THE BRICK INDUSTRY ASSOCIATION

TECHNICAL NOTES on Brick Construction

12007 Sunrise Valley Drive, Suite 430, Reston, Virginia 20191 | www.gobrick.com | 703-620-0010

3C
July
2026

# 2022 TMS 402/602 Building Code and Specification – Anchored Veneer

**Abstract:** This *Technical Note* discusses the provisions for anchored veneer in the 2022 version of TMS 402/602 *Building Code Requirements and Specification for Masonry Structures*. Subjects discussed include prescriptive and engineered design methods, backing requirements, out-of-plane stability, veneer tie requirements, general anchored veneer requirements, and material specifications for anchored veneer components. Appendix A contains sample calculations for design and selection of veneer ties for wind and seismic out-of-plane loading.

**Key Words:** anchored veneer, backing, cavity, deflection, engineered design method, Modeling Analysis method, out-of-plane deflection, Prescriptive Basic method, Prescriptive Enhanced method, stability, Tributary Area method, veneer ties.

## SUMMARY OF RECOMMENDATIONS:

### Design Method Selection

- Select design method by referring to Table 1
- Factors affecting selection of design method include seismic design category, veneer tie type and out-of-plane loading

### Prescriptive Design Methods

- Two prescriptive options:
  - Prescriptive Basic
  - Prescriptive Enhanced
- See Table 2 for the maximum veneer tie spacing and tributary area per tie based on the design method

### Prescriptive Drainage Space and Cavity Width

- 2 in. (51 mm) minimum drainage space recommended; 1 in. (25.4 mm) minimum drainage space* required
- Cavity width is the distance between back face of veneer to front face of wall framing inclusive of drainage space and materials such as continuous insulation and sheathing
- When allowable bearing strength of sheathing exceeds 100 psi (0.689 MPa) or ties bear directly on framing, measure cavity width from face of sheathing
- Maximum cavity widths are 1 in. (25.4 mm), 4 in. (101.6 mm) and 6 in. (152 mm) depending on backing

* Permitted to be a 1 in. (25.4 mm) nominal dimension in the IRC and a 1 in. (25.4 mm) specified dimension in the IBC to account for construction tolerances.

### Prescriptive Veneer Tie Requirements

- Adjustable and nonadjustable veneer tie assembly component requirements are shown in Table 3 and Table 4.
- For cavity widths ≤ 4 in. (101.6 mm), use ties with minimum W1.7 (MW11) wire
- For cavity widths > 4 in. (101.6 mm) and ≤ 6 in. (152 mm), use ties with minimum W2.8 (MW18) wire
- For eye and pintle ties, use minimum W2.8 (MW18) wire

### Prescriptive Backing Requirements

- Height of veneer on wood light framing with corrugated ties is limited to 30 ft (9.14 m) or 38 ft (11.58 m) at a gable
- Height of veneer on cold-formed steel or wood light framing with adjustable ties may exceed 30 ft (9.14 m) or 38 ft (11.58 m) at a gable when designed to accommodate differential movement
- Prescriptive fastening requirements by backing and veneer tie type are shown in Table 5

### Engineered Design Methods

- Required when project conditions exceed prescriptive design limits
- Two engineered methods:
  - Tributary Area
  - Modeling Analysis

### Tributary Area Method

- Deemed-to-comply tie stiffnesses and strength values can be determined from Table 6
- Calculate tie force based on tie stiffness per equations in Table 7
- Pre-calculated veneer tie forces or tributary areas are in Table 8 and Table 9

### Modeling Analysis Method

- Allows the most flexibility and autonomy in design of brick veneer
- Analysis must consider the relative stiffness of the veneer, veneer tie and backing
- Iterative process; reanalyze veneer if cracking moment is exceeded

### General Anchored Veneer Requirements

- Use units complying with applicable ASTM standards
- Minimum required unit width is 2.625 in. (66.7 mm)
- When the height of the backing exceeds typical floor-to-floor heights, evaluate out-of-plane stability (see Table 10)
- For veneer not laid in running bond, include veneer wire reinforcement in bed joints
- Corbelling is limited to prescriptive requirements
- Limit applied vertical load and moment to 20 lb (89 N) and 180 in.·lb (20,340 N·mm) respectively
- For most typical buildings, use Level 1 special inspection

# INTRODUCTION

Anchored brick veneer consists of a nominal 3 or 4 in. (76 or 102 mm) thick exterior single wythe of brickwork mechanically attached to a backing with corrosion-resistant metal veneer ties that span a cavity between the veneer and the backing. Within the cavity is a drainage space and, as required, continuous insulation. The backing can consist of either wood framing, cold-formed steel framing, concrete or masonry. As this is a veneer, the brick is permitted to support only its own self-weight and limited applied loads. From a structural perspective, its primary purpose is to transfer lateral loads such as wind and seismic loads to the backing.

The TMS 402 *Building Code Requirements for Masonry Structures* (TMS 402), and the *Specification for Masonry Structures* (TMS 602) [Refs. 9 and 10] include provisions for anchored masonry veneer that were updated in 2022. These provisions include requirements for both prescriptive and engineered design methods. Commercial, institutional and multifamily buildings generally use the *International Building Code* (IBC) [Ref. 6], which references the TMS 402/602 requirements for anchored masonry veneer. One- and two-family houses and townhouses generally use the *International Residential Code* (IRC) [Ref. 8], which includes prescriptive requirements for anchored masonry veneer within the IRC itself that are similar to the TMS 402/602 requirements.

The remainder of this *Technical Note* provides detailed information on the anchored masonry veneer requirements by discussing materials, design methods and general requirements. Where warranted, differences between the anchored veneer requirements in the 2022 version of TMS 402/602 and the previous version published in 2016 are discussed.

# MATERIALS

## Brick and Other Clay Masonry Units

Clay masonry units used in anchored veneer are required to meet applicable ASTM standards [Ref. 1]:

- ASTM C62, *Standard Specification for Building Brick (Solid Masonry Units Made from Clay or Shale)*
- ASTM C126, *Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units*
- ASTM C212, *Standard Specification for Structural Clay Facing Tile*
- ASTM C216, *Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)*
- ASTM C652, *Standard Specification for Hollow Brick (Hollow Masonry Units Made from Clay or Shale)*
- ASTM C1405, *Standard Specification for Glazed Brick (Single Fired, Brick Units)*

When one of the engineered design methods is used, units that do not meet the ASTM standards listed above can be tested to determine the material properties for design.

