building blocks

Autoclaved Aerated Concrete

A New Tool in the Structural Engineer's Toolbox

By Keith Itzler, PE

For the first time, building code provisions for Autoclaved Aerated Concrete (AAC) are included in the 2005 MSJC Code (ACI- 530-05/ASCE 5-05/ TMS 402-05), in mandatory Appendix A. The inclusion of AAC in the MSJC Code is a significant milestone for AAC in the United States. It is the result of countless hours of engineering investigation, education, research, and industry effort.

AAC is a cementitious material that can be used in a variety of building applications. AAC provides many of the positive attributes of concrete masonry and precast concrete, particularly fire resistance, while at the same time providing a material that is easy to work with and very light weight. Its structural capabilities have been compared to timber.

The inclusion of AAC in the code now makes AAC a universally accepted structural material. To stay current in our practice, structural engineers should begin to learn about this material, and understand where it can be used effectively in our designs.

Autoclaved Aerated Concrete was invented in 1924 by Dr. Axel Eriksson (Sweden) in response to the shortage of timber that existed in Europe at the time. It has been used in all types of construction in Europe and around the world for over 75 years. The material is manufactured in block form, which can be used in load bearing wall construction, and in precast panels for floor or roof construction. AAC can also be used as a building cladding supported on a steel or cast-in-place concrete sub-frame.

AAC was introduced in the US approximately 12 years ago, and extensive research has been conducted by manufacturers to create national standards. Underwriters Laboratories (UL) fire ratings are available for the material, as well as a wide variety of test data describing physical properties. ASTM Standard C1386, *Precast Autoclaved Aerated Concrete (PAAC) Wall Construction Units*, ASTM Standard C1452, *Reinforced Autoclaved Aerated Concrete Elements*, and ASTM C1555, *Standard Practice for Autoclaved Aerated Concrete Masonry* have been published; and other standards are being developed by ASTM International. The masonry form of the material has been accepted by the ICC Evaluation Service Inc. (Report ER-6062), and numerous building designs have been completed throughout the country over the last decade based on local building official review and NER approval documents. The inclusion of AAC in the MSJC Code now makes relying on these special approvals unnecessary. ACI Committee 523a is also currently developing a design guide for the use of AAC floor and roof panel construction.

Impact on Building Systems

The choice of AAC in a structure impacts a number of building systems, ranging from load-carrying elements to how the building is heated and cooled. In selecting a structural system, the various choices should be reviewed and evaluated systemically, in the context of other building systems, for compatibility. In the case of AAC, drastically reduced building weight, superior sound and heat insulating properties, exceptional fire ratings, installation flexibility, and ease and speed of construction all come into play.

The many positive attributes of AAC stem from its constituent materials and its macroscopic structure. The raw materials used to manufacture AAC include sand, cement, lime, water, and gypsum. These materials are blended together to form a slurry, and aluminum oxide is introduced into the mix in the manufacturing process. Simplistically, the aluminum reacts with the cement creating a hydrogen gas. As the gas leaves the mix it causes the slurry to rise in its mold, similar to a cake rising in an oven. The slurry then hardens creating a cementitous product with air voids uniformly distributed throughout its volume. AAC's macroscopic structure is similar to that of closed cell foam with tiny air bubbles distributed throughout. To complete the process, the material is subject to a high pressure steam cure (autoclaving), which allows the AAC to gain strength and achieve volumetric stability.

Physical Characteristics

One of the most striking attributes of AAC is its extreme light weight. The density of AAC is less than one third that of conventional stone concrete, with common densities of approximately 35 to 40 pounds per square foot. This low density makes the material easy to handle and economical to ship; and has significant implications with respect to reducing building weight, overall dead load, and the seismic forces imparted on a structure's lateral force resisting system. As a specific comparison, an 8-inch thick AAC slab weighs approximately 30 pounds per square foot compared to an 8-inch thick hollow core slab weighing approximately 70 pounds per square foot. This is a reduction in dead load of over 50 percent.

