CSVTU Research Journal

Vol. 10(2), 92-101, 2021 ISSN: 0974-8725

Review Article

A Review on Usage of Autoclaved Aerated Concrete (AAC) Blocks in Masonry in Central Region of Chhattisgarh

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Received October, 2021; received in revised form December 08, 1, 2021; Accepted December 12, 2021, Published 2021

Abstract

Environmental crisis due to air pollution & soil degradation have been a worrisome domain from ages due to usage of few traditional materials such as red brick in construction industry. As per projection by global status report 2016, building constructions will grow by 50% in 2050. Therefore, we need to cater demand of new construction without harming the environment. In response to these challenges such as scarcity of resources, air pollution, dependability on fertile soil, etc.; Autoclaved Aerated Concrete (AAC) blocks have gained widespread use in many areas including Europe, South America, the Middle East, and the Far East. But its major disadvantage is its crack formation in masonry. This review article focusses on use of AAC block in place of traditional bricks and to minimize its major disadvantage of crack formation on masonry. for the best optimum use of this novel material by seeking best possible techniques for application in masonry such as by taking care of few points such as proper curing, keeping drying shrinkage to optimum level & spread awareness about these blocks to bring it in main stream as an alternative to conventional building material in Chhattisgarh.

Keywords: AAC Block, Masonry, Energy Efficiency, Sustainability, Insulation, Cost Effective.

1. Introduction

Clay, sand, lime, iron oxide, and magnesia are in usage to create red brick [1]. Sand from natural soil is generally used for these tasks. Because a vast amount of rich soil is needed for its production, big-scale soil mining can cause alteration in land use patterns along with various negative environmental consequences. A huge amount of coal is needed to dry the bricks in the kiln, which causes tremendous pollution in the air and harms people's health. In order to safeguard the environment, the government outlawed earth mining for brick manufacturing across the country on June 24, 2013 (2), necessitating the development of new innovative construction materials to complement the conventional red clay brick. Fly ash bricks have a number of drawbacks, including low compressive strength, size restrictions, and a higher rate of breakage [2]. Because of the high heat conductivity, a new material is required. Autoclaved aerated concrete (AAC) block, with its many benefits and properties, is a modern and innovative material for modern building [1,2].

Autoclaved aerated concrete blocks (AAC) were created by Dr. Johan Axel Eriksson in 1923 [20]. In the United Kingdom, it contributes for more than 40% of all building, while in Germany, it accounts for 60%. AAC Block (Autoclaved Aerated Concrete) is a green building material that is lightweight and certified for use in commercial, industrial, and residential construction. In India, there is a significant demand for these blocks [2].

Table 1 Comparison of properties of ACC block red clay brick and fly ash brick [2]

Properties	**AAC block**	**Red clay brick**	**Fly ash brick**
Dry density (kg/m^3)	1610-1900	1610-1900	1710-1830
Compressive strength (N/mm2)	2-6	3.5-35	4-7
Water absorption (should not be more than % of its own weight)	20	10	15-20
Thermal conductivity (w/m k)	0.2-0.4	0.5-1	0.2-0.42
Sound insulation (db)	40-45	45	37-39
Mortar consumption	• Smooth Surface • Fewer joints • Require of less mortar	• More joints • Requirement of more mortar	• Irregular Surface • More joints • Requirement of more mortar

In the last five years, demand for these blocks has increased tenfold, and they are being hailed as the most environmentally friendly and innovative building material of the century. The objective of this paper is to find the suitability of AAC block usage in Chhattisgarh along with environmental as well as socioeconomic factor affecting its usage.

1.1 Constitute Materials

Cement, Fly Ash, Sand, Lime Powder Gypsum, Aluminium Powder/Paste, and Mixing Water are in use as raw materials for bricks production. Following section elaborate the individual elements:

Cement: It is a substance with adhesive and cohesive qualities that allows it to bind material fragments together into a compact mass. Concrete's most important component is cement. Due to differences in compound composition and fineness, different brands of cement have been shown to exhibit variable strength development characteristics and rheological behaviour. Ordinary Portland cement (Chettinad) of grade 53 according to IS 12269-1987 is utilised in various previous researches [1].

Fly Ash or Sand: AAC blocks are made with silica-rich materials like fly ash or sand as a key element. Fly ash is used in the production of AAC blocks by the majority of AAC firms in India. Fly ash slurry is made by mixing fly ash with water [1]. The resulting slurry is combined with additional components like as lime powder, cement, gypsum, and aluminium powder in the amounts specified in the formula. Sand, on the other hand, may be used to make AAC blocks. A 'wet' ball mill finely grinds sand in the presence of water, resulting in sand slurry. Sand slurry, like fly ash slurry, is blended with other substances.

