REINFORCED STRUCTURAL CLAY BRICK

strong, versatile solution

BY JEFF ELDER, PE

Those inexperienced in the use of reinforced structural clay brick might think that a brick is a brick and limit its application to conventional methods associated with veneer. Brick veneers are defined by their ability to support their own weight while limited by mortar to resist tension. When the mortars' resistance to tension is exceeded, brick must be joined or supported by other materials such as brick ties, shelf and ledger angles, wood, steel, concrete and other backup systems.

Researchers have spent years investigating ways to provide tensile resistance to brick. Patterned after reinforced concrete, reinforceable structural clay brick create the form and become the aggregate to support compression forces. Reinforcing steel resists the tension. Oversized holes are placed in the brick and align vertically to create a place for reinforcing steel. Grout is placed in brick cells to bond reinforcing steel to the brick.

Structural clay brick are specified under ASTM C652 as hollow, fired clay brick with a percentage void volume greater than 25%, generally ranging between 35% and 60%.

Learning Objectives

1. Reinforced Structural Clay Brick (RSCB) are designed using most of the same equations and details as Concrete Masonry Units (CMU).
2. RSCB are two to three times stronger than CMU.
3. RSCB have fire ratings of one to four hours.
4. RSCB use expansion joints whereas CMU use control joints
5. Any design detail created using brick veneer can be created using structural brick. Not every structural brick detail can be created using veneer brick.
6. RSCB can act as beams, columns, loadbearing walls, structural panels and curtain walls.
7. RSCB are available in a wide variety of colors, sizes, shapes and textures.

See page 47 for test.

net area compressive strength of clay masonry units (psi)		net area compressive strength of masonry (psi)
TYPE M OR S MORTAR	TYPE N MORTAR	
1700	2100	1000
3350	4150	1500
4950	6200	2000
6600	8250	2500
8250	10,300	3000
9900		3500
13,200		4000

Table 1. Compressive Strength of Clay Masonry. For SI: 1 lb per square inch = 0.00689 Mpa. (IBC 2105.2.2.1.1) *2003 International Building Code. Copyright 2003. Falls Church, Virginia: International Code Council, Inc. Reproduced with permission. All rights reserved.*

mortar	type	proportions by volume (cementitious materials): PORTLAND CEMENT[a] OR BLENDED CEMENT[b]	MASONRY CEMENT[c] M	MASONRY CEMENT[c] S	MASONRY CEMENT[c] N	MORTAR CEMENT[d] M	MORTAR CEMENT[d] S	MORTAR CEMENT[d] N	hydrated lime[e] or lime putty	aggregate measured in a damp, loose condition
CEMENT-LIME	M	1	–	–	–	–	–	–	¼	Not less than 2¼ and not more than 3 times the sum of the separate volumes of cementitious materials
	S	1	–	–	–	–	–	–	over ¼ to ½	
	N	1	–	–	–	–	–	–	over ½ to 1¼	
	O	1	–	–	–	–	–	–	over 1¼ to 2½	
MORTAR CEMENT	M	1	–	–	–	–	–	1	–	
	M	–	–	–	–	1	–	–	–	
	S	½	–	–	–	–	–	1	–	
	S	–	–	–	–	–	1	–	–	
	N	–	–	–	–	–	–	1	–	
	O	–	–	–	–	–	–	1	–	
MASONRY CEMENT	M	1	–	–	1	–	–	–	–	
	M	–	1	–	–	–	–	–	–	
	S	½	–	–	1	–	–	1	–	
	S	–	–	1	–	–	1	–	–	
	N	–	–	–	1	–	–	1	–	
	O	–	–	–	1	–	–	1	–	

Table 2. Mortar Proportions [IBC 2103.7(1)]. **a. Portland cement conforming to the requirements of ASTM C150, b. Blended cement conforming to the requirements of ASTM C595, c. Masonry cement conforming to the requirements of ASTM C91, d. Mortar cement conforming to the requirements of ASTM C1329, e. Hydrated lime conforming to the requirements of ASTM C207.** *2003 International Building Code. Copyright 2003. Falls Church, Virginia: International Code Council, Inc. Reproduced with permission. All rights reserved.*

Photos courtesy of Colonial Brick

Fox Studio, Livonia, designed by Giffels, Hoyem, Basso, now IDS, Troy, used both 4 x 8 x 16 custom color Brownstone flashed (with center score) as a veneer and 8 x 8 x 16 (with center score) as a structural unit.

