Fast and Green construction with

Autoclaved Aerated Concrete prefab products

New ways of AAC application – AIRCRETE Building System

Authors: Willem van Boggelen

Publishing Date: May 2014

Abstract:

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. This paper introduces an AIRCRETE Building System and AIRCRETE Technologies which are specifically designed for high-quality residential and industrial applications. Fast construction with AAC panels will be highlighted as a resourceful and cost-effective modular building technique for existing and newly developing AAC markets. This review will focus on an integrated AAC building system that goes beyond the traditional AAC block masonry.

Keywords: Green building, fast installation, energy efficient construction, reinforced AAC panels, new building system.

About the author:
Dipl. Eng. Willem van Boggelen holds an academic degree in Mechanical Engineering and Fluid Mechanics and has over 35 years of profound industry experience, working with more than 100 different AAC plants across the world. His international expert status on AAC is confirmed by many publications, consulting evaluations, lectures and technical conferences. Mr. van Boggelen is an independent Technology Consultant and Chairman of the Board of Aircrete Group N.V., supporting the organization with know-how and innovations on systems technology.

Introduction

Autoclaved Aerated Concrete is nowadays one of the most sustainable building materials. Outstanding thermal efficiency and universality of application are the main reasons for the success story of AAC throughout the 20th century. Already today, aircrete has secured its place in the future of sustainable construction outperforming alternative building materials in natural insulation, fire resistance and eco-friendliness. Designers, architects, builders and producers of AAC constantly invest in further research and development. New environmental regulations set the bar high for desired energy efficiency of existing building materials. Lower density AAC products can potentially cater for the energy efficiency requirements. However, it reduces structural properties of aerated concrete meaning that load-bearing capacity of aircrete products disappears together with the possibility of using AAC in multiple level constructions. Taking commercial interest into account, builders, and eventually house owners, focus more on cost-effective construction which requires fast, easily installed, recyclable, versatile and less labour intensive building systems. Reinforced AAC panels are a perfect solution if structural and efficient construction is desired. This article will review in details the benefits of using AAC panels over AAC blocks and describe how AIRCRETE Building System offers a unique solution to fast, economic and green construction for the CIS markets.

Background – AAC Blocks and Panels

The versatility of AAC material and inherent thermal and acoustic resistance allow it to be used in different climatic zones in a wide range of applications, which cater to the building traditions of many countries. The product can be used in **social construction** of single-and multifamily residences, apartment blocks; **commercial construction** of offices, high-rise structures, hotels, retail stores, warehouses, etc.; and **industrial construction** of power plants, factories.

Blocks

Blocks made from aircrete are mostly used as wall products and infill, foundation and insulation material. AAC blocks are non-reinforced and predominantly used as a non-load bearing material. Benefits of using AAC blocks compared to bricks (eg. sand-lime, ceramic or concrete) as well as gypsum boards are widely known and have been applied all over the world since the pre-WWII days. AAC blocks have maintained its popularity throughout the years, many AAC plants have been installed particularly in the last decade. However, the AAC block market is slowly becoming obsolete. The abundance of AAC blocks is vividly present in the major AAC markets, such as India, China, Poland and Russia, creating pressure on the sales

price of the material. Heavy competition with bricks and self-compacting concrete forces AAC producers to enter in a price war, inevitably leading to profit losses and disregard of product quality. Overall, AAC block has surely become a commodity material that is losing its potential. AAC panels, on the other hand, can adequately satisfy social, commercial and industrial sectors' needs for fast, flexible and cost-effective building solution.

Panels

Mature AAC markets (such as Western Europe, Scandinavia, Japan, Australia, etc.) have already long embraced the positive prospects of using **reinforced AAC elements** and shifted its attention towards fast, easy and commercially efficient building with AAC panels. Ever since Siporex has introduced steel reinforced elements in 1930s, reinforced AAC panels have paved its way into the load-bearing structures. AAC panels constitute a wide array of products that together make up a very flexible and thus hugely beneficial building system. Assuming different building codes, state norms and architectural designs, AAC floor, roof, wall and cladding (façade) panels can successfully satisfy the needs of commercial, industrial and social construction in developing and already mature AAC markets.

