Autoclaved aerated concrete (AAC) is often called an ‘innovative new building material,’ despite being used in Europe for the past 70 years and in the United States for at least a decade and a half. Although AAC is on the market, gaining acceptance has been slow and painful—as is often the case for new products introduced into the U.S. construction industry.¹

However, autoclaved aerated concrete has two things going for it that could push it more into the mainstream. The first is the design provisions for AAC masonry developed by the Masonry Standards Joint Committee (MSJC), the nationally recognized code-writing group administered by The Masonry Society (TMS), and cosponsored by the American Concrete Institute (ACI) and the Structural Engineering Institute of the American Society of Civil Engineers (SEI/ASCE). Aside from some differences in ‘allowables’ and material properties, the MSJC provisions help ensure engineers familiar with traditional masonry are also able to build using AAC.

The second motivating factor that could increase the use of AAC is the current emphasis on sustainable, energy-efficient construction. As described throughout this article, autoclaved aerated concrete’s naturally insulating, fireproof, and sound-resistant characteristics make it a desirable building material for both commercial and residential construction.
Typical AAC Material Properties

<table>
<thead>
<tr>
<th>Strength Class</th>
<th>Specified Compressive Strength</th>
<th>Nominal Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAC 2.0</td>
<td>2.0 MPa (290 psi)</td>
<td>400 to 500 kg/m³ (25 to 31 pcf)</td>
</tr>
<tr>
<td>AAC 4.0</td>
<td>4.0 MPa (580 psi)</td>
<td>500 to 800 kg/m³ (31 to 50 pcf)</td>
</tr>
<tr>
<td>AAC 6.0</td>
<td>6.0 MPa (870 psi)</td>
<td>700 to 800 kg/m³ (44 to 50 pcf)</td>
</tr>
</tbody>
</table>

While lighter than other mass building materials (e.g., concrete or concrete masonry), AAC still has the thermal advantages of a massive material. (Figure 1 [page 42] shows its insulating and load-bearing capacities in comparison to similar materials.) It creates seamless, airtight walls that are virtually maintenance-free. As a structural material, AAC is most suitable for low- to mid-rise buildings. It has been used for churches, educational facilities, dormitories, hotels, multi-family housing, and single-family homes. AmeriSuites Hotels recently built two four-story hotels in Georgia using AAC because of its high fire resistance and sound insulation capabilities. Taller buildings have employed AAC panels over structural steel frames to take advantage of the material’s thermal mass and insulating properties. This author also knows of a recent New York City residential high-rise using AAC panels as cladding.

AAC basics

Autoclaved aerated concrete is a lightweight, cellular, concrete-like material that is plant-manufactured as blocks or panels for exterior and interior walls; panels are also used for floor and roof decks. The material’s density is less than 30 percent that of conventional concrete, although this means its compressive strength is similarly reduced. Nevertheless, AAC is produced as solid masonry blocks or large reinforced panels, and is more than able to provide buildings with both structure and insulation.
reinforcement, at least partially to provide strength during shipping, although this also contributes to their structural qualities. Panels, which typically have tongue and groove edges, can be oriented either vertically or horizontally for wall construction or laid flat as floor and roof panels.

All AAC blocks and panels are initially solid. Blocks to be reinforced are cored, either at the plant or onsite, to provide space for reinforcement. A building constructed with AAC typically needs no additional insulation, but its surfaces are generally finished. Exterior surfaces are usually coated with a breathable, polymer-modified stucco or paint—finishes are available in nearly any color or texture. Interior surfaces can be left uncoated or covered with wallpaper or gypsum board. The latter is attached to pressure-treated furring strips for exterior walls or directly to the AAC for interior walls.

**How to Specify AAC**

The accepted model specification for all masonry structures in the United States is the Masonry Standards Joint Committee’s (MSJC’s) *Specification for Masonry Structures* (TMS 602/ACI 530.1/ASCE 6). Beginning with the 2005 edition, it incorporates provisions specific to autoclaved aerated concrete (AAC) construction. As a standardized model specification for AAC panels is still under development by the American Concrete Institute (ACI), the manufacturers’ model specifications are currently the best resource.

Good model specifications for both autoclaved aerated concrete masonry units (Division 04 22 26) and AAC panels (Division 03 45 00) are also available from AAC manufacturers. For AAC masonry units, many of the specification provisions are listed below. In general, the requirements for panels are equivalent.

