Designing With Glass Block: Abundant Applications Provide Practical, Aesthetic and Green Solutions

Glass block is a unique building material. It has a dynamic relationship with light—both natural and artificial. As light changes so do the material’s appearance and the surrounding environment. A great range of light and privacy is available depending on the pattern and transparency of the glass block. Used creatively, this building material can produce dramatic aesthetic effects.

The transparency of light depends on the pattern of glass block used. The results range from maximum light transmission to increasing degrees of privacy. Even with the most opaque block, or when using glass blocks as accent pieces, the result is the same—a visual connection from inside to out, or connecting to inside spaces. This sensory stimulant offers more than just aesthetics—it is considered a necessary component of a psychological and physiological healthful living and working environment. This brick made of glass also provides energy efficiencies, sound control, security and even visual texture. Today, with the growing commitment to green building, its properties and benefits may contribute to U.S. Green Building Council (USGBC) LEED® (Leadership in Energy and Environmental Design) certifications.

Glass block can be used in residential as well as commercial projects, as non-load bearing walls, windows, or partitions. An astonishing range of applications is possible with a corresponding variety of aesthetic results. Glass block have been used in police stations, subway terminals, schools, parking garages and gymnasiums, in addition to numerous private and commercial new construction and renovations. Consider some interior uses: as a contemporary shower stall, a kitchen island or backsplash, or as the sidelights at the front door. Yet, before building aesthetics and even...
design can be considered, it is crucial to become familiar with the technical properties of glass block. Working with glass block requires a certain level of skill and a thorough understanding of the material.

**Structural Properties**

Glass block is manufactured through a simple, yet exacting process. Silica sand, soda ash, and limestone are mixed and melted in tanks heated to 2,300 degrees Fahrenheit. From those tanks a precise amount of molten glass is poured into a half-block mold. Two halves are sealed together, creating a partial vacuum within the unit, and then fed into an oven (called a lehr) to slowly cool and, in the process, strengthen. This is the annealing process. Each block is then treated with a special edge coating of polyvinyl butyral to increase mortar bond and allow for expansion and contraction. Each block is tested for clarity and consistency.

The unit can be hollow or solid and come in a variety of sizes, shapes, patterns, and textures. The most commonly used units are square (6-, 8-, or 12-inch sizes). Rectangular units (4x8-inch and 6x8-inch) are also available, as are bull-nosed edge blocks for finishing horizontal and vertical panels, and various corner and angular blocks.

What makes the choice of block all the more interesting is the wide range of patterns. Clear block with its smooth face offers high visibility and light transmission. Wavy and fluted patterns allow for moderate levels of visual privacy while maintaining high light levels. Even greater privacy comes with stippled, diamond, and tightly ribbed designs. Fibrous glass inserts are also available to provide maximum privacy and further temper light and heat transmission.

Since glass block is made of glass and typically bonded together with mortar, it does not require any maintenance or special care. The durability is therefore exceptional because of the thickness of the faces and mortar bonding of the blocks. Unlike a typical glazing system or window, whereby the whole glass pane requires replacement upon damage, breakage in a glass block wall or window typically only requires a single block replacement. Many installations are over 50 years old, well beyond the typical life cycle of a window. This represents a considerable savings in material and maintenance.

Generally, two thicknesses are available. The standard 3-7/8-inch glass block includes the largest selection of patterns, sizes and shapes. Each 3-7/8-inch thick glass block is designed to provide stability and durability, as well as good insulation values, sound transmission, and fire resistance ratings. Thinner 3-1/8-inch block is specifically designed for prefabricated panels of limited size, for use as windows.

In exterior applications, maximum wall areas are based on design wind pressure. Twenty pounds per square foot is a commonly accepted value for wind load resistance for wall construction. The maximum area for exterior panels constructed of standard block is 144 square feet, with a maximum height of 20 feet or a maximum width of 25 feet. This panel is designed to withstand a 20 psf wind load—equivalent to about an 88-mph wind—with a 2.7 safety factor. If larger panels are required, horizontal and/or vertical stiffeners or shelf angles and expansion joints need to be incorporated to maintain the maximum areas recommended per component panel. Design of these structural members must be based on the design wind load and to an L/600 deflection (where L equals the distance between supports).