AIRCRETE Building System

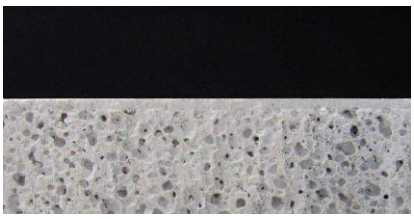
AIRCRETE Building System is an established modular construction concept that uses reinforced prefab AAC panels and specials to create a customized building solution to achieve faster and more economical construction. It capitalizes on modularity of building that AAC elements can offer.

Precise product dimensions, ease of handling and light weight contribute to superior building technique with AAC panels. Depending on the design, complete houses / apartment blocks / warehouses / distribution centers can be built from standardized AAC panels.

Components of AIRCRETE Building System

The following AAC elements constitute the components of the AIRCRETE Building System:

Component	Dimensions	Can be made by AIRCRETE Plant
Partition Panels	Length: < 3.5 m Width: 70-150 mm	✓
Wall Panels	Length: < 8 m Width: 100-500 mm	✓
Roof Panels	Length: < 8 m Thick: 100-300 mm	✓
Floor Panels	Length: < 8 m Thick: 100-375 mm	✓
Cladding Panels	Length: < 2 m Thick: 35-40mm	✓
Lintels	Length: < 3 m* Thick: 100-200mm	✓
Blocks	Length: < 600 mm Thick: 50-500 mm	✓



SUPER SMOOTH FINISH

AIRCRETE Panels have a unique SUPER SMOOTH surface due to the most innovative European production technology. A double wired high-speed cutter closes the aerated concrete pores leaving an exceptionally smooth surface on both sides of the panel.

Figure 1. AIRCRETE Building System components (*U-lintels up to <6 m in length)

AAC partition panels are widely applied in the social and commercial construction, serving as an internal non-load bearing separating wall. They are more cost and thermally efficient than gypsum boards and are perfect substitute for AAC blocks which are used to separate spaces and fill gaps. Partition panels are lightly reinforced for transportation purposes, floor high and are installed vertically. Similarly, **AAC wall panels** can serve as internal load-bearing structure or an outer wall. In contrast to partition panels, these panels are medium/heavily reinforced to be able to hold weight of multiple storey buildings. Installation of AAC partition/wall panels is fast (≈25 – 35m2 a day per worker) and economical with minimal waste residue on-site due to accurate dimensions and SUPER SMOOTH surfaces. The high precision on thickness (+/- 0.3 mm) makes the panel suitable for double sided applications. AAC wall panels are also popular in building large commercial and industrial projects. Heavily reinforced, they are assembled horizontally between a concrete/timber/steel frame and are extremely fast to install (≈100m2 a day with a crew of 3 and a crane). **AAC roof** and **floor panels** are an ideal solution for any floor or roof structure and are an essential component of AIRCRETE Building System thanks to excellent combination of strength, thermal and acoustic insulation. Both types of panels are heavily reinforced, profiled (depending on the design) and fulfill accurate span-load requirements. Floor panels provide a feeling of a concrete flooring at a substantially lower cost and with better insulation values. Roof panels can be installed flat or angled and are extremely important in securing good thermal resistance of roofing structures. AAC industrial wall, roof and floor panels also serve as **firewalls**, protecting the potential flammable goods inside the buildings. Roof/floor panels are widely used in social and industrial high-rise application with an average assembly rate of ≈230 m2 a day. **AAC Cladding Panels** within our building system play the role of decorative material that can easily substitute heavy and expensive ceramic and brick facades. These façade boards are thin

Fig.2 Industrial warehouses – AAC Panels used on the wooden and steel structures.

(35mm) and light (~20kg) but solid as they are reinforced with ultrathin coated or galvanized steel mesh. Unaffected by sunlight, rain and thermites these panels are painted with water-resistant paint (high silicon content), making it extremely durable. As part of the AIRCRETE Building System, cladding panels can be directly fixed on aircrete, steel, timber or concrete frames with a layer of insulation in-between, if required.