The minimum thickness of all anchored masonry veneer units is required to be 2.625 in. (66.7 mm). When using prescriptive design methods, the maximum height and thickness of units is 16 in. (406 mm) and 5 in. (127 mm) respectively with a specified weight no more than 50 psf (2.4 kPa).

## Mortar

Mortar used in anchored veneer is required to meet ASTM C270, *Standard Specification for Mortar for Unit Masonry* [Ref. 1]. Pre-blended dry mortar mixes per ASTM C1714, *Standard Specification for Preblended Dry Mortar Mix for Unit Masonry* [Ref. 1], are also permitted. Consider the compatibility between a particular brick and mortar when determining mortar Type. Type N mortar is suitable for most veneer brickwork. See the *Technical Note* 8 Series for more detailed information about masonry mortar.

## Veneer Ties

Wire components of veneer ties must conform to one of the following ASTM standards [Ref. 1]:

- ASTM A1064/A1064M, *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete*
- A580/A580M, *Standard Specification for Stainless Steel Wire*

Sheet-metal components of veneer ties must conform to one of the following ASTM standards [Ref. 1]:

- ASTM A1008/A1008M, *Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Required Hardness, Solution Hardened, and Bake Hardenable*
- ASTM A480/A480M, *Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip*
- ASTM A240/A240M, *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications*

## Veneer Wire Reinforcement

Veneer wire reinforcement consists of wires placed in the bed joint of the brickwork such as in the case of veneer not laid in running bond. This reinforcing is required to meet one of the following ASTM standards [Ref. 1]:

- ASTM A1064/A1064M, *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete* with knurling per A951/A951M, *Standard Specification for Steel Wire for Masonry Joint Reinforcement*
- ASTM A580/A580M, *Standard Specification for Stainless Steel Wire*, Type 304 or 316 stainless steel with knurling per A951/A951M
- ASTM A1064/A1064M for deformed wire

For clay and concrete masonry unit backing, joint reinforcement is permitted to be used as veneer wire reinforcement. In this case, the longitudinal wires in the bed joints of the backing and the veneer are connected across the cavity with cross wires, which act as veneer ties. However, truss-type reinforcement is not permitted across cavities in anchored veneer unless engineered.

## Grout

When structural clay masonry units are used or the clay brick veneer has been engineered and requires reinforcing, grout is required to fill the core holes of the units. In these or similar cases, grout must meet ASTM C476, *Standard Specification for Grout for Masonry* [Ref. 1]. Where the compressive strength $f'_m$ of the brickwork, inclusive of both brick and mortar, exceeds 2000 psi (13.79 MPa), the grout compressive strength tested in accordance with ASTM C1019, *Standard Test Method for Sampling and Testing Grout for Masonry* [Ref. 1], must meet or exceed the compressive strength of the brickwork.

# DESIGN METHODS

The 2016 and 2022 versions of TMS 402 both include prescriptive and engineered design approaches. The 2022 version of TMS 402 expands and restructures the approaches into four paths:

- Prescriptive Basic method
- Prescriptive Enhanced method
- Tributary Area method
- Modeling Analysis method

Formally, both the Tributary Area method and Modeling Analysis method are categorized as engineered design methods; however, the Tributary Area method could be better described as a hybrid method between prescriptive and engineered. In this method, the calculations are limited to simple formulas that were developed based on more extensive engineering analysis.

The 2022 version of TMS 402 uses the Seismic Design Category (SDC) and the out-of-plane loading $p_{veneer}$ to determine the design method permitted for the anchored masonry veneer as shown in Table 1. For $p_{veneer}$, the strength level design wind pressure as defined by the components and cladding chapter of ASCE/SEI 7-22 [Ref. 3] usually governs. Where out-of-plane seismic loads govern, it is recommended to use these values for $p_{veneer}$. The additional requirements for high wind and seismic loads from the 2016 version of TMS 402 were incorporated into the Prescriptive Enhanced tie requirements of the 2022 version of TMS 402.

**TABLE 1**
**2022 TMS 402 Permitted Design Method for Anchored Veneer**

| All Other Veneer Tie Types Out-of-Plane Loading $p_{veneer}$, psf (kPa)[1] | Permitted Design Method | | Corrugated Veneer Ties Out-of-Plane Loading $p_{veneer}$, psf (kPa)[1,2] |
|---|---|---|---|
| | Seismic Design Category A, B or C | Seismic Design Category D or Higher | |
| ≤50 (2.39) | Prescriptive Basic[3] or Engineered | Prescriptive Enhanced or Engineered | ≤37.5 (1.79) |
| >50 (2.39) and ≤75 (3.59) | Prescriptive Enhanced or Engineered | Prescriptive Enhanced or Engineered | >37.5 (1.79) and ≤56.2 (2.69) |
| >75 (3.59) | Engineered | Engineered | >56.2 (2.69) |

1. $p_{veneer}$ = strength level out-of-plane loading on veneer per ASCE/SEI 7-22, psf (kPa).
2. Where corrugated sheet metal veneer ties are used, values are 75% of those shown for all other veneer tie types.
3. Prescriptive Enhanced can be used if desired.

Per Table 1, the Prescriptive Basic requirements are intended to apply to buildings with both moderate wind and seismic loads. For buildings in areas with higher wind or seismic loads, the Prescriptive Enhanced requirements or the Engineered methods apply. The Prescriptive Enhanced requirements indicate closer spacing of ties than the Prescriptive Basic requirements. Note that for buildings using corrugated sheet metal ties, the limiting $p_{veneer}$ values are lower than those for buildings utilizing other veneer tie types.

For sample calculations showing the use of these design methods, see Appendix A: Design Examples.

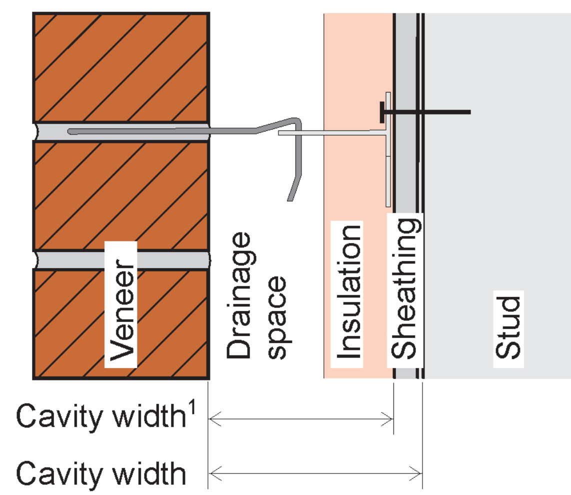
# PRESCRIPTIVE DESIGN METHODS

## Drainage Space (Air Space) and Cavity Width

Anchored brick veneer inherently includes a space between the brick and the backing. Over the years, multiple terms have been used to describe this space behind the inside face of the brick, which has caused confusion.