Lime Powder: Lime powder is obtained for AAC manufacture by either crushing limestone to a fine powder at the AAC facility or acquiring it in powder form directly [2].

Despite the fact that acquiring lime powder is more expensive than investing in lime crushing equipment such as a ball mill, jaw crusher, or bucket elevators, many enterprises prefer to do so. Lime powder is stored in silos made of mild steel (MS) or brick and mortar, depending on the preferences of the person.

Gypsum: Gypsum is a common building material that comes in powder form and it is kept in silos [1].

Aluminium Powder/Paste: Various producers produce aluminium powder/paste, which is readily available. Because only a little amount of Aluminium powder/paste is required, it is normally weighed manually and put to the mixing machine [1].

Mixing Water: In SCC mixtures, only water that meets the standards should be utilised [1]. Where recycled water is utilised, it must meet the specifications and be collected from concrete manufacturing operations.

Fig. 2 Composition of AAC Blocks

2. Literature Review

Wahane (2017) [1] studied manufacturing process of AAC and concluded that Because of the AAC blocks' modest weight, they are more stable in the framework of structures. Buildings made using AAC blocks are more reliable and safer since the impact of an earthquake is directly proportionate to the weight of the building. Cutting and placing is easier, and as it is made up of non-biodegradable material, they did not attract mould.

Gautam and saxena (2013) [2] compared traditional red clay brick with AAC block and concluded that AAC cost per cubic meter is2950 Rs whereas red brick cost 2620 Rs, being costlier initially AAC have various higher edges as compare to traditional brick such as eco-friendly, light weight heat resistance also reduces overall construction cost of building.

Kumar and satischandra (2017) [3] monitored *e*nvironmental conditions of AAC blocks usage of high-rise buildings at Tadepalli, Andhra Pradesh and found that CO_2 emission is less as compare to traditional bricks.

Rathi et al. (2015) [4] explored comparative cost analysis using AAC block in which it was found that density of AAC blocks as 1/3 that of traditional clay brick. As the built-up area increases, saving in cost of steel is about 17.9%.the savings in cost of materials such as sand, aggregate and cement for different types of buildings is 41.7%.the overall saving in cost of construction for different types of buildings is 20.99%.

Saiyed et al. [5] examined AAC block properties and concluded that aerated autoclaved concrete (AAC) blocks is novel material for construction industry and found AAC block is lightweight, fire resistant, recyclable and eco-friendly material and saves time of construction.

Dixit and Borsaikia (2019) [6], studied bond strength of Autoclaved Aerated Concrete (AAC) masonry using various joint materials for good bond strength and observed that it could be achieved using a combination of cement slurry coating with ordinary mortar of lean cement content.

Chakravarthy (2019) [7], made comparative analysis of AAC blocks and red clay brick considering parameters such as size of block, time of execution and cost and concluded that it saves 20% construction time and labour and overall cost is reduced in high rise building made up of AAC in comparison to red clay.

Netula et al.(2017) [8], employed ETABS to investigate and compare structures with various infill materials (bricks, AAC blocks, and hollow concrete blocks). When compared to brick masonry, the bending moment and shear stresses in beam members of AAC block masonry and hollow concrete masonry structures are found to be smaller, and proposed that in seismically prone areas in India, AAC blocks and hollow concrete masonry can be utilised to replace traditional brick masonry.

Ahmed et al.(2014) [9] explored on the compressive strength of foamed concrete that can be developed to reach structural strength compared to autoclaved concrete and reported that aerated light weighted concrete can be considered as economic materials and consumptions of by-products and waste material such as fly ash.

Habib et al.(2015) [10] suggested that to meet the housing shortage of the country necessary steps should be taken to introduce new and better alternative building material.

Moon and Vaissonvarshese (2015) [11] studied about how foam concrete can be used for sustainable construction as a building material, their studies shows that better mechanical and physical properties of concrete can be obtained with the replacement of send with quarry dust in mix. Thus, they found that foam concrete is a sustainable building construction material as sand can be replaced with quarry dust up to 100%.

Bose and Rai (2014) [12], studied the behaviour of AAC in filled RC frame under lateral loading using fema p695 methodology and found the average values of compressive strength and elastic modulus of AAC masonry was observed to be approximately one-third and one-half of collapse probability conventional masonry, respectively and probability of collapse of conventional masonry in filled of almost 3 times the AAC infill.

