so this has to be taken into account in actual use. Consequently, a major goal of this review is to find the best mix ratio that strikes a balance between lightweight qualities, early strength, and long-term performance. Apart from its technical ability, the acceptability of GGBS in building materials depends heavily on sustainability concerns. Significant environmental damage comes from the high level of worldwide CO₂ emissions produced by cement manufacture. Apart from lowering carbon emissions, partially replacing cement with GGBS encourages the

use of industrial waste, therefore supporting the ideals of a circular economy. This makes GGBS-based foamed concrete a financially sensible and environmentally friendly option for contemporary building.

Literature Review

Amran et al. (2022) stressed that foamed concrete blocks' ultimate strength and durability are mostly determined by their curing conditions. Correct curing maximizes hydration, therefore improving compressive strength and lowering porosity. As Abdellatif et al. (2025) observed, lowering permeability and enhancing the microstructure allow industrial byproducts like GGBS to be included to boost long-term performance and endurance. Higher slag concentration improves pore structure and decreases permeability, therefore increasing durability, according to research by Zhang et al. (2024) on foamed concrete made of GGBS.

Examining foamed concrete composed of GGBS, Zhang et al. (2024) found that higher porosity and enhances pore structure, hence improving durability. slag content lowers. Ge et al. (2023) discovered that GGBS enhances the flexural strength and crack resistance of foamed concrete, even if early strength growth is more gradual. Wang et al. (2022) looked into the mechanical properties of foamed concrete and found that GGBS makes it much stronger and better over a long time. According to Liu et al. (2021), GGBS significantly and clearly enhances the microstructure density of lightweight concrete, hence reducing its water absorption.

Chen et al. (2020) found that slag-based binders significantly enhance porous concrete systems' durability and sulfate resistance.

Li et al. (2019) found that foamed concrete made from GGBS (Ground Granulated Blast Furnace Slag) insulates much better than regular concrete made from cement. Xu et al. (2022) highlighted that an optimal GGBS replacement level of around 30–40% effectively improves both compressive strength and long-term durability of foamed concrete. Lowering pore connectivity in porous concrete structures, such as GGBS, reduces permeability and greatly improves durability. Zhao et al. (2020) discovered this. Gupta et al. (2019) state that adding GGBS improves the workability of the fresh concrete mix and reduces the overall heat of hydration during the setting reaction.

Studying curing conditions, Zhou et al. (2023) found that concrete made with GGBS does better when it's cured in wet conditions. This makes the concrete stronger over time. Tang et al. (2022) observed that GGBS improves the interfacial transition zone (ITZ), thereby strengthening the bond between aggregates and cement paste in concrete mixtures. According to Huang et al. (2021), slag-based foamed concrete has a greater ability to resist chloride ion penetration, therefore improving resilience in demanding surroundings. According to Yang et al. (2020), raising GGBS content enhances structural performance and service life by reducing shrinkage and minimizing lightweight concrete cracking.

Cost comparison:

The materials employed largely determine the cost of foamed concrete blocks, especially the ratio of cement to other elements like Ground Granulated Blast Furnace Slag (GGBS). Normal Portland Cement (OPC) is among the most costly ingredients in concrete even if GGBS, a waste from industry, is somewhat inexpensive. Therefore, the general cost of materials may be greatly lowered by partially replacing cement with GGBS. Conventional foamed concrete with higher cement content raises production costs and environmental footprint. Usually, though, when GGBS is used instead of something else—typically between 20–40%—the cost of the binder goes down while keeping or even improving its performance. Though long-run lower maintenance costs and superior durability make GGBS-based concrete more cost-effective even if there is a slight rise in curing time and handling needs. Because it is lightweight, foamed concrete helps to keep building prices down. It minimizes the demand for a lot of reinforcement and in-depth foundation work, cuts transportation expenses, and lowers structural load. When mixed with GGBS, the chemical is reasonably priced and environmentally friendly. Generally speaking, foamed concrete made with GGBS has a better cost- performance ratio than normal concrete does. The best option for new construction nowadays is this as it lowers initial material costs, minimizes maintenance needs, and promotes long-term financial and environmental advantages.

Future Work and Challenges

More research is required to maximize the use of Ground Granulated Blast Furnace Slag (GGBS) in foamed concrete for increased performance. Future studies can focus on finding the best mix of GGBS with other materials like fly ash or silica fume to increase strength and prolong lifespan. Advanced mix design techniques and the employment of chemical admixtures have been further researched to enhance early-age strength, which is often lower in GGBS-based concrete. Further study on large-scale production and field uses of foamed concrete blocks is also needed to evaluate their actual performance. Research on long-term resilience in many contexts, including high temperatures and heavy chemical exposure, has to be conducted. Forecasting and improving material behavior can also be supported by contemporary techniques including artificial intelligence, models, and microstructural examination. Though advantageous, mixing GGBS with foamed

concrete presents particular difficulties. A major concern that could compromise construction timelines is late GGBS hydration's slower early strength development. It's also difficult to keep the foam distribution and stability constant when you're mixing, which can cause the strength and density to change. Another problem is that there are no clear rules for making foamed concrete with GGBS or making sure it is the same in different projects. Performance could also depend on regional differences in the caliber and accessibility of GGBS. The desired results may be attained by a qualified workforce and suitable curing conditions that raise first complexity.

Conclusion

Using Ground Granulated Blast Furnace Slag (GGBS) and a foaming agent, the research effectively shows how light foamed concrete blocks may be made. Including GGBS greatly lowered density in comparison to regular concrete; hence, the blocks were lighter and more appropriate for contemporary construction uses. Using GGBS also lowered cement consumption, hence supporting environmentally friendly building practices and assisting to lower environmental impact. Because of their permeable structure, the built blocks have good thermal and sound insulation as well as enough compressive strength for applications where the wall doesn't hold anything up. Furthermore, the inclusion of GGBS guaranteed good pore distribution and enhanced workability, therefore enhancing consistency and the whole performance of the material. Moreover, underlining the financial benefits of utilizing GGBS is its capacity to maximize the use of industrial waste resources therefore lowering the price of the blocks. All things considered, foamed concrete blocks made from GGBS seem to be rather appealing for more frequent use in the future because they offer a functional, creative, and environmentally friendly alternative for green building.

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