The 2022 version of TMS 402 defines "drainage space" and "cavity" as separate, distinct terms. Using this nomenclature instead of the previously used term "air space" helps to clarify that the space between the back of the veneer and the backing can contain insulation, drainage medium, mortar collection devices or incidental mortar droppings from construction.

A cavity is defined as the space between the interior face of the masonry veneer and its backing. The maximum specified width of the cavity, necessary for determining veneer tie requirements, is the distance from the back side of the veneer to the exterior face of the wall framing members. As shown in Figure 1, the cavity width always includes the drainage space and, if present, the continuous insulation layer. The cavity width can be measured from the face of the sheathing when one or more of the following conditions per Section 13.2.2.3.3 of TMS 402 is met:




1. When the requirements of Section 13.2.2.3.3 are met.

**Figure 1**
**Cavity Width for Anchored Veneer**

- The sheathing has a minimum allowable bearing strength of 100 psi (0.689 MPa).
- The veneer ties have a minimum allowable compressive strength of 200 lb (890 N) and penetrate the sheathing to bear directly on the framing.

Typical OSB and plywood sheathings as well as some gypsum sheathings can meet the bearing strength requirement. In cases where the minimum bearing strength cannot be met, such as with foam sheathing, the veneer tie must penetrate the sheathing and transfer load directly to the framing.

**Cavity Drainage and Air Movement.** Drainage space is defined in the 2022 version of TMS 402 as the space within the cavity that allows for the drainage of water. In cases where the cavity is measured from the face of the sheathing and no insulation is present, the drainage space and the cavity will be the same dimension. Movement of air also occurs within the drainage space. Previous misinterpretations of the term "air space" purported that the space needed to be completely free of all materials, including incidental mortar, mortar collection devices and veneer ties, which was not the intent. Using the term "drainage space" allows the focus to be on providing a space that allows and does not impede the movement of water and air.

For both prescriptively designed and engineered veneer, TMS 402 requires a minimum drainage space of 1 in. (25.4 mm). When continuous insulation is present within the cavity, provide the same minimum dimension of 1 in. (25.4 mm) between the inside face of the brick and the exterior face of the insulation. While TMS 402 requires this minimum, BIA recommends a 2 in. (51 mm) minimum in order to lessen the possibility of mortar bridging. Having an area clear for drainage of the water that reaches this space behind the brickwork is crucial to the function of anchored veneer. See the *Technical Note* 7 Series for more information on drainage accessories, mortar collection devices and detailing of the drainage cavity.

**Cavity Width Allowances.** The 2022 version of TMS 402 provisions require a minimum cavity width of 1 in. (25.4 mm), but the maximum cavity width can be either 4 in. (101.6 mm) or 6 in. (152 mm) depending on the following:

- Veneer tie type, size and thickness of its components
- Veneer tie fastener type, size and its penetration into the backing

When the dimension of the cavity exceeds 6 in. (152 mm), the assembly is outside the bounds of the Prescriptive Design requirements, and engineered design per the Modeling Analysis method must be used.

The maximum cavity width dimensions in the 2016 version of TMS 402 are either 4⅝ in. (117 mm) or 6⅝ in. (168 mm). However, this dimension is measured from the face of framing in all cases and includes a typical ⅝ in. (15.9 mm) sheathing thickness. Once these factors are considered, and assuming the sheathing meets the minimum allowable bearing strength, the maximum cavity dimension is comparable between the 2016 and 2022 versions of TMS 402.

## Veneer Tie Spacing

**Field of Veneer.** Table 2 shows the maximum tributary area per tie and maximum tie spacing when the veneer wall system meets the prescriptive requirements of the 2022 version of TMS 402. Within the maximum tributary area limit, horizontal and vertical spacing of ties can vary provided that the maximum spacing is not exceeded.

**TABLE 2**
**Prescriptive Veneer Tie Spacing**

| | Prescriptive Basic | Prescriptive Enhanced |
|---|---|---|
| Maximum tributary area per tie | 2.67 ft² (0.248 m²) | 1.78 ft² (0.165 m²) |
| Maximum spacing | 24 in. (610 mm) | 16 in. (406 mm) |

**Edges of Veneer.** Veneer ties must be located within 12 in. (305 mm) of unsupported edges such as vertical corners, openings and movement joints, except at the top of the veneer and support locations. The distance from the top of the veneer to the first row of veneer ties must not exceed one-half the maximum spacing given in Table 2. This condition occurs not just at the overall top of the wall, but beneath each horizontal expansion joint within the veneer. At supported edges, veneer ties are required to be located within 16 in. (406 mm) of the edge. This case corresponds with locations where the brick bears on a shelf angle, lintel or foundation, where the dimension from the veneer tie to the edge must be larger to reduce the potential for conflict with the flashing present at these locations.

## Veneer Tie Component Requirements

A definition for "veneer tie" was added to the 2022 version of TMS 402 in order to avoid using the term "anchor." Previously, "anchor" was used to describe veneer ties, metal straps used in intersecting wall sections and anchor bolts, which all have different functions. Additionally, the term “veneer tie” coordinates with the separate but similar term “wall tie” which is used in composite and non-composite masonry wall construction.

The prescriptive requirements cover components of the ties, such as thickness of the sheet metal attached to the backing, diameter of the wire laid in the mortar bed of the brick, and the number of legs for an eye and pintle system. While *Technical Note* 44B reviews the provisions in more detail, this *Technical Note* focuses on the minimum wire size, which changes with maximum specified cavity width, as shown in Table 3 and Table 4.

Because veneer ties typically rely on embedment in mortar for strength, the veneer tie component sizes are limited by the thickness of the mortar joints. The component embedded in the mortar joint cannot be more than one-half the joint thickness. In cases where veneer wire reinforcement or joint reinforcement is used, the combined thickness of the components cannot exceed one-half the mortar joint thickness. As a result, it is recommended to avoid stacking or crossing components and instead coordinate placement in different bed joints to avoid conflict.

