Potential, Limitations and Sustainability of Autoclaved Aerated Concrete (AAC)

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1. INTRODUCTION
The sustainability of construction materials and products continues to be a hotly discussed topic in Italy. For a product to succeed in a highly regulated market, in fact, it must be capable of responding to the pressures exerted by the complex technical, social and economic system from which our efforts to change our surroundings spring, and which motivates us to transform and recover the buildings around us.

For the technologies used for the building envelope in particular, a tendency to choose products chiefly on the basis of their energy-saving properties began to lose ground in the 1990s, when attention shifted to ecologically compatible products, i.e., those which have a low environmental impact, are economically competitive, and involve innovative processes.

Process innovation is not restricted solely to manufacturing, but involves an integrated approach which sees the product as part of a whole system of relationships that come into being during its life cycle, and thus attempts to ensure that these relationships can unfold more smoothly.

Though this systems-oriented approach translates, for example, into a greater attention to maintenance conditions and to recycling salvaged materials, it also means greater flexibility through products that can be adapted to changing design and service conditions. Finally, it means that design criteria will include dimensional coordination, integrated utilities, and “clean”, well-organized construction sites.

This paper discusses an on-going study carried out as part of a research program dealing with the sustainability of certain building envelope technologies now under way at the Politecnico di Torino Department of Construction and Territorial System Engineering. Consequently, the study addresses the sustainability of load-bearing autoclaved aerated concrete wall construction units.

2. METHODOLOGY
Autoclaved aerated concrete (AAC) is produced from extremely fine silica-base materials such as cement, lime and other hydraulic binders which are mixed with water to form a slurry. Reagents are then added which trigger a chemical reaction, generating gas which forms minute air cells in the slurry. Additives can also be used to improve the consistency and quality of the finished product. After the mixture has set in special molds, the mass is cut into
the desired formats. The products are then steam cured under pressure in autoclaves, where they are chemically and dimensionally stabilized.

In order to assess several characteristics and properties of this material, three commercial brands of autoclaved aerated concrete blocks for load-bearing wall construction were investigated. These three brands, all of which are readily available on the Italian market, will be designated below as A, B and C. For each brand, ten blocks were sampled from pallets taken from different lots. These blocks were analyzed and then used to prepare three test specimens.

Block morphology was evaluated first. Specifically, blocks were assessed as regards color, prism configuration, face flatness, edge straightness, presence of cracks, protuberances and chipping, and deviations from stated nominal dimensions.1

Type A blocks were a uniform off-white with a minimum of gray specks. As regards appearance, type A blocks were free from edge chipping2, corner chipping3, deviations from flatness, surface discontinuities and cracks. An important morphological feature of these blocks is the presence of lifting grips located along the short sides of the block. Dimensional tolerances on block length, height and thickness complied with the maximum deviations specified in UNI U32.10.241.2 “Autoclaved aerated concrete units for masonry – Acceptance criteria”4.

Type B blocks were a fairly intense gray. Color was uneven, with a number of dark gray specks. As regards appearance, type B blocks exhibited several edge chips, corner chips, deviations from flatness and surface discontinuities, which were measured with a gauge and straightedge5. All sides of the blocks are smooth, with no lifting grips. As for the previous type, dimensional tolerances on length, height and thickness of type B blocks complied with the maximum deviations specified in UNI U32.10.241.2 “Autoclaved aerated concrete units for masonry – Acceptance criteria”6.
Type C blocks were an uneven dark gray with a number of black specks. As regards appearance, type C blocks exhibited numerous edge chips, corner chips, deviations from flatness and surface discontinuities, which were measured with a gauge and straightedge. All sides of the blocks were smooth, with no lifting grips. Measured deviations for block length, height and thickness were ± 0.7 mm.

In the second stage of the study, laboratory tests were carried out in order to investigate the blocks’ chemical composition, density, capillary absorption and freeze-thaw resistance. Atomic absorption spectrophotometry and wet method chemical analysis were used to determine the percentage by weight of the various components. The specimens prepared from three representative blocks showed substantial differences in the percentages of soluble silica, calcium oxide, aluminum oxide and sulfur trioxide (SO₃). Density also showed significant differences, ranging from 0.554 to 0.665 kg/dm³.

In tests for dimensional stability, capillary absorption and freeze-thaw resistance, type C blocks showed significant deterioration and spalling, with the corners crumbling to the extent that they broke away completely. This weakness on the part of the type C block is linked to its porosity as indicated through the microscopic test. While type A and B blocks have pores measuring 0.5 to 2 mm in diameter and a few 3 mm macro-pores, type C blocks have pore diameters between 0.6 and 0.9 mm and a few 2 mm macro-pores. In addition, the majority of the cells are closed.

The third part of the investigation addressed the following assessment parameters: manufacturing process, transport, installation, durability and maintainability.

In assessing the product manufacturing process, it was found that type A and B blocks are produced in technologically advanced facilities, where current environmental protection regulations are followed and particular attention is devoted to recovery of processing waste, sludge, and atmospheric emissions of vapors and other substances. By contrast, the production facility for type C blocks is marginally compliant with current requirements, and no special attention is given to environmental concerns.
As for transport, the three types of block are shipped by rail to some extent, though road transport – which has a higher environmental impact – predominates. Direct shipments are made to all parts of Italy, with no appreciable differences between the three brands.

