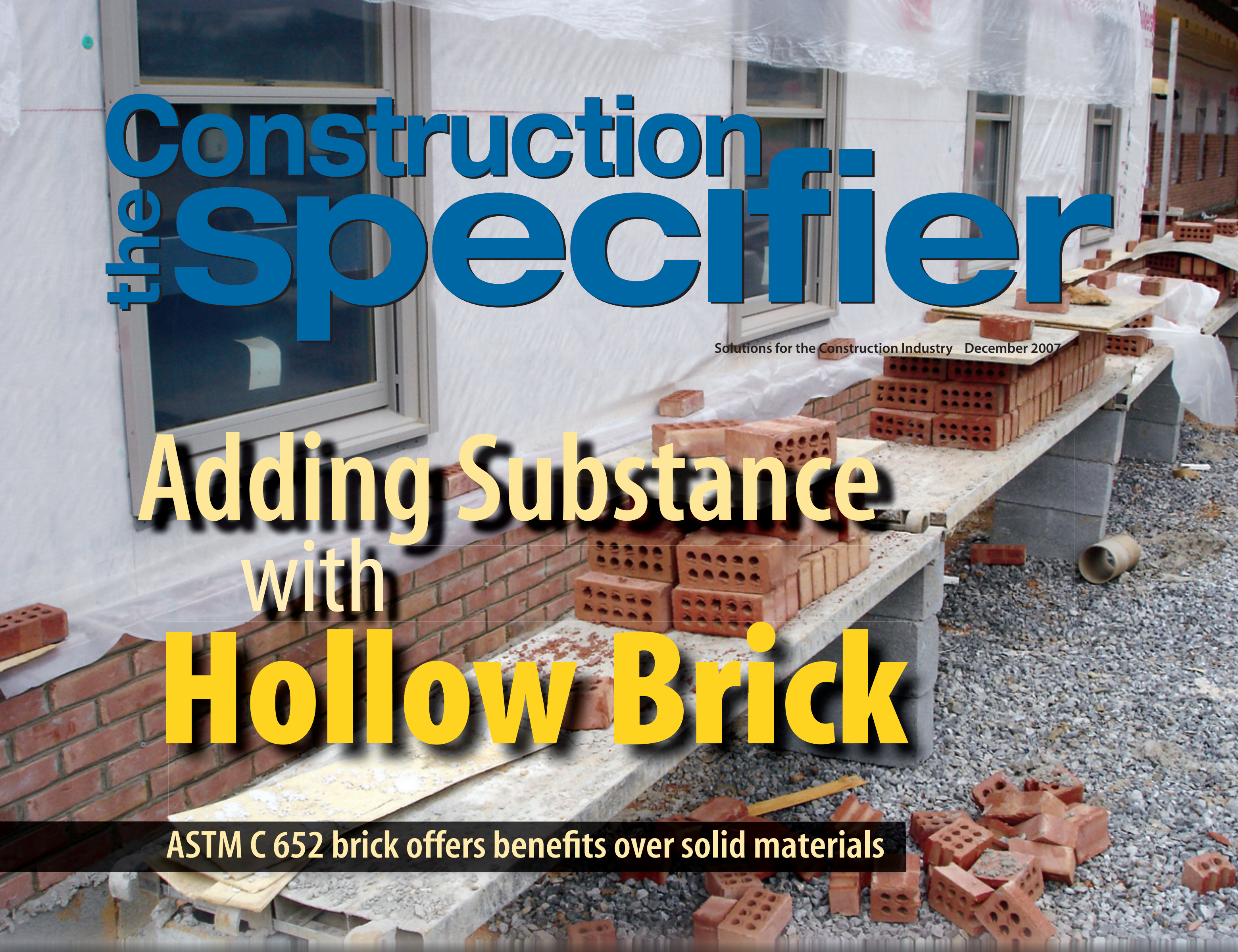
the Construction Specifier
Solutions for the Construction Industry December 2007



All photos courtesy General Shale Brick

Adding Substance with Hollow Brick

ASTM C 652 brick offers benefits over solid materials

by Richard M. Bennett, PhD, PE, Richard M. Kelso, PhD, PE, and Jim Bryja, PE, SE

One of the oldest building products in the world, brick remains a popular and durable wall covering. However, its use has taken on new meaning as design professionals specify and incorporate environmentally responsible construction that considers appropriate use of natural resources.