Fig. 3 Cladding panels application (L x W x H – 2m x 0.6m x 35 mm)

Advantages of AIRCRETE Building System

AIRCRETE Building System is a well-organized system that boasts multiple advantages over traditional ways of construction. Depending on local climate zone and seismic activity, any type of buildings using aircrete panels can be built (using exclusively aircrete materials buildings up to 4-5 stories can be built). Applying AIRCRETE prefab system AAC producers actually work together with their end customers to simplify construction processes on-site. According to pre-approved plans, almost **all building materials come from one source**, namely an aircrete factory. Installation time and efforts are significantly reduced thanks to large-sized AAC panels that arrive on-site prefabricated and that are easily installed, compared to blocks, and that do not need to be cut on-site. This **labour-efficient and waste free workability allows to speed up the whole project and minimize labour expenses**. Simple interior and exterior finish offered by AIRCRETE Building System is crucial for fast and effective construction, compared to time-consuming stuccoing and brick laying. **The SUPER SMOOTH surfaces on the panels enable a fast and economic finishing**. The joints between the panels are skimmed with a special gypsum-rich mortar to make a smooth integration with the surface. SUPER SMOOTH surface requires minimal finishing on-site thus allowing for significant savings because the need for expensive plastering is eliminated. AIRCRETE Building System benefits the local building contractors, however, the most significant benefit of this building system is the reduction of the total cost of ownership for the home owners. Additionally, valuable advantage of building with AAC is the **light weight of the complete building** that positively affects the

foundation works. Constructing with AAC panels also **improves thermal homogeneity of the building** contributing to better microclimate and comfort inside living and working spaces.

Thanks to large flexibility of AIRCRETE production processes, AAC panels can always be made according to customer-specific wishes when standardized building does not apply. State-of-the-art AIRCRETE cutting technology, for example, allows to make panels as thin as 35mm and as long as 8m with customized profiles which significantly improves the range of AAC application. AIRCRETE

Building System components have a density ranging from 300kg/m3 to 800kg/m3 which allows to achieve substantial compressive strength of up 10MPa which is required for load-bearing structures. Importantly, prefab modular system can be easily combined with other building materials, such as concrete slabs, blocks, bricks and metal beams. This gives room for design creativity and more load-bearing capacity to AAC buildings. Increasingly, AAC after-treatment lines are being incorporated in the new and existing AAC factories in order to cater for diverse customer wishes. After-treatment line also plays an important role in the AIRCRETE Building System concept as it allows to saw the dimensions of the AAC panels (e.g. cladding panels) in accordance to the specific architectural design. Same line allows to make U-blocks, U-lintels and mill out the required surfaces for the "rising star" of AAC market – thin AAC façade boards. Not surprisingly, AAC as decoration material is an increasingly growing trend (in North America, for example).

Fig.4 Affordable Social Housing built using AIRCRETE Building System.

Source: Giora Gur

Overall, modular-type construction with AAC panels using AIRCRETE Building System significantly **reduces overall building time** as well as considerably **saves finishing** and **general building costs**. Small amount of tools, 1 crane, one crew and the building can be constructed turn-key using AIRCRETE Building System. Assembly is easily done using a light-weight crane and, in case of partitions, with the help of a panel lifting car. Standard thin bed mortar (or glue) is used to connect the panels together. Substituting labour intensive AAC block masonry with complete

prefab housing solutions from panels is the next step towards more efficient construction. It is an ideal solution for CIS market since it provides a solution for the fast building requirements at a competitive construction cost.

Unique industry approach of AIRCRETE

AIRCRETE Europe does not only help to technically prepare and supply machinery for AAC plants. We apply a unique industry approach and support the future AAC producers in customizing their plant to manufacture a full scope of prefab elements for integrated building solutions. We support the

Identify – Housing Design

Existing design (Customer) or New design (Customer/AIRCRETE)

↓

Determine – Wind category, climate zone, soil type, seismic location

↓

Establish – AAC panels are suitable for the project

↓

Design – Floor, Wall, Roof and Partitioning Plan

Based on the available AAC elements - detailed drawings

↓

Define – Part List

- Total amount of panels, lintels, blocks
- Dimensions of each element
- No. of steel/concrete/wood beams (if applicable)
- Finishing elements (anchors, roof, windows, doors, electrical, plastering, etc.)