**Adjustable Veneer Ties.** Adjustable veneer ties are permitted for all backing types. However, adjustable veneer ties are the only type permitted for cold-formed steel framed backing. Table 3 shows the requirements for key components of adjustable veneer ties for all backing types. The adjustable part of the tie must be placed such that the measurement from the inside face of veneer to the end of the adjustable part is no more than 2 in. (51 mm). Refer to *Technical Note* 44B for figures illustrating various adjustable veneer ties and tie assemblies.

**TABLE 3**

**Adjustable Veneer Tie Assembly Component Requirements**

| Component in Adjustable Veneer Tie Assembly[1] | Specified Cavity Width, in. (mm) | Adjustable Veneer Tie Assembly Component Requirements |
|---|---|---|
| Sheet metal components | ≤6 (152) | Minimum $\frac{7}{8}$ in. (22.2 mm) wide, base metal thickness minimum 0.06 in. (1.5 mm) |
| Wire components | ≤4 (101.6) | Minimum W1.7 (MW11) wire |
| | ≤6 (152) | Minimum W2.8 (MW18) wire |
| Eye and pintle components | ≤4 (101.6) | One or more pintle legs of minimum W2.8 (MW18) |
| | ≤6 (152) | Two or more pintle legs of minimum W2.8 (MW18) |
| Barrel components | ≤6 (152) | Minimum outside barrel diameter of $\frac{3}{16}$ in. (4.76 mm) |

1. Joint reinforcement in accordance with Table 4 is permitted for use in an adjustable veneer tie assembly provided that a tab or two eyes formed of minimum W2.8 (MW18) wire are welded to joint reinforcement.

**Nonadjustable Veneer Ties.** Nonadjustable veneer ties can be used with wood-framed backing and clay or concrete masonry backings. Table 4 shows the component requirements for such veneer ties.

**TABLE 4**

**Nonadjustable Veneer Tie Assembly Component Requirements[1]**

| Backing Type[2] | Nonadjustable Veneer Tie Type | Specified Cavity Width, in. (mm) | Nonadjustable Veneer Tie Type Requirements |
|---|---|---|---|
| Wood light framing | Corrugated sheet metal | 1 (25.4) | Minimum $\frac{7}{8}$ in. (22.2 mm) wide, base metal thickness minimum 0.03 in. (0.8 mm) |
| | Sheet metal | ≤4 (101.6) | Minimum $\frac{7}{8}$ in. (22.2 mm) wide, base metal thickness minimum 0.06 in. (1.5 mm) |
| Clay or concrete masonry | Unit wire tie | ≤4 (101.6) | Minimum W1.7 (MW11) wire |
| | | ≤6 (152) | Minimum W2.8 (MW18) wire |
| | Joint reinforcement | ≤4 (101.6) | Minimum W1.7 (MW11) longitudinal wires with cross wires spaced at maximum of 16 in. (406 mm) o.c. |
| | | ≤6 (152) | Minimum W2.8 (MW18) longitudinal wires with cross wires spaced at maximum of 16 in. (406 mm) o.c. |

1. Reference Table 3 for adjustable veneer tie requirements.
2. Nonadjustable veneer ties are not used with concrete or cold-formed steel framed backings.

## Veneer Tie Fastener Requirements

Table 5 lists the minimum fastener type, size, penetration and pullout resistance for all backing types. All fasteners must be corrosion resistant.

**Wood Light Framing.** Depending on the veneer tie type used, wood screws or nails can be used to fasten the veneer tie to the wood light framing. For either fastener, when sheathing is present, the noted penetration depth is increased by the thickness of the sheathing. When screw fasteners are used to attach adjustable or sheet metal veneer ties to wood light framing, the screw must be a minimum No. 10 size with sufficient length to penetrate a minimum of 1⅜ in. (34.9 mm) into the backing.

When corrugated sheet metal ties are used, screws must be minimum No. 10 size with sufficient length to penetrate a minimum of ⅝ in. (15.9 mm) into the backing. For these ties, the use of ring-shanked nails is also permitted. The protruding rings around the shank of a ring-shank nail increase the pullout capacity of the fastener over the smooth shank of a common nail. The ring-shank nails must be a minimum of 0.131 in. (3.33 mm) in diameter and 2½ in. (63.5 mm) long and must penetrate into the backing a minimum of 1⅜ in. (34.9 mm).

**Cold-Formed Steel Framing.** Use minimum No. 10 sheet metal screws that extend through the metal framing. The penetration of the screw beyond the back face of the metal framing requires a minimum of three full-profile, untapered exposed threads to be visible. The base metal of the cold-formed steel framing must be a minimum of 0.043 in. (1.1 mm).

**Concrete, Clay Masonry or Concrete Masonry.** Prior to the 2022 version of TMS 402, connection of veneer ties to masonry backing consisted of either fixed joint reinforcement or adjustable joint reinforcement assemblies, and the connection of veneer ties to concrete backing consisted of dovetail anchors. The 2022 version of TMS 402 permits the use of proprietary fasteners installed after the completion of the backing in accordance with the minimum pullout strength requirements in Table 5.

**TABLE 5**

**Prescriptive Fastening Requirements by Backing and Veneer Tie Type[1]**

<table>
<tr><th>Backing Type</th><th>Veneer Tie Type</th><th>Specified Cavity Width, in. (mm)</th><th>Minimum Fastener Type and Size</th><th>Minimum Fastener Penetration into Backing[2]</th></tr>
<tr><td rowspan="4">Wood light framing</td><td rowspan="2">Corrugated sheet-metal[3]</td><td>1 (25.4)</td><td>Ring-shank nails<br>2.5 in. (63.5 mm) ×<br>0.131 in. (3.33 mm)</td><td>1⅜ in. (34.9 mm)<br>Locate fastener within ½ in. (12.7 mm) of the 90° bend in the veneer tie.</td></tr>
<tr><td>1 (25.4)</td><td>No. 10 screw(s)</td><td>⅝ in. (15.9 mm)<br>Locate fastener within ½ in. (12.7 mm) of the 90° bend in the veneer tie.</td></tr>
<tr><td>Sheet metal fastener</td><td>≤4 (101.6)</td><td>No. 10 screw(s)</td><td>1⅜ in. (34.9 mm)</td></tr>
<tr><td>Adjustable veneer tie</td><td>≤6 (152)</td><td>No. 10 screw(s)</td><td>1⅜ in. (34.9 mm)</td></tr>
<tr><td>Cold-formed metal framing</td><td>Adjustable veneer tie</td><td>≤6 (152)</td><td>No. 10 screw(s)</td><td>Minimum of three exposed threads visible on opposite side of cold-formed steel framing member. Cold-formed metal framing shall be corrosion resistant and have a minimum base metal thickness of 0.043 in. (1.1 mm).</td></tr>
<tr><td>Concrete</td><td rowspan="2">Adjustable veneer tie<br>Unit wire<br>Joint reinforcement</td><td rowspan="2">≤6 (152)</td><td colspan="2" rowspan="2">Fasteners shall meet the pullout resistance requirements listed below:<br>Minimum design strength: 335 lb (1490 N)<br>Allowable load: 200 lb (890 N)</td></tr>
<tr><td>Clay or concrete masonry units</td></tr>
</table>