AAC's cellular properties allow the material to act as an excellent insulator. From the standpoint of fire ratings, few materials can outperform autoclaved aerated concrete. Tests conducted by Underwriters Laboratories provide four-hour fire ratings for AAC walls that are as thin as four inches. Load-bearing floor panels that are six inches thick can also provide a four-hour fire rating.

As a building insulator in an exterior wall, mid-range densities of AAC provide a static R value of 1 to 1.25 for every inch of AAC material provided. An eight-inch thick AAC block wall provides a minimum R value of eight. This can be contrasted to conventional uninsulated concrete block, which typically provides an R value of approximately one for the same wall thickness. In addition to

Marriott Hotel, Lincoln, RI: AAC Floor Panels Supported on Light Gauge Metal and Steel Framing (Photo by Dewberry) static insulating properties, energy use studies taking into account the thermal mass properties of AAC have documented significant operational energy savings in buildings constructed of AAC.

As a building system, AAC is very compatible with a variety of finishing systems. The floor panels do not require a suspended ceiling. Floor panels may be "pop-corned," and walls may be painted, or skim coat plastered to render out visible joints. If desired, plaster quality finishes can be achieved. The AAC manufacturing process allows floor panels to be fabricated flat, without camber, eliminating the need for a topping slab. Properly grouted floors can accept pad and carpet and provide an acceptable floor without any preparation. For tile, glue-down carpet, and rolled floor coverings, only flash patching of the grout keys are required.

AAC qualifies as a "green" construction material. Composed of natural materials, it is non-toxic and environmentally safe. Waste fly-ash may also be incorporated into the mixture. AAC does not give off any harmful emissions during production. On a volume basis, the amount of energy consumed to produce AAC is two to three times less than other building materials.

AAC also has a green "cradle-to-cradle" life cycle. At the end of a building's useful life, AAC panels can be disassembled and reused; or when demolition is indicated, AAC debris can be pulverized and used in the manufacture of new AAC material.

Structural Design

The structural design of AAC is based on an ultimate strength approach. The new MSJC Code provisions for AAC mirror those of Chapter 3 of the 2002 MSJC Code, which specifies code requirements for the ultimate strength design of conventional masonry. Design formulas should be very familiar to structural engineers who have designed conventional masonry. As with concrete and other types of masonry, design parameters are calibrated to the compressive strength of AAC, f'_{AAC}.

A significant difference between AAC masonry and conventional masonry is the mortar that joins the block units. AAC masonry is laid with thin set mortar, and joint thickness is on the order of 1/16 of an inch. The thin set mortar, which is specially formulated for the AAC, provides a joint that is stronger than the AAC masonry units. Accordingly, the compressive strength of AAC is solely controlled by the strength of the units themselves.

Wire joint reinforcement is not required in AAC, nor can it be accommodated in the thin set mortar joints. The physical properties of AAC and testing on numerous shear wall test specimens indicated that the minimum prescriptive reinforcement usually required for conventional masonry is not required for AAC and is therefore not required by the MSJC Code provisions. Horizontal shear wall reinforcing, when required by analysis, can be provided by mild steel reinforcing grouted into bond beams.

AAC can be designed either reinforced or unreinforced. For unreinforced designs, the tensile bending strength of AAC is specified in the MSJC Code as 80 psi with upper bounds determined by mortar properties. Steel in reinforced AAC designs is identical to that used in conventional masonry. The usual bar sizes that are employed are #4 and #5, and typical bar spacing is either 24 or 48 inches on center in keeping with the two (2) foot module associated with AAC block. Grout should conform to ASTM C 476.

