DESIGNING ANCHORED BRICK VENEER ABOVE 30 FEET WITH A BACKING OF WOOD FRAMING

Wood framing is increasingly used to construct mid-rise structures to a maximum of five stories. Designing and detailing anchored brick veneer on such structures may be a challenge to designers only familiar with the prescriptive provisions of the TMS 402, Building Code Requirements for Masonry Structures [Ref. 2] since they restrict the height of the veneer to a maximum of 30 feet (9.14 m) and 38 feet (11.58 m) for a gable.

This *Brick Brief* reviews alternative design and detailing options for anchored brick veneer with a proposed height exceeding 30 feet and a backing of wood framing that serves as the main force resisting system for the building. Included are typical approaches to alternative design, differential movement calculations, and typical designs and detailing considerations.

DESIGN APPROACH

Podium Design. One structural solution for a four or five story building consists of two to three stories of wood framing above one or two stories of concrete, concrete masonry, or steel construction. This is commonly referred to in the building industry as a "podium" or pedestal structure. The more-rigid podium base serves as a place to bolt a steel shelf angle to support the anchored brick veneer above the podium. The veneer below the top of the podium can be supported by the foundation at or near the first floor level – thus dividing the extent of cumulative vertical differential movement into smaller portions.

If the height of veneer supported by the shelf angle anchored to the top of the podium is less than or equal to 30 feet (9.14 m) or 38 feet (11.58 m) to the top of a gable, then the prescriptive provisions of TMS 402 for anchored masonry veneer may be applied. If the height is more, then all or some height of the veneer supported by the shelf angle must be designed by the alternative design provisions of TMS 402.

Alternative Design for a Portion of Veneer. Generally, designers only use TMS 402 Section 12.2.1 Alternative Design when some aspect of the project does not allow the prescriptive requirements for anchored masonry veneer to be applied. In some cases, a designer may choose to use Section 12.2.1 Alternative Design to design a specific portion of the veneer, and choose to follow

the Section 12.2.2 Prescriptive Requirements when determining construction for the remainder of the veneer.

Alternative Design. The TMS 402 12.2.1 Alternative Design provisions (commonly referred to as rational veneer design) stipulate the following:

1. The forces applied to the veneer are distributed through the veneer to the anchors and the backing using the principles of mechanics.
2. Deflection of the backing is limited to maintain the stability of the veneer.
3. The veneer is not subject to either the flexural tensile stress provisions (TMS 402 Chapter 8), or the nominal flexural tensile strength provisions (TMS 402 Chapter 9).
4. The veneer must meet the General veneer provisions (TMS 402 Section 12.1), the prescriptive requirements for stack bond (TMS 402 Section 12.2.2.9), and the prescriptive requirements for higher seismic areas (TMS 402 Section 12.2.2.10).

The behavior of the veneer, the anchors and the backing should be considered for both in-plane and out-of-plane loading. In regard to in-plane loads, research has documented that there is little, if any, load transferred from the veneer to the backing [Ref. 6]. For out-of-plane loads, the amount of load carried by a given anchor depends on whether the veneer has cracked near mid-height or not [Ref. 5]. Out-of-plane cyclic load tests of such systems suggest that critical anchor loading will always be in tension [Ref. 5].

There are essentially eight steps that should be considered when applying TMS 402 Section 12.2.1 Alternative Design to anchored brick veneer. It should be noted that most of the steps below are usually considered or calculated when applying the TMS 402 Section 12.2.2 prescriptive requirements for veneer. This design procedure was adapted from the *Design Guide for Anchored Brick Veneer Over Steel Stud Systems* [Ref. 3].

1. **Veneer Performance.** The level of performance expected of the anchored brick veneer during and after a short-term loading event should be established. Generally, the expected level of performance is correlated with the Risk Category of the building which

is based on the nature of the Occupancy as defined by the 2015 IBC or ASCE 7. Most buildings qualify as Risk Category II where damage to nonstructural elements like anchored brick would be anticipated and the extent of damage would be correlated to the severity of the wind or seismic event. It is recommended that the procedure outlined below be limited to anchored brick veneer on Risk Category I or II buildings.

2. **Loads.** The lateral loads (wind and seismic) and the gravity loads (dead and live loads) must be calculated and load combinations determined.