1. TMS 402 Table 13.2.2.3, General Prescriptive Anchored Veneer Requirements.
2. Where sheathing is present, the minimum penetration shall be into the structural member behind the sheathing.
3. Corrugated sheet metal ties shall not be used on veneers greater than 30 ft (9.14 m) in height, or 38 ft (11.58 m) in height at a gable.

## Limiting Veneer Height

For projects using wood light framing and corrugated ties, the height of the veneer is limited to 30 ft (9.14 m) or 38 ft (11.58 m) at a gable. For other projects using wood light framing and projects using cold-formed steel framing, the veneer is permitted to exceed 30 ft (9.14 m) in height above the vertical support, provided that it is designed and detailed to accommodate differential movement.

Designing for differential movement is most critical in the case of wood framing. Brickwork expands over time while wood framing shrinks, causing increased differential movement in the long term. This becomes most visible at openings and penetrations through the veneer, where other building components such as windows cross the plane between the veneer and the wood framing. Details where these conditions occur require more consideration to accommodate the expected movement. This includes the specified veneer ties, which must be capable of handling the anticipated differential vertical movement between veneer and wood backing without disengaging [Ref. 4].

# ENGINEERED DESIGN METHODS

The engineered design methods are required to be used when $p_{veneer}$ exceeds 75 psf (3.59 kPa). However, the engineered design methods are allowed to be used as an alternative anywhere the Prescriptive Basic or Prescriptive Enhanced design methods are permitted. TMS 402 has always provided an option for the rational design of a masonry veneer assembly; however, the provisions were based on principles of mechanics and provided minimal guidance.

The 2022 version of TMS 402 greatly expands the engineered approach to include two options: the Tributary Area method and the Modeling Analysis method. Of these two, the Tributary Area method provides increased guidance to engineers in conducting an appropriate design. Generally, designers should consider it first and use the Modeling Analysis method if the requirements of the Tributary Area method cannot be achieved. The Modeling Analysis method is similar to the previous Alternative Design method and provides the most flexibility and autonomy for rational design of the masonry veneer assembly.

## Tributary Area Method

The Tributary Area method is a partially engineered design method based on analyses conducted on anchored veneer walls of varying tie stiffnesses, backing stiffnesses, wall heights, mortar Types and veneer units [Ref. 5]. The analyses assumed prescriptive cavity widths and simple spans in the backing, excluding multi-span backings, cantilevered backings and backings interrupted by openings. These analyses were used to determine empirical equations for the force in veneer ties based on tie stiffness.

The Tributary Area method can be used if all the following conditions are met:

- Masonry units conform to applicable ASTM standards.
- Thickness of the masonry units does not exceed 5 in. (127 mm).
- The wall assembly must be a vertical application without sloping.
- Any out-of-plane corbelling, if present, must meet the code requirements for non-loadbearing conditions.

The Tributary Area method allows the use of stiffness and strength values that are tabulated or determined by testing. The tabulated values are based on the 2022 version of TMS 402 prescriptive veneer tie requirements. The TMS 402 provisions include minimum requirements related to veneer tie testing procedures, but they do not stipulate detailed test procedures or protocols. Veneer tie manufacturers often conduct in-house testing of their products. Professional judgment should be applied when using values from in-house testing data.

Outlined below are two approaches for using the Tributary Area method: one solving for the force in the tie and the other solving for the maximum tributary area for a given tie strength.

When using the Tributary Area method, consider the following approach:

1. **Select veneer tie type and determine tie stiffness and strength.** Select veneer tie type appropriate for the wall assembly and the corresponding stiffness and strength values from either Table 6, veneer tie manufacturer test data or other test data. Veneer tie type will depend on the cavity width and backing material covered in the previous sections of this *Technical Note*.

**TABLE 6**

**Permitted Stiffness and Strength Values[1]**

| Veneer Tie Type | Design Strength | Allowable Load | Stiffness |
|---|---|---|---|
| Corrugated sheet metal | 125 lb (556 N) | 75 lb (334 N) | 500 lb/in. (87.6 N/mm) |
| Adjustable – slotted | 330 lb (1468 N) | 200 lb (890 N) | 3000 lb/in. (525 N/mm) |
| Adjustable – two-leg pintle | 210 lb (934 N) | 125 lb (556 N) | 2500 lb/in. (438 N/mm) |
| Unit wire veneer ties and joint reinforcement | 210 lb (934 N) | 125 lb (556 N) | 20,000 lb/in. (3500 N/mm) |

1. Veneer ties meeting prescriptive veneer tie type and backing requirements

2. **Based on the tie stiffness in Step 1, calculate the required force in the veneer tie.** Use the out-of-plane seismic or wind loading applied to the veneer ($p_{veneer}$) to calculate the strength level or allowable stress level force required in the veneer tie for a chosen tributary area, $A_t$, using the equations in Table 7.

**TABLE 7**

**Tributary Area Method Veneer Tie Force Equations**

| Tie Stiffness | Strength Level[1] or Allowable Stress[2] Force in Each Veneer Tie |
|---|---|
| $k_{tie}$ ≤ 2500 lb/in. (350 N/mm) | $2pA_t$ |
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | $2.5pA_t$ |
| 8000 lb/in. (1401 N/mm) ≥ $k_{tie}$ > 5000 lb/in. (876 N/mm) | $3pA_t$ |
| $k_{tie}$ > 8000 lb/in. (1401 N/mm) | $4pA_t$ |

1. $p_u$ for strength level force
2. $p_{allow}$ for allowable stress level force

3. **Select a veneer tie from manufacturer's data based on required force.** Confirm that selected tie components meet the 2022 version of TMS 402 prescriptive veneer tie component requirements discussed earlier in this *Technical Note* and in *Technical Note* 44B. If the required veneer tie force cannot be met, repeat Step 3, adjusting veneer tie spacing and corresponding tributary area.

