DEVELOPMENTS IN AUTOCLAVED AERATED CONCRETE MASONRY

Norman J. Bright

1. ABSTRACT

The paper reviews Autoclaved Aerated Concrete (AAC) as a material which has been adopted worldwide except in Canada and USA. The manufacturing process, raw materials and product properties are described. Recent developments and trends are included related to changing market and legislative requirements.

2. INTRODUCTION

Autoclaved Aerated Concrete (AAC) has been in commercial production for some sixty or so years. It commenced in Scandinavia and its production and use has spread to all five continents but is not currently produced commercially in the USA or Canada. There was a plant near Montreal but it closed more than 20 years ago. There is, however, a great surge of interest in these two countries and in the USA there is a small mobile plant which can manufacture small quantities of blocks for demonstration purposes. Much of the current interest is in the potential to use fly ash as the bulk raw material in the manufacture of AAC as has been done in the UK for some 40 years.

3. WORLDWIDE PRODUCTION

In Europe, Germany is the largest producer of AAC followed by the UK. In both countries the majority of the production is in the form of blocks. The total production in Western Europe is of the order of 8 million m$^3$ per annum. See Fig.1.

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1 Group Development Director, Kingsway Group plc, Rectory Road, Grays, Essex, RM17 6AP, United Kingdom.
### Indicative annual volumes of AAC masonry Western Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>AAC Masonry (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>200,000</td>
</tr>
<tr>
<td>Denmark</td>
<td>25,000</td>
</tr>
<tr>
<td>Finland</td>
<td>20,000</td>
</tr>
<tr>
<td>France</td>
<td>300,000</td>
</tr>
<tr>
<td>Germany</td>
<td>4,000,000</td>
</tr>
<tr>
<td>Italy</td>
<td>100,000</td>
</tr>
<tr>
<td>Netherlands</td>
<td>200,000</td>
</tr>
<tr>
<td>Spain</td>
<td>10,000</td>
</tr>
<tr>
<td>Sweden</td>
<td>10,000</td>
</tr>
<tr>
<td>Switzerland</td>
<td>15,000</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>2,500,000</td>
</tr>
</tbody>
</table>

In Asia, Japan is a large producer, although almost exclusively in the form of reinforced panel units rather than masonry and there are several plants in South Korea. In China there are many plants and AAC blocks are much in evidence when travelling around. There are also plants in Turkey.

There are plants in Africa, South America and Australia. (1)

### 4. MANUFACTURE

AAC is the lightest form of masonry in widespread use. Although it is classed as concrete it contains no coarse aggregate. The raw materials are cement and/or lime as binders, fly ash and/or finely ground sand or shale as aggregates, aluminium powder or paste (in small quantities to act as the rising agent) and water. It is factory produced in the form of blocks (or larger reinforced units) and cured in giant autoclaves.

The whole process is completed within 24 hours, i.e. the material that is mixed one day is taken out of the autoclaves the following day. The material is fully cured as a result of this process and is ready for use after being allowed to cool. (2)

The energy used in production is low compared with, say clay bricks and the overall raw material use is low on a volume for volume basis.

The method of production is the raw materials are normally weigh batched mixed and discharged into large trucks. The mixed material is a wet slurry which approximately half fills the moulds (trucks). During the space of the next 1/2 hour to 2 hours depending on the manufacturer's process the material rises to fill the mould. This large cake stiffens to a soft cheese-like state and is then cut by batteries of reciprocating wires to form blocks (or reinforced units) in a wide range of thicknesses. The offcuts are recycled and systematically re-used in the mix as standard procedure. As a recent development, an increasing number of manufacturers are grinding or
crushing waste or damaged autoclaved material and re-using it in the process. Trains of these large cakes are then put into autoclaves and cured. They are usually in the autoclaves for up to 12 hours in total with a period of full pressure in excess of 10 times atmospheric pressure. This high pressure steam curing process causes a chemical reaction, combining lime and silica to form complex calcium silicate hydrates which govern the properties of the finished material. The aerated internal structure (Fig.3) is formed by the aluminium powder reacting with lime to form hydrogen.

Fig.2
There are large differences of detail between one manufacturer's method of production and another. This is often influenced by the available raw materials and whether the market is for blocks or larger reinforced units. In principle a plant which is designed to produce reinforced units is also capable of producing blocks with slight modification. Plants designed specifically for blocks can however have lower capital costs than those designed to produce reinforced products.

