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Autoclaved Aerated Concrete (AAC): Material Properties, Architectural Applications and Sustainability Considerations

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ABSTRACT

Autoclaved Aerated Concrete (AAC) which is a light weight, precast and porous material is very much into sustainable construction. In this paper we review its make-up, production, characteristics and also the different forms it takes which includes walls, facades, roofs and interior partitions. Main benefits of the material are its thermal and acoustic insulating quality, low density and that it uses recycled materials which in turn reduces its environmental impact. Also, we discuss its use in architecture, what its limitations are and also into what direction research is headed, structural optimization, durability and modular construction. AAC is a flexible and eco-friendly option to traditional masonry which presents itself as a solution for efficient, sustainable and innovative modern building design.

1.INTRODUCTION

Autoclaved Aerated Concrete (AAC) is a precast, lightweight material used in walls, roofs, and facades. It is a porous concrete created through a distinctive chemical reaction between a silica-rich source, such as sand or fly ash, and a lime or cement binder. The mixture does not include coarse aggregates which are cured under high temperature and pressure inside an autoclave. This process gives the material's strength, durability and stability. The low-density property cuts down on the building dead loads and speeds up construction. Besides these properties, its great thermal insulation and fire resistance add its values to sustainability and energy-efficient architecture. Today, the AAC product is popularly known as an eco-friendly choice compared to traditional clay bricks and concrete blocks in both residential and commercial projects. This research paper looks at the architectural uses of AAC, including its application in structural components, facades, and envelopes, as well as its sustainability aspects related to carbon footprint, embodied energy, and life-cycle performance.

2.BACKGROUND STUDY

2.1 AAC DEFINITION AND CLASSIFICATION

Autoclaved Aerated Concrete (AAC) is a lightweight, precast foam concrete formed by mixing the following materials in certain proportions: cement, lime, fine aggregates, water, and an expansion agent that forms air bubbles.

It is categorized into four types based on the composition:

- sand-based • fly ash-based • recycled (AAC-R) • fiber-reinforced.

These classifications assist in analyzing AAC's performance, strength, durability, sustainability, and suitability for architectural applications.

2.2 AAC PRODUCTION AND RAW MATERIALS COMPOSITION

AAC is produced using readily available materials like lime, aluminium, port-land cement, anhydride and fine sand. The typical mixing proportions are 17.17% lime, 17.87% cement, 0.09% aluminium, 2.35% anhydrite, and 62.52% fine sand by weight. In experimental tests, fine sand was subtly replaced with recycled AAC (AAC-R) in proportions varying from 0% to 50%, while the other components were fixed constant. The materials were mixed with expansion agents like water and aluminium powder, then poured into molds (20 × 20 × 100 cm) which kept for about 5 minutes. The aluminium reacts with silica to form hydrogen bubbles. After the material settled, it was cut into blocks and cured in an autoclave at 12 bar pressure and 180–190°C for 8 hours, producing lightweight, high-strength AAC blocks.

2.3 RECYCLING AAC

Several researches have been made on the concept of replacing silica-based materials in AAC with industrial wastes to build up its sustainable values. The expanded perlite waste reduces the thermal conductivity but holds up the strength only up to 10% replacement while iron tailings and desulfurization slag weakened compressive strength beyond 15%. By doing the incineration process the bottom ash improves the pore consistency and overall strength compared to conventional AAC, and by using glass waste it attains the same strength. In addition, the replacement of sand and lime with sugar sediment reduced weight and improved compressive strength, generating blocks suitable for construction without added insulation.

2.4 MECHANICAL AND PHYSICAL PROPERTIES

The performance of AAC blocks depends firmly on its microstructure which determines its strength, durability and porosity properties.

DENSITY: Has a typical density of 400-800kg/m³ which is considered significantly lower than the conventional concrete there by reducing the dead loads on the structures.

COMPRESSIVE STRENGTH: Ranges between 2-3 Mpa, adequate for non-load bearing walls and low-rise load bearing applications. **THERMAL CONDUCTIVITY:** AAC provides excellent thermal insulation, has coefficients between 0.11 - 0.19 W/ mk, helps in reducing the energy demand for passive cooling and heating techniques.

SOUND INSULATION: The porous structure enhances the acoustics feature of the material by making it suitable for applications in facade and partition walls.

2.5 ENVIRONMENTAL AND ENERGY CONSIDERATIONS

The manufacturing of AAC blocks uses low value raw material and energy than conventional concrete blocks and clay bricks. Although autoclaving absorbs heat energy, the lightweight composition and reduced operational energy offset this. By using fly ash and recycled AAC it further decreases its carbon footprint. LCA reports show AAC has 30–40% lesser embodied carbon than typical masonry, and its recyclability and low waste make it favorable under IGBC and LEED green building systems.

3. ARCHITECTURAL APPLICATIONS OF AAC

3.1 STRUCTURAL AND SEMI STRUCTURAL USE

AAC blocks are applied in both load bearing and non-load bearing walls, offering reduced weight and improved thermal insulation. In modular housing AAC is employed in partition walls, providing adequate amount of space division along with improved acoustic properties. The panels are incorporated with reinforced concrete frames to utilize the structural performance and thermal efficiency. Additionally, AAC also assist as infill material between beams and columns structural, which contributes to the whole structure stability and improved thermal insulation.

