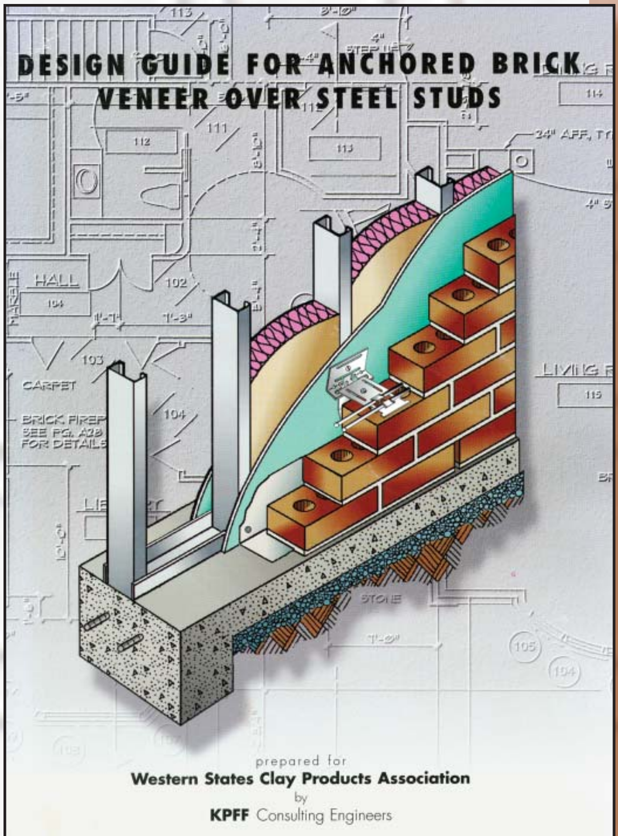
Design of Brick Veneer Over Steel Studs

Masonry cladding systems for buildings have been around for eons; however, the use of brick veneer backed by steel wall studs has only been popular since the late 1960's. Since then, the system has proven to be a cost effective alternative to more traditional methods of veneer support, such as CMU or wood framing. Many projects have been successfully built, while others have not performed so well over time. The rapid acceptance of the steel stud backing system preceded the development of adequate design and construction standards. In 1995, the Western States Clay Products Association published the first edition of their Design Guide for Anchored Veneer over Steel Stud Systems. That design guide has recently been updated and republished.

By Greg Schindler



Cover of the Design Guide

Unlike other typical subjects in structural engineering, such as steel floor framing or concrete slab design, there seems to be no generally accepted process of design or description of metal stud backing systems for veneer walls. Usually, the structural design of the exterior skin of the building is not included in basic structural engineering services. In the case of brick veneer on steel studs (BV/SS) systems, often the entire description of the system consists of the stud gauge and spacing shown on the exterior wall sections by the architect. Not having negotiated any additional fee for the design of the exterior wall, the structural engineer may give the architect some guidance in the form of sizing a typical stud and ledger angle, but that's about it. Unless the building exterior wall is extremely simple and consistent around the building, typical wall sections often do not adequately describe all the unique conditions that really should be considered, such as structure deflection, building drift, cantilever sill or parapet conditions, interaction of different materials, and many more issues.

In reality, it is often left up to the metal stud installer to determine how to actually put the wall together. This may be appropriate for one-story simple systems where the brick bears on the foundation with the studs only providing lateral stability. For multi-story and more complicated projects, it is my opinion that the structural engineer should take an active role in the design of the exterior wall system. This should be done on an additional service basis. To do an adequate job of design and detailing of the BV/SS system takes real effort, and sometimes several drawings, to describe the construction details.

Performance

Design life and performance objectives are important qualitative issues that should be discussed with the owner. Since buildings will not last forever, the owner and designer should establish a reasonable design life and performance level for every project. The WSCPA Design Guide defines two basic levels of performance for BV/SS systems. The basis for distinguishing between levels is the anticipated system life.