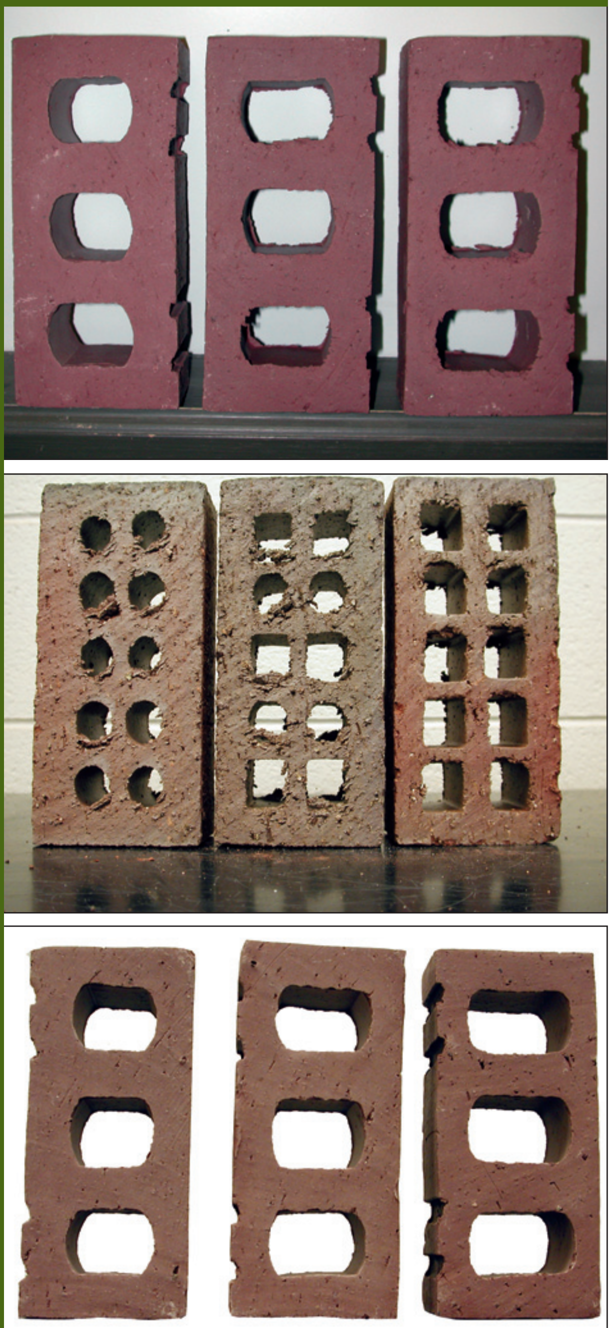
Simply put, brick is fired clay that does not deplete natural resources. It is typically manufactured regionally, minimizing transportation distances to job-sites. In cases where it is transported significant distances, brick is often shipped by rail, which increases efficiency and reduces fuel requirements.

Recycled from old brick or culled from the manufacturing process or construction site, this material can be ground up and used for landscaping chips and brick dust. It creates no hazardous waste and is durable, producing a long product life with very little maintenance requirements.

Brick can contribute to a building's indoor air quality (IAQ), eliminating the need for paint or adhered finishes, and thereby reducing volatile organic compounds (VOCs) and lessening the potential for mold growth. A structure's fire safety and impact resistance can also be increased with brick, which does not emit toxins when exposed to fire. Additionally, this material provides thermal mass, reducing energy requirements by slowing the transfer of heat and cold.

While brick have typically been 'solid' units, ASTM International specifications currently allow up to 25 percent coring. However, manufacturers are increasingly producing hollow brick exceeding this amount. This article examines this building material, including its physical properties and performance, and specification to enhance a project's sustainable design.

Figure 1



ASTM International C 43, Standard Terminology of Structural Clay Products, *recognizes both facing and hollow brick. In the top photo, ASTM C 216 solid brick with 25 percent coring is on the left, standing next to C 652 hollow brick (28 and 32 percent coring). In the middle photo, ASTM C 216 solid brick (22 percent coring) can be seen along with C 652 hollow brick (30 and 34 percent coring). The bottom photo features ASTM C 216 solid brick (24 percent coring) and another two C 652 hollow brick products (29 and 32 percent coring).*

ASTM C 216 and C 652 specifications

ASTM C 43, *Standard Terminology of Structural Clay Products*, defines brick as a:

> solid or hollow masonry unit of clay or shale, usually formed into a rectangular prism while plastic and burned or fired in a kiln. Facing brick is defined as brick for general purposes where appearance properties such as color, texture, and chippage are important; see Specification C 216 (*Standard Specification for Facing Brick [Solid Masonry Units Made from Clay or Shale])* and Specification C 652 (*Standard Specification for Hollow Brick [Hollow Masonry Units Made from Clay or Shale]).*

This ASTM definition recognizes both C 216 and C 652 brick as facing bricks. Figure 1 shows both.

