International Journal of Research in Engineering, Science and Management
Volume 8, Issue 5, May 2025
https://www.ijresm.com | ISSN (Online): 2581-5792

Optimization and Performance Evaluation of AAC Blocks: A Study on Compressive Strength Enhancement

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***Abstract*: Autoclaved Aerated Concrete (AAC) blocks are lightweight, precast building materials made from a mixture of cement, lime, silica (usually sand), water, and aluminum powder, which causes the material to expand and form a porous structure. The standard mix proportions typically consist of 10-15% cement, 20-30% lime, 50-60% silica, and a small amount of aluminum powder. Mix Proportion I is the most effective, achieving the highest compressive strength of 7.8 MPa at 28 days. Optimization of mix design, especially in Mix I, plays a significant role in enhancing the performance of AAC blocks. Thus, Mix I is recommended for further production and application in construction due to its superior strength characteristics with mix proportion of Cement-25% , Fly ash-50%, Lime-10%, Sand-10%, Aluminum Liquid-0.2%, Gypsum-0.2% & Water- 0.65% . The production process includes mixing, molding, curing using water curing, and drying. AAC blocks are tested for compressive strength. These properties make AAC blocks an ideal choice for sustainable, energy-efficient construction, offering significant advantages in terms of strength, insulation, and environmental performance.**

***Keywords*: AAC Blocks, lightweight concrete, Compressive Strength, Sustainability.**

1. Introduction

Autoclaved Aerated Concrete (AAC) was first developed in the early 20th century to address rising energy costs and material shortages. It consists of inorganic materials like quartz sand, gypsum, lime, cement, water, and a small amount of aluminum powder. The interaction of aluminum with calcium hydroxide releases hydrogen gas, creating small air pockets, resulting in the characteristic porous structure of AAC blocks. This introduction provides a foundation for understanding the significance of AAC in modern construction, especially in high-rise buildings and sustainable development projects. Autoclaved Aerated Concrete (AAC) was first developed in the early 20th century to address rising energy costs and material shortages. It consists of inorganic materials like quartz sand, calcite gypsum, lime, cement, water, and a small amount of aluminum powder. The interaction of aluminum with calcium hydroxide releases hydrogen gas, creating small air pockets, resulting in the characteristic porous structure of AAC blocks. This introduction provides a foundation for understandings the significance of AAC in modern construction, especially in high-rise buildings and sustainable development projects.

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2. Literature Review

Author(s): Narayanan N., Ramamurthy K. They studied on Autoclaved Aerated Concrete: Properties, Testing and Design" his report was published in 2000. This paper reviews the structural and physical properties of AAC blocks, focusing on the impact of material composition and autoclaving processes on strength and thermal performance.

Author(s): Wong Y.C., Ravindran V., Hamid Z.A. They studied Compressive Strength of AAC Blocks in Structural Applications his report was Published: 2012 The paper investigates the compressive strength of AAC blocks and compares them with other conventional masonry materials.

Author(s): Ghafoori N., Ramyar K. Durability They studied of "Autoclaved Aerated Concrete under Harsh Environmental Conditions" his report was Published: 2016.This study focuses on the durability of AAC blocks, particularly their resistance to moisture and freeze-thaw cycles.

Author(s): Patel H., Shah S. They studied "Energy Efficiency in Buildings Using AAC Blocks his report was" Published, 2017. A study demonstrating how AAC blocks contribute to the energy efficiency of buildings by reducing heat transfer.

Author(s): Yewale P.S., Pise A.T. They studied "Sustainability of AAC Blocks in Green Building Design" his report was Published: 2016.This paper evaluates the environmental benefits of AAC blocks, emphasizing their energy efficiency and lower carbon footprint compared to traditional building materials.

Author(s): Karthikeyan K., Saravanan R. They studied "Thermal Insulation Performance of AAC Blocks in Energy-Efficient Buildings" his report was Published 2018. This study examines the thermal insulation properties of AAC blocks, showcasing their effectiveness in reducing energy consumption in buildings, particularly in regions with extreme temperature variations.

Author(s): Rahman M.M., Biswas S., Kumar D. They studied "Water Absorption and Shrinkage Behavior of AAC Blocks" his report was Published: 2016. This research evaluates the water absorption and shrinkage characteristics of AAC blocks, concluding that their porosity leads to higher water absorption compared to concrete blocks, necessitating surface treatments.

Author(s): Kumar S., Jain V. They studied "Influence of Aluminum Powder on AAC Block Properties" his report was Published: 2013. This paper explores the role of aluminum powder in the AAC manufacturing process, emphasizing how its quantity affects the aeration process and the resulting block density, strength, and insulation properties.

Author(s): Liang H., Wang P., Zhao L. They studied "Improving the Durability of AAC Blocks in Humid Conditions" his report was Published: 2019. The study focuses on enhancing the durability of AAC blocks in humid environments through surface treatments.