Level 1 is intended to provide a high level of quality, and long or extensive design life. The actual length of time used for the design life would be established or set by the owner and designer. Buildings of this type might include many public or institutional buildings. Specifically, these are buildings where the additional costs associated with higher quality are judged to be necessary in meeting the overall project requirements. A higher level of design, detailing and quality of materials such as stainless steel ties, and better flashing and sheathing, should be considered for Level 1 situations.

Level 2 is intended to provide a good level of quality and an average design life. Buildings of this type might include: general office, industrial, and residential buildings. These are buildings where it is decided that the additional cost of Level 1 quality is not economically justified or necessary.

The design of the BV/SS system is developed around several basic performance assumptions:

1. Brick veneer is nonstructural.

2. Brick veneer will be allowed to crack under service wind and seismic loading. Crack widths will be controlled to between 0.02 and 0.04 inches by limiting steel stud deflections to L/360 for service loads.

3. The BV/SS system provides two planes of weather protection to accomplish the code service requirements. The exterior brick veneer acts as the primary barrier (open rain screen). The interior flashed cavity acts as the secondary barrier (drainage wall) for weather resistance.

4. Tie forces are computed for three conditions and designed for the maximum lateral force.

- Uncracked brick veneer, with brick veneer and steel studs sharing lateral load.
- Cracked brick veneer, with steel studs supporting all lateral load.
- Ties support an ultimate tributary lateral load of two times the brick veneer weight.

5. The steel stud backing is designed to support full lateral load.

Expanding on these ideas:

Nonstructural – The term nonstructural characterizes the BV/SS system as isolated from the building structural frame and secondary members. This means that the veneer does not support the building, or provide any assistance to the stability of the building as a whole. It carries no load other than itself. Complete isolation is difficult to obtain. However, buildings do move. They move due to the effects of gravity, thermal changes, moisture and wind or seismic loading. When a building moves, the nonstructural veneer must not become locked between building elements. Inadequate attention to the design or construction details for the isolation of the system from the rest of the building is a common cause for unacceptable performance.

Two-inch Air Gap

Cracking and Leakage – It should be assumed that, due to wall deflection under load, the wall will crack and leak to some degree. Adequate attention must be paid to controlling the water that will penetrate the wall. The cracks will primarily be at the horizontal bed joints, and their size will be directly related to the deflection of the wall system. This brings up the question of what stiffness should the backing studs have to limit this deflection. Recommendations vary from L/175 all the way to L/2000. The former is a common limit for non-masonry walls. The latter is generally considered the limit required to prevent cracking under service loads. Two common values are L/600 and L/360. Of course, the less deflection there is the smaller the cracks will be. The WSCPA Design Guide recommends L/360 under the assumption that under normal conditions the brick will leak and controlling the water is more important than the size of the crack. Other sources recommend L/600. For Level 1 projects, the tighter deflection limit should be considered.

Water Control – Improper handling of water is one of the main reasons that some BV/SS installations in the past have not performed adequately. If you assume that water will penetrate the outer brick barrier, then controlling and directing the water back out of the cavity is very important. Consideration must be paid to the cavity size, flashing design, and weep holes. The guide goes into more detail on rainscreen concepts, mechanisms of leakage through brick, water and air barriers, flashing and sheathing issues.

Tie Design – The ties are designed, differently depending on whether the bricks have cracked or not. Studies have shown that until the load on the wall is sufficient to cause cracking, the ties closest to the stud supports will carry most of the out-of-plane load. The wall load needed to cause this cracking is calculated and compared to the design load. If the wall is in the cracked state, the bricks are assumed to act as

Spandrel Type System with Horiz. Joints at window Heads two simple spans over the stud span. Therefore, ties at the end of these two spans take all the reaction, regardless of tie spacing. This typically results in a larger tie force than if the wall load was distributed evenly among all ties. The Design Guide goes into more detail regarding tie design.

