Autoclaved Aerated Concrete (AAC): A Sustainable Building Material

Dr. Mohammad Arif Kamal
Associate Professor, Architecture Section
Aligarh Muslim University, Aligarh

Introduction

Autoclaved aerated concrete (AAC) is a derivative of fly ash that is combined with cement, lime and water and an aerating agent. AAC is produced as blocks and panels. Autoclaved aerated concrete, is concrete that has been manufactured to contain lots of closed air pockets. Lightweight and fairly energy efficient, it is produced by adding a foaming agent to concrete in a mould, then wire-cutting blocks or panels from the resulting ‘cake’ and ‘cooking’ them with steam (autoclaving). It is an approved eco-friendly building material that comes from industrial waste and is made from non-toxic ingredients. With AAC, the construction process can be about 20 per cent faster. It weighs only about 50 per cent of a standard concrete block and possesses high thermal insulation and is acoustics-friendly. It also has better fire resistance than fly ash and is non-combustible.

AAC was perfected in 1924 by the Swedish architect and inventor Dr. Johan Axel Eriksson, working with Professor Henrik Kreüger at the Royal Institute of Technology [1]. Dr. Johan Axel Eriksson was looking for an alternate building material with properties similar to that of wood – good thermal insulation, solid structure and easy to work with – but without the disadvantage of combustibility, decay and termite damage. AAC is a highly thermally insulating concrete-based material used for both internal and external construction. Besides AAC’s insulating capability, one of its advantages in construction is its quick and easy installation, because the material can be routed, sanded, or cut to size on site using standard carbon steel power tools. AAC is well suited for urban areas with high rise buildings and those with high temperature variations. Due to its lower density, high rise buildings constructed using AAC require less steel and concrete for structural members. The requirement of mortar for laying of AAC blocks is reduced due to the lower number of joints. Similarly, the material required for rendering is also lower due to the dimensional accuracy of AAC. Even though regular cement mortar can be used, most of the buildings erected with AAC materials use thin bed mortar in thicknesses around 1/8 inch, depending on the national building codes. AAC materials can be coated with a stucco or plaster compound to guard against the elements, or covered with siding materials such as brick or vinyl.

Performance Summary of Autoclaved Aerated Concrete

Appearance: Autoclaved aerated concrete is light coloured. It contains many small voids (similar to those in aerated chocolate bars) that can be clearly seen when looked at closely. The gas used to ‘foam’ the concrete during manufacture is hydrogen formed from the reaction of aluminium paste with alkaline elements in the cement. These air pockets contribute to the material’s insulating properties. Unlike masonry, there is no direct path for water to pass through the material; however, it can wick up moisture and an appropriate coating is required to prevent water penetration.

Structural capability: The compressive strength of AAC is very good. Although it is one-fifth the density of normal concrete it still has half the bearing strength, and loadbearing structures up to three storeys high can be safely erected with AAC blockwork. The AAC is 3-4 times lighter than traditional bricks, therefore, easier and cheaper to transport. Usage reduces overall dead load of a building, thereby allowing construction of taller buildings. Entire building structures can be made in AAC from walls to floors and roofing with reinforced lintels, blocks and floor, wall and roofing panels available from the manufacturer. AAC floor panels can be used to make non-loadbearing concrete floors that can be installed by carpenters. Lightweight blocks reduce mass of a structure, thus decreasing the impact of an earthquake on a building.
Thermal mass: The thermal mass performance of AAC is dependent on the climate in which it is used. With its mixture of concrete and air pockets, AAC has a moderate overall level of thermal mass performance. Its use for internal walls and flooring can provide significant thermal mass. The temperature moderating thermal mass is most useful in climates with high cooling needs.

Insulation: AAC has very good thermal insulation qualities relative to other masonry. A 200mm thick AAC wall gives an R-value rating of 1.43 with 5% moisture content by weight. With a 2–3mm texture coating and 10mm plasterboard internal lining it achieves an R rating of 1.75 (a cavity brick wall achieves 0.82). A texture-coated 100mm AAC veneer on a lightweight 70mm or 90mm frame filled with bulk insulation achieves a higher R rating than an otherwise equivalent brick veneer wall (see Insulation; Lightweight framing). Relative to their thickness, AAC panels provide less insulation than AAC blockwork, e.g. a 100mm blockwork AAC wall has a dry state R-value of 0.86 and a 100mm AAC wall panel has a dry state R-value of 0.68.

