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MECHANICAL AND DURABILITY ASSESSMENT OF AAC BLOCKS INCORPORATING CERAMIC WASTE POWDER AND GLASS FIBERS

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ABSTRACT

This study presents a dual-modification approach for enhancing the performance of autoclaved aerated concrete (AAC) by partially replacing natural sand with ceramic waste powder (CWP) and incorporating alkali-resistant glass fibers (GF). A 15% replacement of sand with finely processed CWP was adopted as the optimum level based on prior findings, while glass fibers were introduced at dosages of 0.1–0.3% by total dry weight. Mechanical and durability properties were experimentally evaluated following IS standards. Results showed that replacing sand with 15% CWP increased compressive strength from 2.75 MPa to 3.25 MPa due to its pozzolanic reactivity and filler effect. The addition of glass fibers further enhanced the performance, with 0.2% fiber content achieving the highest compressive strength (3.48 MPa) and split tensile strength (0.42 MPa), along with reduced water absorption and moisture content. A slight decline in performance was observed at 0.3% due to fiber agglomeration. All mixes maintained lightweight densities within the IS 2185 (Part 3): 1984 range (547–565 kg/m³), preserving AAC’s thermal and handling advantages. These findings demonstrate that combining ceramic waste with minimal glass fiber reinforcement offers a practical, sustainable, and experimentally validated strategy to improve the strength and durability of AAC without compromising its lightweight character.

Keywords: Autoclaved Aerated Concrete (AAC), Glass Fiber Reinforcement, Ceramic Waste Powder; Sustainable Construction, Waste Utilization, Green Building Materials.

1. INTRODUCTION

In recent years, the construction industry has been compelled to undergo major changes in response to climate change concerns, depletion of natural resources, and the high environmental costs of traditional materials. These pressures have accelerated the search for eco-friendly building solutions that support circular economy practices. One such material is autoclaved aerated concrete (AAC), first produced in Sweden during the 1920s, which is valued for being lightweight, thermally insulating, fire-resistant, and significantly less energy-intensive to produce compared with conventional clay bricks (Raj et al., 2018; Kalpana & Mohith, 2019; Kamal, 2020; Michelini et al., 2023; Wang et al., 2025).

AAC is manufactured by combining cement, lime, water, and fine aggregates such as sand or fly ash, along with a small quantity of aluminum powder that serves as a gas-forming agent. The reaction between aluminum and the alkaline mix releases hydrogen, creating the characteristic porous structure. Subsequent autoclave curing leads to the formation of crystalline tobermorite, which contributes to the material’s stability and thermal efficiency (Kalpana & Mohith, 2019; Cai et al., 2016; Kunchariyakun et al., 2015; Shabbar et al., 2016). Typically, AAC has a density in the range of 400–800 kg/m³ and requires far less embodied energy—about 3.6 GJ per 100 m² of wall—compared to around 62 GJ for an equivalent clay brick wall (Azmodeh et al., 2024; Michelini et al., 2023). While AAC offers clear environmental and functional advantages, it is hindered by inherent drawbacks such as brittleness, relatively low compressive and flexural strength, and high water absorption (Pachideh & Gholhaki, 2019; Bhosale et al., 2019; He et al., 2019). These weaknesses limit its application in seismic-prone regions where improved mechanical resilience is required. To address these challenges, recent studies have pursued two main approaches: (i) replacing virgin raw materials with industrial byproducts to enhance sustainability, and (ii) reinforcing AAC with fibers to strengthen its mechanical properties (Pehlivanlı et al., 2015; Fládr & Bílý, 2018; Kumar et al., 2022).

Regarding raw material substitution, various researchers have shown that integrating industrial or agricultural wastes—such as fly ash, iron tailings, coal bottom ash, and rice husk ash—into AAC mixtures can enhance performance while lowering environmental impact (Cai et al., 2016; Kunchariyakun et al., 2015; Drochytka et al., 2013). For example, rice husk ash has been reported to improve thermal insulation and reduce autoclaving time, whereas iron tailings can accelerate tobermorite formation and boost compressive strength. In one study, Feng et al. (2024) demonstrated that replacing as much as 60% of the siliceous–calcareous component with concrete slurry waste (CSW) could produce compressive strengths up to 3.15 MPa, with further gains when nanosilica was added. Efforts to recycle AAC waste back into new products have also been promising. Qin and Gao (2019), for instance, blended waste AAC powder into Portland cement mixtures, which not only improved early-age strength but also enhanced CO_2 sequestration by up to 19% of the binder mass—supporting the feasibility of closed-loop production systems.