3. **Stud Design.** Most exterior walls will likely support gravity loads in addition to supporting the lateral load imparted from the veneer through the ties. Studs located in these walls must be sized and spaced according to the demand of all loads – both gravity and lateral. Generally, the design of most studs will be governed by flexure or bearing capacity. Studs serving as backing for anchored brick veneer should also be designed to limit their deflection, assuming a uniform lateral load and a deflection limit of L/360. The stud size and spacing should consider the serviceability limit state, which should be determined based on the required moment of inertia:

$$I_{req} = \frac{5W_{design}L_{max}^4}{384E\Delta_{max}}$$

Where:
   E = Modulus of elasticity of stud
   W_{design} = Total static design load on anchored brick veneer, wind or seismic
   I_{req} = Required moment of inertia
   L_{max} = Maximum stud span
   Δ_{max} = Maximum out-of-plane allowable deflection

4. **Tie Design.** The governing lateral load must be established and used to determine the size and spacing of veneer ties (anchors).

   a. Calculate maximum demand on ties:
      i. Calculate static out-of-plane load at which first cracking occurs in brick veneer:

$$W_{cr} = \frac{8M_{cr}}{L_{max}^2}$$

   Where:
      M_{cr} = f_r x S (Cracking Moment)
      f_r = 180 psi (Modulus of Rupture for brick veneer)
      S = Section modulus

      ii. Calculate total static out-of-plane load that will result in cracking:

$$W_{total} = W_{cr}\frac{[EI]_{brick} + [EI]_{studs}}{[EI]_{brick}}$$

      iii. Compare W_{total} to W_{design} and calculate maximum tie force (T_{max}):

   If $W_{total} \leq W_{design}$, then the veneer has cracked and;

$$T_{max} = \frac{W_{cr}L_{max}}{2}$$

   If $W_{total} > W_{design}$, then the veneer has not cracked;

$$T_{max} = (W_{design})\left(\frac{[EI]_{brick}}{[EI]_{brick} + [EI]_{studs}}\right)\left(\frac{L_{max}}{2}\right)$$

   b. Choose tie manufacturer whose brick tie has sufficient ultimate capacity:

$T_{capacity} \geq 1.25\ T_{design}$ (Where $K_{tie} \leq 2$ kips per in.)

$T_{capacity} \geq 2.0\ T_{design}$ (Where $K_{tie} > 2$ kips per in.)

   Verify capacity and stiffness by appropriate test data.

5. **Story Drift.** The design and details of the anchored brick veneer must accommodate the calculated story drift.

6. **Seismic Detailing.** The anchored brick veneer must conform to TMS 402 Section 12.2.2.10 seismic prescriptive requirements.

7. **Resist Water Penetration.** The veneer and backing should be detailed to resist water penetration in the same manner as veneer meeting the TMS 402 Section 12.2.2 prescriptive requirements.

8. **Differential Movement.** The vertical differential movement between the material used for backing and anchored brick veneer must be calculated and accommodated in the design in the same manner as veneer meeting the TMS 402 Section 12.2.2 prescriptive requirements.

DIFFERENTIAL VERTICAL MOVEMENT
Wood Framing. Wood products may be affected by shrinkage, creep, and settlement. In fact, a 12-foot story of wood framing may experience a reduction in height

of as much as 1/3 to 1/2 inch. The following should be considered and accounted for during the design process.

- **Shrinkage and Swelling.** The cumulative effect of wood shrinkage as moisture content changes is a significant consideration for mid-rise construction. The total shrinkage in wood framing can be estimated by summing the shrinkage of each horizontal lumber member in walls and floors (wall plates, sole plates, and floor joists). Section 2304.3.3 of the 2015 International Building Code (IBC) [Ref. 1] requires a shrinkage analysis for wood structures supporting more than two floors and a roof. Also, Section 2303.7 of the 2015 IBC requires wood shrinkage to be considered when using lumber fabricated when green.

Wood begins to shrink when it dries beyond the fiber saturation point – about 27 to 30 percent Moisture Content (MC) for most wood species. Wood continues to shrink until the Equilibrium Moisture Content (EMC) is reached – the point at which the wood stabilizes with the surrounding atmospheric conditions. MC values for typical wood material are shown in Table 1. The final equilibrium moisture content (EMC) value of wood inside a building envelope in most U.S. locations is between 8 and 12 percent [Ref. 7].

Table 1 – Typical Moisture Content Values in Wood [Ref. 7]

Material	Condition of Seasoning	Prevalent Region	Moisture Content
Solid-Sawn Dimension Lumber	S-GRN (unseasoned)	Southwest U.S.	27 – 30%
	S-DRY, KD or KD-HT (seasoned)	All U.S. except southwest	19%
	MC 15 or KD 15	--	15%
Engineered Wood Product	Laminated Veneer Lumber (LVL), Parallel Strand Lumber (PSL), I-Joist, Cross-Laminated Timber (CLT)	--	4 – 8%

While wood species have different shrinkage coefficients, cross-grain shrinkage for plates and joists is usually estimated for design at about 6 percent or 0.0025 per 1 percent change in MC. The amount of shrinkage parallel to the grain (length of studs) is approximately 1/40 of the value for cross-grain shrinkage and is generally neglected in design [Ref. 11].