Fig. 5 Flowchart for AIRCRETE Housing Solution Process

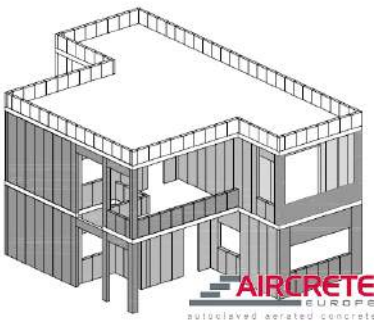


Fig. 6 Initial housing design **Converted housing design** **Ready built house**

direct market development of new AIRCRETE plants by offering total housing solutions, based on AIRCRETE Building System. In such a way, we are able to help investors understand and satisfy the needs of building contractors and property owners who are looking for more efficient ways of building.

AIRCRETE designs total housing solutions and converts existing construction designs into an integrated building system for residential, commercial and industrial sectors. When choosing the panel dimensions and portfolio of products for future application of AIRCRETE Building System we carefully study the required building design and local factors, such as climate, norms and regulations. This leads to optimal analysis of cutting sizes in order to minimize waste levels in the production process and optimize the throughput of products. Our customized approach strongly affects the production cost, resulting in a more competitive construction cost for the end customer.

AIRCRETE Building System is fully supported by AIRCRETE production engineering solutions, meaning that every AIRCRETE plant can manufacture the complete range of aircrete elements needed to assemble designed building. AIRCRETE SUPER SMOOTH technology is the only available technology in the world market that allows the production of reinforced panels and blocks with SUPER SMOOTH surface. Fast, green and cost-effective construction using prefab AIRCRETE Building System is a next step towards the market expansion because beyond the existing AAC commodity market there is a worldwide demand for integrated building solutions.

Green Building

AIRCRETE technology has developed over the last years and brings green and durable living closer to all of us. Energy saving building is now more than a trend across many countries. Institutional Directive issued by EC in 2010 set the target to achieve publicly constructed and owned buildings to be nearly zero-energy buildings after 2018 and all buildings by end of 2020 to be nearly zero-energy. New Energy Efficiency Directive of 2012 complements the EC Directive of 2010 by setting a goal for decrease in energy consumption of Member States.

What does zero carbon, zero energy or energy neutral building mean?

A zero carbon building, or carbon neutral building, is one that causes no increase in CO_2 (carbon dioxide) emissions. It means that energy consumption against energy delivered by its site should be in balance, or neutral. To achieve this objective an obvious step is to reduce energy consumption of buildings which has a direct impact on building products as well as construction processes. World supported

governmental objectives for green housing (GHG) set firm requirements to building methods and materials produced by the local building industries. Today, in most

Western European countries the required Rc (thermal resistance) values of >6 m2 K/W for flooring, walls and roofing are a standard. For instance, Passive Houses in the Netherlands can obtain Rc values of up to 10 m^2 K/W.

Low density AAC products

For the aircrete producers this global trend of strict energy efficiency offers more opportunities than threats. The key aspect in successfully adapting to new regulations will be offering building solutions supported by products that have the combination of excellent thermal and mechanical properties. The so-called AIRCRETE Technology Triangle explains the importance of high-quality AAC in durable and energy efficient construction, taking main AAC properties as the fundament.

The thermal conductivity has to come down considerably to comply with the new EU regulations. AIRCRETE technologies have also accommodated the production of low density