The second key approach to improving AAC performance is the use of fiber reinforcement. Fibers such as carbon, polypropylene, basalt, and glass have been found to significantly enhance crack resistance, flexural capacity, and dimensional stability (Laukaitis et al., 2009; Pehlivanlı et al., 2015; Kumar et al., 2022). Hydrophilized carbon fibers tend to yield the greatest strength improvements, whereas modified polypropylene fibers often provide better bonding at the interface. Hybrid and inorganic fiber systems are also gaining interest; for example, Pakravan et al. (2017) showed that combining steel and polypropylene fibers improved ductility and post-crack performance. Likewise, Song et al. (2024) found that glass fiber-reinforced AAC panels produced in factories reached compressive strengths of 4.23 MPa and flexural strengths of about 1 MPa, while also reducing brittleness and enhancing fire resistance.

Recently, ceramic waste—particularly gypsum–ceramic waste (GCW) and tile waste powder—has gained attention as an eco-friendly substitute for natural sand. This is especially relevant in areas like the Indian subcontinent, where uncontrolled sand extraction has severe environmental impacts (Abdul Manaf et al., 2022; Yusrianto et al., 2022; Feng et al., 2024). Yusrianto et al. (2022) found that replacing up to 15% of fine aggregates with GCW yielded compressive strengths of 7.22 MPa and provided superior sound absorption, making it well-suited for non-load-bearing walls. Similarly, Wang et al. (2025) observed that ceramic waste ground to particles smaller than 0.09 mm increased pozzolanic reactivity and improved AAC structural integrity. For fiber-based enhancements, Chougule and Chougule (2020) showed that adding woven glass fiber mesh increased AAC compressive strength from 2.1 MPa to 3.0 MPa, while also improving crack resistance and dimensional stability. Likewise, Arslan et al. (2021) found that applying glass fiber-reinforced cementitious plasters with 1% fiber content greatly boosted the seismic resistance of AAC infill walls. Supporting this, Memari et al. (2010) demonstrated that GFRP laminates applied to AAC lintels enhanced both flexural and shear performance, in line with ACI 440.2R guidelines. Natural fibers are another promising reinforcement option. For example, Beskopylny et al. (2023) incorporated coconut and sisal fibers into non-autoclaved AAC, which resulted in bending strength increases of up to 47% and thermal conductivity reductions of about 15%. In a separate study, Stel'makh et al. (2022) added microsilica and ground granulated blast furnace slag (GGBS), producing a denser microstructure and higher compressive strength, as verified by scanning electron microscopy (SEM).

Studies using waste-based fine aggregates, like gypsum–ceramic waste (Yusrianto et al., 2022) and concrete slurry waste (Feng et al., 2024), have shown improvements in strength, insulation, and acoustic behavior. However, these mixes still suffer from AAC's characteristic brittleness. On the other hand, glass fiber-reinforced AAC (Song et al., 2024; Chougule & Chougule, 2020) can enhance tensile strength, crack resistance, and dimensional stability, but its continued reliance on virgin sand reduces the overall sustainability gains.

Based on preliminary trials by the authors, it was established that replacing 15% of natural sand with ceramic waste powder (CWP) provided the most favorable balance between strength, durability, and workability in autoclaved aerated concrete (AAC). Building on this foundation, the present study extends the investigation by introducing low-volume alkali-resistant glass fibers (0.1–0.3%) into the optimized CWP mix. The combined modification was experimentally evaluated through compressive strength, split tensile strength, water absorption, dry density, and moisture content tests in accordance with IS standards. This dual approach enables a deeper understanding of how CWP enhances matrix densification and pozzolanic reactivity, while glass fibers act as micro-reinforcements to improve crack resistance and tensile performance. To the best of the authors' knowledge, no prior experimental study has systematically explored the synergy between an optimum level of ceramic waste substitution and minimal fiber reinforcement in AAC under standard autoclaving. This work therefore contributes a novel experimental pathway to addressing AAC's inherent brittleness and sustainability challenges, highlighting its potential as a greener and structurally improved material for lightweight masonry applications.

2. METHODOLOGY

A. Materials

1. Cement: Ordinary Portland Cement (OPC) was used as the main binder in AAC production, facilitating hydration and C–S–H formation for strength development. Under autoclaving, it also promotes tobermorite formation, enhancing the material's long-term strength and stability.

Table 1: Chemical compositions of ordinary Portland cement

Compound	Percentage
CaO	63
SiO_2	22
Al_2O_3	5
Fe_2O_3	3
MgO	2
K_2O	0.4
Na_2O	0.6

2. Fly ash: Fly ash, a coal combustion byproduct rich in reactive silica and alumina, was used as a supplementary cementitious material. In the AAC, it participates in pozzolanic reactions, reduces cement consumption and carbon emissions, and enhances workability and thermal insulation.