Sound insulation: With its closed air pockets, AAC can provide very good sound insulation. It has superior sound absorption qualities due to porous structure of blocks. Combining the

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AAC Block</th>
<th>Clay Brick</th>
<th>CLC Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size</td>
<td>600mm x 200mm x 100-300mm</td>
<td>230mm x 115mm x 75mm</td>
<td>600mm x 200mm x 100-300mm</td>
</tr>
<tr>
<td>Precision in Size</td>
<td>Variation 1.5 mm (+/-)</td>
<td>Variation 5 mm (+/-)</td>
<td>Variation 3mm (+/-)</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>30 - 40 Kg / Cm²</td>
<td>25 -30 Kg / Cm²</td>
<td>20-25 kg / Cm²</td>
</tr>
<tr>
<td>Dry Density</td>
<td>551-650 kg /M3 (Over Dry)</td>
<td>1950 kg /M3</td>
<td>800 – 1000 kg / M3 (oven Dry)</td>
</tr>
<tr>
<td>Wet Density</td>
<td>Approx. 800 - 850 Kg.</td>
<td>Approx. 2400 Kg.</td>
<td>Approx. 1200 – 1500 Kg.</td>
</tr>
<tr>
<td>Wastage</td>
<td>Upto 5%</td>
<td>Upto 20%</td>
<td>Upto 10%</td>
</tr>
<tr>
<td>Boking</td>
<td>Done in Autoclaves with High Pressure Steam; ready in 12 hours</td>
<td>Done in Clay Kilns</td>
<td>Done in open Sun; only ready in 25 days</td>
</tr>
<tr>
<td>Fire Resistance</td>
<td>Up to 6 Hours for 200mm thickness</td>
<td>2 Hour</td>
<td>2 Hour</td>
</tr>
<tr>
<td>Sound Reduction (DB)</td>
<td>45 for 200 mm Thick Wall</td>
<td>50 for 230 mm thick wall</td>
<td>50 for 200mm thick wall</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>Approx. 0.16 – 0.25</td>
<td>Approx. 0.81</td>
<td>Approx. 0.70</td>
</tr>
<tr>
<td>Surface Quality/Fungus problems</td>
<td>None; smooth clean finish with no fungus</td>
<td>Fungus and salinity problems on the surface (Reh)</td>
<td>Same as AAC Blocks</td>
</tr>
<tr>
<td>Adaptation to various Surface Finishes</td>
<td>Smoother surface results in better coating application</td>
<td>Inconsistent surface</td>
<td>Same</td>
</tr>
<tr>
<td>Mortar Consumption</td>
<td>0.018 Per M3 with 1:6 / 0.5 Bag of Cement</td>
<td>0.1 Per M3 with 1:6 / 1.35 Bag of Cement</td>
<td>0.025 Per M3 with 1:6 / 0.5 Bag of Cement</td>
</tr>
<tr>
<td>Construction Time</td>
<td>Reduced by upto 50% compared to clay bricks</td>
<td>Double AAC Blocks</td>
<td>Reduced by upto 30% compared to clay bricks</td>
</tr>
<tr>
<td>Energy Saving</td>
<td>32% [App.] Air-Condition Load Both Heating and cooling will come down</td>
<td>No Saving</td>
<td>Upto 20% saving</td>
</tr>
<tr>
<td>Cost Benefit Factor</td>
<td>Dead Load Reduce Structural Cost.</td>
<td>No Saving</td>
<td>Less than AAC</td>
</tr>
<tr>
<td>Contribution to Carpet Area</td>
<td>2-3 %</td>
<td>No saving</td>
<td>No saving</td>
</tr>
<tr>
<td>Chemical Composition</td>
<td>Fly Ash used min. 50% which reacts with (Lime &amp; Cement) to form AAC which is an Inert Material</td>
<td>Soil is used which contains many inorganic Impurities like sulphates Etc. Which results in efflorescence</td>
<td>Fly Ash used</td>
</tr>
</tbody>
</table>

Table 1: Comparative Cost Analysis of AAC Block, Clay Brick and CLC Blocks (Source: www.kansalindia.in)
AAC wall with an insulated asymmetric cavity system gives a wall excellent sound insulation properties. AAC offers sound attenuation of about 42 dB, blocking out all major sounds and disturbances. It is ideal for schools, hospitals, hotels, offices, multi-family housing and other structures that require acoustic insulation.