Wall Configurations

Brick veneer walls can be divided into two general configurations: spandrel systems and floor-to-floor systems. Spandrel systems are typified by strip window walls where the studs are supported at, and pass by, the floor slab to create spandrels between the windows at each level. Such a system relies on the studs to not only resist the out-of-plane wall loads, but to also carry the vertical weight of the wall. Typically, a steel ledger angle, also known as a shelf angle or relieving angle, is attached to the studs, usually at the window head. A continuous drift, or horizontal slip, joint is provided just below the ledger. See *Figure 1*. In this type of design, it is very important to provide this slip plane consistently around the building. This is especially important in earthquake country, where the magnitude of design drift can be significant. When the building drifts out-of-plane, the spandrel panel stays vertical and moves with the floor to which it is attached. The window system and any brick column covers will then need to be designed to "tilt" between the spandrels of adjacent levels.

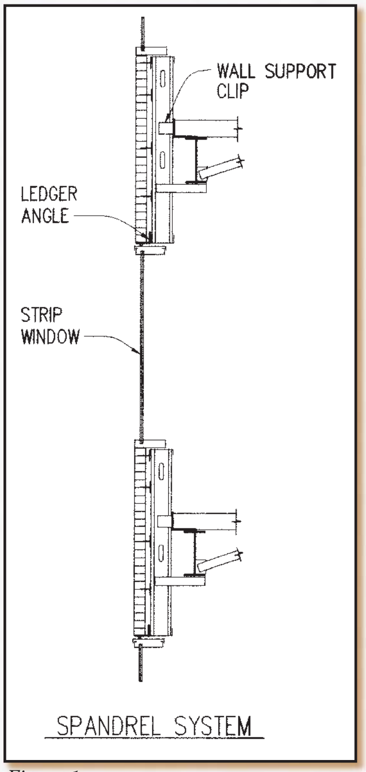


Figure 1

Floor-to-floor systems are different in that the studs span, as the name implies, from a ledger angle at one floor slab to another at the floor above. See *Figure 2*. The out-of-plane drift is handled by tilting of the story-high wall segment. It is still important to pay attention to providing a consistent slip joint for in-plane drift. This type of wall can be a solid wall or have punched window openings. If openings are included, care must be given to design the system to span as a unit between the floors. Openings should have lintels and NOT ledgers. The entire weight of the wall must be carried at the ledger, whether it is attached to the studs or to the floor directly. Therefore the weight of the brick above openings must stay in the brick, and span around the opening via a lintel and pass down the jamb brick to the ledger below. This is demonstrated in *Figure 2*. An easy way to remember this is that lintels span to masonry and ledgers are supported by the building. Putting a ledger angle above an opening causes two points of support in the same segment of wall, which will lead to unnecessary cracking.

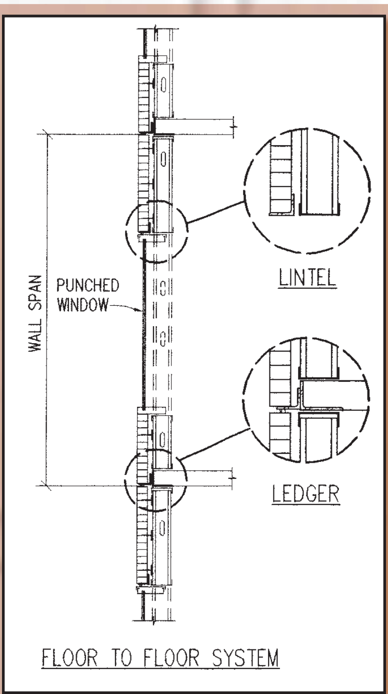


Figure 2

Components

Besides the brick itself, the complete BV/SS system consists of several components that must be specified and detailed properly.

Steel Studs

Steel stud selection is largely dictated by stiffness criteria. Steel studs are typically cold-formed. More information about steel studs can be found at the Steel Stud Manufacturers Association (SSMA), AISI, and other similar organizations. The minimum steel thickness of 43 mil. (18 gauge) is required to provide adequate material for welding and for screw anchorage. The studs should be galvanized to a minimum of G60 in accordance with ASTM A 525 (G90 if a higher level performance is desired). Steel stud spacing selected for design should be compatible with the sheathing module for ease of construction.