Brick have typically been manufactured to meet ASTM C 216. While they are called 'solid' brick, these products can have from three to 10 holes, and up to 25 percent void space.

Governed by ASTM C 652, hollow brick is classified as H40V or H60V. The former has void areas greater than 25 percent, but not greater than 40 percent, while the latter has void areas greater than 40 percent, but not greater than 60 percent. This article only addresses H40V brick, which is the typical hollow brick used for veneer construction. (H60V brick is generally specified only in reinforced, structural brick construction.)

The requirements for ASTM C 216 and C 652 brick are very similar. Both are manufactured in two grades—SW (severe weathering) and MW (moderate weathering). The requirements in the two specifications for meeting grade SW are identical.

There are three types of ASTM C 216 brick:

- FBS, which is facing brick for general use;
- FBX, which is facing brick with a higher degree of precision and lower permissible variation than FBS; and
- FBA, which is facing brick with a characteristic architectural effect resulting from non-uniformity in size and texture. (The letter suffixes S, X, and A indicate features related to appearance.)

Similarly, there are three similar types of hollow brick: HBS, HBX, and HBA. The dimensional tolerances, chippage ranges, and tolerances on distortion are the same for hollow and solid materials.

As previously mentioned, ASTM C 216 solid brick can have up to 25 percent coring, with no part of any hole less than 19 mm (0.75 in.) from any edge of the brick. Hollow brick can have both cores and cells, where the former is defined as a void space equal or less than 968 mm^2 (1.5 si) and the latter is greater than 968 mm^2. Cells cannot be situated less than 19 mm from an exposed edge. On the other hand, cores can

Figure 2

Material type	Minimum required equivalent thickness for fire resistance			
	One hour	Two hour	Three hour	Four hour
Solid brick of clay or shale	2.7	3.8	4.9	6.0
Hollow brick of clay or shale, unfilled	2.3	3.4	4.3	5.0
Hollow brick of clay or shale, grouted or filled with approved material	3.0	4.4	5.5	6.6

be 3.2 mm (0.125 in.) closer to the edge, or not less than 15.9 mm (0.625 in.) from an exposed edge.

Voids for hollow ASTM C 652 brick are in the 30 percent range for typical brick veneers, as opposed to the current 24 percent for solid ASTM C 216 brick. This reduces the brick's weight. Hollow, modular-size brick weighs about a third of a pound less than modular solid brick, while hollow, engineer-size brick weighs about half-pound less than solid engineer brick.

Hollow brick's physical properties

The National Brick Research Center (NBRC) examined the physical properties of six different brick types.[1] Researchers compared a hollow and solid brick of each type, studying properties such as compressive strength, flexural bond strength, cold water absorption, boiling water absorption, C/B ratio (*i.e.* cold water to boiling water absorption ratio), and the initial rate of absorption.

The study concluded there was no significant difference between the properties of the hollow and solid brick of each type. It also found hollow brick can be expected to behave similarly to its solid counterpart in terms of its durability and structural performance properties.

Fire resistance

The fire rating of masonry is determined based on equivalent thickness, meaning the brick thickness multiplied by the percent solid. For a given actual thickness, a hollow brick will have a smaller equivalent net thickness than a solid brick. However, codes allow a higher rating per equivalent thickness for a hollow brick than a solid one. This is based on actual testing and the fact air is an excellent insulator. Figure 2 lists fire resistance from the 2006 *International Building Code (IBC)*.

Consider an ASTM C 216 solid brick (actual 25 percent coring) with a typical thickness of 88.9 mm (3.5 in.). The equivalent thickness is 0.75 *x* 88.9 mm=66.7 mm (0.75 *x* 3.5 = 2.62 in.) or approximately a one-hour rating. A hollow brick with 30 percent voids and the same actual 3.5-in. thickness would have an equivalent thickness of 0.70 *x* 88.9 mm = 62.2 mm (0.70 *x* 3.5 = 2.45 in.). This gives a fire rating of 1.14 hours, or greater than ASTM C 216 brick. The hollow brick can have as much as 34 percent coring and still produce the same fire rating as the ASTM C 216 brick. Thus, most hollow brick slightly improve a wall's fire rating.