Interior walls are designed to a lateral load of 5 psf. Interior glass panels are permitted to be larger (up to 250 square feet) than similar exterior panels because of the lower load levels.

**Non-load bearing.** Sometimes referred to as “bricks,” glass blocks do not have the load-bearing capabilities as do other masonry products. In fact, glass block can only carry the load of its own weight. Therefore, where panels are inserted into openings, provisions must be made to support the construction above. The available structural support systems assure that the load from the surrounding wall is not transferred to the glass panel and that the possible deflection of the supporting members does not crack the panel.

At the same time, adequate provisions must be made for differential movement between the glass and the surrounding wall. It is recommended that expansion joints in the surrounding wall be located at the sides and top of each glass panel. This will isolate the panel and prevent a movement crack in the wall from projecting through the glass panel.

**Mortar considerations.** Unlike other masonry products (i.e., brick, concrete block, etc.), glass block is non-porous and does not absorb any moisture. Because of this, the consistency of glass block mortar must be stiffer (like peanut butter) than the wetter mortar used with other masonry products. All head and bed joints must be completely filled with mortar, and all joints struck smooth to prevent penetration and migration of moisture.

All model building codes allow the use of Type “S” or “N” mortar with glass unit masonry construction. Type “S” mortar is recommended for exterior applications. Type “S” consists of 1 part Portland cement, 1/2 part lime, and sand equal to 2-1/4 to 3 times the amount of cementitious material (cement plus lime), all measured by volume. (For exterior glass block panels, an integral type waterproofer is recommended.) No antifreeze compounds or accelerators should be used.

During final cleaning, common mortar-removing chemicals (muriatic acids of any strength) should not be used. Not that these chemicals are detrimental to glass; however, if they are strong enough to remove mortar off the faces of the block, they are also strong enough to remove the thin cement/lime film off the mortar joints, thereby exposing the sand aggregate. Rough joints such as these are highly susceptible to water intrusion.

**Panel reinforcement.** Horizontal joint reinforcement is important to control cracking due to expansion and contraction. This joint reinforcement should be spaced no more than 16 inches...
Joint reinforcement should also be placed in the bed joint immediately above and below openings in the glass block panel. For curved walls, the inner wire is cut periodically so the reinforcement can be bent to the radius of the curve. The reinforcement is pressed into the partially filled mortar joint, then covered with the remaining mortar and trowelled smooth. Mortar joints should not be furrowed.

Expansion strips, made of dense fibrous glass, polyethylene, or mineral wood replace mortar at the jambs and head and at intermediate structural locations to allow for panel expansion and contraction.

**Panel anchoring.** Three methods for anchoring glass block panels are recommended to accommodate lateral support along the top and sides of each panel — panel anchor, channel, and chase systems. These supports are designed to resist the applied loads, or a minimum of 200 pounds per lineal foot of panel, whichever is greater.

**Panel anchors:** Available in stainless steel or hot-dipped galvanized steel, panel anchors tie glass block panels into the surrounding frame at head and jamb locations. Anchors are used along the jambs and at the head, or they can be used in combinations with channel construction where one type of detailing is at the jambs and the other at the head. Anchors are normally placed a maximum of every 16 inches on center. This means that for an 8 x 8-inch block, panel anchors would be placed in every other course.

**Channel framing:** Either a metal channel or metal angles combined to form a channel can be used. The channel opening (for a nominal 4-inch-thick block) must be 4-1/4 inches to 4-1/2 inches wide by a minimum of 1-3/8 inches deep to allow for a 1-inch minimum recess of glass block into the channel and for placement of the expansion material inside the channel. It is critical that the channel opening be square, not tapered as in standard channels, so as not to pinch the edges of the glass block. The oversized opening allows the insertion of packing material and sealant between the recessed faces of the glass block and channel legs.

**Chase method:** A recessed chase can be inserted into concrete or masonry jambs and head, eliminating the need for anchors or metal channels. The dimensions described must be similar to those described above for metal channels.

**Expansion joints.** To accommodate movement of the glass, expansion strips 3/8-inch thick, are required along the top and sides of glass block panels. These joints are filled with a resilient material such as polyethylene, which allows the panel to expand and contract. In exterior walls, joints must be well caulked to prevent water penetration.

