STRUCTURAL BRICK MASONRY WALLS

By John G. Tawresey

Brick as a building material has been around for a long time. There are many types of brick: adobe brick, clinker brick, common brick, dry press brick, economy brick, engineered brick, facing brick, fire brick, hollow brick and many others. Some have estimated that 80% of the world's existing buildings are constructed with brick, yet most structural engineers have little knowledge of how to use brick in their structures.

Figure 1: Hollow Brick

Steel, concrete and wood dominate current construction. Has brick fallen behind because it is no longer viable? Perhaps, but I think it has fallen behind because most engineers don't know how to take advantage of its unique properties.

Did you know that in some jurisdictions you can construct a brick retaining wall without a back slope cut? The wall can be built from the front side; no one needs to go behind the wall. Did you know it is easier to build a curved brick wall than a straight one? A serpentine retaining wall can offer significant cost advantages. Did you know that bricks expand with time? When reinforced, cracks tend to heal. The wall will prestress itself. Did you know that an average hollow brick has a compressive strength of 10,000 to 12,000 psi. and some have compressive strengths in excess of 20,000 psi.

The properties of the material are interesting enough, but the design opportunities are endless. It is better than playing with Lego's, because you can design your own brick shapes. Custom dies can be produced at reasonable costs. You can even patent the colors and shapes.

This is nothing new. Fluted Roman columns fabricated in stone likely consumed more resources than the same column constructed in brick. Cover the outside with mortar and from a distance you cannot tell the difference. I wonder if the designer was an engineer? Notice in *Figure 2* that there is a running bond (overlapping units) using circular bricks of different diameters.

Figure 2: Fluted Roman Brick Column

The author started designing with brick more than 30 years ago. My first assignment was to design and conduct tests on a new 3.5-inch thick hollow brick masonry system. The system was reinforced and allowed 4-inch thick brick bearing walls for the first time. The previous minimum thickness was 6 inches. As a result, more than 100 homes were built using the brick unit instead of wood framing. The market never grew because masons weren't interested in building speculative housing. However, the knowledge and experiences gained with the house program opened new doors for commercial uses.

Figure 3: Brick Panels

Figure 4: Starbucks Tower

The first prefabricated brick panel curtainwall used the same 3.5-inch thick units. Hundreds of projects followed. Many different sizes and shapes of units have been used. Some of the panelized projects became load bearing, not just curtainwall. Some projects were not panelized, but were constructed in place and attached to the building like a panel. We called the system *laid in place panels*. Some projects are like conventional veneers, but were reinforced to eliminate ties to the backing. We called this *structural brick veneer*. Most recently veneers with reinforcement and grout in the space between the brick and the backing have been used. We call these *reinforced veneers*. All of these systems, load-bearing, panels, laid in place panels, structural brick veneer and reinforced veneer take advantage of the flexibility and strength of the brick masonry.

Most applications of brick masonry are on exterior walls, although sometimes they are used inside the building for the appearance. Brick exterior walls function to separate the interior of the building from the exterior environment. They are air, water and thermal barriers. Sometimes they also support the structure. The design issues are complex, but no more complex than walls constructed of other materials.

Water leakage is always a concern. Like other wall systems, performance is primarily dependent on the details. Flashing of brick masonry walls is necessary. The now popular concept of the rainscreen is easily applied to structural brick walls. However, like most other materials, brick exterior walls usually rely on primary and secondary lines of defense to resist water penetration into the building rather than just a rainscreen.

Figure 5: Starbucks Corner Panel

When used as a panel, brick can be detailed the same as a precast concrete exterior panel, including the connections to the building primary structure. The design methods are similar to those used for reinforced concrete panels. The only differences lie with connection and reinforcing details. Flaws, such as cracks in the units, tend to weaken larger areas than those occurring in reinforced concrete. Therefore, the connections need to be larger, engaging more than one cell or unit. Most panel projects use hollow brick units, as shown in *Figure 1*, with reinforcement in the cells.

For projects in high seismic risk regions, brick panels offer opportunities for isolation from the structural frame not easily obtained in other brick systems. The tower at the Starbucks headquarters in Seattle was panelized to isolate the intricate brick facade from the building structure. The brick was required to accommodate more than 2 inches of drift between floors. The tower had four floors. The structural concept was to build structural corners to be attached to a single floor, with the brick between the corners supported by the corners. The result was a box system for each floor, supported at the corners, (*Figures 4 and 5*).

Structural Brick Veneers have been used extensively in the northwestern United States. They are essentially the same as conventional brick veneers except that the brick is reinforced. Hollow bricks that can be reinforced are a necessary part of the system. The reinforcement increases the structural capacity of the brick wall. The spacing of the ties, typical in conventional veneers, can be increased and in most cases, the spacing can be increased to the distance between building floors or columns. The conventional veneer ties are eliminated and are replaced by more substantial connectors. The

Figure 6: Structural Brick Veneer Connector

Figure 7: Reinforced Veneer on Steel Studs Before Grouting

connectors are usually attached to the primary structural system of the building instead of a separate backup wall.