3.2 BUILDING ENVELOPE APPLICATIONS

In building envelope, the AAC panels are increasingly applied in facade systems, providing lightweight and durable solutions for building exteriors. When used as external cladding, the panels optimally enhance the aesthetic features and thermal insulation of the entire building. Proper surface finishes and joint detailing are critical in preventing moisture ingress and maintaining the performance of AAC facades. Further-more by supporting thermal reduction in building envelope, the AAC contributes significantly in improving the energy efficiency of the building by supporting passive cooling or heating strategies in sustainable architecture.

3.3 ROOFS AND FLOOR SLABS

AAC blocks are incorporated into composite slab systems, integrating the benefits of AAC with other materials such as reinforced concrete for enhanced structural and thermal performance. AAC roof panels provide a lightweight alternative option to the conventional roofing systems, reducing the building's structural loads while enhancing efficient thermal insulation.

3.4 INTERIOR AND FUNCTIONAL SYSTEMS

Within interior spaces, AAC blocks are used extensively in interior partition walls, acoustics walls, ceilings, and fire-resistant barriers. Its unique sound absorption and fire-resistant properties make it ideal for both residential and commercial buildings. The materials also enable us for flexible architectural detailing, offering a variety of textures, finishes, and color treatment that improves the aesthetic appeal of the structure. Moreover, the AAC blocks have enhanced compatibility with modular and prefabricated construction systems which facilitates faster assembly and better precision in architectural execution.

4. SUSTAINABILITY AND ENVIRONMENTAL ASPECTS

Recent research proves that the AAC blocks provide a notable environmental sustainability feature through lower impacts on the surroundings compared to conventional port-land concrete masonry. AAC manufacturing uses recycled industrial products reducing raw material consumption and embodied energy. Life cycle assessment data indicate reduction in CO₂ emissions and use typical energy use of 30 – 60 % compared to ordinary concrete or clay brick units. It is largely because of its low material density property which substitutes for high carbon materials and also the operational phase is more efficient. Recycling AAC waste is particularly closed loop-based system which further improves the environmental performance, reducing greenhouse gas emissions and the burden on the resources. However, some environmental impacts remain tied to specific inputs, like the energy for autoclaving, transport of raw materials, and alkaline activators used in certain AAC mixtures. Effective strategies to maximize sustainability including optimize mix design, using more recycled contents, reducing transport distances, and improving the embodied energy of the material.

5. LIMITATIONS

Autoclaved Aerated Concrete (AAC) has outgrown some of what could make it a more popular choice in the construction industry. We see large scale that it is lower in compressive strength which is a issue as we compare it to dense or reinforced concrete. That shortcoming rules it out for use in heavy load bearing or high-rise structures. Also, the high price tag of the special manufacturing equipment such as autoclaves and precise mixers which we see is a issue. Which in turn plays out most in areas that do not have developed production facilities. Also, we have the issue of its low resistance to moisture and poor durability. AAC has a very porous structure which in turn causes it to absorb water easily. This in turn causes issues like efflorescence, surface cracking and in the long term will cause damage if not properly sealed or maintained. Also, it's brittle which makes handling and installation a challenge. Secondly, there is no quality control and standard when AAC is produced. Variability in raw materials and curing practice usually leads to inconsistent performance for products from different manufacturers. Finally, regardless of how much potential recycling of AAC wastes has, extensive reuse is still restricted. This is because the energy-intensive process of crushing and grinding and the probable loss of mechanical strength for recycled blends hinder it.

6. FUTURE SCOPE

Future in research of Autoclaved Aerated Concrete (AAC) we see improvement of its structural and environmental performance. We are to put forward strength through fiber reinforcement, hybrid composites, and optimized pore structures which in turn will open up wider load bearing applications. We are into sustainable mix designs which include recycled AAC, fly ash, and industrial by-products. Also very important are long term durability studies under real environmental elements like moisture, freeze-thaw, and salt exposure. We put forward to see to it that standardization, quality control and energy efficient autoclaving processes which play a key role in reducing embodied carbon. Also, we are to report on better surface finish, water proofing and fastener systems for humid climates. Also, we are look at AAC's role in prefabricated and modular construction which will in turn achieve faster, more sustainable and cost-effective building solutions without compromising quality and structural reliability.

7. CONCLUSION

Autoclaved Aerated Concrete (AAC) which is a light weight, sustainable and very flexible building material has great use in present day construction. It has low density, is a good thermal insulator, fire resistant and has good acoustic properties which makes it appropriate for use in walls, facades, roofs and interior partitions. In terms of production AAC benefits from the use of industrial by products and recycled materials which in turn reduces embodied energy and carbon footprint. Although it has issues of lower compressive strength, moisture sensitivity and high initial cost we are seeing research into fiber reinforcement, hybrid systems, optimized mix design and prefinished construction which is expanding its uses. With improved durability, standardization and energy efficient production methods AAC is to play a key role in sustainable architecture. As a whole AAC is a very promising material for eco-friendly, energy efficient and innovative building solutions.

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