Reinforced brick makes brick homes more economical

A new concept in residential construction: A single-wythe, reinforced brick home

By Walter Laska
Staff Architec
Masonry Advisory Council
Park Ridge, Illinois

Brick homes now can be built more economically than they could be before. A single-wythe, load-bearing brick home just built in a Chicago suburb proves it. The 2,370-square-foot, two-story house has comparable or better features than a new wood-frame tract home nearby. But if the reinforced brick house were priced the same as the wood-frame house, it would still yield a 26% profit. Why? Because contrary to what many people think, the cost of reinforced masonry construction is low. Interior and exterior finishes can be provided by the masonry walls.

The single-wythe, reinforced brick home was built in the same manner that the Western States Clay Products Association built 30 homes in the Seattle area in 1975. Because Seattle is in a seismic area, the 4-inch-thick brick walls of the homes were reinforced with vertical steel rebar. Unfortunately, local industry (predominantly lumber) did not embrace the system. Chicago, however, provides no advantage to either the manufacturing or transporting of wood or masonry products.

REINFORCED SINGLE-WYTHE WALLS: A BRIEF HISTORY

Following World War II, the housing industry underwent a major change. Instead of building brick homes of double- or triple-wythe brick bearing walls, builders began veneering wood-frame homes with brick. Wood-frame construction was less expensive than double- and triple-wythe brick construction. The result: the amount of masonry used in housing decreased. Brick was used only as a veneer or not at all, replaced by some form of siding instead. Builders began offering brick as an optional item for which they charged a premium.

This is unfortunate because the high compressive strength of brick makes it an ideal material for load-bearing walls. Brick rarely has a compressive strength less than 6000 psi, and if desired it can be manufactured with strengths in excess of 14,000 psi.

Brick's structural shortcoming, however, has been its low tensile strength, which usually is about 90% less than its compressive strength. A mortar joint rarely has a tensile bond strength greater than 50 psi. This limits the height of unreinforced masonry walls and makes some means of lateral support necessary to withstand wind and seismic forces. Floors, roofs, columns, piers, pilasters, and cross walls can all provide this lateral support.

Vertical reinforcing steel can provide lateral support too. About 40 years ago, at about the same time wood was replacing brick in residential construction, architect and engineers in the western United States began designing engineered masonry walls that resist the dynamic lateral forces of earthquakes. The walls were reinforced vertically and horizontally with steel rebar.

Unconcerned about earthquakes, most designers in the Midwest and eastern United States never designed engineered masonry buildings. Instead they used empirical design. One widely used code based on empirical design is The American Standard Building Code Requirements for Masonry (ANSI A41.1). This code requires lateral supports to be spaced no further apart than 18 times the nominal wall thickness. In other words, tall unreinforced walls have to be built thicker, which often makes the cost of masonry construction uncompetitive.

Tall thin masonry walls are now possible, however, if the masonry is reinforced and designed using ultimate strength design methods. Research reports cited in the Uniform Building Code and the BOCA Basic/National Building Code permit this type of engineered design (Ref. 2 and 3). And as the main story illustrates, reinforced masonry buildings, even single-family homes, are cost competitive.

The reinforced brick walls

Figure 1 shows a typical wall section developed for the single-wythe, reinforced brick walls of this Chicago-area home. The walls varied from 8 to 23 feet high at the gable peak. Workers placed and grouted #4 vertical steel rebar into the cores of the 4-inch brick at 3-foot intervals on the first floor and at 4-foot intervals on the second floor. Rebars were placed closer in areas where unbraced wall heights exceeded 8 feet.

When the masons laid the first course of brick, they carefully noted which cores required rebar. Rebar placement drawings were developed to assist in this procedure. Rebar was cut into 4-foot lengths, enabling the masons to easily thread the brick over the rebar. All cores were filled with grout as the coursing progressed (Figures 2 and 3). A 15-inch bar splice was provided as specified by code. Important: A half bond coursing was required to provide clear access to the brick cores for vertical steel placement and to obtain proper mortar bond. This