Ledgers, very similar to the ledgers of more conventional veneers, can support the dead load of the Structural Brick Veneer. Or, separate discontinuous connectors can be used to support the dead load since the reinforced brick can span between them. These connectors are similar in design to those used to support brick panels.

For more information on veneers and structural brick veneers, two documents prepared by Western States Clay Products Association are available: the *Design Guide for Structural Brick Veneer*, Second Edition, July 2004 and the *Design Guide for Anchored Brick Veneer over Steel Stud Systems*, Second Edition, August 2004

Reinforced veneers are a new development. Before 1960, it was common to fill the cavity behind a veneer with mortar. This concept was abandoned in favor of an open cavity. The belief was that the water penetration of the outer wall could be better controlled in the open cavity, preventing it from reaching the backup wall. Recent study and experience has brought this concept into question. Perhaps the old way is better. Filling the cavity with grout may reduce water penetration. There are several reasons. First, because the cavity is filled the water barrier is more complete. Second, the water that does enter cannot flow within the cavity. It moves with capillary and gravity forces only, thus limiting migration to the interior.

Another advantage for grouting and reinforcing the cavity is the increased flexibility for connecting the brick to the backup. For walls with articulated surfaces, reinforcing and grouting the cavity can result in significant cost savings. This is because the reinforcement is attached to the backing, while the veneer is attached to the reinforcement. Significant cost savings can result because of the geometric flexibility for making the tie between the veneer and the backing.

No matter what construction methods are used, panels, Structural Brick Veneer, reinforced veneer or others, a brick masonry wall has a lot of mass. This is often helpful in climates where sun loading and daily temperature swings are large. Light colored brick can be used in hot climates and dark colored brick used in cold climates.

The best use of a brick wall is when it does double duty. It acts both as an exterior wall with its esthetic and maintenance advantages and as part of the building structure. One project required a shear wall with significant seismic loading. A brick wall was constructed and used as a backing for 12 inches of concrete gunite (*Figure 8*).

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Figure 9: Brick Panels as Concrete Forms

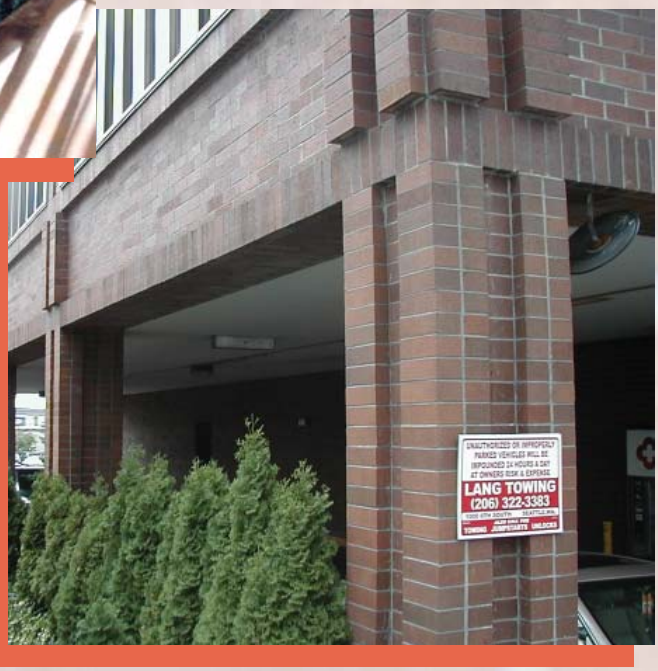

Figure 8: Brick Wall for Gunite Backup

In another project, brick panels were constructed and used as formwork for a concrete frame. The panels were erected and connected together to complete the form, followed by the reinforcement and concrete. The brick form was included as part of the load resistance of the system.

And in this recent project (*Figure 9*), a new University addition was designed to replicate the original building, as well as add seismic support. The new building was structurally tied to the old building, with the new building providing most of the lateral support. Significant lateral loads needed to be resisted with structural elements that match the stiffness of the old building but with additional ductility. The solution was a double wythe reinforced brick and CMU walls. This structural system also made it easier to replicate the old building.

Figure 10: University Project (Photo by James F. Housel

The largest brick I have seen measures 12 x 8 x 16 inches. The smallest one measures 1 x ½ x 2 inches. There are white brick and black brick and everything in between. You can even create brick sculptures.

When it comes to structural engineering of brick masonry, the design options are endless. I think we should provide our clients with more opportunity to select the brick option.▪

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Figure 11: Brick Sculpture