Thermal performance

Brick veneer walls are known to increase the thermal performance of structures due to their mass. Thermal mass has the desirable properties of reducing the amplitudes of heat transfers through building sections under real-world, dynamic conditions, as well as delaying them. Experimental work and monitoring of test structures has shown brick veneer structures save heating and cooling energy.[2]

The enhanced energy performance of brick veneer structures comes from two sources. One is a brick's mass and the other is its insulating value and cavity. Obviously, reducing

Hollow brick does not mean empty performance. An ASTM C 652 brick with 33 percent coring has a 43 percent greater thermal resistance than a non-cored masonry unit.

a brick's mass by increasing the coring would reduce its thermal mass benefits. However, hollow brick have better insulating properties than their solid counterparts due to the air in the voids. A standard ASTM C 216 brick with 25 percent coring has a 27 percent greater thermal resistance than a non-cored brick. An ASTM C 652 brick with 33 percent coring has a 43 percent greater thermal resistance than a non-cored brick, or a 12 percent greater thermal resistance than an ASTM C 216 brick.

Simulation of the energy use of buildings—in locations such as Chicago, Washington, D.C., and San Francisco—has shown virtually identical thermal performance in ASTM C 216 and C 652 brick. In other words, increased thermal resistance offsets the decrease in thermal mass and the use of hollow brick does not reduce the known energy benefits of brick.

Specifying hollow brick in a project does not entail far more mortar. While studies show a slight increase in mortar when compared to solid brick, it remains within normal tolerances and the industry's standard estimate.

Construction with hollow bricks

One question raised over specifying hollow brick in a project is the potential for increased mortar use. Studies performed at NBRC and by a brick manufacturer showed a slight increase in use of mortar with hollow brick versus its traditional solid counterpart.[3] However, the research also showed mortar usage was within normal tolerances and the industry's standard estimate of seven bags of mortar per 1000 brick. Therefore, there is no need to use additional mortar when installing hollow brick.

Another question that has been raised is the moisture penetration resistance of walls constructed with hollow brick versus a solid material. ASTM E 514, *Standard Test Method for Water Penetration and Leakage Through Masonry*, showed no significant differences in water leakage between hollow and solid brick walls.[4] The most important factor in reducing permeability is workmanship, irrespective of the masonry unit type.[5] Modern-day cavity drainage wall construction also provides excellent moisture resistance, even if water penetrates the brick wall.

Hollow brick's reduced weight makes it easier on the laborer and the mason. The coring percentages with hollow brick are not sufficiently large to require face shell bedding. The mason can easily make a full bed with furrowed mortar, identical to current construction practice. In other words, hollow brick can be laid in the same manner and with the same productivity as solid brick, with the lighter weight helping reduce installer fatigue.

Hollow brick construction results in wall coverings with less mass, which is of benefit in seismic and structural design. The force in seismic design is directly proportional to the mass—a reduced mass results in a smaller force. With more municipalities across the country adopting seismic codes, including areas where seismic design is not required, the use of hollow brick will be advantageous. The lighter weight also reduces the load on foundations, lintels, and shelf angles.

Environmental benefits of hollow bricks

In the National Home Builders Association's (NAHB's) *Green Home Building Guidelines*, seven guiding principles to achieve responsible resource-efficient construction are outlined.[6] Under the second—Resource Efficiency—hollow brick is specifically mentioned:

> When specifying materials, consider the amount of resources going into the product and whether other alternatives are available. Examples are specifying hollow brick that meets the requirements of ASTM C 652 and is made from less material than face brick that meets ASTM C 216.

The National Institute of Standards and Technology's (NIST's) Building for Environmental and Economic Sustainability (BEES) program is a systematic methodology for selecting building products achieving a balance between environmental and economic performance. As its name suggests, BEES has two aspects–environmental and economics. The former is quantified based on an environmental lifecycle assessment (LCA); the latter is measured using a lifecycle cost approach. The two performance measures are synthesized into an overall performance measure using a multivariate decision analysis approach.

Projects incorporating hollow brick can reap the benefits of not only cost efficiencies, but also reduced material waste and other sustainable factors.

Hollow brick can be laid in the same manner and with the same productivity as its solid counterpart, with the lighter weight helping reduce installer fatigue.

A brick's weight is an extremely critical value for this program. The functional unit in BEES is a square foot of wall surface. Most data (*e.g.* emissions and energy) are given in terms of per pound of brick. Thus, the weight of a square foot of wall surface is crucial. Every pound of brick saved equals a reduction in the impact on the environment. Brick is fired to lower absorptions with the increased coring. Emissions standards and limits set by the U.S. Environmental Protection Agency (EPA) are based on tons per hour. Lighter brick allow a manufacturer to make more units for a given amount of emissions. The lighter weight also means less fuel for shipping.