Exterior Sheathing

Wall sheathing requirements will vary with the quality level desired for the project and the climate at the project location. There are many options and systems available. The wall sheathing consists of an air infiltration barrier and water resistant gypsum board sheathing, being the most common. Some materials have an exterior water proof surface and may be sealed by just taping the joints. Architects debate as to whether an additional water barrier is needed, but it is a good idea to provide a positive barrier, especially in Level 1 quality projects.

Cavity

The cavity acts to provide a buffer for wind-driven rain, and allows water that penetrates the brick veneer to run down the inside brick face without migrating across the cavity space. The recommended air gap has increased over the years. One inch used to be common; however, now the recommended gap is two inches between brick and sheathing or insulation. A two-inch gap will minimize water "bridging" across the gap by obstructions or mortar droppings.

Flashing and Weeps

Continuous flashing is necessary for the removal of water that enters the cavity space. Flashing should be placed at any location where the cavity is interrupted, such as where the masonry is bearing on steel or concrete. This typically occurs at locations such as brick ledgers, lintels, and window sills. End dams should be provided to prevent water migration around windows or other obstructions. It is important that the flashing extend through the wall in order for it to function. Flashing stopped within the wall increases the chance for leaks, and likely will not function. Full head joint weep holes (the entire head joint is left open) should be provided above the flashing or ledger to drain water back out through the brick veneer.

Brick Ties

Brick ties and their attachment are important components of the BV/SS system. Adjustability in the vertical direction is important for ease of construction, and to isolate in-plane brick veneer movements from the backing. Tie must have positive anchorage to both the studs and the brick. The tie is typically screwed or bolted to the steel stud backing. In Seismic Design Category D and above, ties must engage the #9 gauge wire spaced not more than 18 inches on center vertically. The wire is not reinforcement of the veneer. It is for increasing the strength and ductility of the connection of the tie to the veneer. Thus, the wire does not have to be continuous or lapped like wall reinforcement. Corrosion resistance of the ties is very important. Ties should be hot-dip galvanized as a minimum. Stainless steel would be preferred for Level 1 projects.

Corrosion of the tie fasteners, both oxidation type corrosion and galvanic type, is a large subject that can't be adequately covered here. See the Design Guide for extensive information on that subject.

Vertical Expansion Joints

I am often asked how to space and locate expansion joints. A general rule of thumb is 30 feet on center; however, there is more to it than that. Vertical expansion joints need to be provided at various strategic locations in the BV/SS wall system. Expansion joint placement is dictated by several factors, including, climate, configuration, temperature, and structural support. Expansion joints should be provided at the following locations:

- At or near wall corners
- At wall discontinuities
- At changes in height
- At changes in thickness
- Adjacent to large openings
- Adjacent to dissimilar materials
- At abutments to other building elements
- At a maximum spacing of 30 ft on center.

(Note that other references use 25 ft. max.)

Vertical expansion joints should also be provided at other locations where the brick might crack.


Typical Spandrel System Framing

Building Movement and Drift

Buildings move in many ways that are often overlooked and under-appreciated by architects and engineers. Proper design and detailing should consider issues like lateral drift, thermal expansion, growth and shrinkage of materials with time, and vertical deflection. Those subjects can warrant an entire article on their own. Suffice it to say that a thorough job of design and detailing of a complete BV/SS wall system is a project in itself, and should not be left to a few notes on the architect's wall sections. The WSCPA Design Guide has much more information on all of these topics.▪

Greg Schindler, PE, SE is an Associate with KPFF Consulting Engineers in Seattle, WA, and is a former president of NCSEA. Mr. Schindler currently serves on the Editorial Board of Structure Magazine.

The Design Guide for Anchored Brick Veneer Over Steel Stud Systems, Second Edition, is available through the Western States Clay Products Association and is one of several design guides on brick design authored for the association by KPFF Consulting Engineers.

All photos are of the Western Washington University Communications Building and are courtesy of Zimmer Gunsul Frasca Architects.