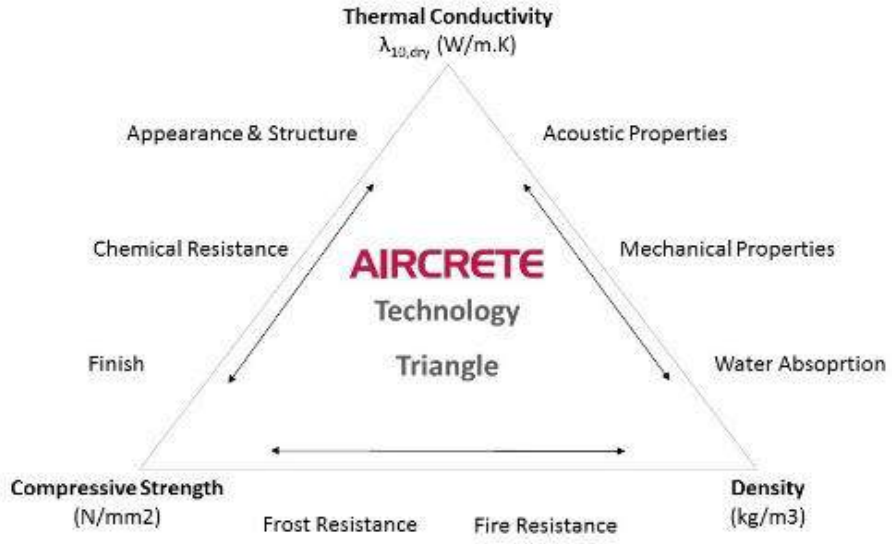


Fig. 7 AIRCRETE Technology Triangle

	Ultra-light density	Low density	High density
Compressive Strength (N/mm^2)	**0.5 – 2**	**3 – 5**	**5 – 10**
Density (kg/m3)	**110 – 300**	**300 – 500**	**500 – 800**
Thermal conductivity (W/mK)	**0.044 – 0.07**	**0.07 – 0.11**	**0.12 – 0.16**

Fig. 8 Typical AAC characteristics

(300kg/m3) blocks and panels with a λ value of 0,07-0,08 W/mK. Density is directly linked with compressive strength and achieving a good combination of the two and reducing the thermal conductivity is a real challenge. Only by having the right quality of raw materials, precise formula design with additives and state-of-the-art production technology, low density AAC elements can be made with precise dimensions and super smooth surface at above described values.

Green building standards force aircrete industry to focus also on ultra-low density products. AAC blocks at densities of 110 – 130 kg/m3 with a thermal conductivity of λ=0,044 W/mK are not an exception anymore. Products up to 200 thickness will address the target of reducing energy consumption considerably. Due to the limited mechanical properties (compressive strength) ultra-light AAC products are non-load bearing and are mainly used for insulation purposes.

Considering AIRCRETE Building System, ultra-low density products form an excellent combination with AAC panels. An example can be the aircrete sandwich panel design which combines standard AAC panels (600kg/m3) with ultra-light aircrete products to achieve an Rc value of 6.5 m2 K/W. Both solutions help to maintain the wall thickness within commercially viable width of 500 mm. In case an Rc value of up to 10 m2 K/W or higher is required a double or triple sandwich panel design with low density AAC panels (300kg/m3) and rigid polyisocyanurate (λ=0.021 W/mK) or mineral wool (λ=0.037 W/mK) in between. This aircrete sandwich system with ultra-light AAC or other highly-insulating materials are made in hard (cured) products on an automatic or semi-automatic assembly lines at the factory floor. The production methods for the lower densities needs a delicate production technology and a simple cutting process with no cake tilting or turning movements, no sticking problems and no

H+H Thermostein MW

Insulation: Mineral Wool

Thickness – 400 mm

Rc = 6.25

Ytong Energy plus

Insulation: Multipor

Thickness – 400-500 mm

Rc = 6.5-8.9

H+H Thermostein

Insulation: Phenolic Foam

Thickness – 400 mm

Rc = 7.69

Fig. 9 New generation of Energy Neutral AAC building. Source H+H International and Xella Nederland

mechanical separation devices in green or hard shape.

Air Leakage

Importantly, in order to use less energy to constantly heat up and cool the building, **appropriate air tightness** has to be attained according to EU regulations EN-13829, in other words, poor sealing that might result in drafts must be eliminated. Air infiltration and exfiltration rate falls within the competency of design decisions (e.g. multiple layer windows/doors), ways of building as well as characteristics of adopted materials. Tight tolerances of AAC products and application of thin-bed adhesive improve the chances of highly air tight building. Ventilation of housings with fresh air is secured by heat exchangers in the installation phase. The risk of building with AAC blocks comes with the large amount of joints that need to be manually glued during assembly. Building with AAC panels minimizes the amount of joints that need to be skimmed thus making the construction less prone to air release. It is crucial to note that, even though the walls can be subsequently plastered, improper gluing during AAC block laying results in the decreased air tightness levels. Thus, for high performance of energy neutral buildings large format AAC panels are preferred over the blocks when it comes to energy-saving and speedy construction. A shift towards greener building marks an end of thick mortar brick laying. Achieving a perfectly carbon neutral housing also implies abandoning of hand grips in blocks and profiles in AAC wall panels as all sides of the building product in energy efficient construction shall be covered with a thin layer of adhesive in order to minimize air leakage.