At the bottom of the opening, a water-based asphalt emulsion is placed on the sill prior to laying the first mortar bed. This provides a slip plane for the panel and also prevents water from being drawn out of the glass block mortar by absorbent sill materials, such as concrete, brick, wood, or other porous products.
Curved walls. Curved panels require additional structural support where the curved section joins a straight section and at inflection points in multi-curved walls. One method is to connect the panel to a structural member with panel anchors. Installing a steel plate in a vertical head joint can provide a less visible support. Also, panel reinforcing should be modified to follow the contour of the curve by periodically cutting the innermost parallel wire and bending appropriately.

The inside minimum radius of a curved wall is influenced by the size of block being used. Creating a tighter curve means creating a thinner inside joint, which is not recommended, and a thicker outside joint, which may not be aesthetically pleasing.

Health, Safety and Environmental Benefits
The unique properties of glass block are especially applicable to health and safety issues, in addition to providing a number of environmental advantages. They offer special performance characteristics regarding fire resistance; resistance to surface condensation, light, heat, thermal and shading performance; sound transmission; and hurricane and earthquake resistance. Equally significant is the potential role in green building and contribution to several categories in LEED certifications—both in quantifiable and qualitative measures.

Green building now includes far more than data and performance of building products. Occupants’ comfort and well-being and factors such as daylight are critically important for Green Building—especially when designing for the unique needs of children of all ages. Another factor in Green Building is life cycle analysis, which quantifies the impact of a product or building from raw materials used through its disposal or reuse. While life cycle analysis is, as yet, hard to quantify, it is certainly an issue to consider when specifying green products. Glass block has the advantage of having a relatively low life cycle impact, being both recyclable and manufactured from unlimited natural resources. Moreover, being 100 percent glass, it does not emit any harmful volatile organic compounds (VOCs).

Fire-protection. Presently, no glass block assemblies qualify as fire-rated wall assemblies. Unlike the wall assembly test that measures a material’s integrity, stability and thermal transmission, the glass block window test only determines the ability of the assembly to remain structurally sound and prevent passage of smoke and other noxious fumes during the fire test. Therefore, all assemblies must meet standards set for windows (ASTM E-2010 and NFPA 257) rather than for walls (ASTM E-119).

All UL fire-rated glass block on the market meets a 45-minute or longer duration test. Thicker faced and solid units are available with ratings of 60 minutes and 90 minutes. Basically, the window assembly test consists of exposing a panel to a fire under controlled temperature conditions in a furnace. The panel is removed from the furnace after 45 (or 60 or 90) minutes and immediately subjected to a standard water hose steam test to determine impact and thermal shock effects. A glass block window assembly passes the hose stream test if at least 70 percent of its glass blocks do not develop openings through both faces of the block.

Lloyd Hall, Boathouse Row, Philadelphia, PA
Sited along Boathouse Row in Philadelphia, PA, Lloyd Hall was expected to serve a variety of needs. Funded jointly by the Commonwealth of Pennsylvania and the City of Philadelphia it also needed to be durable enough to withstand the rigors of a demanding public, seven days a week. “We designed Lloyd Hall to be as multi-functional as possible,” says Lisa Armstrong, AIA, Armstrong Kaulbach Architects (now known as AKA), Philadelphia, PA. “It is intended to be all things to all people, while having a highly crafted design to fit in with Boathouse Row. Aesthetically, we were trying to make a statement in connecting with the past and the present, while also reflecting the needs and the look of the future.”

The two-story, 12,000-square foot building features a grand gymnasium, restrooms, banquet facilities, cafe concessions, information center and balcony. Outside, there are accommodations for a large public terrace, stepping down to the water’s edge.

The 4,500-square foot gymnasium, Lloyd Hall’s focal point, houses events ranging from basketball games to weddings. It required materials that were vandal-resistant yet attractive. To meet the dual requirements of high-durability and pleasing aesthetics, Armstrong specified solid glass block for three of the gym’s four walls. From both interior and exterior vantage points, the solid glass block is visually appealing while connoting the sense of openness. The solid glass block transmits 80 percent of available light in both directions, while brightening the interior with natural light. A variety of traditional glazing options were ruled out because of vandalism concerns. “If we didn’t use glass block, we would be looking at a rec center without windows, which would not be appropriate for the park setting,” said Armstrong.
Program title: “Designing With Glass Block: Abundant Applications Provide Practical, Aesthetic and Green Solutions” (10/07, page 179). AIA/CES Credit: This article will earn you one AIA/CES LU hour of health, safety, and welfare credit. (Valid for credit through October 2009). Directions: Refer to the Learning Objectives for this program. Select one answer for each question in the exam and fill in the box by the appropriate letter. A minimum score of 80% is required to earn credit.