The proceeding design approach calculated the required force in the veneer ties. The following design approach calculates the required tributary area based on stiffness and strength of the veneer tie.

- **Alternate Step 2.** Based on tie strength in Step 1, calculate the required tributary area for the selected veneer tie. Use the out-of-plane seismic or wind loading applied to the veneer ($p_{veneer}$), tie stiffness to calculate the required tributary area, $A_t$, using the equations in Table 7.

Table 8 and Table 9 were developed to provide pre-calculated tie forces and maximum tributary areas for a few given cases.

## TABLE 8

### Tributary Area Method Veneer Tie Force

| Tie Stiffness, $k_{tie}$ | Force in Veneer Tie, lb (N)[1] | | | | | |
|---|---|---|---|---|---|---|
| | Tributary Area, $A_t$, in. × in. (mm × mm) | | | | | |
| | 16 × 16 (406 × 406) | | 16 × 24 (406 × 610) | | 24 ×24 (610 × 610) | |
| $p_{veneer}$ = 25 psf (1.20 kPa) | | | | | | |
| $k_{tie}$ ≤ 2500 lb/in. (350 N/mm) | 89 | (395) | 133 | (593) | 200 | (890) |
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | 111 | (494) | 167 | (741) | 250 | (1112) |
| 8000 lb/in. (1401 N/mm) ≥ $k_{tie}$ > 5000 lb·in. (876 N/mm) | 133 | (593) | 200 | (890) | 300 | (1334) |
| $k_{tie}$ > 8000 lb/in. (1401 N/mm) | 178 | (791) | 267 | (1186) | 400 | (1779) |
| $p_{veneer}$ = 50 psf (2.39 kPa) | | | | | | |
| $k_{tie}$ ≤ 2500 lb/in. (350 N/mm) | 178 | (791) | 267 | (1186) | 400 | (1779) |
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | 222 | (988) | 333 | (1483) | 500 | (2224) |
| 8000 lb/in. (1401 N/mm) ≥ $k_{tie}$ > 5000 lb·in. (876 N/mm) | 267 | (1186) | 400 | (1779) | 600 | (2669) |
| $k_{tie}$ > 8000 lb/in. (1401 N/mm) | 356 | (1582) | 533 | (2372) | 800 | (3558) |
| $p_{veneer}$ = 75 psf (3.59 kPa) | | | | | | |
| $k_{tie}$ ≤ 2500 lb/in. (350 N/mm) | 267 | (1186) | 400 | (1779) | 600 | (2669) |
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | 333 | (1483) | 500 | (2224) | 750 | (3336) |
| 8000 lb/in. (1401 N/mm) ≥ $k_{tie}$ > 5000 lb·in. (876 N/mm) | 400 | (1779) | 600 | (2669) | 900 | (4003) |
| $k_{tie}$ > 8000 lb/in. (1401 N/mm) | 533 | (2372) | 800 | (3558) | 1200 | (5338) |
| $p_{veneer}$ = 95 psf (4.55 kPa) | | | | | | |
| $k_{tie}$ ≤ 2500 lb/in. (350 N/mm) | 338 | (1502) | 507 | (2254) | 760 | (3380) |
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | 422 | (1878) | 633 | (2817) | 950 | (4226) |
| 8000 lb/in. (1401 N/mm) ≥ $k_{tie}$ > 5000 lb·in. (876 N/mm) | 507 | (2254) | 760 | (3380) | 1140 | (5071) |
| $k_{tie}$ > 8000 lb/in. (1401 N/mm) | 676 | (3005) | 1013 | (4507) | 1520 | (6761) |

1. Linear interpolation is not allowed.

## TABLE 9

### Tributary Area Method Veneer Tie Tributary Area

| Tie Stiffness, $k_{tie}$ | Tributary Area, $A_t$, ft² (m²) | | | | | |
|---|---|---|---|---|---|---|
| | Force in Veneer Tie, lb (N)[1] | | | | | |
| | 300 (1334) | | 400 (1779) | | 500 (2224) | |
| $p_{veneer}$ = 25 psf (1.20 kPa) | | | | | | |
| $k_{tie}$ ≤ 2500 lb/in. (350 N/mm) | 6.00 | (0.56) | 8.00 | (0.74) | 10.00 | (0.93) |
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | 4.80 | (0.45) | 6.40 | (0.59) | 8.00 | (0.74) |
| 8000 lb/in. (1401 N/mm) ≥ $k_{tie}$ > 5000 lb·in. (876 N/mm) | 4.00 | (0.37) | 5.33 | (0.50) | 6.67 | (0.62) |
| $k_{tie}$ > 8000 lb/in. (1401 N/mm) | 3.00 | (0.28) | 4.00 | (0.37) | 5.00 | (0.46) |
| $p_{veneer}$ = 50 psf (2.39 kPa) | | | | | | |
| $k_{tie}$ ≤ 2500 lb/in. (350 N/mm) | 3.00 | (0.28) | 4.00 | (0.37) | 5.00 | (0.46) |
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | 2.40 | (0.22) | 3.20 | (0.30) | 4.00 | (0.37) |
| 8000 lb/in. (1401 N/mm) ≥ $k_{tie}$ > 5000 lb·in. (876 N/mm) | 2.00 | (0.19) | 2.67 | (0.25) | 3.33 | (0.31) |
| $k_{tie}$ > 8000 lb/in. (1401 N/mm) | 1.50 | (0.14) | 2.00 | (0.19) | 2.50 | (0.23) |
| $p_{veneer}$ = 75 psf (3.59 kPa) | | | | | | |
| $k_{tie}$ ≤ 2500 lb/in. (350 N/mm) | 2.00 | (0.19) | 2.67 | (0.25) | 3.33 | (0.31) |
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | 1.60 | (0.15) | 2.13 | (0.20) | 2.67 | (0.25) |
| 8000 lb/in. (1401 N/mm) ≥ $k_{tie}$ > 5000 lb·in. (876 N/mm) | 1.33 | (0.12) | 1.78 | (0.17) | 2.22 | (0.21) |
| $k_{tie}$ > 8000 lb/in. (1401 N/mm) | 1.00 | (0.09) | 1.33 | (0.12) | 1.67 | (0.15) |
| $p_{veneer}$ = 95 psf (4.55 kPa) | | | | | | |
| $k_{tie}$ ≤ 2500 lb/in. (350 N/mm) | 1.58 | (0.15) | 2.11 | (0.20) | 2.63 | (0.24) |
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | 1.26 | (0.12) | 1.68 | (0.16) | 2.11 | (0.20) |
| 8000 lb/in. (1401 N/mm) ≥ $k_{tie}$ > 5000 lb·in. (876 N/mm) | 1.05 | (0.10) | 1.40 | (0.13) | 1.75 | (0.16) |
| $k_{tie}$ > 8000 lb/in. (1401 N/mm) | 0.79 | (0.07) | 1.05 | (0.10) | 1.32 | (0.12) |