For indirect sales through dealers and retailers, type B blocks have a higher geographic penetration than the other two types, largely because this manufacturer has a larger number of production facilities which are more widely distributed across the country. For this reason, consignments of type B blocks can be made much more quickly for both direct factory sales and retail sales, with an average of around 1 or 2 days between the time of order and delivery to the construction site. By contrast, average delivery times are around 15 to 30 days for type A blocks, and some 10 to 15 days for type C blocks.

As regards on-site storage, the same considerations apply to all three types: blocks are palletized and protected with shrink-wrap plastic, and must be stored in a dry area under cover, raised off the ground by means of wooden blocks or the like, and protected from the elements with water-repellant tarps.

These storage instructions also apply to handling during installation. Type A blocks show decided advantages at the time of erection, as they are provided with lifting grips which make them easier to handle and also ensure healthier conditions for workers. In addition, type A blocks ensure more precise, accurate construction because of their minimal dimensional variations.

As regards durability and maintainability, studies are still under way in a number of European Union member states and in Sweden\(^1\), where this material has been used for over 60 years. Nevertheless, it is already clear that autoclaved aerated concrete blocks, which are produced through an industrial process that results in a certain homogeneity and uniformity, have a high degree of chemical stability which ensures a good level of durability. However, the presence of micro- and macro-pores causes a certain permeability to liquids, which can lead to partial destruction of the matrix through dissolution. In addition, AAC is easily damaged by acids, acid salt solutions and acid vapors. The amount of destruction depends on acid concentration, temperature and relative humidity\(^1\). Consequently, this material must be protected with plaster or cladding of various kinds (e.g., brick, tufa blocks, wood siding, clapboard, ceramic tiles, etc.) to guarantee durability. Maintenance carried out on the coating or cladding used to protect the AAC serves entirely to keep the cover material in good condition, and is not influenced by the differences in the characteristics of the three types of block.

3. CONCLUSIONS

In order to compare the analysis results obtained for the three types of AAC block, an IT tool (simplified LCA) is now being developed. This tool will be used to evaluate block parameters and thus formulate sustainability ratings which can help designers and construction contractors in making decisions.

It is precisely the latter group who, together with the end users of buildings constructed with AAC, will be the major market drivers in improving environmental quality and bringing down the overall cost of this material’s technology. Indeed, as Felix Guattari wrote in “The three ideologies”, “… ecology [though the same applies by extension to sustainability in construction] has three dimensions, each of which is meaningless without the others: the first dimension is social, as it is important that people can express and contribute to the decisions
that involve them; the second is psychological, and concerns the relationships that each of us has with the surrounding world. It is only then that we come to the third, or technical and operative, dimension …”.

And it is in this sense that the debate in the world of architecture is permeated by signs of a keen interest in sustainability, and it is no accident that designers of enormous prestige are striving to find new means of expression such as those discussed by way of example below.

In recent years, the interest shown by many renowned designers in purely ‘ideological’ questions has plummeted, giving way to a freer spirit of experimentation founded on a greater regard for concreteness and a new attitude towards materials and the environment. This has wrought profound changes in the relationship between architectural and technical concerns, which is now more open, more fluid, more diversified. In this connection, we provide two examples: a conversion project and a new construction where AAC was used with particular attention to the issues discussed above.

4. CASE STUDIES

4.1 The School of Engineering building in Brescia
The first case study is the new site of the School of Engineering in Brescia, with a surface area of 32,700 m². The design by Prof. Silvano Tintori employs a modular grid layout which promotes flexibility. This is a major advantage in a university setting, as spaces can be readily adapted to the users’ varying needs. The use of lightweight AAC blocks provided significant design advantages, optimizing acoustic and thermal insulation.

4.2 Pavilion at the ’92 Columbus International Exposition in Genoa
An original interpretation of the material’s use, on the formal level as well as in terms of technology and sustainability, was provided by Renzo Piano with his design for a curtain wall on the large facades of the Pavilion for the Columbus International Exhibition. Brick panels were installed without mortar on a steel frame structure supported by an AAC block wall.
REFERENCES


1 Draft standard UNI U32.10.241.2 “Autoclaved aerated concrete units for masonry – Acceptance criteria” specifies maximum deviations of ±3 mm for length, ±1.5 mm for height, and ±2 mm for thickness.
2 Draft standard UNI U32.10.241.1 “Autoclaved aerated concrete units for masonry – Generalities” defines edge chipping as loss of material along an edge of the unit.
3 Draft standard UNI U32.10.241.1 “Autoclaved aerated concrete units for masonry – Generalities” defines corner chipping as loss of material at an angular point of the element.
4 Procedures for determining tolerances complied with the protocol outlined in UNI U32.10.241.3 Test methods.
5 Procedures for determining chipping, flatness, discontinuities and cracking complied with the protocol outlined in UNI U32.10.241.3 Test methods.
6 Procedures for determining tolerances complied with the protocol outlined in UNI U32.10.241.3 Test methods.
7 These tests were carried out in accordance with the protocol outlined in RILEM RECOMMENDED PRACTICE. Autoclaved Aerated Concrete, Properties, Testing and Design, Rilem Technical Committees 78-MCA and 51-ALC, edited by S. Aroni, G.J. de Groot, M.J. Robinson, G. Svanholm, F.H. Wittman. (1993), printed by E & FN SPON, London, Great Britain, pp 12 to 31, and in accordance with UNI U32.10.241.2 3 Test methods, pp 7 to 8, 14 to 15.
8 These tests were carried out in accordance with the protocol outlined in UNI U32.10.241.3 Test methods, pp.14 to 15.
9 A site review was carried out at each plant, compiling a manufacturing process assessment form.