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Learning Objectives

After reading this article, you should be able to:

- Identify the structural properties of glass block when used as a building material.
- Discuss the unique performance abilities of glass block, such as fire protection, heat and light transmission, sound resistance, vandal resistance, and hurricane and earthquake resistance.
- Assess some of the economic and aesthetic implications of specifying glass block in specific building projects.

Questions

1. What is the maximum square footage for an exterior standard glass block wall built without stiffeners or shelf angles?
   - a. 4 square feet
   - b. 12 square feet
   - c. 144 square feet
   - d. 350 square feet

2. Since glass block is nonporous and does not absorb any moisture, the consistency of the mortar used must be?
   - a. wet
   - b. soft (like butter)
   - c. stiff (like peanut butter)
   - d. dry

3. What should horizontal joint reinforcement do?
   - a. Control cracking due to expansion and contraction
   - b. Be placed no more than 16 inches on center and extend horizontally the length of the panel
   - c. Be pressed into the partially filled mortar joint, then covered with the remaining mortar and troweled smooth
   - d. All of the above

4. Glass block anchoring methods include the
   - a. panel anchors, chase and running methods
   - b. channel, running and panel anchors methods
   - c. panel anchors, channel and chase methods
   - d. channel, chase and running methods

5. Additional structural support for curved walls
   - a. should be placed where the curved section joins a straight section and at inflection points in multi-curved walls
   - b. is not necessary if glass block meets hurricane code
   - c. does not need to follow the contour of the curve
   - d. is independent of the size of the block used

6. All UL fire-rated glass block on the market meets a 45-minute or longer duration test meeting what standard?
   - a. ASTM E-2010 and NFPA 257
   - b. ASTM E-119
   - c. ASTM E-02
   - d. ASTM E-30

7. Solid 3-inch glass block has
   - a. an R-value of 1.75
   - b. U-value of 0.87
   - c. less thermal resistance than single-glazed 1/8-inch-thick plate glass
   - d. a shading coefficient of 3.5

8. Solid 3-inch glass block units that have been ballistics-tested and component-recognized provide what level(s) of ballistics?
   - a. No resistance
   - b. UL level 1
   - c. UL levels 1 and 2
   - d. UL levels 1, 2, and 6

9. Hollow glass block has an STC
   - a. higher than a solid glass block
   - b. lower than a solid glass block
   - c. equal to flat sheet glass
   - d. higher than a 4-inch brick wall

10. Hurricane-rated glass block must
    - a. have a lesser face thickness than standard block
    - b. meet 150 psf design pressure in Dade County
    - c. be mounted in a panel measuring less than 4 feet by 4 feet
    - d. meet ASTM E-1886 and ASTM E-1996 requirements

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For curved construction, 45-minute fire ratings can be obtained provided that the maximum allowable curvature does not exceed a ratio of 2:1 with respect to length of radius to length of assembly width (i.e., chord length), and only installed within masonry fire-rated walls.

**Surface condensation.** Resistance to surface condensation is considered impressive for hollow glass block because of the double face and partial vacuum construction of hollow glass block. In fact, standard glass blocks are considered condensation-free to minus 15 degrees Fahrenheit and thin blocks to minus 8 degrees Fahrenheit. This compares to a single-glaze flat glass, for which condensation can occur when the exterior temperature reaches 33 degrees Fahrenheit.