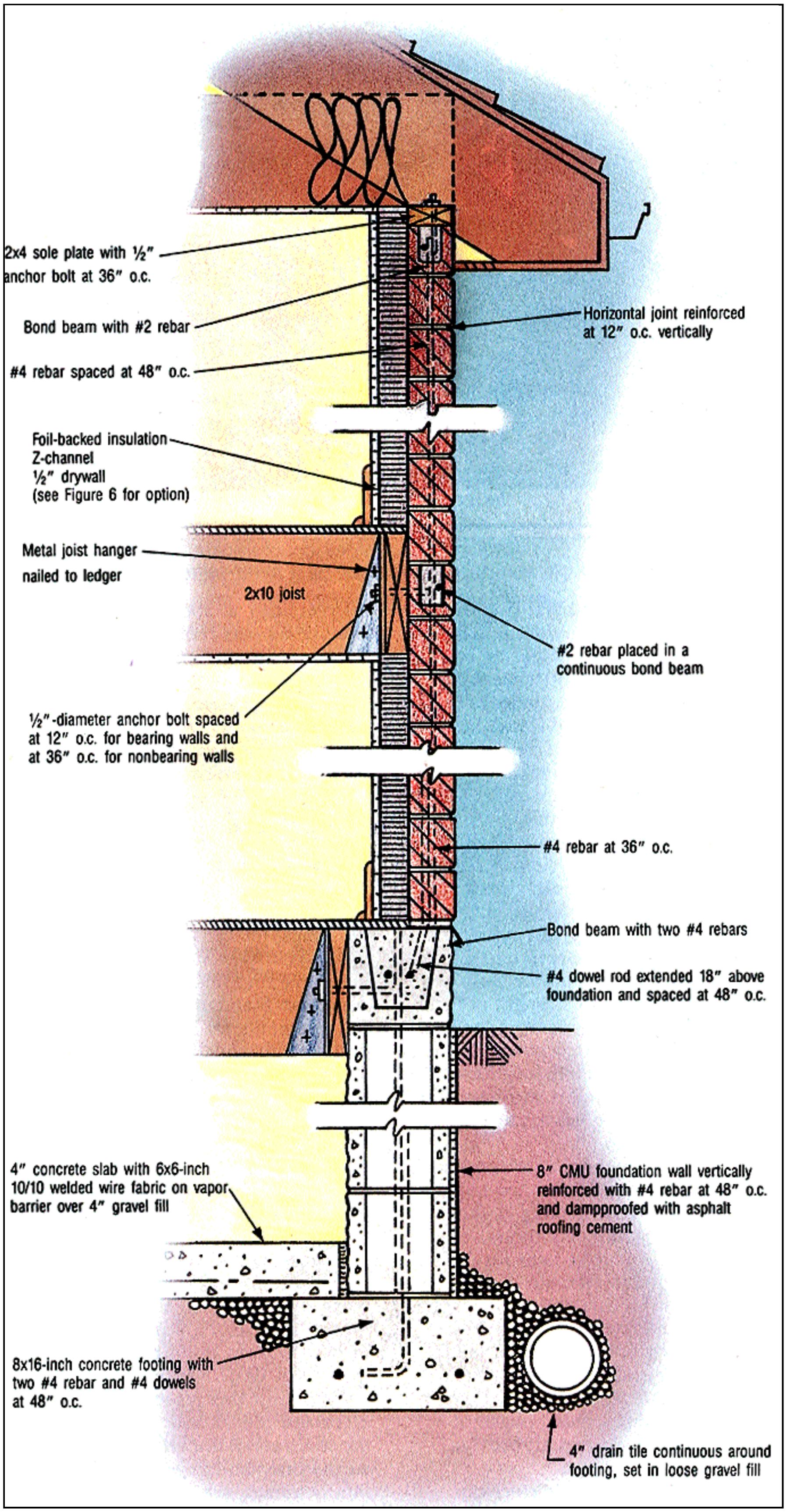

Figure 1. *A typical section of the single-wythe, reinforced brick wall.*

meant corner units had to be cut or custom-made. On this project, the corner units were cut.

The hollow 4-inch brick that was used met the requirements of ASTM C 652, Standard Specification for Hollow Brick (Ref. 1). The actual size of each brick unit was 3⅝ x 3⅝ x 11⅝ inches. Cores were approximately 1¾ x 3½ inches. All cores were filled solid with 2000-psi grout, although only the cores with rebar had to be filled by code. Brick was laid with a portland cement/lime mortar.

Wall-floor and wall-roof connections

For lateral bracing, workers connected the floors and the roof to the walls. For floors, ½-inch-diameter anchor bolts were grouted into a bond beam every 12 inches in bearing walls and every 36 inches in nonbearing walls. Structural calculations determined the spacings and size of the anchor bolts. After the grout had set, carpenters fastened 2x10 ledger joists onto the anchor bolts. Then they set the floor joists in metal hangers attached to the ledger joists (Figure 4). The plywood deck was then added, giving the wall continuous lateral support.

The roof system was connected to the walls in a conventional manner: 2x4 plates were anchored continuously along the top of the wall, providing the carpenters with a means of framing the roof to the walls.