Table 2: Chemical Compositions of the fly ash

Compound	Percentage
SiO_2	41
$Al2O_3$	20
$Fe2O_3$	7
CaO	21
MgO	4
SO_3	3

3. Lime: Quicklime (CaO) was added to the mixture because it reacts with silica (from sand, fly ash, and ceramic waste) under high-pressure steam during the autoclaving process. This reaction results in the formation of tobermorite, which increases the strength and stability of the AAC.

4. Gypsum: Small amounts of gypsum were added to control the AAC slurry's setting time, ensuring adequate workability for uniform gas generation and pore formation, while preventing premature hardening before autoclaving.

5. Aluminum Powder: Finely ground aluminum powder was used as a foaming agent and reacted in the alkaline slurry to release hydrogen gas. The resulting bubbles expanded the mixture, resulting in the AAC's characteristic cellular structure.

6. Ceramic Waste Powder (CWP): Ceramic waste powder (CWP) from discarded sanitaryware and tiles in Uttar Pradesh, India, was oven-dried at 105°C, crushed, and sieved through a 75 µm IS sieve. Its particle size, specific gravity, bulk density, and water absorption were tested per IS 2386 (Parts 1 and 3) to confirm its suitability as a fine aggregate replacement. The selection of 15% CWP replacement was guided by preliminary laboratory trials conducted by the authors, which indicated that this proportion provided the best balance between strength improvement and workability. These preliminary results are not reported here, as the present study focuses exclusively on the dual-modification approach, introducing glass fibers into the optimized CWP mix and evaluating their combined effect.

Table 3: Physical characteristics of the ceramic waste powder

Property	Description
Particle Size	75–300 microns
Color	Light brown
Bulk Density	1.95

Specific Gravity	2.64
Water Absorption	1.75%

7. Glass Fibers: The glass fibers were sourced from a commercial supplier specializing in alkali-resistant chopped strands for cementitious applications. The fibers were 12 mm long with a diameter of 14 µm and were stored in sealed, moistureproof packaging prior to use. The physical and mechanical properties, including the specific gravity, tensile strength, and modulus of elasticity, were verified according to the manufacturer's specifications.

Table 4: Properties of the glass fibers used

Property	Value
Specific Gravity	2.67
Tensile Strength	1700 MPa
Young's Modulus	72 GPa
Softening Temperature	600°C
Diameter of Filaments	14 microns
Length of Filaments	12 mm
Number of filaments per kg. (for 12 mm fibers)	200 million filaments per kg.

The selected fiber dosages—0.1%, 0.2%, and 0.3% by total dry weight—were based on previous AAC studies (Pehlivanlı et al., 2015; Chougule & Chougule, 2020) and preliminary trials, which indicated that low-volume fractions (<0.5%) effectively enhance tensile capacity and crack resistance without increasing density or disrupting the pore structure. The range was designed to evaluate a minimal reinforcement level (0.1%), a hypothesized optimum (0.2%), and an upper threshold (0.3%) beyond which fiber agglomeration, reduced workability, and diminished mechanical gains may occur.

8. Sand: Quartz sand, which was finely ground to enhance the reactivity with lime, served as the primary silica source in the AAC mixture. Some of it was replaced with ceramic waste powder to conserve natural resources, while the sand aided in the formation of tobermorite and provided bulk material.

9. Water: Potable water was used for mixing to initiate cement and lime hydration and enable the aluminum–alkali reaction. Its content was controlled to ensure proper workability and uniform pore formation.

B. Manufacturing Process

1) Raw Material Preparation:

All raw materials were carefully prepared to meet the required physical and chemical specifications before mixing. Ordinary Portland cement (OPC), lime, gypsum, sand, and fly ash were used in their dry forms. Ceramic waste, obtained from discarded tiles and sanitaryware, was oven-dried at 105 °C, crushed, and sieved through a 75 µm IS sieve to serve as a partial sand replacement. Alkali-resistant glass fibers (≈12 mm in length) were stored in moisture-free conditions to prevent degradation, while aluminum powder, used as the foaming agent, was kept in sealed containers to avoid premature reactions. Potable water conforming to IS standards was used throughout the mixing process.

2) Mixing: The mixing procedure was carried out in a mechanical mixer to ensure homogeneity of the constituents. Initially, the dry materials—cement, lime, gypsum, fly ash, sand, and ceramic waste powder—were thoroughly blended. Glass fibers were then introduced gradually in dosages of 0.1%, 0.2%, and 0.3% by total dry weight, with care taken to prevent fiber clumping and to achieve uniform dispersion. Once the dry mixture was homogenized, water was added to produce a workable slurry. Finally, aluminum powder was gently incorporated into the mix, where it reacted with the alkaline medium to release hydrogen gas, thereby initiating pore formation. The slurry was stirred for 1–2 minutes to ensure even gas distribution without collapsing the foam structure.