**Light and heat transmission.** The light transmission in glass block is nearly equal to that of flat glass. For example, the following figures apply to light transmission:

### Patton Park, Detroit Recreation Center, Detroit, MI

Since 1949, the Detroit Recreation Department's (DRD) Patton Park has served a neighborhood located between the industrial and commercial centers of southwest Detroit. Since the 1970s, the brick walls of the recreation center had become a canvas to express a diversity of cultural interests. These activities led the area’s residents, who used the facility on a regular basis, to raise safety concerns. Originally, the enclosure walls of Patton Park’s indoor/outdoor pool featured a pair of elegant glass doors that opened onto an outdoor sundeck. Over the years, panels of plywood, substituted for vandalized glass, soon became the only barrier separating the pool from the weather. Near-constant abuse of the facility, caused by graffiti and vandalism, contributed to significant deterioration of the building. Eventually, the damage was so great that the renovation of the park, including the soccer/baseball fields, gymnasium and swimming pool, became mandatory to safely keep the facilities open for the community’s use.

Plans for the new Patton Park were finalized in 2004 and Ralph Calder & Associates, Architects—now merged with David Milling Architects, Ann Arbor, MI—was approved to complete the renovation plans. With the building’s foundation intact, the reconstruction effort included a focus on the replacement of the windows around the gymnasium and pool area. Aluminum windows and plastic glazing are typical choices in window replacement, however, Ralph Calder & Associates decided that, in response to past concerns expressed by the local community, the choice warranted a more secure and durable building product. The firm turned to solid glass block products, for the solution.

After testing the block using gunfire and various other destructive measures, DRD officials approved the block according to the Urban Proof Concept Design specifications, a standard unique to the city of Detroit, which is used to determine the viability of products used in construction projects.

The scope of work at Patton Park included a 36,000-square-foot renovation and a 9,000-square-foot addition. In total, 3,500 square feet of solid glass block was specified throughout the building to replace more than just the exterior windows, as originally planned. The new two-and-a-half story atrium entrance, which features more than 1,200 square feet of glass block, is flooded with natural light during the day and glows incandescently across the park by night.

Above the street level entrance, 10-foot square panels brighten the exercise and dance spaces. Thirty-six glass block windows measuring 40 inches by 40 inches were incorporated into the design of the center’s perimeter brick walls. Punched openings admit light into the gymnasium, meeting room, senior citizen area, art room, weight room and administrative offices.

After two years and a $10 million makeover, the DRD’s Patton Park reopened its doors in May of 2006. It did not take long for the hustle and bustle of the city’s life to return to the gym floor. “We are very pleased with the results,” says Dennis Anderson, AIA, now with David Milling Architects. “People who wanted to tear the building down and who objected to the remodeling couldn’t believe their eyes when it was completed.”
The differences between the shading coefficient of glass block and flat sheet glass is significant. Thin glass block can reduce the shading coefficient of 1.00 for 1/8-thick flat sheet by 35 percent to 0.65 (and down to 0.45 for tightly ribbed patterns). Contributing to this, experts say, is the louvering effect of glass block’s horizontal mortar joints, which helps reduce light transmission from the higher sun. The size and orientation of the block can, therefore, affect the amount of shading that occurs.

**Sound transmission.** Sound transmission class (STC) is a rating that provides an estimate of the sound-absorbing performance of the partition for general building design purposes. The rating is designed to correlate with subjective impressions of the sound insulation provided against the sound of speech, radio, television, music and similar sources of noise in offices and dwellings. STC value represents an average of sound transmission losses between the 125 Hz and 4,000 Hz frequencies.

The sound-reducing characteristics of glass block are most notable in the hollow block with its partial vacuum (35 STC to 40 STC). With thick-faced and solid block, the STC is 48 and 53, respectively. This compares with about 29 STC for flat sheet glass (1/8-inch thick), 45 STC for single width 4-inch brick wall and 50 STC for 6-inch solid concrete masonry unit wall system. Because of this feature, coupled with other properties, the NYC Transit Authority uses this product throughout their transit systems.

**Impact resistance.** Glass blocks are inherently stronger than conventional glass because of the thickness of the faces and the mortar that binds the blocks together. As a result, glass blocks are more difficult to break and, therefore, provide resistance and are a deterrent to forced entry and vandalism.

Solid 3-inch glass block units provide the greatest resistance to breakage and are ballistics-tested and qualified to UL levels 1, 2 and 6. Even greater resistance to forced entry can be achieved by using metal grid systems that accommodate the solid units. In the case of mortared systems, single blocks can be replaced at minimal expense compared to conventional glass, which requires replacement of the full pane or panel.

