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Applied Research Paper:
Autoclaved Aerated Concrete as a Green Building Material

Stefan Schnitzler
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INTRODUCTION

Autoclaved aerated concrete ("AAC"), though relatively unknown in the United States, is currently one of the many building products being touted as "green" or "environmentally friendly." This paper briefly examines the advantages and disadvantages of building with AAC, paying particular attention to the aspects of the product that may lend to its designation as a sustainable building material.

AUTOCLAVED AERATED CONCRETE – BACKGROUND

Though largely new to the United States, AAC is not a new building material. Developed in Sweden in the 1920s in response to increasing demands on timber supplies, AAC is a lightweight manufactured building stone. 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.[1] According to one manufacturer, AAC now accounts for over 40% of all construction in the United Kingdom and more than 60% of construction in Germany.[2]

The Manufacturing Process

Autoclaved aerated concrete is a precast product manufactured by combining silica (either in the form of sand, or recycled flyash), cement, lime, water, and an expansion agent - aluminum powder, and pouring it into a mold. With respect to structurally reinforced AAC products like lintels or roof panels, steel rebar or mesh is also placed in the mold. Once added to the concrete, the aluminum powder reacts with the silica, resulting in the formation of millions of microscopic hydrogen bubbles. The hydrogen bubbles cause the concrete to expand to roughly five times its original volume. The hydrogen subsequently evaporates, leaving a highly closed-cell aerated concrete. The now aerated concrete is cut into blocks or panels which are then steam and pressure-cured in an autoclave.

AAC Product Types

AAC, unlike traditional concrete masonry units ("CMU"), is a solid block/material system with integrated insulative and structural components, and is available in a variety of products that can be used in both load and non-load-bearing applications. Complete load bearing applications, however, are limited to low-rise construction, though cladding and large panels are available to take advantage of AAC's insulative, fire proofing, and other benefits on mid- and high-rise projects. Additionally, the large wall, floor, and roof panels, measuring up to 20 feet long, 2 feet wide, and in

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[1] AAC has been used in the United States for approximately 10 years. The United States' late adoption of the material is likely due to 1) the high initial capital expenditures required in setting up domestic AAC manufacturing facilities, and 2) the fact that, unlike many of the countries where AAC is an established product, the vast majority of residential buildings in the United States utilize timber-frame construction.

[2] *See* TruStone America, http://www.trustoneamerica.com/what.html

various thicknesses, are also used in load-bearing capacities and are common in commercial and industrial applications.

The remainder of the AAC system consists of blocks, also called "units" which are stacked using thin-set mortar, as opposed to the traditional cement-based mortar used in CMU construction. The blocks are available in a variety of sizes and types, e.g., 1) standard blocks, typically measuring 24 inches long, 8 inches high, and in thicknesses between 6 (non-load-bearing) and 12 inches; 2) jumbo blocks, which reduce construction time; 3) U-blocks, which have a channel running the length of the block that once filled with concrete, provides structural support as headers and on the top course of each floor (the "bond beam"); and 4) cored blocks, which are used adjacent to corners and openings and have a centered, 4 inch vertical core at one end of the block to form a continuous vertical core through the wall that is then filled with rebar and concrete. AAC lintels with integrated structural support are also manufactured and are an alternative to using the U-block system for headers.

Due to AAC's design flexibility and combined structural and insulation components, an entire structure can be built using the one material. Exterior surfaces can be finished with stucco, traditional veneers or siding, while interior walls can be plastered, painted, or left unfinished, in addition to traditional sheetrock finishes. Further, AAC is easy to use and can be cut and manipulated with normal wood-working tools.

ADVANTAGES OF BUILDING WITH AUTOCLAVED AERATED CONCRETE

AAC Reduces Additional Material Use and Minimizes Waste and Pollution

The ability of a product to reduce material use, utilize recycled products, and avoid toxic emissions are key criteria in determining whether a product qualifies as "green" or can be used in a sustainable manner.[3] Autoclaved aerated concrete performs extremely well in these regards.

First, AAC consumes a relatively small amount of raw material relative to the amount of finished product produced. Because AAC is approximately 80% air, the finished product is up to 5 times the volume of the raw material consumed in its production. Additionally, the raw materials that are consumed are generally abundant and found in most geographic regions, allowing them to be locally sourced. Furthermore, much of the raw materials used in AAC production may consist of recycled materials, including copper mine tailings and flyash, a byproduct of coal-fired power plants.

Second, with respect to embodied energy, AAC consumes approximately 50% and 20% less energy than that needed to produce concrete and CMUs, respectively.[4]

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[3] *See* Environmental Building News, *Building Materials: What Makes a Product Green?* (January 2000)
[4] *See* Safecrete - *http://www.safecrete.com/23.htm*

Additionally, the manufacturing process produces no waste or pollution and the final product is completely recyclable.[5]

The manufacturing of AAC also results in a product that is lightweight, strong, inorganic, non-toxic, and does not shrink, rot, warp, corrode, off-gas or otherwise deteriorate.[6] Due to its light weight and dimensional accuracy, AAC can be assembled with minimal waste and a reduced need for additional equipment. AAC is also termite and mold resistant, and nearly fireproof.[7] This extreme durability makes the product virtually maintenance free, eliminating the need for repair materials, pesticides, and chemical treatments, while also lowering operating costs.

Most significantly, because AAC comprises structural, insulation (both thermal and sound), and fire resistant material all in one product, significant environmental and material savings can be achieved. Wood otherwise needed for structural framing and sheathing can be avoided, as can fiberglass insulation, furring, sheetrock, and the like. The use of AAC in lieu of conventional timber frame construction reduces demand for old growth lumber and trees that would otherwise help mitigate CO2 emissions.