- **Creep.** Wood members under long-term loading continue to deform or "creep" over time. Where total deflection under long-term loading must be limited, increasing member size on lower floors is one way to provide extra stiffness to allow for this time dependent deformation. Under long term loading, the expected (average) lateral deflection could be 1.5 times the initial deflection for seasoned (dried) lumber and 2.0 times the initial lateral deflection for unseasoned (green) lumber [Ref. 9]. Green wood may creep 4 to 6 times the initial deformation as it dries. Compressive creep (axial shortening of loadbearing studs) is in the range of 1/8 to 1/4 in. (3.2 to 13 mm) per story with magnitude progressively increasing from upper to lower stories [Ref. 4].

- **Take-Up.** Wood framing can shorten from settlement (consolidation) of construction gaps commonly referred to as "take-up." Since settlement is difficult to predict as some gaps may disappear as the building is loaded during construction and before installation of anchored masonry veneer, 1/10 in. (2.5 mm) per floor seems reasonable [Ref. 11].

Clay Brick Veneer. Anchored brick veneer experiences thermal and irreversible moisture expansion. A 12-foot height of brick veneer may grow as much as 1/16 to 1/8 in. in service.

- **Thermal Expansion.** TMS 402 and the Brick Industry Association list the average linear thermal expansion coefficient for brick masonry as 4×10^{-6} in./in °F [Ref. 10]. A temperature change of 100°F is generally used for design purposes resulting in a thermal expansion coefficient of 4×10^{-4} in./in.

- **Moisture Expansion.** Irreversible expansion of brick occurs in the first few weeks after exiting the kiln and will continue at a diminishing rate for several years. The Brick Industry Association recommends a design coefficient of linear moisture expansion of 5×10^{-4} in./in. for brick veneer [Ref. 10].

- **Creep.** Creep in brick masonry primarily occurs in the mortar joints and is negligible.

OTHER CONSIDERATIONS

Anchorage. As the height of structures and the corresponding magnitude of differential movement increases, anchors (ties) connecting a veneer to its backing must be capable of accommodating this movement while also performing their primary function of transferring lateral forces from the veneer to the studs. Generally, this is best accomplished through the use of two-piece adjustable anchors which are designed to accommodate vertical differential movement between the veneer and the backing. Although TMS 402 provisions permit corrugated anchors to attach anchored masonry veneers to wood backing, two-piece adjustable anchors are recommended for buildings with anchored brick veneer higher than 30 feet (9.14 m) from grade. The two-piece anchor specified should be capable of accommodating the anticipated vertical movement between the wood frame as it shrinks and the anchored brick veneer as it expands.

Minimizing Wood Frame Movement. One of the most effective means to minimize wood frame shrinkage is to reduce the number of wood framing components that can shrink. If applied judiciously, such measures can reduce shrinkage by as much as half.

Several strategies to accomplish this are listed below.

- Minimize use of top and sole wood plates as much as possible.
- Specify wood plates with lower moisture content.
- Specify engineered wood floor joist systems. Such systems have lower moisture contents than dimension lumber systems and as a result shrink less.
- Specify metal hangers to support floor joists. Use of metal hangers effectively removes the shrinkage of the joists from the wall load path.
- Require lumber to be stored properly at the job site. Proper protection from weather and storage off ground can significantly decrease wood shrinkage.
- Require dry-in of the wood frame as soon as possible. Leaving wood framing in an exposed condition for an extended period of time is not advisable. Framing should be underroof and exterior walls closed-in as quickly as possible.
- Enclose openings as late in the construction process as possible. This gives the wood frame more time to dry.