**Hurricane resistance.** Research following the devastation of Hurricane Andrew—the second most costly catastrophe in the U.S.
after Hurricane Katrina—found that the most significant hurricane damage was from wind-blown debris made up of building parts. Studies also found that the most decisive cause of building frame collapse was the failure of doors and windows. Miami-Dade and Broward Counties consequently implemented changes in the Building Code relating to glazing systems. Many states have since adopted hurricane code requirements.

Hurricane-resistant glass block has a greater face thickness than standard glass block. It meets large missile tests referenced in the International Building Code in accordance with ASTM E-1886 and ASTM E-1996.

<table>
<thead>
<tr>
<th>Panel Size and Design Pressure Rating</th>
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<tbody>
<tr>
<td>4 ft. x 4 ft. = 100 psf Design Pressure</td>
</tr>
<tr>
<td>4 ft. x 8 ft. = 80 psf Design Pressure</td>
</tr>
<tr>
<td>6 ft. x 6 ft. = 68 psf Design Pressure</td>
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Panel sizes and design pressures relating to Dade County High Missile Impact Tests.

**Earthquake resistance.** Glass block panels inherently have two attributes that make them safe in earthquakes. One is their rigidity relative to a tall building’s rigidity. When used in tall buildings, the glass block panels experience earthquake motions that cycle back and forth very slowly relative to the vibration frequency of the glass block. Thus, the glass block’s ride during an earthquake is a smooth ride. The building acts like the soft shock absorbers in cars that soften passengers’ ride from the irregular imperfections in the road.

The second attribute of the glass block is the rigidity of the glass block panel relative to the rigidity of short buildings or residences. The critical vibration frequency is greater than the more severe vibration frequency of the earthquake ground shaking. Therefore, the g-forces from the earthquake are not amplified or turned into the ground motion as other architectural items, such as chandeliers or bookshelves.

**Lighting Design Considerations**

Glass block has a dynamic relationship with both natural and artificial light. The affect of artificial light on glass block can vary dramatically with the type and intensity of light and the pattern of the glass block. In architectural applications, halogen, incandescent and fluorescent light sources are the most commonly used.

- In order to evenly light a glass block, use a “wall washing” technique by placing the light source 12 inches to 18 inches in front or behind the panel. Keep the light source parallel to the face of the panel in horizontal or vertical configurations.
- Using a “spotlight” technique of focusing directly on the glass block panel, the sidewalls and mortar will absorb the light differently from the central portion of the panel, thus producing an uneven look. To ensure an even lighting effect, place the light sources evenly every 12 inches to 18 inches along the ceiling or side walls.
- Curved or angular panels require both horizontal and vertical light fixture placements. When combining different types of light sources, the use of the same color spectrum will bring a more uniform effect. Alternatively, different colored lights can produce special effects.
- Neon tube lighting placed behind a glass block panel can create special “hot spots.” For more even lighting, neon tubes may be placed directly behind the mortared course lines or along a panel’s perimeter.

**Safety and Daylighting for Schools**

“There is no question that getting more light to the level of the student in the classroom has become a priority,” says principal Wade Simpson, AIA, Welles Pugsley Architects (WPA), Las Vegas, NV, which has designed twenty one new middle schools since creating a prototype in 1994 for Clark County School District, a continually expanding school district. The firm made use of solid glass block for window areas and non-load bearing exterior walls to increase the amount of daylight coming into a classroom without compromising security. The average cost of the schools whose overall size is approximately 150,000 square feet is $29 million.

The solid glass block is placed in random patterns throughout the schools. In a cafeteria, for example, it was used in an exterior wall application in order to bring light in off the curve. “The buildings are constructed out of concrete masonry units,” says Simpson. “The glass can easily be installed by the masons and can be put into place as they build the wall. By using glass block, one subcontractor has responsibility for putting up the entire wall, including the windows. Eliminating the coordination of efforts and removing the possibility of delays in getting materials, does make the overall project more cost-effective.” Solid glass block cuts down on the time and cost for maintenance since it is less expensive to replace a damaged unit than the entire window.

The acoustic value of solid glass block is also an advantage in school design,” adds Simpson, who points out that three inches of solid glass block helps minimize noise.