The designer must specify the type of brick. Hollow brick are designated as either HBS (hollow brick standard) or tighter spec HBX (hollow brick extra). Use HBX when a higher standard for dimensional and aesthetic tolerances are required and a higher cost can be justified.

When brick are subject to frequent conditions of freezing when saturated, the designer is directed to specify Grade SW (severe weathering) brick.

Structural clay brick are commonly available in nominal widths of 4″, 5″, 6″ and 8″. They come in nominal lengths of 8″, 12″ and 16″ with heights that range from 2¼″ to 8″.

Compressive Strength

As strength of brick is often related to color, it is important that an architect specify the color of brick early in the design process. This allows the structural engineer to maximize the strength performance of design elements. For most manufacturers, the lighter the brick color, the lower the compressive strength of the system; conversely, the darker the color, the higher the compressive strength of the system.

The designer is referred to the specified manufacturer to obtain the *compressive strength of unit* for all colors specified. The designer is then directed to the appropriate building code to cross reference *compressive strength of unit* with design value *compressive strength of masonry.*

When using the International Building Code (IBC 2003), refer to Table 2105.2.2.1.1. (See Table 1.) Similar tables are found in the masonry section of other codes. The specified *compressive strength of masonry* is referenced by designers as the f'_m value. Values of historical test data have been adjusted statistically in the table to insure a conservative design value.

Typical allowable design values for hollow clay masonry range between 2600 psi and 5300 psi. At two to three times the standard value for concrete masonry, the use of these higher values can help to reduce deflections, wall thickness, beam depth, bar diameter and bar lap requirements.

To select an f'_m value higher than those listed in the table is acceptable; however, the value must be verified by building prisms of the brick, mortar and grout specified prior to and during construction.

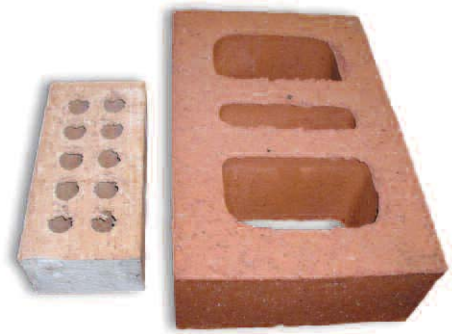
type	parts by volume of portland cement or blended cement	parts by volume of hydrated lime or lime putty	aggregate, measured in a damp, loose condition	
			FINE	COARSE
FINE GROUT	1	0–1/10	2¼–3 times the sum of the volumes of the cementitious materials	-----
COARSE GROUT	1	0–1/10	2¼–3 times the sum of the volumes of the cementitious materials	1–2 times the sum of the volumes of the cementitious materials

Table 3. Grout Proportions by Volume for Masonry Construction. (IBC 2103.10) ***2003 International Building Code. Copyright 2003. Falls Church, Virginia: International Code Council, Inc. Reproduced with permission. All rights reserved.***

material	item number	construction	minimum required equivalent thickness for fire resistance [a, b, c] (inches)			
			4 hour	3 hour	2 hour	1 hour
BRICK OF CLAY OR SHALE	1-1.1	solid brick of clay or shale[d]	6	4.9	3.8	2.7
	1-1.2	hollow brick or tile of clay or shale, unfilled	5.0	4.3	3.4	2.3
	1-1.3	hollow brick or tile of clay or shale, grouted or filled with materials specified in Section 721.4.1.1.3	6.6	5.5	4.4	3.0

Table 4. Rated Fire-Resistance Periods of Clay Masonry Walls [IBC 721.4.1(1)]. For SI: 1″ = 25.4 mm
a. Equivalent thickness as determinded from Section 721.4.1.1, b. Calculated fire resistance between the hourly increments listed shall be determined by linear interpolation, c. Where combustible members are framed in the wall, the thickness of solid material between the end of each member and the opposite face of the wall, or between members set in from opposite sides, shall not be less than 93% of the thickness shown, d. For units in which the net cross-sectional area of cored brick in any plane parallel to the surface containing the cores is at least 75% of the gross cross-sectional area measured in the same plane. ***2003 International Building Code. Copyright 2003. Falls Church, Virginia: International Code Council, Inc. Reproduced with permission. All rights reserved.***

Metro Loft, Royal Oak, designed by Neumann/Smith & Associates. Re-rod and concrete pre-fab flooring attached to 8 x 4 x 12 brick single wythe walls.



Solid face brick and hollow structural unit.

Metro Loft, Royal Oak, constructed of Mission (yellowish, buffish) and Sunset, flashed to bring out color variation. Larger core holes for re-rod and grouting.