1. The compressive strength of the AAC ($f'_{AAC}$) should be specified based on the strength classes in ASTM International C 1386, *Standard Specification for Precast Autoclaved Aerated Concrete (PAAC) Wall Construction Units*. Density can also be specified to correspond to thermal, acoustic, or weight requirements.

2. Compressive strength and density are directly linearly related.

3. Cold weather practices should be specified. These include heating the AAC units to at least 4.4 C (40 F) before applying thin-bed mortar; this mortar reaches full strength faster than typical masonry mortar, but is also more sensitive to cold.

4. Hot weather practices should be specified, including spreading thin-bed mortar no more than 1.2 m (4 ft) ahead of the units and setting the units within one minute.

5. Thin-bed mortar, at no more than 3.2 mm (1/8 in.) thick, should be used for AAC masonry construction. This mortar is specifically formulated for AAC masonry and must have strengths higher than the units.

6. The first course of blocks is laid plumb in a 6.4 to 19.1-mm (¼ to ¾-in.) thick leveling bed of standard masonry mortar. All other joints are mortared full-face with thin-set using notched trowels with both head and bed joints approximately 1.6 mm (1/16 in.). For walls not designed to carry shear, head joints can be left unmortared.

7. AAC masonry should be laid in running bond with a minimum 152-mm (6-in.) overlap.

8. When AAC masonry is reinforced, the grout cells must be at least 76 mm (3 in.) square or 76 mm in diameter. Reinforcement must be completely encased in grout placed with a slump between 203 and 279 mm (8 and 11 in.).

9. AAC masonry walls should not be loaded sooner than 12 hours for uniform loads or three days for concentrated loads.
Contributing to sustainable construction
AAC is made primarily from sand and lime, two of the most abundant materials on earth. The manufacturing operation generates no direct pollution, is energy-efficient, and returns all waste material directly back into the process. The energy needed to produce a cubic meter of AAC (including raw materials, transportation, and manufacturing) is relatively low—about 1240 MJ (345 kWh).

As a building material, its light weight reduces foundation sizes and saves on transportation and construction expenses. The lower mass also reduces the lateral forces generated by earthquakes, as discussed later in this article.

The low density and air void system contribute to other properties, such as thermal and acoustic insulation. According to Richard E. Klingner, PhD, of the Department of Civil, Architectural, and Environmental Engineering at the University of Texas (UT) Austin, AAC walls “have a realistic R-value of at least 1 per inch with significant thermal mass and no thermal bridging.” These attributes allow AAC to serve as the entire insulation system for most buildings and can help a facility optimize energy performance.

The big advantage of AAC as a wall system is not just as insulation, but also as thermal mass. Solid AAC walls exposed on both sides minimize changes in interior temperature due to daily heating and cooling of the exterior, and allow reductions in heating and cooling requirements. With solid, airtight walls, AAC buildings allow no infiltration. The material can even absorb or release moisture to a room, diminishing swings in relative humidity.

The impact of thermal mass on R-value was investigated by the Del E. Webb School of Construction at Arizona State University. This resulted in the development of a factor known as the ’dynamic benefit of massive systems (DBMS),’ by which the static R-value is multiplied to provide an equivalent R-value, DBMS varies by climate (for example, 2.48 in Phoenix, Arizona, but only 1.48 in Minneapolis, Minnesota). Using this theory, a 203-mm (8-in.) AAC wall in Phoenix has an equivalent R-value of 20.8, while the same one in Minneapolis results in an equivalent R-value of 12.4.

AAC’s inherent properties also contribute to outstanding sound insulation and absorption—a typical 203-mm AAC wall has a sound transmission class (STC) rating of 50, meaning it reduces the transmission of sound through the wall by 50 decibels—much higher than for typical frame walls. AAC walls also have Underwriters Laboratories (UL)-tested fire ratings of at least four hours, slightly better than conventional concrete of the same thickness. AAC is mold-resistant, impervious to termites, and has no off-gassing of toxic substances.

Construction with AAC is simple and efficient, producing very little waste. Blocks and panels can be easily cut with hand tools or woodworking tools. What waste there is onsite can be used as fill or even reprocessed as an oil-absorbent material or cat litter.