Author(s): Das A., Banerjee P., Sharma R. They studied "Moisture Resistance of AAC Blocks in Coastal Areas" his report was Published: 2018. This study examines the performance of AAC blocks in coastal areas with high humidity and salt exposure

3. Objectives

The primary objective of this project is to investigate the fabrication process, compressive strength, and durability of Autoclaved Aerated Concrete (AAC) blocks, and to evaluate their potential as a sustainable alternative to conventional building materials. The specific objectives are:

1. To Promote the use of AAC blocks as a sustainable building material.
2. To Determine the Compressive Strength of AAC Blocks.
3. To Conduct experimental studies on AAC block properties

4. Methodology

A. Material

1) Cement

Cement is a fine powder that is used as the binding agent in concrete, mortar, and other construction materials. It is a key component in the construction industry, playing a crucial role in holding structures together. Provides binding properties and Strength. Cement is the primary binding material in AAC blocks. Ordinary Portland Cement (OPC), usually of 43 or 53 grade, is commonly used. It reacts with water and other materials to form a hardened matrix that gives the block its strength. The specific gravity of cement is approximately 3.15, indicating its relatively high density.

2) Sand

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. It's a vital component of many ecosystems and has various industrial applications. Adds Strength, Durability, and Thermal insulation. Sand, particularly fine quartz sand, is used as a silica source. It reacts with lime during the autoclaving process to form calcium silicate hydrates, which are responsible for the block's structural strength. The specific gravity of sand typically ranges from 2.60 to 2.70.

3) Fly Ash

Fly ash is a fine powder produced as a byproduct of coal combustion in power plants. It's a key component in various construction and industrial applications. Enhance Workability, Reduces Cement Content. Fly ash is often used as a partial or full replacement for sand in AAC blocks. It is a byproduct of coal combustion and is highly pozzolanic, meaning it reacts with calcium hydroxide to form additional cementitious compounds. Fly ash improves the workability and insulation properties of AAC blocks. Its specific gravity is generally around 2.10 to 2.30.

4) Aluminum Powder or Paste

Aluminum powder is a fine, granular or powdered form of aluminum metal. It is commonly used in various industrial, commercial, and consumer applications due to its unique properties. Foaming agent, Creates Air bubbles. Aluminum powder or liquid aluminum is used as a foaming agent. When mixed into the slurry, it reacts with the alkaline components (especially lime) and releases hydrogen gas. This gas forms small, evenly distributed bubbles that remain trapped in the mixture, giving the AAC block its characteristic porous and lightweight structure. The specific gravity of aluminum liquid or powder typically ranges from 2.50 to 2.70.

5) Water

Water is a clear, colorless, and odorless liquid substance that is the most abundant compound on Earth. It is a vital component of all living organisms and plays a crucial role in many biological, chemical, and physical processes. Hydrates Cement, facilitates mixing.

6) Lime

Lime is a versatile and widely used building material, known for its binding, whitening, and disinfecting properties. Stabilizes pH, Improves workability. Lime, usually in the form of quicklime (calcium oxide), is essential for the chemical reaction with silica to form the strength-giving compounds during autoclaving. Lime also contributes to the expansion process when reacting with aluminum powder. Its specific gravity ranges between 2.20 and 2.40.

7) Gypsum

Gypsum plays a key role in brick production, primarily as an accelerator and strength enhancer in fly ash-lime-gypsum bricks. Gypsum is added in small quantities to regulate the setting time of the cement. It helps prevent flash setting and improves the finish of the blocks. Gypsum also aids in the formation of stable compounds during curing. Its specific gravity is approximately 2.30.

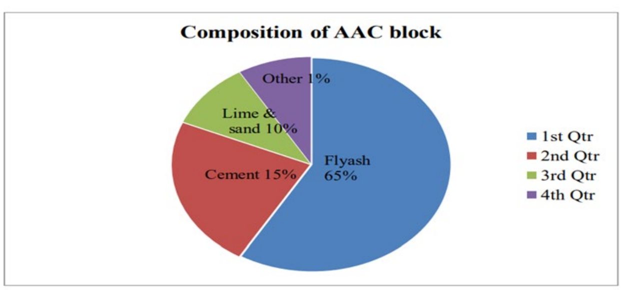

Fig. 1. Manufacturing process of AAC block

The process of making AAC (Autoclaved Aerated Concrete) blocks involves several key steps that transform raw materials into lightweight, durable building blocks. Here's a detailed breakdown of the AAC block-making process.

B. Manufacturing Process of AAC Block

1) Raw Materials Preparation

The primary raw materials used to make AAC blocks are:

- Cement: Portland cement is the primary binder.
- *Lime*: High-calcium lime is used as an essential ingredient.
- *Fly Ash*: Fly ash serves as the primary source of silicon.
- *Water*: Water activates the chemical reaction and helps form the concrete mixture.
- *Aluminum powder*: This acts as a foaming agent.

These ingredients are prepared and stored properly for efficient mixing.

2) Mixing

The ingredients are mixed in a high-efficiency mixer to form a slurry. The process follows these general steps:

- Cement, lime, and Fly Ash are mixed with water to form a thick paste.
- Aluminum powder is added in a controlled amount, which reacts with the lime and water to produce hydrogen gas. This reaction causes the mixture to rise, forming bubbles or air pockets in the mix.
- The aluminum powder reaction creates a foamy structure, which is the key to AAC's lightweight properties.