Fig. 10 Passive House (Netherlands)

AAC floor panels

AAC wall and roof panels

Finished house

Outside walls – block (300kg/m3; wid. 480 mm), inside walls – panel (600kg/m3; wid. 150mm).

Conclusion

AIRCRETE has perfected a building system with AAC panels in order to satisfy the growing demand for fast, cost-effective and sustainable construction. AIRCRETE Building System is a proven efficient building concept that is successfully being applied in the Netherlands and can be introduced in every country that has AIRCRETE production facility. AIRCRETE Building System is perfectly suitable to address the rising need for a more affordable social housing because it allows to save costs on installation time and finishing. Natural insulation, low density and fire resistance contribute strongly to AAC's image of being a number one building product for more energy efficient and sustainable future.

CIS, and specifically Russian, markets are long accustomed to the use of aircrete in all types of construction, however, AAC panel market is underdeveloped in the CIS countries today. AAC block and concrete/sand lime alternatives are still the most popular building materials for wall filling and individual family houses. Not all existing producers of AAC blocks can offer strict dimensional accuracy as product tolerances vary considerably across CIS, depending on the local production standards. This does not offer the possibility of applying thin mortar layer installation for quicker and more thermally efficient building. AIRCRETE Building System assumes both highly accurate aircrete panels and thin bed mortar for better building, hence, it can be said that CIS building industry underutilizes the benefits of these two widespread European practices. In order to achieve faster and more cost-effective construction and attempt to comply with energy efficient standards of construction, large-sized and highly accurate AAC panels (with SUPER SMOOTH surfaces) need be introduced to the CIS markets. CIS markets are also making an effort to reach energy-efficient construction (≥ Rc = 6 m2 K/W) looking for structural low density products in the coming years, however, further investments are needed in selective production technology and knowledge transfer to be able to achieve this goal.

AIRCRETE Building System is a technological and architectural development that lowers the cost of production and the cost of ownership for the AAC producer and the AAC consumer respectively. Facing strong competition from precast concrete and brick industries, AIRCRETE's vision on standardized manufacturing and harmonized cooperation between AAC market players shall strengthen the AAC industry as a whole. As for AAC blocks, they shall surely remain in use along with panels, given the complementary nature of these two as demonstrated by AIRCRETE Building System. Mature AAC markets however are changing from m3 to m2 production, moving away from pallets of standard sized blocks to prefabricated building systems that can be easily installed on-site.

Literature resources:

1. European Commission, 2014. Energy Efficiency Directive. Accessed at http://ec.europa.eu/energy/efficiency/eed/eed_en.html
2. European Council for an Energy Efficient Economy (eceee), 2013. Understanding the Energy Efficiency Directive - Steering through the maze #6: A guide from eceee. Accessed at http://www.eceee.org/eceee_Maze_guide6EED.pdf
3. Waite M.B., O'Brien S.M., 2013. AIR LEAKAGE: DIFFICULTIES IN MEASUREMENT, QUANTIFICATION AND ENERGY SIMULATION. National Institute of Building Sciences. Accessed at http://c.ymcdn.com/sites/www.nibs.org/resource/resmgr/BEST/BEST2_018_WB6-1.pdf
4. CSR Panel Systems, 2010. Power Clad Detached Houses – External Wall – Design and Installation Guide.
5. W.van Boggelen, 2005. Developments and opportunities for AAC with modern production technology. 4th International Conference on Autoclaved Aerated Concrete, London, ISBN 978-04-15383-56-1.
6. W.van Boggelen, 2011. The contribution of AAC in securing a sustainable future. 5th International Conference on Autoclaved Aerated Concrete, Bydgoszcz, ISBN 978-83-89334-26-4.
7. W.van Boggelen, 2012. Key Technology for the Application and Production of Reinforced AAC products. 7th International Conference on Autoclaved Aerated Concrete, Brest.