# Preparation and properties of porous aerated concrete

Ahmed Aidan, Zarook Shareefdeen, Bogdan Bogdanov, Irena Markovska, Dimitar Rusev, Yancho Hristov, Dimitar Georgiev

***Получаване и свойства на порест газобетон:*** *Автоклавният газобетон (АГБ) се отличава с голяма здравина и способност да издържа на високи температури и влажност. Поради тези причини, автоклавният газобетон получи изключително голяма популярност през последните години. Той все по-често се използва от конструктури, архитекти и строители. На практика от 1980 година, в световен мащаб се наблюдава все по-голяма употреба на този материал и засилен строеж на нови заводи за неговото производство в САЩ, Източна Европа, Китай, Бахрейн, Индия, Австралия и други страни. В момента този продукт се произвежда в повече от 420 заводи по целия свят.*

***Key words**: автоклавен газобетон, изходни суровини, получаване, свойства*

## INTRODUCTION

Porous concrete, especially Aerated Autoclaved Concrete (AAC) was first developed by a Swedish engineer between the years 1920 and 1932 [1]. He was searching for a material with the properties of wood, but without the disadvantages of wood. Near the end of World War II, AAC became widely used. Vast areas of cities and industries lay in waste and tremendous rebuilding became necessary, particularly in Germany and England, where wood and steel were scarce. Since 1980, there has been a worldwide increase in the use of AAC materials and new production plants are being built in the United States, Eastern Europe, China, Bahrain, India, Australia and other contries in the world [2-4]. Hence, AAC is increasingly used by developers, architects and homebuilders [5]. The first plant in North America opened in 1996. Four major AAC plants now exist in the United States. It is now being produced in more than 420 factories around the world [1,6].

Concrete made with natural aggregate originating from hard rock has a density within a narrow range because the specific gravity of most rocks varies little. Thus, in practice, the density of normal weight concrete lies within the range of 2200 to 2600 $Kg/m^3$ [7]. Using concrete with a lower density is possible. Therefore, result in significant benefits. The use of concrete with a lower density permits construction on ground with a low load-bearing capacity. Furthermore, with lighter concrete, the framework can withstand a lower pressure, when compared to normal weight concrete. Concrete, which has a lower density, also gives better thermal insulation than ordinary concrete [7].

Due to the growing demand of AAC, a present paper is underway to investigate production of high quality AAC with changes to specification, raw materials and production procedures. This paper presents a technical review of the process, lab scale production method and some preliminary data of AAC blocks.

## EXPERIMENTAL PROCEDURE

Raw materials for AAC production are listed in Table 1 and their functions are discussed as follows. Ideal sand contains silica, $SiO_2$, which is one of the important components in production of AAC. It is preferred to have 90 % or above $SiO_2$ in the production of AAC but requires minimum of 85%. Autoclaved products (AAC) preferably contain a crystallized form of silica, e.g. quartz, which helps to increase the crystallinity of the calcium silicate hydrate formed in the autoclave. The specific surface area of the silica is important. In most cases the silica sand is grounded to the required fitness by ball milling. Finer sand reduces the processing time, decreases the degree of crystallization, and increases the compressive strength. Cement with higher surface area will have higher strength. The quicklime is one of the sources of $CaCO_3$ that is used in AAC production and it is considered as the main binding agent. There are two types of quick lime: hard burnt lime and soft burnt lime. In the production of AAC, hard burnt lime is used. The quicklime is necessary to provide heat in the mixture. Without quicklime, the gas generation process and the stiffening would be inhabited and the whole process slowed down. Gypsum is calcium sulfate $CaSO_4$, which is added into the production of AAC in order to increase the compressive strength of the block. Moreover, it is added to avoid the cake collapsing in low densities. The gypsum has primarily an influence on the settling times. Aluminum Powder provides the process with required hydrogen $H_2$ to expand the product. When Aluminum powder is mixed with other ingredients, hydrogen gas will raise with solids to the surface and this will double the size of the cake. AAC is a low-density product (350-800 kg/m$^3$). The porosity of AAC is achieved by a gas generation agent (aluminum powder or paste). The aluminum reacts with the hydroxides from cement and quicklime. Hydrogen gas makes the mass expands. Water is used for two purposes, for generating steam and for the process itself. Water has a significant influence on the strength development and final strength of the cement paste. A basic rule is: the higher water content, the less the final strength.