Table 5: Proportion of ingredients in the mixture (expressed as a percentage of the total dry weight)

Sample	Cement (%)	Fly Ash (%)	Silica Sand (%)	Ceramic Waste Powder (%)	Lime (%)	Gypsum (%)	Aluminum Powder (%)	Glass fiber (%)
1	16	38	30	0	10	2.5	0.06	0

2	16	38	25.5	4.5 (15% replacement of sand)	10	2.5	0.06	0
3	16	38	25.5	4.5 (15% replacement of sand)	10	2.5	0.06	0.1
4	16	38	25.5	4.5 (15% replacement of sand)	10	2.5	0.06	0.2
5	16	38	25.5	4.5 (15% replacement of sand)	10	2.5	0.06	0.3

1. Casting:

The prepared slurry was poured into 150 × 150 × 150 mm molds, filling them to 75–80% of their volume to allow for expansion during the initial setting phase. The hydrogen gas generated by the aluminum–alkali reaction formed fine bubbles throughout the matrix, giving AAC its characteristic cellular structure. The dispersed glass fibers acted as internal reinforcements, influencing dimensional stability, density, and mechanical behavior. The molded slurry was left undisturbed for 24 hours to expand and consolidate into a coherent green mass suitable for further processing.

2. Demolding and Cutting:

After the initial setting period, the expanded AAC mass was demolded and trimmed to achieve precise block dimensions of 150 × 150 × 150 mm. This step ensured geometric uniformity and eliminated the need for additional finishing prior to curing.

3. Autoclaving:

The trimmed blocks were subjected to high-pressure steam curing in an autoclave at 180–200 °C under 12–14 bar pressure for 10–12 hours. The curing cycle included gradual pressurization to ~4 bar over 4 hours, constant curing at ~12 bar for 6 hours, followed by slow depressurization to minimize the risk of thermal shock. This controlled process facilitated the formation of crystalline tobermorite, thereby improving strength, durability, and dimensional stability.

4. Cooling and Storage:

Upon completion of the autoclaving cycle, the blocks were allowed to cool gradually within the chamber to avoid cracking due to thermal gradients. They were then stored under dry and shaded conditions for 24–48 hours to allow moisture evaporation. Each block was inspected for pore uniformity, dimensional accuracy, and the absence of visible cracks before being subjected to experimental testing.

C. Experimental Program

(1) Compressive Strength Testing

The compressive strength of AAC blocks was evaluated to determine the effect of ceramic waste powder (CWP) and glass fiber (GF) additions on load-bearing capacity. Testing followed IS 6441 (Part 5): 1972 for cellular concrete and IS 516 for compressive strength determination. Natural sand was partially replaced with CWP, and GF was added at 0%, 0.1%, 0.2%, and 0.3% (by total dry mix weight) across four batches. After autoclave curing at 180–200 °C and 8–12 bar, blocks were cut into 150 mm cubes. Each specimen was tested in a compression testing machine (CTM) under a gradually applied load until failure, with maximum load recorded. Compressive strength (MPa) was calculated using:

Compressive strength (MPa) = Maximum load (N) / Cross-sectional area (mm²)

Three specimens per batch were tested, and the average values, presented in Table 6, were used for comparative analysis of structural performance.

(2) Water Absorption Testing

The porosity and moisture uptake of the AAC blocks were evaluated via a water absorption test. Oven-dried specimens (105 °C for 24 h) were weighed (W_1), immersed in water for 24 h, surface-dried, and reweighed (W_2). Water absorption (%) was then calculated as:

Water Absorption (%) = $(\{W_2 - W_1\}/W_1) * 100$

Three specimens per batch were tested, and the mean values were used to evaluate the effect of ceramic waste powder and glass fiber incorporation on the moisture resistance of AAC blocks.

(3) Dry Density Testing

Dry density was measured as per IS 6441 (Part 1): 1972, which outlines the standard procedure for cellular concrete products. This property is essential for evaluating weight-related performance, influencing thermal insulation, structural efficiency, and handling during construction. Cube specimens (150 × 150 × 150 mm) were extracted from autoclaved AAC blocks, with four sets prepared for glass fiber contents of 0%, 0.1%, 0.2%, and 0.3%. Each sample's volume (V) was calculated in cubic meters, and the initial weight (W_1) was recorded using a precision digital balance. The specimens were then oven-dried at 105 °C for 24 h to remove residual moisture, after which the dry weight (W_2) was measured. Dry density (kg/m³) was calculated using:

Dry density (kg/m³) = W_2/V

The average value of three samples per batch was considered for analysis.