Schnitzler (2006) [13] studied AAC block properties and *c*oncluded that due to very low usage of raw material, high durability, cost effectiveness, energy efficiency and ability to recycled AAC deserve “green” designation

Hooman et al. (2017)[14], compared AAC block and hollow block concluded that the strength of AAC block is higher than hollow block and is light in weight and it can be used in insulation purpose. . These blocks are used to make prefabricated constructions since they are light and easy to cut, drill, and saw.

Kamal (2020)[15] focus the cost effectiveness of AAC block and concluded that, the production price of AAC blocks at the manufacturing unit is from Rs. 3200/- to Rs. 3600/ per cubic meter as per the rates in India in the year 2019.it is used in various countries like Europe, America, Australia Gulf countries because of its advantages and cost effectiveness and termed it as green material.

Helonde[16] compared AAC block and traditional brick, and found that the AAC block density is 1/3 of traditional brick, 80 percent less in weight and up to 20 percent reduction in construction cost

Vengala et al.(2019)[17] observed that when the blocks were heated to 1500°C and then immediately immersed in water to cool to room temperature, their compressive strength was dramatically diminished. A strength drops of over 35% was recorded. As a result, it is not suggested to spray water directly on the AAC Block surfaces during a fire. In the event of a 1:6 lean cement mortar mix, a joint mortar thickness of 2mm is not suggested. When using a 1:6 proportion as a mortar joint, a minimum of 4 mm thick CM is recommended.

Boggelen [18] examined AAC block structure concluded Architects, contractors, and builders now have additional options for creating distinctive and imaginatively designed structures because to advancements in AAC design, production, and application technology. The use of AAC blocks and prefabricated panels and parts can significantly reduce the overall construction time. AAC's position in the building materials industry is strengthened by advances that cut manufacturing costs. AAC has an edge over other similar construction materials in terms of accuracy and smooth finish, which is highly desired in the Benelux, Japan, and Scandinavian nations. And It is strongly advised that the AAC industry continue to work toward harmonisation and standardisation, as well as cooperating as a whole to grow the AAC market.

Kubica and galman (2017) [19] reported findings of experimental tests and analysis of the behaviour of tiny walls composed of AAC blocks with thin joints and unfilled head joints subjected to diagonal compression are presented in their work. The study's goal was to see how successful two different methods of superficial strengthening with CRFP mats were. In comparison to the unstrengthen wall, superficial strengthening applied on the head joints (IIC series) gave a 45 percent increase in crack resistance; no increase in crack resistance was detected in IIIC series walls. It suggests that placing CFRP strips over the empty head joints, as was done in the IIC series, is a better manner of superficial strengthening. And allowed for larger deformation of masonry wall at failure.

Rathod et al. (2017) [20], studied the factors affecting the usage of AAC block in central Gujarat region and found that it is environment friendly and energy efficient material and one of best replacement of traditional bricks..

Mishra and aithal (2021)[21] studied Socio-Economic Suitability of AAC Block in Nepal and concluded that as compared to traditional brick work less mortar is required ,saves time 4 times, number of joints were reduced by 14-17 times. and approx 18 percent economical than normal bricks. However, engineers and construction contractors were unaware of the use of AAC as an alternative construction material, so understanding of AAC as a construction material was limited. AAC was discovered to be used by clients who needed a light-weight construction material, and the trend is continuing. In addition, the number of residential buildings is expanding. However, the usage of AAC still has a low social acceptance rate. Interest from the client and a lack of technical knowledge. The acceptance of AAC is hampered by these problems.

Singh et al. (2021) [22] reported the fly ash based (AAC) blocks are a useful resource for the building sector that is made from waste from coal-fired thermal power plants. These fly ash-based (AAC) blocks have an average compressive strength of 4.18 N/mm2. The results show that even larger compressive loads might have been used to confirm the compressive strength, allowing for the usage of fly ash-based AAC blocks in high-rise structures or bridges with significantly increased loads. In comparison to clay bricks, fly ash based (AAC) blocks offer greater civil engineering qualities and are also more cost effective. The usage of AAC blocks in the construction of building materials can give appropriate methods for managing this potentially valuable resource for long-term development while avoiding negative environmental consequences. More advancements are required to produce fly ash bricks with more acceptable physicochemical qualities that are useful in the construction sector.