3) Pouring into Molds

The foam mixture is then poured into molds, usually made of steel or plastic. The molds are typically sized to produce blocks with dimensions such as 600 x 200 x 150 mm (or other customizable sizes).

4) Curing in Molds

After pouring, the mixture is left to cure in the molds for a specific time, typically around 1 to 3 hours, during which the mixture hardens to a semi-solid state.

5) Cutting and Shaping

Once the mixture has set and become sufficiently firm, the large block of AAC material is removed from the molds. This block is still soft enough to be cut using specialized wire cutters or saws. The cutting process includes:

- Cutting the large block into smaller, uniform-sized blocks (for example, 600 x 200 x 150 mm blocks).

6) Shaping

The blocks are shaped with precise dimensions, ensuring uniformity for easy installation.

7) Curing

- The autoclave provides the necessary heat and pressure to complete the chemical reactions, which

Table 1
Typical composition of AAC blocks

Materials	Percentage by volume of block Mix-I	Percentage by volume of block Mix-II	Percentage by volume of block Mix-III
Cement	25%	20%	15%
Fly ash	50%	55%	65%
Lime	10%	10%	10%
Sand	10%	10%	10%
Aluminum Liquid	0.2%	0.2%	0.2%
Gypsum	0.2%	0.2%	0.2%
Water	0.65%	0.65%	0.65%

strengthens the blocks and gives them their lightweight, durable, and insulating properties.

- The curing time typically lasts between 8 to 12 hours, during which the blocks undergo a transformation that significantly improves their structural integrity.

8) Finishing

Once the blocks have cooled down, they are inspected for quality control. This includes checking for:

- Dimensional accuracy
- Strength (measuring compressive strength)
- Surface finish (smooth or rough depending on requirements)
- Any defects such as cracks, air pockets, or inconsistent foaming.

If the blocks pass quality checks, they may be labeled, packed, and stored. If any defects are found, the blocks may be reprocessed or discarded.

5. Results & Discussion

Table 2
Compressive strength of AAC blocks

Mix Proportion	Compressive Strength of Blocks (N/mm^2)		
	3 Days	7 Days	28 Days
I	3.0	4.5	7.8
II	2.9	4.2	7.3
III	2.8	3.9	6.8

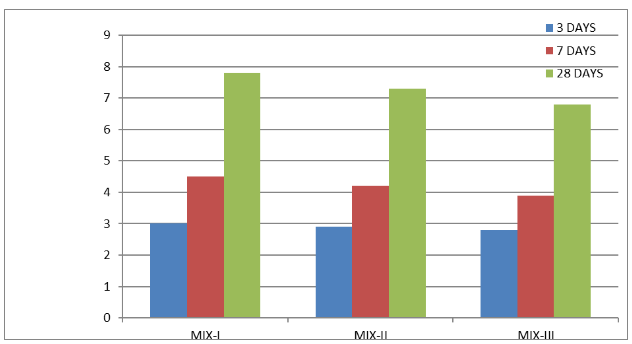

Fig. 2.

The compressive strength of AAC blocks was evaluated for three different mix proportions (labeled I, II, and III) over curing periods of 3, 7, and 28 days. The results are summarized below:

From the data, the following observations can be made:

Initial Strength Development: All mix proportions exhibited early strength gain by day 3. Mix II had slightly higher initial strength than Mix I and Mix III.

7-Day Strength: Mix I continued to gain strength at 7 days, while Mix II showed a slight decline compared to its 3-day strength. Mix III maintained the same value at 3 and 7 days, suggesting a slower rate of strength development.

28-Day Strength: At 28 days, all mixes showed significant improvement in compressive strength. Mix I achieved the highest value (7.8 MPa), followed by Mix II (7.4 MPa) and Mix III (7.1 MPa). This indicates that Mix I had the most favorable combination of raw materials and curing behavior.

The accompanying bar graph reinforces these trends, where Mix I consistently outperforms the others, particularly at the 28-day mark. The gradual increase in strength aligns with the expected hydration and curing process of AAC blocks, which rely on the proper reaction of cementitious materials and autoclaving conditions.

6. Conclusion

The experimental evaluation of compressive strength for three different AAC block mix proportions over curing periods of 3, 7, and 28 days revealed that Mix I consistently outperformed Mix II and Mix III at all stages of testing. While all mixes showed early strength development, Mix I demonstrated the highest strength gain, reaching 7.8 MPa at 28 days, which is notably superior to Mix II (7.4 MPa) and Mix III (7.1 MPa).

The superior performance of Mix I can be attributed to its optimized composition, particularly the balanced ratios of cement (25%), fly ash (50%), lime (10%), and other additives. This mix promotes better hydration and internal microstructure formation, which enhances compressive strength over time.

Based on these findings, Mix I is recommended for further use in AAC block production, especially for applications where higher structural strength is essential. Its performance also reinforces the potential of AAC blocks as a sustainable, energy-efficient alternative to traditional bricks in modern construction.

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