(4) Moisture Content Testing

Moisture content was determined as per IS 2185 (Part 3): 1984 to evaluate the hygroscopic properties of AAC blocks containing ceramic waste powder (CWP) and varying glass fiber (GF) contents. Cube specimens (150 × 150 × 150 mm) were oven-dried at 105 °C for 24 h to remove free moisture, cooled to room temperature, and weighed to obtain the dry mass (W_1). The samples were then stored under standard laboratory conditions for 72 h to allow natural moisture absorption. The final weight (W_2) was recorded, and moisture content (%) was calculated using:

Moisture Content (%) = $[(W_2 – W_1)/W_1] \times 100$

The procedure was repeated for three specimens from each batch to ensure consistency and reliability, and the mean values were considered for analysis.

(5) Split Tensile Strength Testing

Split tensile strength was determined using the diagonal compression method as per IS 5816:1999 to evaluate the tensile performance of AAC blocks incorporating ceramic waste powder (CWP) and glass fibers (GF). Cube specimens (150 × 150 × 150 mm) were prepared with 15% fine aggregate replaced by CWP, and GF dosages of 0.1%, 0.2%, and 0.3% by binder weight. All samples underwent autoclave curing at 180–200 °C and 8–12 bar for 8–12 h, followed by cooling under ambient conditions. For testing, each cube was placed diagonally between the platens of a compression testing machine, and load was applied along the vertical diagonal axis until splitting failure occurred. The maximum load sustained was recorded, and split tensile strength (MPa) was calculated using the standard equation.

$fct = 2P/(\pi.a.a)$ [For cube samples]

where fctf_{ct}fct is the split tensile strength (MPa), PPP is the maximum load at failure (N), and aaa is the cube side length (mm). Three specimens per batch were tested, and the mean value was used for analysis.

3. RESULTS AND DISCUSSION

Table 6: Physical and mechanical properties of AAC blocks with 15% ceramic waste powder (CWP) and varying glass fiber content

Sample	Glass Fiber content (in%)	Ceramic waste powder content (in%)	Compressive Strength [MPa]	Density [kg/m³]	Water Absorption (in%)	Moisture Content (%)	Split Tensile Strength [MPa]
1	0	0	2.75	565	8.10	8.30	0.29
2	0	15	3.25	547	9.20	9.30	0.38
3	0.1	15	3.32	552	8.90	9.00	0.39
4	0.2	15	3.48	556	8.60	8.70	0.42
5	0.3	15	3.28	554	8.75	8.85	0.40

1. Compressive Strength

Replacing 15% of the sand with CWP increased the strength from 2.75 to 3.25 MPa because of the pozzolanic reactivity and matrix densification. Adding glass fibers further improved the values to 3.32, 3.48, and 3.28 MPa at 0.1%, 0.2%, and 0.3%, respectively, with 0.2% as the optimum from enhanced crack bridging and load transfer. The decline at 0.3% is attributed to fiber agglomeration. This optimum contrasts with prior reports (≥0.3%) and is linked to the finer particles and reactivity of CWP, enabling effective reinforcement at lower fiber volumes and demonstrating a unique synergy that is absent in single-modification AAC.

2. Water Absorption

Water absorption serves as an indicator of porosity and durability. The control sample exhibited 8.10% water absorption. A noticeable increase to 9.20% was observed with the inclusion of 15% ceramic waste powder alone

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(Sample 2), which was attributed to increased microporosity due to the presence of finer ceramic particles. With the addition of glass fibers, water absorption progressively decreased: 8.90% (0.1% fiber), 8.60% (0.2% fiber), and 8.75% (0.3% fiber). This trend suggests that fibers help restrict the formation of continuous capillary pores and enhance the integrity of the matrix, leading to lower water ingress.

3. Density

All the AAC samples exhibited densities well within the lightweight classification defined by IS 2185 (Part 3):1984. The control sample (Sample 1) presented the highest density at 565 kg/m³. With the substitution of 15% ceramic waste powder (CWP) and no fiber addition (Sample 2), the density decreased to the lowest recorded value of 547 kg/m³. This reduction can be attributed to the lower specific gravity and finer particle size of CWP than those of natural sand, which results in a lighter matrix.

Introducing glass fibers led to a slight increase in density, with values ranging from 552 kg/m³ to 556 kg/m³ for fiber contents between 0.1% and 0.2%, before a marginal drop to 554 kg/m³ at 0.3% fiber content. This increase is likely due to improved particle packing and reduced void content facilitated by fiber–matrix interactions. Even with these variations, all the measured densities remained within the acceptable limits for AAC applications, ensuring structural performance alongside weight efficiency.