1. Linear interpolation is not allowed.

## Modeling Analysis Method

The Modeling Analysis method is more advanced than the Tributary Area method and allows the most flexibility and autonomy for designing clay brick masonry veneer. The 2022 version of TMS 402 lists the following design assumptions for the distribution of the forces to the veneer, veneer tie and backing using a rational design approach:

- Analysis of the wall assembly and distribution of the wind and seismic loads must be based on the principles of mechanics and take into account the relative stiffness of the veneer, veneer tie and backing.
- Veneer must be considered cracked where flexural tensile stress exceeds the modulus of rupture.
- Locations where the veneer is to be considered cracked are permitted to be modeled as hinges in the engineered design.

The following steps outline a possible path for design based on the Modeling Analysis method:

1. **Assume tie stiffness and spacing.** Initial tie stiffness can be used from Table 6 or available test data. Similar to other design methods, the veneer tie type will depend on the cavity width and backing material as discussed in the previous sections of this *Technical Note*. The prescriptive 16 × 16 in. (406 × 406 mm) spacing can be used for the initial spacing if no specific spacing is required to accommodate the veneer geometry or layout of architectural features or components.
2. **Model veneer, veneer tie and backing stiffness with assumed tie spacing.** The model should incorporate the influence of the backing stiffness on the veneer. Models that account for the veneer alone can be unconservative. Model output will distribute the forces to the veneer, veneer tie and backing. The backing and veneer can be designed using these distributed forces based on their relative stiffnesses. Iterative analysis is needed to account for the changes in load distribution that occur when the veneer cracks.
3. **Select a veneer tie from the manufacturer's catalog based on the required force in the tie and the required minimum stiffness.** Because increased stiffness will change the distribution to the veneer, tie and backing, the analysis should be rerun using the published values from the selected manufacturer's veneer tie data to confirm the force distribution to all components of the wall assembly.

# GENERAL REQUIREMENTS OF ANCHORED VENEER

## Out-of-Plane Stability

The 2022 version of TMS 402 introduced provisions for veneer stability under out-of-plane deflection, as shown in Table 10. This table provides an upper bound for out-of-plane deflection based on the slenderness of the veneer. The height of the backing ($h_b$) divided by the specified veneer thickness is used to determine the limits under the service level wind load and the strength level seismic load respectively. When the veneer extends multiple stories, $h_b$ represents the height of backing on each floor. Generally, out-of-plane stability will govern the design only when the height of the backing exceeds typical floor-to-floor heights. As an alternative, performing a stability analysis is permitted to show the required minimum factor of safety, 1.5, against this overturning under strength level loading. The additional forces to the veneer ties and backing resulting from the analysis must be included in the design.

**TABLE 10**

**Maximum Deflection of the Backing for Stability**

| $h_b$[1] / $t_{sp}$[1] | Wind[2], $\delta_{service}$ | Seismic[3], $\delta_{ultimate}$ |
|---|---|---|
| 67 | $h_b$ / 240 | $h_b$ / 100 |
| 100 | $h_b$ / 360 | $h_b$ / 150 |
| 133 | $h_b$ / 480 | $h_b$ / 200 |
| 167 | $h_b$ / 600 | $h_b$ / 250 |

1. $h_b$ = height of backing; $t_{sp}$ = specified thickness of veneer.
2. Under application of 0.42 times the strength level wind load and applicable to backing whose stiffness is the same for service level and strength level wind loads. If the stiffness is not the same, separately evaluate stability using strength level wind loads and using the deflection limits for seismic loads.
3. Under application of the strength level seismic load.

## Veneer Not Laid in Running Bond

Wire reinforcement is required in bed joints for veneer not laid in running bond to provide continuity across head joints. TMS 402 defines running bond as a bond pattern in which there is a minimum overlap between units in adjacent courses by one-fourth the unit length. Although it does not meet the definition of running bond, brickwork laid in a random ashlar pattern may provide equivalent interlock to running bond in many cases.

The required minimum area of reinforcement is 0.00028 × specified cross-sectional wall area. For a veneer that has a nominal thickness of 4 in. (101.6 mm), TMS 402 permits using one of the following with a maximum vertical spacing of 18 in. (406 mm) to meet this requirement:

- (1) W1.7 (MW11) wire with deformations knurled in conformance with ASTM A951/A951M, *Standard Specification for Steel Wire for Masonry Joint Reinforcement*
- (1) D2 (MD13) deformed wire
- W1.7 (MW11) joint reinforcement conforming to ASTM A951/A951M

## Limiting Applied Loading

Anchored veneer is not intended to resist lateral and gravity load apart from its own self-weight. However, it is understood that small items will be attached to the veneer. In order to limit the applied loadings of these small items, the 2022 version of TMS 402 restricts these attachments to the following resultant forces over a 5 ft × 5 ft (1.52 m × 152 m) area:

- 20 lb (89 N) vertical force
- 180 in.·lb (20,340 N·mm) moment

If the attachment projects no more than 12 in. (305 mm) from the face of the veneer, TMS 402 deems this to comply with the moment requirement. When anchored veneer is designed using the Modeling Analysis method, limits are not imposed when superimposed loadings are accounted for in the design.

## Deflection of Horizontal Support Members

TMS 402 requires that structural beams that support anchored veneer be designed to limit the deflection due to allowable stress level from dead and live loading to L/600. This limit aims to prevent visible serviceability effects from all loads applied during and after installation of masonry and includes both immediate and long-term deflections due to shrinkage and creep. For anchored veneer, this provision commonly applies to lintels and shelf angles.