Mortar

Mortar used in reinforceable structural clay masonry assemblies is commonly specified by proportions. (See Table 2.) There are three types of mortars: Portland cement-lime, mortar cement and masonry cement. In addition, Type S mortars are prescribed for structural masonry as a minimum.

A common mistake is to over specify the mortar type. Since Type M mortars are the strongest mortars, they are often specified to insure strength of the assembly. Type M mortars have a high cement content which increases shrinkage of mortar and reduces the bond strength. In addition, the extra cement makes cleaning more difficult. Type M mortars are generally limited to below grade applications. When specifying mortars, do not call out for a mortar compressive strength testing.

Grout

Grouts for reinforceable structural clay masonry are prescribed according to Table 3 by proportion. Use coarse aggregate grout (1 part cement, 2 parts pea gravel and 3 parts sand) for applications where there is sufficient room for all of the reinforcing. Fine grouts are commonly used in smaller cells — typically 4˝ and 5˝ wide brick.

Fluidity is essential for proper placement of grout around reinforcing. A grout slump of 8˝ to 11˝ is recommended. Due to the high moisture content of grout, a volume expander, fluidifying and water reducing agent are added.

Fire Resistance

Reinforceable structural clay brick also provide fire resistance. Structural clay brick are fired in kilns at maximum temperatures around 2000°F. This allows brick to retain strength during a fire and when subjected to fire hose streams, thus enhancing public safety. Structural brick are non-combustible and do not give off toxic emissions. Prescribed code values are located in Table 4. Fire ratings from 1 to 4 hours can be achieved from this table. To select a fire rating, solid percentages of structural brick are converted to an equivalent brick thickness and compared with minimum required thicknesses for various fire ratings. Structural brick may be made solid for the intent of this table by filling all cells with grout, expanded shale, sand, pea gravel, crushed stone, slag, pumice, scoria, expanded clay, slate, slag, fly ash or cinders.

Insulative R-Values

Structural clay brick can also provide insulative properties. Uninsulated brick have insulation resistance (R)-values of approximately 0.2 R/inch. By insulating the cells that are not grouted, higher insulation values can be achieved. Structural clay brick can be insulated with perlite or foamed-in-place polyurethane to achieve R-values approaching 1-R/inch.

When insulation requirements exceed those provided above, insulate the wall the same as for brick veneer. Add a layer of closed cell polystyrene insulation to the back of the brick and fur out as required.

Reinforcement

From a design standpoint, reinforceable structural clay brick are similar to concrete masonry units (CMU). An architect or engineer familiar with the design of CMU uses many of the same details. Horizontal bar reinforcing is placed in bond beams. A grout stop fabric of paper or mesh is placed directly below bond beams to prevent grout from dropping into intentionally ungrouted cells.

Horizontal joint reinforcing is typically specified at 16˝ increments and ends are lapped 6˝. Reinforcing is typically continuous around corners. Horizontal reinforcing helps to control cracking and to transfer loads to vertical reinforcing.

Movement Joints

Concrete masonry uses control joints (CJs) in walls to control shrinkage of the concrete through the dynamic cycle of wetting and drying. CJs are commonly recommended at spacings of 20´ to 25´ centers and are created by starting and stopping the units to form a vertical joint. Reinforcing is terminated at the joint; sealants protect the joint from the elements. In some cases, a sash block and preformed gasket are used to help control alignment of the two faces. Care should be given to the aspect ratio of the wall to insure that cracking does not occur at more frequent spacings.

With structural clay brick, expansion and contraction will occur with varying temperatures; predominant direction of movement is expansion. When expansion of brick controls the design, the movement joint needs to be free of materials that will not compress. (See Figure 1.)

Expansion joints (EJs) are not required at the same locations and spacing as in brick veneer. This is because brick veneer does not have the ability to resist tension caused from expansion. Common spacing of EJs in horizontally reinforced clay brick are generally spaced at 60´ centers. If an EJ is not preferred at the corner, horizontal reinforcing in bond beams must be continuous around the corner, a minimum of 36 bar diameters. Lap continuous reinforcing with corner bars to insure that tension created in the brick at the corner can be transferred to the reinforcing.

Where clay brick and concrete block

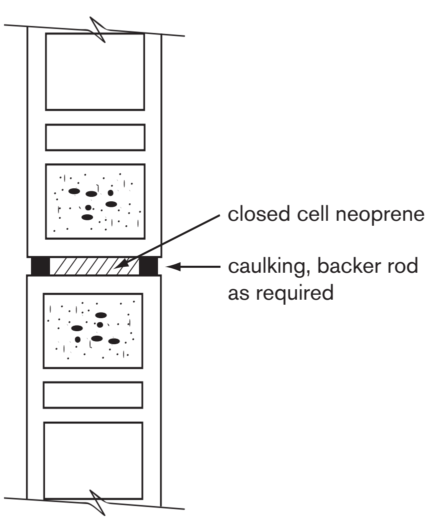


Figure 1.

are combined, use CJs as required for concrete block.