4. Moisture Content Test

The moisture content results revealed that both CWP and glass fiber addition influenced the water retention characteristics of the AAC blocks. The control sample had a moisture content of 8.30%. The inclusion of 15% CWP alone (Sample 2) resulted in the highest recorded moisture content of 9.30%, likely because the fine particle size of CWP increases microporosity and enhances water retention. When glass fibers were incorporated, the moisture content decreased progressively—reaching 9.00%, 8.70%, and 8.85% for 0.1%, 0.2%, and 0.3% fiber contents, respectively. This reduction suggests that glass fibers disrupt capillary pathways and enhance the matrix's microstructural integrity, thereby reducing water ingress. The lowest moisture content was achieved with 0.2% fiber addition, suggesting that this is the most effective dosage for minimizing water absorption without negatively impacting other mechanical properties.

5. Split Tensile Strength Test

The split tensile strength results clearly demonstrated an improvement in performance with the addition of CWP and glass fibers. The control AAC block reached 0.29 MPa. With 15% CWP replacement (Sample 2), the tensile strength increased substantially to 0.38 MPa, which was attributed to the pozzolanic reactivity and fine particle distribution of CWP, which increased the bond strength within the matrix. Adding glass fibers further improved the tensile strength, with 0.1% fiber content reaching 0.39 MPa and 0.2% yielding the highest value at 0.42 MPa. This enhancement can be attributed to the crack-bridging effect of the fibers, which helps distribute tensile stresses and delays crack propagation. However, at 0.3% fiber content, the tensile strength decreased slightly to 0.40 MPa, likely because of fiber clumping, which compromises the mix uniformity and stress transfer efficiency. The optimal tensile performance was achieved with 0.2% fiber addition, indicating that a balanced combination of CWP and moderate fiber dosage maximizes the structural efficiency of AAC blocks while maintaining their lightweight nature.

6. Graphical Summary of AAC Block Performance Parameters

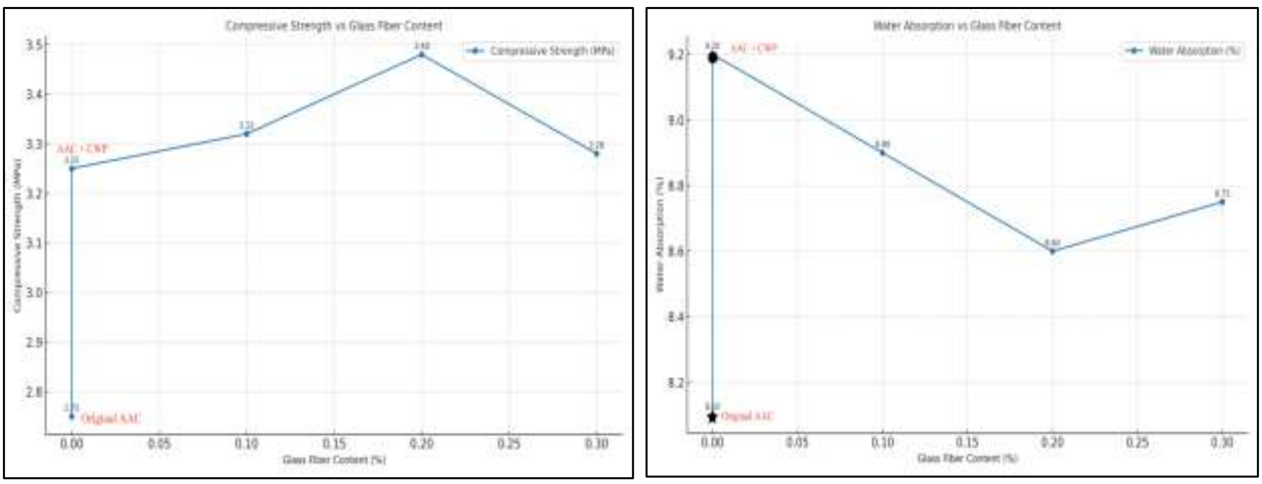

Figure 1: Influence of glass fiber dosage on the compressive strength and water absorption of AAC blocks with 15 % ceramic waste powder