**Table 1.** Raw materials and typical amounts for production of AAC

| Raw materials | Per 1 m$^3$ at 500 kg/m$^3$ dry density | |
|---|---|---|
| | with Sand | with Ash |
| A. Sand [kg] | 320-340 | - |
| B. Cement [kg] | 65-75 | 90-100 |
| C. Lime [kg] | 65-75 | 50-60 |
| D. Gypsum [kg] (anhydrite) | 15 | - |
| E. Aluminium [kg] | 0.5-0.6 | 0.5-0.6 |
| F. Production water [kg] | 230 | 250 |
| G. Pulverized Fuel Ash (PFA) [kg] | - | 320-340 |
| H. Water for steam [kg] | 140 | |
| I. Fuel oil [kg] | 11-12 | |
| J. Electric energy [m$^3$] | 13-16 | |
| K. Mould oil [L] | 0.15 | |
| L. Grinding balls [kg] | 1 | |

Figure 1 summarizes the steps of the lab scale production of AAC.

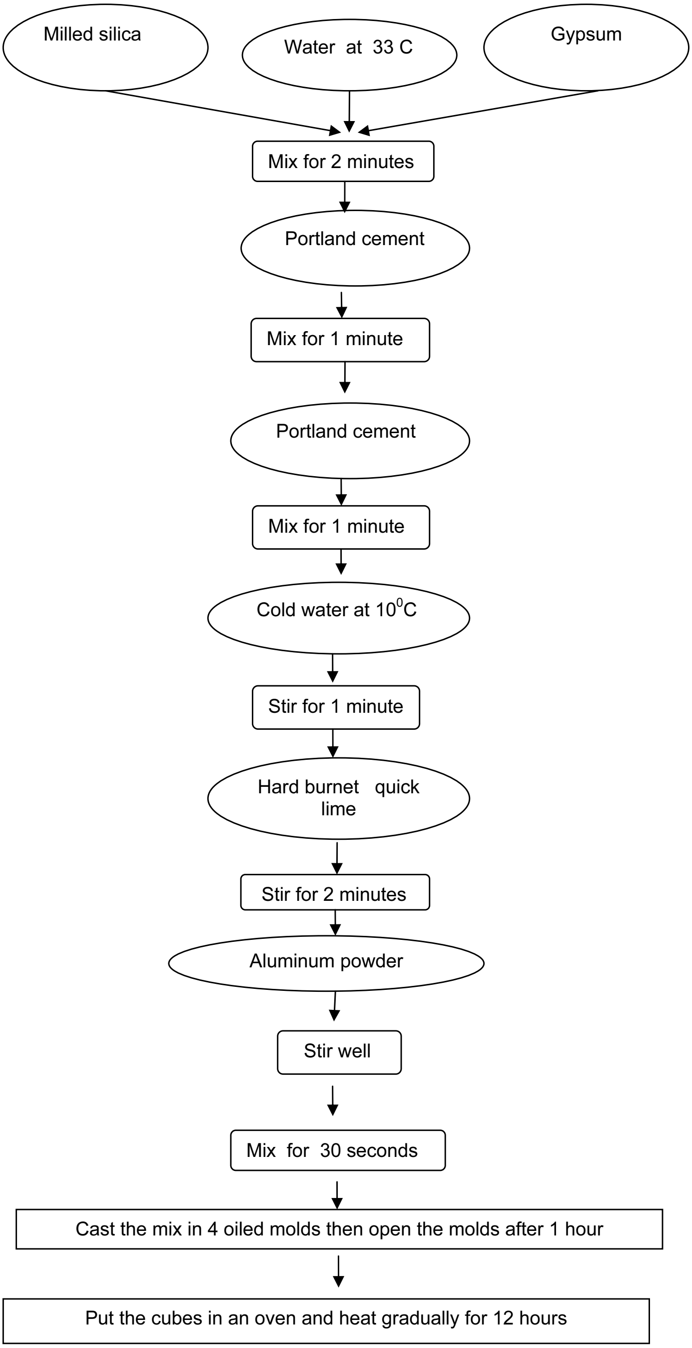


**Figure 1.** Steps of the preparation of AAC

Finely ground sand (70, 80, 90, 100 and 110 μm grain size sands, respectively were used) is mixed with water, cement and quicklime. At the end of the mixing process, aluminum powder is added. The slurry is poured into a mold, where the cement and the quicklime react with water. The slurry stiffens and the temperature rises. Simultaneously, the aluminum powder reacts with the hydroxides from the quicklime and cement. Hydrogen is produced, which expands the mass and forms pores in the mass. The mass needs approximately 1-3 hours to reach sufficient hardness for cutting. It is removed from the mold dried.