Fire and vermin resistance: AAC is inorganic, combustible and does not explode; it is thus well suited for fire-rated applications. Depending on the application and the thickness of the blocks or panels, fire ratings up to four hours can be achieved. AAC is non-combustible and fire resistant up to 1600°C. It can withstand up to 6 hours of direct exposure. Due to structure of blocks, AAC cannot be damaged or infested by termites and other pests. It does not attract rodents or other pests nor can it be damaged by such.

Durability and moisture resistance: The purposely light-weight nature of AAC makes it prone to impact damage. With the surface protected to resist moisture penetration it is not affected by harsh climatic conditions and does not degrade under normal atmospheric conditions. The level of maintenance required by the material varies with the type of finish applied. The porous nature of AAC can allow moisture to penetrate to a depth but appropriate design (damp proof course layers and appropriate coating systems) prevents this happening. AAC does not easily degrade structurally when exposed to moisture, but its thermal performance may suffer. A number of proprietary finishes (including acrylic polymer based texture coatings) give durable and water resistant coatings to AAC blockwork and panels. They need to be treated in a similar fashion with acrylic polymer based coatings before tiling in wet areas such as showers.

Toxicity and breathability: The aerated nature of AAC facilitates breathability. There are no toxic substances and no odour in the final product. However, AAC is a concrete product and calls for precautions similar to those for handling and cutting concrete products. It is advisable to wear personal protective equipment such as gloves, eye wear and respiratory masks during cutting, due to the fine dust produced by concrete products. If low-toxic, vapour permeable coatings are used on the walls and care is taken not to trap moisture where it can condense, AAC may be an ideal material for homes for the chemically sensitive.

Environmental impacts: Weight for weight, AAC has manufacturing, embodied energy and greenhouse gas emission impacts similar to those of concrete, but can be up to one-quarter to one-fifth that of concrete based on volume. AAC products or building solutions may have lower embodied energy per square metre than a concrete alternative. In addition, AAC’s much higher insulation value reduces heating and cooling energy consumption. AAC has some significant environmental advantages over conventional construction materials, addressing longevity, insulation and structural demands in one material. Total energy consumption for producing ACC is less than ½ of what it takes to produce other building material. When used, it helps to reduce at least 30% of environmental waste as opposed to going with traditional concrete. There is a decrease of 50% of greenhouse gas emissions. When possible, using autoclaved aerated concrete is a better choice for the environment.

Buildability, availability and cost: Although AAC is relatively easy to work, is one-fifth the weight of concrete, comes in a variety of sizes and is easily carved, cut and sculpted, it nevertheless requires careful and accurate placement; skilled trades and good supervision are essential. Different sizes of blocks help reduce the number of joints in wall masonry. Lighter blocks make construction easier and faster. It reduces the construction time by 20%. They are easy to install. AAC sets and hardens quickly. Blocks can be easily cut, drilled, nailed, milled and grooved to fit individual requirements. Thick-bed mortar is more forgiving but is uncommon and not the industry preferred option. It also simplifies hydro-sanitary and electrical installations, such as pipes or ducts, which can be installed after the main construction is complete. The construction process with AAC produces little waste as blockwork offcuts can be reused in wall construction [3].