Vikas and pajgade (2013) [23] The impact of masonry infill on the seismic response of multi-story buildings under seismic loading is demonstrated in this study using real-world examples. The base shear experienced by models using AAC blocks was much lower than that experienced by models using ordinary clay bricks, resulting in lower member forces and As a result, employing AAC blocks instead of traditional clay bricks can save money on building. In an RC frame, the performance of AAC block infill outperformed that of conventional brick infill.

Sahu (2018)[24] studied about supplementary cementitious material from recycled CLC and AAC block dust and concluded that CLC (Cellular Light Weight blocks Concrete)and AAC block dust have specific gravity of 2.18 and 2.10, respectively, which is excessively low when compared to the specific gravity of regular Portland cement (which is found to be 3.15). CLC and AAC block dust have a consistency of 45 and 53, respectively, which is higher than standard Portland cement. The 28-day compressive strength of a mortar cube shows that replacing 20% of the OPC with CLC block dust and 15% of the OPC with AAC block dust can be done without a significant loss of compressive strength (within 10%). CLC block dust replacement can even boost compressive strength to a certain extent. This is owing to the presence of greater calcite in CLC replacement mortar specimens, as determined by XRD examination. As a result, it can be inferred that recovered CLC and AAC block dust may be used to create environmentally friendly binder materials.

Dewi et al. *(2017) [25]* Used bamboo and AAC block to reduce the weight of precast concrete beam and concluded that the flexural strength and density have not been affected significantly by the concrete quality. The density and flexural strength of lightweight bricks are both affected by their height. There was a substantial relationship between the type of fracture and the beam's final flexural stresses. Beam strength varies greatly owing to variances in bamboo reinforcement slip failure. More study is needed to improve the bond strength between bamboo and concrete.

Tianxiang Pi et al. (2021) [26] conducted experimental and analytical research on core-column non-mortar aerated concrete block masonry was reported which described at the construction methods and mechanical characteristics. The study was divided into four sections: (a) masonry construction technique; (b) masonry compressive strength, deformation performance, and compression mechanism; (c) masonry shear strength and shear mechanism; (d) numerical simulation analysis of compression and shear specimens

Li, F., Chen et al. (2021) [27] explored Fundamental Properties and Thermal Transferability of Masonry Built by Autoclaved Aerated Concrete Self-Insulation Blocks With a compressive strength of 4.0 MPa and a dry density of 558 kg/m3, the best products of the AAC self-insulation block were created. The thermal conductivity of the AAC self-insulation block was 0.11 W/(mK). This is less than the 0.16 W/(mK) limit of a standard AAC block of comparable strength and density. They are self-insulating and high heat resistance.

Dimkovic [28] reported that by putting the Improved ISO AAC coder through its paces with crucial worst-case signals, we were able to demonstrate a considerable speed boost while maintaining ISO 13818-7-bit stream compatibility. Higher coding performance with reduced NMR was rewarded with each advancement in coding tools. AAC has shown to be a cutting-edge audio codec capable of delivering "transparent" CD quality at low data rates while maintaining decent quality at high compression ratios. When compared to other MPEG codecs, AAC offers the most versatility.

Rathore et al. (2018) [29] reviewed various studies with a focus on AAC block buildings sitting on plain ground with plan irregularity or conducting static and dynamic stress tests on AAC blocks. To put it another way, structural researchers are mostly concerned with the local compression effect, physical properties, structures on plain ground, economic studies, thermal comfort, and blocks with openings, but only a few are concerned with the effect of seismic loading on fully filled AAC blocks and Brick infill buildings, as well as buildings with soft storey at different floors.

Penna et al. (2012) [30] studied use of flat-truss bed-joint reinforcement to improve the seismic performance of AAC masonry. Their research provides the findings of an experimental campaign that included in-plane cycle testing on autoclaved aerated concrete (AAC) masonry panels with glue-mortar-filled narrow bed- and head-joints. Some of the specimens are constructed of unreinforced masonry, while others have masonry walls that are merely reinforced by bed-joint flat-truss reinforcement. A probable strength criterion is provided based on the results of testing, which are supplemented by particular tests done on Wallette's constructed using the two alternative building processes. The findings show that adding bed-joint reinforcement improves masonry resistance while also increasing displacement capacity, decreasing damage.

2.1 Advantages

- Fire Resistant: The Autoclaved Aerated Concrete (AAC) Blocks have a fire resistance of 2 to 6 hours, depending on their thickness. These blocks are ideal for environments where fire safety is a top priority.

- Autoclaved Aerated Concrete (AAC) Blocks are made up of inorganic materials that aid in the prevention of termites, damages, and losses.