The unbraced heights of bearing walls ranged from 8 to 17 feet.

Wall openings

Window and door openings in the load-bearing brick walls required special attention. Lintels had to be designed to carry structural loads as well as the dead load of the brick above the lintels. Steel angle lintels were used on this project, although reinforced brick lintels also could have been used. Steel rebars were installed in the brick cores near the jamb locations to increase lateral stability.

The thickness of the window frame and the window manufacturer selected influence how window frames are attached to the masonry. On this project, masons set special steel recepta-

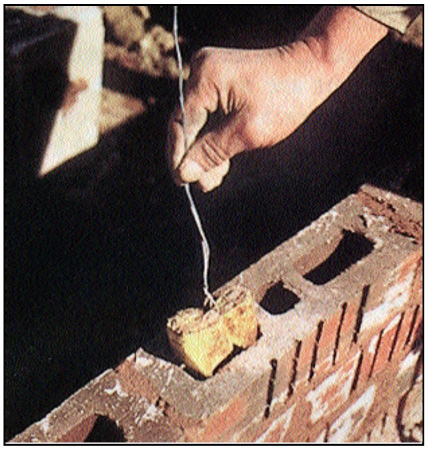

Figure 2. *Before grouting, sponges previously inserted in the cores are pulled up to remove any mortar droppings.*

Figure 3. *Using small buckets, workers then pour grout into the cores a few courses at a time. Pumping grout in high lifts could reduce cost more.*

cles, known as wall plugs, into the mortar beds around the window openings (Figure 5) Then, on the interior, they nailed wood furring strips into these wall plugs. The protruding flanges of the window frames were then nailed and glued to the wood furring. The windows were caulked with sealant afterward.

Installing the drywall and insulation

Drywall and insulation can be installed in two ways: with Z-shaped channels or with hat-shaped channels (Figure 6). Hat-shaped channels are installed over the insulation, and Z-shaped channels are installed between sections of insulation. On this project, Z-shaped channels were pneumatically attached to the brick wall at 2-foot intervals using ¾-inch, round head, brass P-nails with barbed shanks. Rigid polyisocyanurate insulation faced with foil on both sides was cut into 2-foot sections and inserted in the channels.

Because each Z-channel creates a break in the insulation, though, the R value of the wall is lower than the R value obtained when using the hat-shaped channels. To eliminate this thermal bridging (and increase the R value by 4), an extra ½ inch of continuous insulation was added to the wall before drywalling.

Stopping water penetration

Though the wall is only a single wythe, water penetration problems are not expected. Less hairline cracking should occur from flexure caused by wind loads because the wall is reinforced and all cores are fully grouted. The little water that may penetrate will run down the foil-backed insulation (insulation joints are taped for this reason) to the flashing at the base of the wall. The flashing at the base is turned up and taped to the foil-backed insulation.

Basement foundation walls

The basement foundation walls of this reinforced brick home were built of 8-inch architectural concrete block, an uncommon practice in the Chicago area (Figure 7). To prevent cracking from backfilling pressures, these walls also were reinforced. Workers installed #4 rebar at 4-foot intervals and tied them into a continuously reinforced bond beam located at the top of the wall. With their finished face turned inward, the split-face concrete blocks provided the basement with a ready-to-use recreation room. After completing the foundation, workers set #4 dowel rods into the bond beam to tie the brick walls to the foundation.

Good workmanship critical

Figure 4. *Floor joists are hung from ledgers that are bolted to an integral bond beam in the brick wall.*