AAC Has High Thermal Efficiency

Autoclaved aerated concrete is further considered a sustainable building product because of its excellent insulating qualities resulting in increased energy efficiency. AAC's thermal efficiency stems from three factors. First, AAC structures result in solid wall construction with integrated insulation. Entire wall coverage prevents the thermal bridging associated with conventional stud-framed walls, which essentially leave cold gaps around every stud and header.

Second, the solid wall construction of AAC structures creates an airtight building envelope, minimizing uncontrolled air changes while helping maintain desired indoor temperatures and maximizing the efficiency of HVAC equipment.

Third, AAC structures benefit from the added value of thermal mass and low thermal conductivity. Though an eight inch AAC wall has a steady state R-value of approximately 8.4, here in Sacramento, the same wall has an "effective" or "mass-enhanced" R-value of about 21.[8] The benefits of thermal mass, however, vary by

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[5] *See* Emerging Construction Technologies – Autoclaved Aerated Concrete, http://www.new-technologies.org/ECT/Civil/autoclaved.htm; Autoclaved Aerated Concrete- Manufactured Building Block Made of All Natural Materials, http://www.toolbase.org/TechInventory/techDetails.aspx?ContentDetailID=690

[6] *Id.*; PATH Case Study, *Autoclaved Aerated Concrete: Better Building Blocks Make Better Homes* (August 2006)

[7] *Id.*

[8] *See* Autoclaved Aerated Products Association, *Thermal Performance for AAC Block- Residential Application,* http://www.aacpa.org; Del E Webb School of Construction at Arizona State University, *A Comparison of Innovative Exterior Wall Construction Techniques*; Environmental Building News, *Thermal Mass and R-Value: Making Sense of a Confusing* Issue (April 1998)

location, and are greatest in regions where the outdoor temperature fluctuates above and below the desired indoor temperature over a 24-hour period.[9]

AAC Reduces Noise Pollution and Improves Indoor Air Quality

An additional quality contributing to the sustainability of a building product is its ability to reduce and absorb noise or to improve or maintain indoor air quality.[10] Due to its millions of independent air cells, which dampen sound transmission, AAC has excellent sound insulation and absorption qualities.[11] Because of this benefit, many of the first applications of AAC in the United States have been the construction of hotels and freeway sound walls.

Moreover, because AAC construction has very low air infiltration and is mold resistant, indoor air quality of AAC structures is improved relative to competitors. AAC's performance as both a structural and insulation material also eliminates the need for other materials (like fiberglass insulation) that may contribute to poor indoor air quality.

AAC Structures Are Well-Suited to Withstand Fires, Earthquakes, and Other Natural Disasters

AAC is inorganic, noncombustible, and virtually fireproof. It receives a 4 hour UL fire rating and has a melting point of over 2900 degrees Fahrenheit.[12] As a result, the use of AAC eliminates the need for additional fireproofing materials. Moreover, because AAC is completely inert, it does not emit toxic gases even when exposed to fire.

AAC buildings can be engineered for earthquake and hurricane prone areas, and such buildings have performed well to date. For example, the vast majority of AAC homes in the 1995 Kobe, Japan earthquake survived substantially undamaged.[13] They also were immune from fires started during the earthquake and even acted as firebreaks. The ability of AAC structures to withstand fires and natural disasters minimizes waste, contamination to the surrounding environment, and the need for repair materials, while also lowering insurance costs.

AAC Structures Are Price Competitive

AAC buildings constructed near a supplier's manufacturing facilities can presently be built at approximately the same cost as traditional timber-frame

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[9] *Id*.
[10] *See* Environmental Building News, *Building Materials: What Makes a Product Green*? (January 2000)
[11] *See* Autoclaved Aerated Products Association, http://www.aacpa.org; PATH Case Study, *Autoclaved Aerated Concrete: Better Building Blocks Make Better Homes* (August 2006)
[12] *Id*.
[13] *See* http://www.taylortradingco.com/installationguides/Taylor%20Trading%20AAC%20benefits%20&%20introduction%20with%20text/17.htm

construction.[14] Though AAC's light weight helps lower shipping costs, AAC construction becomes less cost effective the farther the building site is from a manufacturing facility. Even in regions where the cost of building with AAC may currently be higher than conventional building methods, this higher initial cost must be balanced against savings due to lower operating and maintenance costs, the structure's longer lifespan, lower initial outlays for required heating and cooling systems, and lower insurance costs.

By way of example, one AAC company reports that Costco has built several AAC buildings in the southern United States at an average of savings of $80,000 per building in initial costs and $60,000 in annual heating and cooling costs compared to its traditional concrete block buildings.[15]

DISADVANTAGES OF BUILDING WITH AUTOCLAVED AERATED CONCRETE

There are few disadvantages to building with autoclaved aerated concrete. First, there are currently only five AAC manufacturing facilities in the United States. As a result and as mentioned above, projects far from manufacturing facilities will suffer from higher initial costs. Both the costs and availability of AAC are expected to improve as AAC manufacturers invest in additional plants.

Second, building with AAC has a learning curve both with respect to the construction community as well as with local governments. Few contractors are a currently familiar with the product, and trained masons must adjust to using thin-set mortar as opposed to traditional cement-based mortar, which requires less precision in its application. Local building departments, design review boards, and planning commissions are also largely unfamiliar with AAC and must be educated with respect to the products ability to satisfy local building codes.

CONCLUSION

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.

Additional information can be found by consulting AACPA, the Autoclaved Aerated Concrete Products Association.

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[14] PATH Case Study, *Autoclaved Aerated Concrete: Better Building Blocks Make Better Homes* (August 2006)

[15] Safecrete - Costco Wholesale Testimonial, http://www.safecrete.com/testimonials/Taylor%20Trading%20Costco%20Testimonial/costco.htm