- The AAC blocks' porous nature allows for better sound absorption. The AAC's Sound Transmission Class (STC) rating blocks up to 45 decibels. As a result, AAC blocks have shown to be the most suitable material for the building of walls in auditoriums, hotels, hospitals, studios, and other similar structures.

- Because of the AAC blocks' small weight, they are more stable in the framework of structures. Buildings constructed using AAC blocks are more dependable and safer since the impact of an earthquake is exactly proportionate to the weight of the structure.

- Because the AAC block is so simple to handle, move, and cut, standard wood-cutting equipment like drills, band saws, and so on may be used to cut and align the AAC. Furthermore, the AAC blocks are bigger and have fewer joints. As a consequence, building work is completed more quickly.

- In terms of strength, AAC blocks are far superior. The structural integrity of the building is enhanced by the increased strength of these blocks. AAC is made of non-biodegradable elements that do not decay or attract mould, ensuring that interiors remain clean and long-lasting.

- When compared to traditional red brick, AAC blocks weigh about 80% less, resulting in a significant reduction in deadweight. Furthermore, because of the lower deadweight, less cement and steel are used, resulting in significant cost savings.

- AAC Blocks have a pleasing look and may be easily adapted to any architectural style. AAC may be used to create almost any design.

- There are no hazardous gas substances in autoclaved aerated concrete products. The product does not attract or harbour pests.

- Because moisture may harm buildings from both external and interior sources, moisture prevention is a top priority. Rain and groundwater are examples of external moisture sources. Internal moisture, generally in the form of humidity, can create condensation on the wall's surface as well as inside the wall. The porous nature of AAC makes it suitable for use in a variety of applications. AAC is characterised by "macro" pores and has a porous structure. Small air bubbles uniformly dispersed throughout the material are known as macro pores. As a result, water absorption into the AAC material is low.

- AAC is a non-toxic material that does not harm the environment, including the air, land, and water. Waste from the cutting process is recycled with raw materials and used again throughout the manufacturing process. There is almost no trash created during construction. When compared to the creation of other materials, the energy used in the manufacturing process is minimal. There are no pollutants produced throughout the production process, and there are no by-products or harmful waste products. Natural raw resources are used to make AAC. The final product is three times the volume of the raw materials utilised, resulting in a very resource-efficient and ecologically beneficial product.

- One of the most appealing aspects of AAC blocks is their low weight. The cellular structure of these blocks was formed during the manufacturing process. AAC blocks have an extremely low weight construction because to millions of tiny air cells. These lightweight blocks have a density of between 540 and 640 kg/m3, making them lighter than water.

Fig. 2 Advantages of AAC Blocks

2.2 Disadvantages

- Installation during rainy weather: AAC is known to crack after installation.
- AAC blocks are non-loadbearing material; thus, it may be used solely for partition walls.
- Because AAC blocks are fragile, they demand more care while handling and shipping than clay bricks.
- Despite the high per-unit cost of an AAC block, the overall cost of masonry is inexpensive since it requires less mortar for installation.
- Because of its delicate nature, long thin screws, as well as the use of a drill bit or hammering, are required for wall hangings and cabinets. A large diameter wall plug, which is more expensive than a standard plug, will be required. Because AAC blocks might fracture, we can't hammer them for chiseling

services. Although a carpenter's saw may be used to cut the wood, it is time-consuming and needs specialized labour.

2.3. Review Perspective

These studies shows that yet there is necessity to conduct further studies to have clear notion that can cracks be avoided completely while using ACC blocks in Chhattisgarh & Environmental factor affecting its usage. To promote the use of AAC blocks in Central region of Chhattisgarh with best suitable techniques to reduce its crack disadvantages, so that it replaces red bricks completely in upcoming future. The studies should focus on

i. To study suitability of AAC Blocks in Central part of Chhattisgarh state.
ii. To study the techniques and methods to avoid cracks in AAC blocks masonry.
iii. To find the socio-economic factors affecting its usage in Chhattisgarh state

Conclusion

AAC Block is a cutting-edge technology with several benefits for addressing the building industry's environmental issue. ACC blocks have the potential to become a complete replacement for typical red clay bricks, according to a study. Despite their greater initial cost, these blocks cut overall building costs significantly. To overcome a few drawbacks, such as the formation of cracks, which are commonly visible in finished or under construction projects, and to make it an unique material in future building in the state of Chhattisgarh, certain technological intervention and steps are necessary.

Conflict of interest

The author declares no conflict of interest.

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