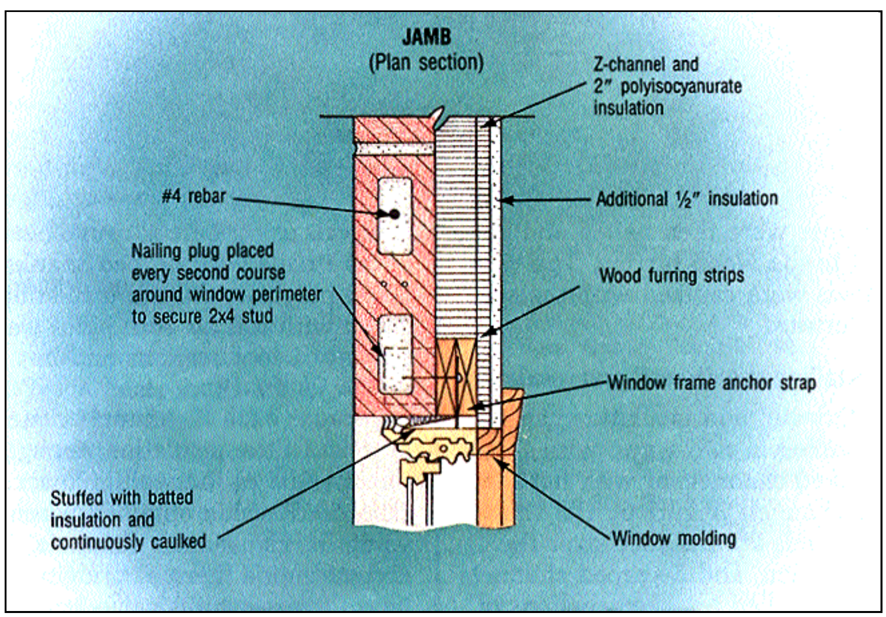

Figure 5. *Workers nail window flanges into steel plugs that were placed in every other mortar joint around the window perimeter.*

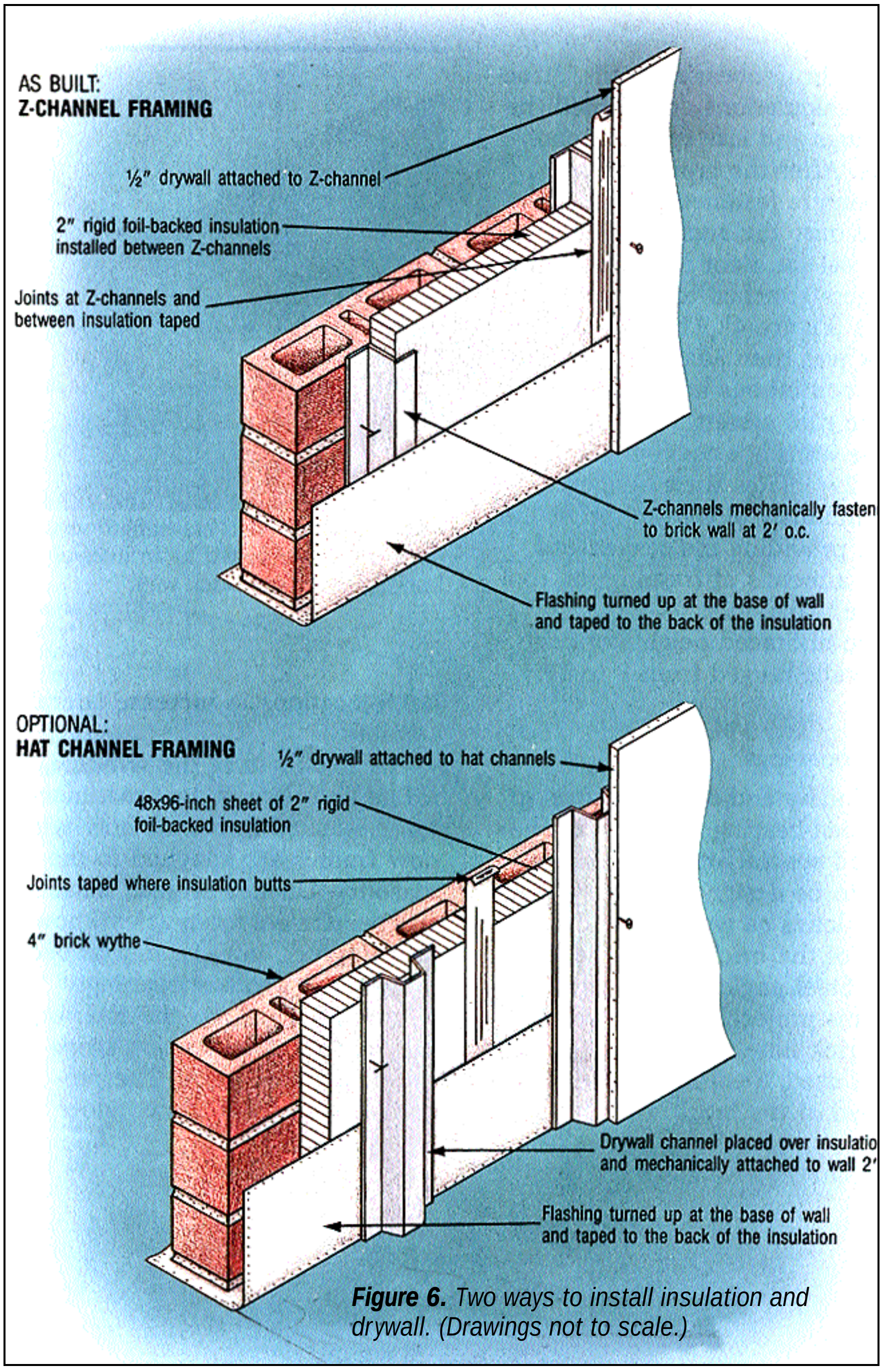

Figure 6. *Two ways to install insulation and drywall. (Drawings not to scale.)*

Figure 7. The architectural face of the split rib concrete block is turned inward to give the basement walls an appealing interior finish that needs no painting or other treatment.