All of the established manufacturers have made developments in their processes. The most modern plants are more automated, cleaner, more energy efficient and produce minimal waste. The use of waste materials such as fly ash as a raw material is on the increase. The use of fly ash is very well established in the UK where the majority of AAC block production is based on fly ash. A particular advantage of fly ash is that it has the right particle size for AAC manufacture (3) and does not require grinding in ball mills. This reduces both the capital cost and the running cost compared with using ground sand or shale as the raw material.

5. APPLICATIONS AND PROPERTIES

Throughout the world AAC blocks are used in a variety of applications for internal and external walls in a variety of thicknesses and face dimensions. The face dimensions range with block lengths from 400mm - 600mm commonly and height from 200 - 250mm. Much larger face dimensions are now used in some areas in conjunction with mechanical lifting and placing methods.

 Thicknesses can range from a minimum of 50mm (used in non-loadbearing partitions plastered both sides) up to 500mm or more used in solid external walls (usually rendered externally). The thicker blocks are sometimes provided with hand holes in the perpends to facilitate handling and laying. Some manufacturers can provide blocks tongue and grooved or grooved both ends.

The precise form of AAC and its market acceptability depends on the construction methods and design requirements of the country or region.
Clearly reinforced AAC tends to be required where there is significant seismic activity. Unreinforced AAC masonry is widely used in Europe where seismic activity is low. Bed joint reinforcement is often used to control cracking particularly around window openings etc. The high fire resistance combined with high thermal insulation of AAC is an important factor in its choice for projects.

Over the last twentyfive years the Building Regulations in most European countries have progressively tightened in respect of the energy conservation requirements and this process is continuing. This has resulted in a range of different densities combined with different block thicknesses to provide economic wall constructions to suit the methods of construction in the various countries. The creation of the European Single Market will not affect this in the short term as there is no plan to harmonise Building Regulations across Europe. Nevertheless in the longer term greater harmonisation leading to a reduction in product variety is inevitable.

However a major development is taking place as a direct result of the Construction Products Directive of the European Single Market. Under the auspices of the European Standards organisation (CEN). Harmonised European Standards and Test methods are being prepared which will apply all across Europe. For AAC therefore there is already a draft European Standard for the Specification of AAC Masonry units together with draft pan European Standard Test methods. This is part of an evolutionary process which will remove technical barriers to trade in Europe. In addition it will enable AAC block masonry regardless of where it is produced in Europe to be used in a single European structural design method (Eurocode 6 - Masonry).

Although AAC is a relatively low strength masonry material it is suitable for a large number of low rise loadbearing wall applications. This together with the other advantages of lightness and ease of use (4) combined with good thermal, acoustic and fire performance accounts for its widespread use.

The compressive strength of AAC blocks is in the range from about 2.5N/mm² to 8N/mm². The common range of dry densities is from 400kg/m³ to 800kg/m³. There is a broad relationship between compressive strength and density (5) and the optimum strength/density ratio varies depending on the economically available raw materials.

6. THERMAL PERFORMANCE

The thermal performance of AAC has been studied from the earliest days. There is a well known empirical rule relating the thermal conductivity of masonry to density adjusted for moisture content known as the Jakob Curve (6). As this covers the whole range of masonry densities it had been accepted for many years that it applied equally to AAC. In the event, as more and more accurate laboratory testing of the thermal conductivity (λ) of AAC was carried out it was discovered that there was a different curve for AAC which demonstrated that the Jakob Curve undervalues the thermal performance of AAC masonry (7).

7. ACOUSTIC PERFORMANCE

A standard way of calculating the acoustic performance of a masonry
wall is to use the Mass Law developed in the 1950s from a large experimental programme. Following discoveries that AAC masonry had superior performance to that predicted by the Mass Law, research has produced an AAC Mass Law (8). See Fig. 4.

8. CONSTRUCTION METHODS

There are two principal methods of constructing AAC blockwork, both of which are widely used. One is conventional mortar joints using relatively low strength mortar (1:2:9 or 1:1:6 cement:lime:sand) and the other is thin joint using special thin joint mortar supplied by the AAC producer. Traditionally AAC built with conventional mortar is finished with gypsum plaster or cement/lime/sand rendering. The closer tolerances of thin joint AAC masonry allows thin sprayed finishes to be applied without the mortar joints showing through. The increased attention which is being given to thermal performance is encouraging the use of lightweight mortars and thin joint mortars.

9. THE FUTURE

All of the major producers of AAC carry out continuous research into raw materials, manufacturing processes and performance in use. The details of available raw materials, markets and legislative requirements are changing constantly. The aerated concrete industry has had a long history of being innovative, responding to and anticipating change. This has led to its ever increasing use throughout the world. Many feel that this material now has a place as a major construction material in the USA and Canada in one form or another.
10. REFERENCES