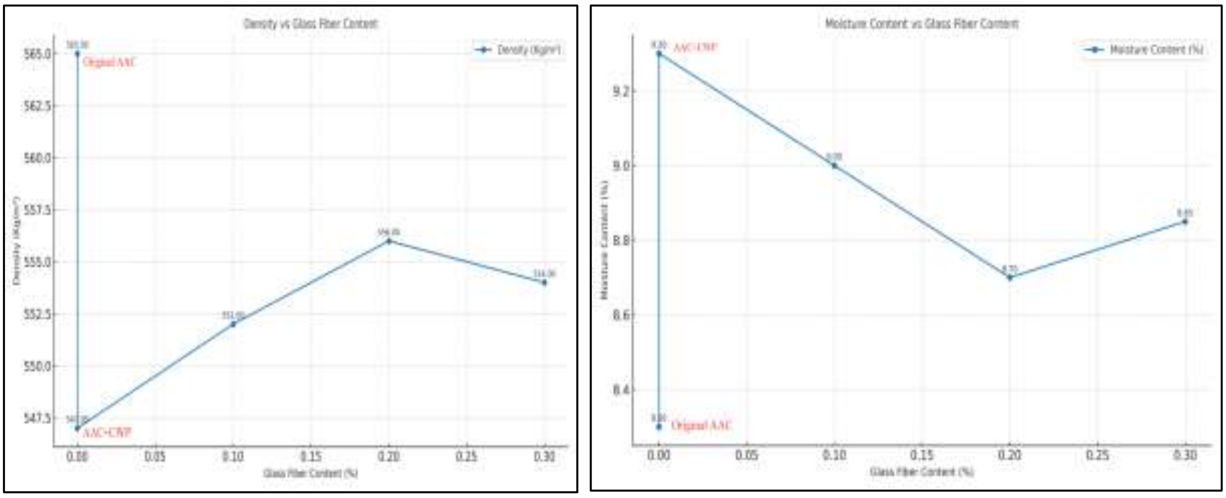

Figure 2: Effect of glass fiber content on the density and moisture content of AAC blocks with 15 % ceramic waste powder

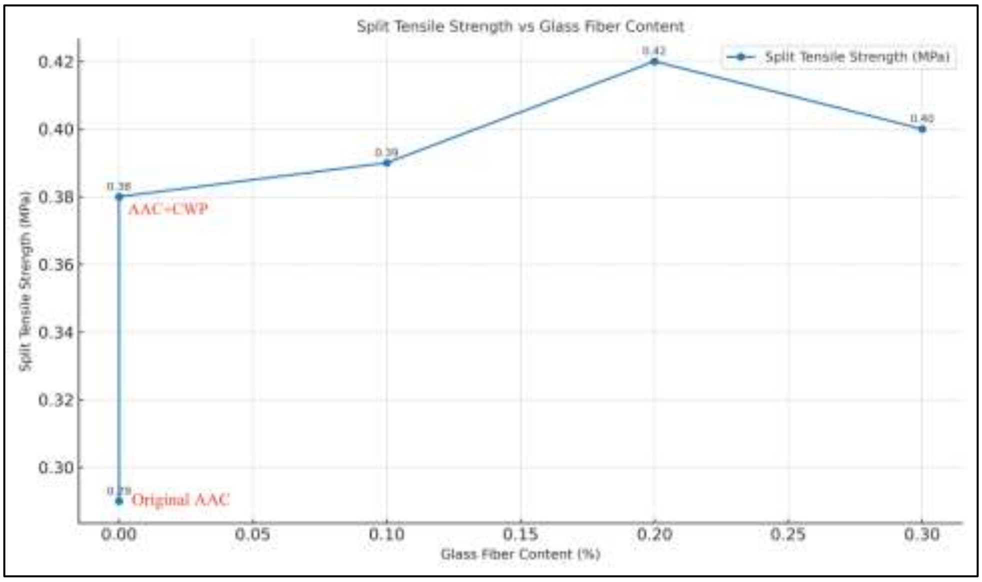

Figure 3: Variation in the split tensile strength of AAC blocks with different glass fiber dosages at 15 % ceramic waste powder replacement

The effects of varying the glass fiber content on the performance of autoclaved aerated concrete (AAC) blocks were evaluated across multiple parameters. The compressive strength improved significantly with the inclusion of 0.2% glass fibers, reaching its peak value, whereas a slight decline was observed at the 0.3% dosage. Both water absorption and moisture content tended to decrease with increasing fiber content, reflecting improved resistance to moisture penetration; however, a marginal increase was noted at the highest fiber level (0.3%). The dry density of the blocks also increased slightly with increasing fiber content, peaking at 0.2% and then decreasing slightly thereafter. A comparable pattern was observed for the split tensile strength, which increased with increasing fiber reinforcement and reached its maximum value at 0.2%, followed by a minor reduction at 0.3%. These results indicate that the incorporation of glass fibers up to an optimal dosage of approximately 0.2% can effectively enhance the mechanical strength and durability characteristics of AAC blocks.

4. CONCLUSION

1. Partial replacement of natural sand with 15% ceramic waste powder (CWP) enhanced the compressive strength of AAC blocks from 2.75 MPa (control) to 3.25 MPa. This improvement was primarily attributed to the pozzolanic activity and microfiller effect of finely ground ceramic particles, which refined the pore structure and improved bonding within the matrix.