Gary Burleson, a former concrete contractor in the Phoenix area, recently had his own home built with AAC masonry units. “The house is everything we expected and then some,” he says. “It’s incredibly quiet and our maximum summertime electric bill has been only $85 for a 4000-square foot house.” In comparison, estimates from the Salt River Project (one of Phoenix’s major utilities) project the average annual electricity expense for a similar wood-frame home to be more than $3000.

Designing AAC structures
Since AAC’s introduction into the United States in the mid-1990s, all buildings have been designed using engineering fundamentals or manufacturers’ design guides. Those may be adequate methods, but communicating them to designers and local building officials on a project-by-project basis is slow and costly.

In 1998, AAC manufacturers decided to augment their project-specific approach by a concerted effort to develop and work for the adoption of design and construction provisions for AAC through national consensus standards such as those developed through ASTM, ACI, the MSJC, and model codes. Although extensive research on the material had already occurred in Europe, manufacturers realized U.S. design and construction provisions would need to be homegrown, with the additional backup that would come from testing in the country.

The first step of the newly formed Autoclaved Aerated Concrete Products Association (AACPA) was to study the behavior of AAC structures as they would be used in the United States, and to direct that research to develop the technical justification for domestic design and construction provisions. Led by Klingner, this research began by testing shear walls built from AAC masonry units and panels.

“We tested shear walls built with AAC masonry units, and also with horizontal and vertical AAC panels,” explains Klingner. “Then we took the configuration that appeared to behave the least well—vertical panels—and used that configuration to build a two-story sub-assembleage.”

This building was subjected in the laboratory to simulated earthquake forces, allowing investigators to verify and refine the design provisions that had been developed based on the individual walls’ behavior.

Test results from UT Austin and elsewhere were converted directly to draft code language based on:
- the existing strength-design chapter of the MSJC Building Code Requirements for Masonry Structures (ACI 530/ASCE 5/TMS 402) for AAC masonry; and
- ACI 318, Building Code Requirements for Structural Concrete and Commentary, for reinforced panels.
The advantages of autoclaved aerated concrete (AAC) were highlighted by The New American Home, built in Orlando, Florida, as a model during the 2008 International Builders’ Show (IBS)—see the photo on page 40. The project’s focus was on sustainable construction as defined by the National Association of Home Builders’ (NAHB) Green Building Guidelines. Although not initially designed for AAC construction, when builder Robertson Homes considered the options for achieving sustainability objectives, it chose AAC for the majority of the walls.

The MSJC refined those drafts, approved them, and published them as Appendix A of the 2005 MSJC Code. That document, which has since been updated with a 2008 version, is a complete strength-design code for AAC masonry structures and elements. Additional information on the MSJC design provisions for AAC masonry is given in the fifth edition of the Masonry Designers’ Guide, published by The Masonry Society. Analogous design provisions for reinforced AAC panels are still being considered by the American Concrete Institute; in the meantime, manufacturers’ recommendations are available.

Test results, coupled with sophisticated nonlinear dynamic analysis, were also used to develop the following seismic design factors:
- \( R \) — the response modification coefficient; and
- \( C_d \) — the deflection amplification factor.

This pair of seismic design factors is important for U.S. designers, as most of this nation’s geographic areas have some seismic risk. The seismic design factors have been approved in the 2007 Supplement to the International Building Code, and are currently being considered by the National Institute of Building Sciences’ (NIBS’) Building Seismic Safety Council (BSSC) process for inclusion in ASCE 7, Minimum Design Loads for Buildings and Other Structures.

With this new design code, AAC masonry structures become straightforward to design and acceptable under the International Building Code (IBC) and the International Residential Code (IRC), since the MSJC Code is incorporated by reference. All load combinations of ASCE 7 apply and...
strength reduction factors ($\Phi$) are provided both for reinforced and unreinforced masonry.

With respect to reinforced AAC masonry shear walls, the 2007 *Supplement to the IBC*:

- has no restriction on their height in Seismic Design Category (SDC) A and B;
- limits them to 10.7 m (35 ft) in SDC C; and
- prohibits their use in SDC D and above.

“I am informed by colleagues the highest load-bearing AAC buildings are about seven stories,” says Klingner. “I believe the economic advantages of AAC run out at that height because of its compressive and shear strength—the walls need to be too thick. Seismic restrictions are also relevant. I have run design examples using the $R$ and $C_d$ values from the 2007 *Supplement*. Possibilities max out at three to four stories.”