Detailing. Accommodating the vertical differential movement between brick veneer and wood framing is critical – especially at masonry openings and penetrations. The following details allow for a reduction in wood framing height and an increase in brick veneer height [Ref. 8].
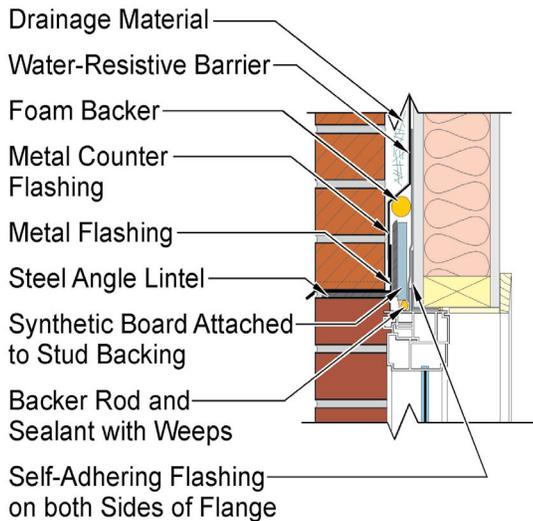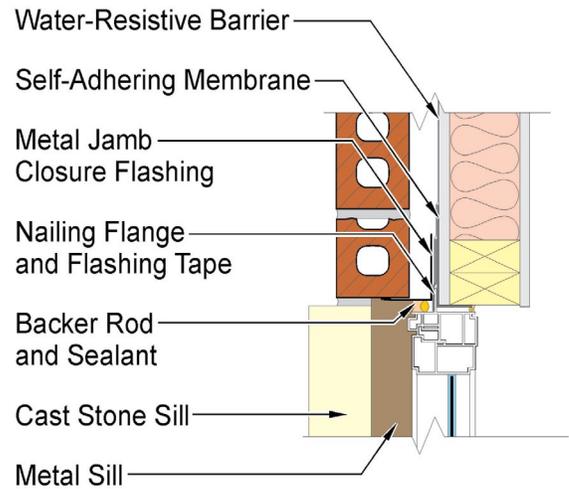

Water-Resistive Barrier
Self-Adhering Membrane
Metal Jamb Closure Flashing
Nailing Flange and Flashing Tape
Backer Rod and Sealant
Cast Stone Sill
Metal Sill

Figure 2. Window Jamb Detail

Nailing Flange and Flashing Tape
Backer Rod and Sealant
Metal Sill with Air Space to Allow for Shrinkage of Wood Frame and Slight Growth of Brick Veneer
Cast Stone Sill
Self-Adhering Membrane
Water-Resistive Barrier

Figure 3. Window Sill Detail

Drainage Material
Water-Resistive Barrier
Foam Backer
Metal Counter Flashing
Metal Flashing
Steel Angle Lintel
Synthetic Board Attached to Stud Backing
Backer Rod and Sealant with Weeps
Self-Adhering Flashing on both Sides of Flange

Figure 1. Window Head Detail

Water-Resistive Barrier
Penetration Sleeve with Flanges at Brick to Accommodate Movement
Pipe Penetration
Sealant and Band Clamp to Secure Water-Resistive Barrier to Sleeve
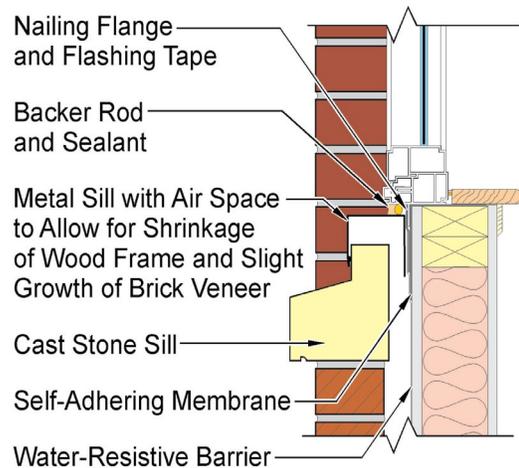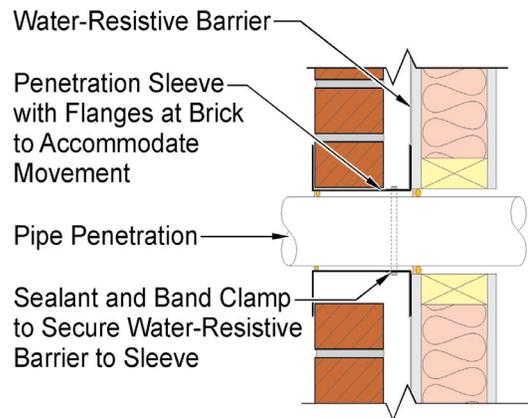
Figure 4. Pipe Penetration Detail

When the Alternative Design provisions are used, differential movement is considered, and appropriate detailing is applied, it is possible for anchored brick veneer with a backing of wood framing to extend higher than 30 feet (9.14 m) from its support.

The content of this Brick Brief is based on the following paper and presentation:
Clark, C., Danforth, L., and Bryja, J., "Designing Anchored Brick Veneer Above 30 Feet with a Backing of Wood Framing," Twelfth North American Masonry Conference, Denver, CO, 2015.

Brick Briefs are short discussions of a particular topic. The information contained herein must be used with good technical judgment. Final decisions on the use of this information must rest with the project designer and owner.

References
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