2. The incorporation of alkali-resistant glass fibers at dosages between 0.1% and 0.3% further improved mechanical properties. The optimum dosage of 0.2% yielded the highest compressive strength (3.48 MPa) and split tensile

strength (0.42 MPa), owing to effective fiber dispersion and crack-bridging action. At 0.3%, a minor reduction in strength was observed due to fiber agglomeration and reduced workability.

3. All mixes achieved dry densities ranging from 547 to 565 kg/m³, which comply with IS 2185 (Part 3): 1984 requirements for lightweight concrete. These values confirm that the modified AAC blocks retained their inherent advantages of low density, reduced dead load, and favorable thermal insulation.

4. The introduction of CWP slightly increased water absorption because of its porous and fine nature. However, the addition of glass fibers counteracted this effect, reducing absorption from 9.20% (CWP only) to 8.75% at 0.3% fiber content. A similar trend was noted for moisture content, where fibers helped refine the microstructure and limit moisture ingress.

5. The split tensile strength of AAC blocks improved significantly with the dual modification, increasing from 0.29 MPa in the control mix to 0.42 MPa at 0.2% fiber addition. This confirmed the role of glass fibers in crack control and ductility enhancement, though a slight decline was noted at 0.3% due to non-uniform fiber distribution.

6. The combined use of ceramic waste powder and glass fibers presents a sustainable and effective approach to improving the strength, durability, and overall performance of AAC blocks. This method not only reduces dependence on natural sand but also promotes waste utilization, offering both environmental and structural benefits without altering existing autoclaving practices.

Practical Implications and Sustainability

The results of this study highlight that dual-modified AAC blocks—incorporating 15% ceramic waste powder (CWP) and low-volume glass fibers (0.1–0.3%)—can be produced using standard autoclaving methods without requiring any change in existing manufacturing infrastructure. This makes the approach immediately feasible for commercial adoption.

At the selected replacement level, substituting 15% of natural sand with CWP translates into a saving of approximately 150–180 kg of sand per cubic meter of AAC. This not only reduces the exploitation of natural sand reserves but also diverts an equivalent quantity of ceramic waste from landfill streams. From an environmental perspective, published emission factors suggest that such substitution can reduce embodied CO_2 emissions by 4–6% per cubic meter of AAC, while also lowering overall embodied energy compared to conventional mixes.

From an economic standpoint, incorporating ceramic waste—typically available at little to no cost—offers direct material savings. The addition of glass fibers at low dosages (≤0.3% by weight) contributes less than 2% to overall production costs, yet delivers measurable improvements in strength, ductility, and durability. This cost-to-performance ratio makes the modification attractive for large-scale industrial application.

In practical terms, the improved mechanical performance, reduced brittleness, and controlled water absorption enhance the structural reliability of AAC blocks, particularly in non-load-bearing walls and in regions where lightweight yet durable masonry is desirable. Moreover, these modifications maintain AAC’s thermal insulation and ease of handling, further supporting its application in energy-efficient and sustainable construction.

Overall, the combined use of ceramic waste and glass fibers not only advances waste valorization and resource conservation but also contributes directly to the broader goals of sustainable development and green building certifications such as LEED and GRIHA.

Limitations and Future Scope

Limitations of the present study:

1. The investigation was restricted to a single replacement level of 15% ceramic waste powder (CWP), without exploring lower or higher proportions.

2. Glass fiber dosage was limited to the narrow range of 0.1–0.3%, which may not capture the full potential of fiber reinforcement.

3. Only short-term mechanical and durability parameters were assessed; long-term durability under aggressive environments (e.g., freeze–thaw, chloride attack, carbonation) was not considered.

4. The work was conducted entirely at the laboratory scale, and field-scale applications or pilot production trials were not undertaken.

5. Other important performance characteristics of AAC, such as thermal conductivity, fire resistance, and acoustic behavior, were not part of the present scope.

Future scope of research:

1) Explore a wider range of CWP replacement levels to identify the most efficient balance between strength, durability, and sustainability.

2) Investigate hybrid fiber systems (e.g., glass + polypropylene, glass + natural fibers) or alternative fiber types to enhance ductility and crack control.

3) Incorporate advanced additives such as nanomaterials, microsilica, or supplementary cementitious materials to refine pore structure and improve long-term durability.

4) Conduct long-term exposure studies to evaluate resistance to environmental degradation, including thermal cycles, chemical attack, and sustained loading.

5) Perform large-scale field trials to validate laboratory findings and assess constructability, handling, and in-situ performance.

6) Undertake detailed life cycle assessment (LCA) and cost–benefit analysis to quantify the environmental and economic feasibility of dual-modified AAC.

7) Extend investigations to additional functional properties such as thermal insulation, fire resistance, and sound absorption, to provide a comprehensive evaluation of AAC in real-world applications.

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