Selection of face brick as an exterior material can help projects earn points under the U.S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED). For example, Materials and Resources (MR) Credit 5, *Local/Regional Materials,* awards points for the use of materials extracted and manufactured within 805 km (500 mi) of the construction site. Brick is manufactured in many plants across the United States and can often help a project meet the 10 or 20 percent ratios needed.

Lighter weight hollow brick enhances this availability by requiring less energy to transport. The typical flatbed truck can haul 26 cubes of ASTM C 652 brick as compared to 23 cubes of ASTM C 216 brick, an 11 percent savings per trip.

Energy and Atmosphere (EA) Credit 1, *Optimize Energy Performance*, awards up to 10 points for energy use below the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) 90.1, *Energy Standard for Buildings Except Low-rise Residential Buildings*, minimum for commercial buildings. A 10.5 percent reduction earns one point, while 42 percent earns 10 points.

The largest energy user in buildings is typically the heating and cooling system. A significant portion of this energy goes toward replacing heat lost in winter through walls and, similarly, to remove heat gained in the summer. It is generally recognized massive materials (*e.g.* brick) in walls mitigate heat flow by absorbing, storing, and later releasing some of the heat back to the exterior.

One might question whether the smaller mass of ASTM C 652 brick reduces this storage effect as compared to ASTM C 216 solid brick. While it does (to a small extent), hollow brick's air-filled cores offset this reduction. Heat conduction through brick is greatest through solid material, and less through the cross-section were cavities occur. Thus, the thermal performance of hollow brick walls is comparable to those constructed of solid brick. In these authors' experience with automated energy modeling, the use of hollow brick is a positive factor in reducing heat flow and thus energy use, helping to earn a point under EA Credit 1.

Conclusion

As detailed in this article, manufacturers are increasingly producing ASTM C 652 hollow brick. This building material is often available in the same sizes, types, colors, and textures as ASTM C 216 brick. Additionally, hollow units retain the same performance characteristics that have made solid brick a popular and durable wall finish for many years. Hollow brick offer additional advantages that enhance a 'tried and true' and already sustainable product.

Notes

[1] See J.P. Sanders' "The Effect of Void Area on Wall System Performance," published in 2006 at the National Brick Research Center of Clemson University.

[2] See the authors' "Thermal Performance of Hollow Brick Veneer Walls," presented at the 10th North American Masonry Conference in St. Louis, Missouri (June, 2007).

[3] See note 1.

[4] See note 1.

[5] See C.C. Fishburn et al's "Water Permeability of Masonry Walls" (Building Structures and Materials, Report BM87, United States Department of Commerce.) Also, see C.T. Grimm's "Water Permeance of Masonry Walls: A Review of the Literature," within *Masonry: Materials, Properties, and Performance,* an ASTM Special Technical Publication (1987).

[6] See National Home Builders Association's (NAHB's) *Model Green Homebuilding Guidelines* (2006).

Additional Information

Authors

Richard M. Bennett, PhD, PE, is professor of civil and environmental engineering at the University of Tennessee (UT), Knoxville, Tennessee, and has 24 years of experience. He is a member of ASTM International Committee C 15 (Manufactured Masonry Units), and chair of the Flexural and Axial Loads Subcommittee of the American Concrete Institute (ACI) 530 Masonry Standards Joint Committee (MSJC) Building Code Committee. Bennett is a registered professional engineer and regularly teaches masonry design. He can be contacted via e-mail at rmbennett@utk.edu.

Richard M. Kelso, PhD, PE, FASHRAE, is a professor at both the School of Architecture and the College of Architecture and Design at the University of Tennessee. He has retired from Kelso-Regen Associates, where he was a principal for 25 years. Kelso is a Fellow in the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) and has been nominated to the ASHRAE Board of Directors. He can be contacted via e-mail at rkelso1@utk.edu.

Jim Bryja, PE, SE, is manager of engineering services at General Shale Products Corp. (Johnson City, Tennessee), and has more than 30 years of experience in civil engineering. He actively participates in ASTM standards committees and the ACI 530 MSJC Building Code Committee, along with *International Building Code (IBC)* and *International Residential Code (IRC)* building code development. Bryja chairs the National Brick Research Center (NBRC) Wall Systems Committee at Clemson, South Carolina. Bryja is a registered professional engineer in 18 states and a registered structural engineer in Illinois. He can be contacted via e-mail at jim.bryja@generalshale.com.

MasterFormat No.

04 21 00–Clay Unit Masonry

UniFormat No.

B2010–Exterior Wall Construction

Key Words

Division 04
ASTM International
Facing brick
Hollow brick

Abstract

This article examines the unique aspects of hollow brick, along with their physical properties and performance, environmental benefits, and specifications to enhance a project's sustainable design.