Moisture Control

Moisture must be controlled on a regional basis. Experience with concrete masonry unit (CMU) in an area will dictate the preferred method of treating a structure for moisture resistance. For many areas of the United States, single-wythe brick exposing both faces can be treated using a water repellent coating on the exterior face. The expansive characteristic of brick causes reinforcing to go into tension, which then places the brick into compression. This post tensioning reduces cracks and decreases moisture penetration.

When a greater resistance to moisture penetration is required, structural clay masonry must be designed similar to drainage walls with weep holes and flashing running through the wall to the back side of the insulation. Close cell extruded expanded polystyrene, other non-wicking insulations and those not affected by moisture are placed in a continuous layer on the inside face of the brick. All joints in the insulation are taped to create a moisture barrier.

Continuous insulation creates the thermal drop which forces the dew point of the wall to occur in the insulation. This reduces the chance for condensation inside the wall. Any moisture on the surface of the insulation is directed to the flashing where it is directed to the exterior of the building.

Application

Common uses of reinforceable structural clay masonry are loadbearing walls, beams, columns and piers. Other uses are structural brick veneer, curtain walls, brick panels, sound walls and retaining walls.

One and two-story buildings, even those up to 21 stories, are perfect for loadbearing masonry. For a small increase in initial cost as compared with CMU, the owner enjoys major improvements in aesthetics and strength. As an alternative for steel frame and metal stud walls, reinforced structural clay masonry can be

Embassy Suites Hotel, Livonia used both 4˝ x 8˝ x 16˝ Ironstone flashed (with center score) as a veneer and 8˝ x 8˝ x 16˝ (with center score) as a structural unit.

used as both a bearing wall and an enclosure wall providing structure and finish at the same time. Compared with wood framing, structural clay brick offer better acoustical properties, less seismic or wind drift, better fire resistance, less maintenance and no insect or mold damage.

Structural clay masonry is often installed in less time than other framing methods, reducing construction time and finance costs.

Mid-rise hotels and condominiums are a perfect choice for the structural brick curtain wall. High strength of the unit allows taller walls and fewer framing members. Perimeter beam sizes can be reduced and heavy gauge studs are replaced by light gauge ones. On some building sites with limited access, the curtain wall concept has eliminated the need for scaffolding reducing those costs.

Brick veneer on metal studs is laden with complicated construction details and extra labor. Unless properly detailed, wall ties are subject to pullout and corrosion of the stud is possible. Structural brick veneer is a popular alternative to brick veneer as wall ties, heavy structural framing and beams are replaced with reinforced hollow brick. Wall ties are replaced by less frequent structural anchors spaced every 100 sf compared with every 2 sf. Anchors are less susceptible to corrosion. Perimeter masonry beams can be sized for L/240 deflection criteria and not the L/600 prescribed to control veneer cracking. Brick offer greater design flexibility in a wide array of colors, textures and patterns.

Sound walls and miscellaneous enclosure walls are an efficient use of structural clay masonry. Modular in size, they can accommodate large variations in land form. A wide variety of colors add structural and aesthetic advantages.

Structural clay brick are less frequently used in retaining walls. However, because of the flexibility of brick to accommodate variations in wall geometry, the structural brick retaining wall may offer more efficient design options as compared with reinforced concrete.

It is safe to say that any building designed using brick veneer can be designed using reinforced structural clay brick. The reverse is not true.

Complexity of design can be reduced, performance of materials enhanced, overall cost reduced, performance life increased by using reinforceable structural clay brick. Brick's durability is double the useful life of most building materials.

Reinforceable structural clay brick fulfills the intent of sustainable building design.

Take advantage of the structural characteristics of brick while enjoying its long list of other advantages.

For additional information on this subject, go to www.brick-wscpa.org.

Jeff Elder is sales manager for Interstate Brick Company, nationally recognized structural clay brick manufacturer in West Jordan, UT. He has served as past president and currently chairs the technical committee for Western States Clay Products Association (WSCPA), the structural research arm of the brick industry. He is a member of Masonry Standards Joint Committee, Masonry Alliance for Codes & Standards and The Masonry Society. He may be reached at jeff.elder@paccoast.com, 800-280-5290.