The workmanship and communication between architect and masonry contractor on this project were excellent. Both of these are necessary if this system is to be successful. Rebar must be placed in proper amounts at the proper locations. And grout must be mixed to proper proportions and poured and consolidated in the proper manner.

Comparing costs

The reinforced brick home just described was compared to a nearby wood-frame home that is for sale by a developer (Figure 8). The brick house has many of the features of the wood-frame house, but it also has many additional features: walls with an R value of 18 instead of 13, a two-story interior brick wall with an inwall brick sculpture, and a basement with architectural concrete block finish. It also has 200 more square feet of floor area, 1,800 more square feet of lot, and 75% more brick on the exterior. If the brick house was sold at the same price as the wood-frame house, a 26% profit would still be realized.

The reinforced brick home alone is at a further cost disadvantage if you also consider other aspects of construction. For example, the price of both houses included the cost of the land. But the developer of the wood-frame housing project probably paid considerably less for each lot of land than the owner of the reinforced brick home paid for his one lot. Also, tract housing reduces per unit costs, because materials can be purchased in quantity and construction crews can work in production line fashion.

Reinforced brick construction is new to the Chicago area. Greater familiarity with the construction procedure will eliminate “out-of-the-ordinary” delays and reduce costs. High-lift grouting, a faster grouting method used to build the Seattle homes but not used here, also can reduce costs.

The bottom dollar

A 26% profit seems small—and it is. But it shows that a reinforced brick home can be built at a profit even if sold at the price of a wood-frame home. With all its extra features, though, the brick home definitely will be sold at a higher price than the $176,900 quoted for the wood home. According to the 1987 Residential Cost Handbook, published by Marshall and Swift, the brick-reinforced home would be appraised at $77.80 per square foot (excluding the cost of the land). Actual construction cost of the home, excluding the cost of the land, was $48.52 per square foot.

COMPARISON OF TWO HOUSES

Reinforced brick house	Wood-frame house with brick veneer
2,370 square feet	2,170 square feet
Loft or fourth bedroom option	Fourth bedroom option
Partially finished basement	Basement
2½ baths	2½ baths
Connected garage	Connected garage
Air conditioning	Air conditioning
Exterior: 85% load-bearing brick cedar siding	Exterior: 15% brick veneer; majority is
Lot size: 11,175 square feet	Lot size: 9,375 square feet
Wall R value: 18	Wall R value: 13
Cathedral ceiling	
Two-story interior brick wall with brick sculpture	
SELLING PRICE:?	SELLING PRICE: $176,900

Figure 8. *If the reinforced brick house were sold at the same price as a similar nearby wood-frame house, a 26% profit would still be realized. But the brick house has many additional features, including 200 more square feet of floor area and 1,800 more square feet of lot.*

Credits

Owner/architect: Walter Laska, Park Ridge, Illinois

General contractor: Viking Development, Naperville, Illinois

Masonry contractor: Mar-Lu Masonry, Hickory Hills, Illinois

Block manufacturer: Chicago Block Company, Chicago, a member of the Illinois Concrete Products Association

Brick manufacturer: Denver Brick Company, Denver, Colorado

Brick supplier: Bricks Inc., Chicago, a member of the Brick Distributors of Illinois

References

1. "Standard Specification for Hollow Brick (Hollow Masonry Units Made from Clay or Shale)," ASTM C 652, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

2. Engineering Guidelines for Single Unit Brick Wall Construction, 1983, Interpace Industries Inc. and Western States Clay Products Association, 55 New Montgomery Street, Suite 501, San Francisco, California 94105.

3. One- and Two-story Residential Reinforced 4-inch Hollow Clay Brick Construction, Recommendations IV, Uniform Building Code Research Report #3119, April 1976, International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, California 90601.

4. Design of Concrete and Masonry Slender Walls, BOCA Research Report #86-51, April 1987, Building Officials and Code Administrators International, Inc., 4051 West Flossmoor Road, Country Club Hills, Illinois 60477.

Editor's note

This article is based on a paper the Masonry Advisory Council submitted for the 8th International Brick/Block Masonry Conference to be held at Dublin, Ireland, September 19-21, 1988.

PUBLICATION #M880065