AAC Block Units

AAC Block Units are manufactured in accordance with ASTM 1386. AAC blocks are typically two (2) feet long and can be purchased in widths of two (2), four (4), six (6), eight (8), ten (10) and twelve (12) inches thick. Block heights are usually eight (8) inches tall in keeping with conventional masonry coursing, however, taller units are available in "jumbo" sizes. Three to four inch diameter holes, depending on the manufacturer, can be provided in blocks eight (8), ten (10) or twelve (12) inches thick. U-block bond beam units are available, and special shapes and cuts can be easily be fabricated in the field since AAC cut is cut and drilled with the same tools that cut timber.

A variety of strength grades are available for AAC ranging from AAC-2 with a compressive strength of 290 psi to AAC-6 with a compressive strength of 870 psi. The most common structural grade is AAC-4, which provides minimum compressive strength of 580 psi. Not all manufacturers can provide all the block grades, therefore designers should check with their local supplier to check availability.

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Typical Uses

As with any structural material, AAC's ability to be utilized in a project is dependent on a variety of factors including architectural design and layout, building location as it relates to wind and seismic loading, and general project loading and serviceability requirements. This caveat notwithstanding, several generalizations can be made about the potential application of AAC on projects, in order to provide structural engineers with reference points for concept designs.

In general, AAC can be used in most masonry applications and proves most economical in many situations in which dead load is a concern. This might include situations in which poor soil conditions dictate deep foundation systems, or the building configuration requires transfer of loads. An example of the latter might be a load bearing wall apartment building or hotel with parking on the lower level. Parametric studies have shown that considerable savings can be obtained at the transfer level where the loads supported by the bearing wall system are redirected to a column grid system compatible with the arrangement of the parking grid. Similarly, in building renovation or modification projects, AAC's light weight can prove very beneficial for vertical building expansion or to reduce floor loadings associated with dead loads.

SUNY at Stony Brook Graduate Apartments: AAC Masonry Walls and Precast Hollow Core Floors. (Photo by Dewberry)

When AAC floor systems are utilized in conjunction with AAC bearing walls, typical economical building heights are in the six-story range, or less. Where heavier floor systems, such as hollow core planks are incorporated into the design, typical maximum building heights would be about four stories. For seismic design, the value for R can be taken as 3.0, and the value for C_d may also be taken as 3.0. These values were developed at the University of Texas at Austin as part of a shear wall testing program and have been accepted by the ICC.

Exterior walls subject to wind loading usually require reinforced AAC. Typical spans for eight (8), ten (10), and twelve (12) inch thick field reinforced AAC walls are twelve (12), sixteen (16), and twenty (20) feet respectfully. In wall application factory reinforced panels can usually span about twenty (20) feet at an eight (8) inch thickness. The magnitude of the code specified wind loads and fenestration must all be considered in the final design as wall thickness and reinforcing levels are determined.

AAC can also be used for interior partitions similar to concrete masonry. Good impact resistance, fire ratings, sound attenuation properties and low mass have proven to be reasons to select AAC for partition construction. Guidance concerning the required thickness of interior AAC walls can be obtained from the MSJC Code following similar guidelines presented for concrete masonry.

As with any material, AAC also has limitations. In exterior applications AAC should be coated or covered. Direct applied stucco, siding or masonry veneer improve AAC's water resistance properties. Covering AAC also enhances the material's abrasion resistant and surface toughness characteristics which are relatively low compared to conventional concrete. In northern climates AAC is not recommended for foundation construction unless the material is waterproofed because of potential freeze thaw damage associated with water saturated AAC.

Summary

With its introduction into the 2005 MSJC Code, Autoclaved Aerated Concrete should continue to become a more popular construction material. AAC's success will depend on its acceptance by the architectural and structural engineering community, which is now presented with an opportunity to utilize this material. AAC is a unique product with properties that can be very advantageous to the development of future projects. The Autoclaved Aerated Concrete Producers Association (AACPA) and the International Masonry Institute (IMI) can provide more information and technical assistance.▪

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SUNY at Stony Brook Undergraduate Apartments: AAC Floor and Wall Panel Construction (Photo by Bob Zucker)