**RESULTS AND DISCUSSION**

AAC blocks obtained have many useful properties as: lightweight (about a fifth the weight of concrete), non-combustible, unique thermal properties (because of its cellular structure), exceptional sound absorbing characteristics, a vapor permeable and breathable wall system. They are a lot like wood and a pollution free manufacturing process (that makes best use of a minimum amount of energy and natural resources, resulting in a premier green building material). The material's lower weight also makes it easier to transport. Table 2 shows the properties of some of the Aerated Autoclaved Concrete blocks that were made.

**Table 2.** Typical properties of aerated concrete (High pressure steam)

| Dry density (Kg/m$^3$) | Grain size (μm) | Compressive strength MPa | Flexural strength MPa | Modulus of elasticity MPa | Thermal conductivity at 3% moisture |
|---|---|---|---|---|---|
| 450 | 70 | 3.171 | 0.621 | 0.016 | 0.12 |
| 525 | 80 | 3.998 | 0.689 | 0.019 | 0.14 |
| 600 | 90 | 4.481 | 0.827 | 0.027 | 0.16 |
| 675 | 100 | 6.274 | 1.034 | 0.025 | 0.18 |
| 750 | 110 | 7.515 | 1.241 | 0.027 | 0.20 |

The compressive strength of an AAC product is a function of a number of parameters such as density, grain size of sand and amount of binder. By using the optimal relationship between grain size of sand and amount of binder and autoclaving the product in an optimal way, will produce AAC blocks of outstanding performance. In our preliminary study, the result (Table 2) shows that as the grain size of sand increases the compressive strength, the density, flexural strength, modulus of elasticity and thermal conductivity increase. Based on the operative standards and required applications, the blocks obtained have densities of 450 and 750 kg/m$^3$ were selected.

**CONCLUSION**

In this work we have presented the potential benefits of using of Aerated Autoclave Concrete, laboratory method of preparation and some preliminary data on properties of the materials. Furthermore, chemical reactions involved in the process are not well understood, in particular reactions in the autoclave step. Changes to raw materials, reduction in the processing time, increase in the strength of the materials and reduction in the cost of production are the main objectives of our current research focus of this project. Due to the growing demand of AAC, we anticipate this work will draw significant interests from many companies, consultants and municipalities of UAE, Bulgaria and other countries.

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**for correspondence:**

Dr Ahmed Aidan - Department of Chemical Engineering, American University of Sharjah, Sharjah, UAE, e-mail: aidan@aus.edu

Dr Zarook Shareefdeen - Department of Chemical Engineering, American University of Sharjah, Sharjah, UAE

Assoc. prof. Bogdan Iliev Bogdanov – department "Technology of inorganic substances and silicates", Assen Zlatarov University, Bourgas 8010, tel. 056 858 202, e-mail bogdanov_b@abv.bg

Assoc. prof. Irena Georgieva Markovska – department "Technology of inorganic substances and silicates", Assen Zlatarov University, Bourgas 8010, tel. 056 858 401, e-mail: imarkovska@btu.bg

Assoc. prof. Dimitar Rusev Rusev – department "Electrotechnics, Electronics and Machinery construction", Assen Zlatarov University, Bourgas 8010, tel. 056 858 405, e-mail: dr_rusev@ mail.bg

Major assistant Yancho Hristov Hristov – department "Material science and technology ", Assen Zlatarov University, Bourgas 8010, tel. 056 858 473, e-mail: yanchris@abv.bg

Assoc. prof. Dimitar Petrov Georgiev – department "Material science and technology ", Assen Zlatarov University, Bourgas 8010, tel. 056 858 230, e-mail: dgeorgiev@btu.bg

**Докладът е рецензиран.**