**AAC construction**

Construction requirements for AAC masonry are provided in the *MSJC Specification for Masonry Structures* (ACI 530.1/ASCE 6/TMS 602). Requirements for reinforced AAC panels are provided in manufacturers’ recommendations.

Building with AAC is simple and efficient. The material is soft enough to be cut easily onsite with hand tools or bandsaws, although blocks and panels come from the plant with very tight tolerances so little cutting is needed. Construction is fast, since the blocks and panels are lightweight, yet large and easy to assemble.

AAC masonry units are laid similarly to other masonry, except using a polymer-modified thin-set mortar, like tile mortar. The units are placed in running bond with 1.5-mm (1/16-in.) joints (both head and bed) and 152-mm (6-in.) overlaps. After applying the mortar, a unit is positioned as close as possible to the adjacent unit before lowering onto the bed joint; it is then tapped into position with a rubber mallet. Reinforced AAC masonry units have cores cut through the blocks and are reinforced and grouted in the same way as reinforced concrete masonry. Panels are positioned by cranes with special handling clamps. Most panels have keyed joints and connections are reinforced and grout-filled to create a monolithic structure.

As with any unique system, finding experienced builders and labor can be difficult. To increase the pool of skilled masons who know how to build with AAC blocks, the International Masonry Institute (IMI) trains and certifies professionals in AAC construction.

“Contractors are getting involved and bidding it,” said Northern Ohio IMI representative Bob Fozio, who hosted a recent training session for more than 100 participants.

Burleson cautions getting the right contractor is important.

“I think AAC is a wonderful product, but the contractor we had was understaffed and under-experienced. That caused a lot of headaches and we’ve had some cracking in the exterior stucco, which I think is due to workmanship, not the product. I don’t think he properly applied the thin-set.”
As with any building material, proper installation is critical to performance.

Cost considerations
In terms of material costs, autoclaved aerated concrete is not a low-priced system. However, its other advantages—including speed of construction—often outweigh the premium. The price of AAC wall panels 203 mm (8 in.) thick with normal reinforcing is $65 to $70/m² ($6 to $6.50/sf), plus shipping. If heavy reinforcing is used (such as with panels that will be subjected to higher bending stresses due to lateral or eccentric axial loads), then another $11/m² ($1/sf) is added.

Further Resources
For more information on autoclaved aerated concrete (AAC), the manufacturer should be consulted—many have extensive technical information on their Web sites. Further data on the Masonry Standards Joint Committee (MSJC) administered by The Masonry Society (TMS) with co-sponsorship by the American Concrete Institute (ACI) and the American Society of Civil Engineers (ASCE) is available through www.masonrystandards.org.

The Autoclaved Aerated Concrete Products Association (AACPA) has links to technical information and suppliers. Visit www.aacpa.org. The Portland Cement Association’s (PCA’s) site (www.cement.org) also has information on the material. Also, see PCA’s residential site at www.concretehomes.com.

AAC panels have at least twice the material cost of concrete masonry units (CMUs) or AAC units, but provide significant labor- and time-savings on the right type of project. In one day, a five-person crew with a crane can install 75 to 100 single-story wall panels (e.g. 0.6 x 3.0 m [2 x 10 ft]). Experience has shown using AAC panels instead of masonry can cut four to five weeks off a typical four-story hotel project. Still, depending
on local labor rates, the installed price for panels could be approximately five to 15 percent higher than for ‘block.’

The cost benefit for panels come from reduced project time and savings in loan interest, along with earlier access for other trades and earlier occupancy. If project time reduction is not a factor, then AAC blocks are probably more cost-effective than AAC panels. That said, panels are better than block at resisting high-wind loads, since the reinforcement is placed near both faces of the panel, whereas with block of any type the reinforcing is essentially in the wall’s center. The added reinforcing steel and grout cells in CMU construction can add substantial cost (i.e. material and time) often unanticipated when general comparisons are made.

Another savings possibly overlooked is the foundation. An AAC structural shell weighs at least 60 percent less than one designed with other masonry or concrete materials. This translates into significant material savings with a smaller foundation, a lower risk of settlement, and reduced seismic loading.

Autoclaved aerated concrete has had a long, successful history as a sustainable building material long before anyone had ever heard of green buildings. As U.S. codes and construction expertise with AAC masonry units and panels advance, and demand for more sustainable structures increases, this material will likely claim an important role in the design of low- and mid-rise structures.