Advantages of using ACC Blocks

AAC has been produced for more than 70 years, and it offers several significant advantages over other cement construction materials, one of the most important being its lower environmental impact. Some prominent advantages are summarized as below:

- Improved thermal efficiency reduces the heating and cooling load in buildings.
- Porous structure allows for superior fire resistance.
- Workability allows accurate cutting, which minimizes the generation of solid waste.
- Resource efficiency gives it lower environmental impact in all phases of its life cycle, from processing of raw materials to the disposal of waste.
- ACC blocks weigh about one-fifth of typical concrete. They are also produced in sizes that are easy to handle for quick construction. Light weight saves cost and energy in transportation, labor expenses, and increases chances of survival during seismic activity.
- Larger size blocks leads to faster masonry work. It reduces the cost of the project.
- Environmentally Friendly: When used, it helps to reduce at least 30% of environmental waste as opposed to going with traditional concrete. There is a decrease of 50% of greenhouse gas emissions. When possible, using autoclaved aerated concrete is a better choice for the environment.
- Energy Saver: It is an excellent property that makes it an excellent insulator and that means the interior environment is easier to maintain. When it is used, there is usually not a need for any supplementary insulation.
- Fire Resistant: Just like with regular concrete, ACC is fire resistant. This material is completely inorganic and not combustible.
- Great Ventilation: This material is very airy and allows for the diffusion of water. This will reduce the humidity within the building. ACC will absorb moisture and release humidity; this helps to prevent condensation and other problems that are related to mildew.
- Non-Toxic: There are no toxic gases or other toxic substances in autoclaved aerated concrete. It does not attract rodents or other pests nor can it be damaged by such.
- Accuracy: The panels and blocks made of autoclaved aerated concrete are produced to the exact sizes needed before they even leave the factory. There is less need for on-site
trimming. Since the blocks and panels fit so well together, there is a reduced use of finishing materials such as mortar.

- **Long Lasting**: The life of this material is extended because it is not affected by harsh climates or extreme changes in weather conditions. It will not degrade under normal climate changes either.
- **Quick Assembly**: Since it is a lightweight material and easy to work with, the assembly is much quicker and smoother.

### Disadvantages of AAC

There are also some disadvantages of AAC. They are summarised as below [3]:

- **Installation during rainy weather**: aircrete is known to crack after installation, which can be avoided by reducing the strength of the mortar and ensuring the blocks are dry during and after installation.
- **Brittle nature**: They need to be handled carefully than clay bricks to avoid breakages.
- **Fixings**: the brittle nature of the blocks requires longer thinner screws when fitting cabinets and wall hangings and wood-suitable drill bits or hammering in.

### Case Study: Eco-Commercial Building (ECB), Greater Noida, India

The EcoCommercial Building in Greater Noida, India is part of the Bayer Climate Program, which seeks to reduce the company’s greenhouse gas emissions, and improve energy and resource efficiency. It is a Leed Platinum rated Building, part of this effort involved design-ing and constructing net zero energy buildings around the world. So, the building, which became India’s first net zero energy building, was conceived by Bayer as a prototype with plans to build several such buildings to establish new benchmarks for future sustainable developments. The building envelope design was evaluated to analyze its effect on cooling loads and daylighting. Through several iterations, envelope specifications were identified that yielded the highest resistance and minimum payback period. The insulation materials for exterior walls are 150 mm [6 in.] autoclaved aerated concrete (AAC), fly-ash block work and 75 mm [3 in.] polyurethane foam (PUF). Roof insulation materials are 75 mm (3 in.) rigid polyurethane insulation and a 50 mm [2 in.] layer of mineral wool. The envelope design minimizes the energy demand and operating power. It also reduced the size and cost of the HVAC system needed to maintain adequate building presurization, good indoor air quality and a comfortable thermal environment for building occupants [4].

### Conclusion

Autoclaved Aerated Concrete (AAC) is one of the most sustainable building materials today. The unique product flexibility and characteristics allow for high-speed and energy-efficient construction methods. Comprised of all natural raw materials, AAC is used in a wide range of commercial, industrial, and residential applications and has been in use in Europe for over 70 years, the Middle East for the past 40 years, and South America and Australia for approximately 20 years. According to one report, AAC now accounts for over 40% of all construction in the United Kingdom and more than 60% of construction in Germany [5]. Due to its relatively low consumption of readily available raw materials, excellent durability, energy efficiency, relative cost effectiveness, and ability to be recycled, AAC is well deserving of its ‘green’ designation.

### References