## Seismic Detailing

Anchored veneer uses veneer ties to transfer a portion of its seismically induced load to the backing. TMS 402 does not recognize the veneer as providing in-plane resistance to lateral loading from wind or seismic loads unless engineered to do so. As a nonstructural element, veneer must be isolated to prevent transfer of lateral load from the primary seismic force resisting elements to the veneer. Table 11 shows the requirements for designers to detail the anchored veneer, its supporting elements, and its interfaces with the structure. The intent of these provisions is to allow larger story drifts and building deflections to occur without damaging the veneer.

**TABLE 11**
**Seismic Detailing for Anchored Veneer**

| Seismic Design Category | Seismic Detailing Requirement |
|---|---|
| C, D, E, F | Isolate sides and top of veneer from structure |
| E, F | Independently support weight of each story of anchored veneer |

## Water Penetration Resistance

TMS 402 requires that anchored veneer be designed and detailed to resist penetration of water beyond the drainage space and insulation. The drainage space, flashing system and weeps are required to remove moisture from behind the veneer. Although the code permits weeps to be at least 3⁄16 in. (4.8 mm) in diameter and spaced less than 33 in. (838 mm) on center, BIA recommends using open head joint weeps spaced at no more than 24 in. (610 mm) on center. See the *Technical Note* 7 Series for more information on provisions and recommendations for water penetration resistance such as flashing and weeps in anchored veneer wall systems.

The IBC and IRC both require water-resistive barriers (WRBs) for wall assemblies with brick veneer and wood or cold-formed steel framed backing. The use of a WRB is not required by building codes for wall assemblies with masonry or concrete backings, but a WRB is sometimes installed to protect against ingress of incidental moisture or moisture-laden air that reaches that interface. In some cases, an air barrier installed on masonry or concrete backings will also function as a WRB.

## Corbelling

Where corbelling occurs, the veneer must be detailed to limit the maximum projection of both an individual brick unit and the entire corbel unless it is engineered using the Modeling Analysis method. See BIA Brick Briefs *Corbelling* and *Supporting Brick Masonry* for diagrams and equations showing the limits of corbels in prescriptively designed anchored veneer.

## Special Inspection of Anchored Veneer

TMS 402/602 stipulates minimum quality assurance requirements for the inspection of anchored veneer. Depending on the quality assurance level, periodic or continuous inspection may be required.

**Level 1 Inspection.** This level of inspection will apply to the majority of anchored veneer projects, those designed to the prescriptive requirements on most typical buildings assigned to Risk Category I, II or III. It requires the following inspection requirements:

- Verify submittal compliance prior to construction.
- When the height of the veneer exceeds 60 ft (18.3 m) above grade plane, periodically inspect the type, size and location of veneer ties and movement joints.

**Level 2 Inspection.** This level of inspection will apply to anchored veneer projects designed to the prescriptive requirements where the building is assigned to Risk Category IV, such as a fire station or hospital. In addition to the requirements of Level 1 inspection, the following inspection requirements apply:

- Periodically verify the proportions of site-prepared mortar.
- Construct and maintain a sample panel/mock-up.
- Periodically verify compliance of materials and procedures during construction.
- Periodically verify placement of masonry units and mortar joint construction.
- Periodically verify compliance with hot and cold weather masonry construction procedures.

When anchored veneer is designed using an engineered method, TMS 402/602 is unclear regarding the minimum inspection requirements. It is recommended to use engineering judgment to select a level of inspection appropriate for the complexity of the design and the Risk Category of the building, which may include requirements that exceed a Level 2 inspection.

# COMPARISON OF 2016 AND 2022 TMS 402 REQUIREMENTS

Table 12 summarizes the requirements for anchored veneer in the 2016 and 2022 versions of TMS 402.

## TABLE 12

**2016 vs. 2022 TMS 402 Requirements**

| Materials | | |
|---|---|---|
| **Subject of Provision** | **2016 TMS 402** | **2022 TMS 402** |
| Brick and other clay masonry units | ASTM C62, C126, C212, C216, C652, C1405 | |
| | n/a | Maximum height and thickness for prescriptive design: 16 in. (406 mm) and 5 in. (127 mm) respectively with a specified weight no more than 50 psf (2.4 kPa) |
| Mortar | ASTM C270; ASTM C1714 | |
| Veneer ties | Wire components: ASTM A1064/A1064M; ASTM A580/A580M<br>Sheet metal components: ASTM A1008/A1008M; A480/A480M; A240/A240M | |
| Grout | ASTM C476 | |
| Flashing | Installation of flashing is required | |
| Weep holes | Minimum 3/16 in. (4.8 mm) diameter weep holes less than 33 in. (838 mm) on center | |
| **Permitted Design Methods** | | |
| **Subject of Provision** | **2016 TMS 402** | **2022 TMS 402** |
| Prescriptive design | Prescriptive | Prescriptive Basic[1] method |
| | | Prescriptive Enhanced[1] method |
| Engineered design | n/a | Tributary Area method |
| | Alternative design | Modeling Analysis method |
| **Drainage Space (Air Space) and Cavity Width** | | |
| **Subject of Provision** | **2016 TMS 402** | **2022 TMS 402** |
| Terminology | "Air space" | "Drainage space" |
| | "Distance from back of brick to framing" | "Cavity width" |
| Minimum dimension | 1 in. (25.4 mm) | |
| Maximum dimension | 1 in. (25.4 mm) when corrugated ties are used | |
| | 4⅝ in. (117 mm) | 4 in. (101.6 mm) |
| | 6⅝ in. (168 mm) when ties meet additional requirements | 6 in. (152 mm) when ties meet additional requirements |
| Measurement | Measured from face of framing in all cases | Measured from face of sheathing if minimum allowable bearing strength of sheathing is 100 psi |
| **Prescriptive Veneer Tie Spacing** | | |
| **Subject of Provision** | **2016 TMS 402** | **2022 TMS 402** |
| Maximum tributary area for adjustable, corrugated and W1.7 wire ties | 2.67 ft² (0.248 m²)<br>2.00 ft² (0.186 m²) high seismic<br>1.87 ft² (0.174 m²) high wind | 2.67 ft² (0.248 m²) Prescriptive Basic<br>1.78 ft² (0.165 m²) Prescriptive Enhanced |
| Maximum tributary area for all other ties | 3.5 ft² (0.33 m²)<br>2.62 ft² (0.247 m²) high seismic<br>2.45 ft² (0.231 m²) high wind | |
| Maximum spacing | 25 in. (635 mm) vertical<br>32 in. (813 mm) horizontal<br>18 in. (457 mm) high wind | 24 in. (610 mm) Prescriptive Basic<br>16 in. (406 mm) Prescriptive Enhanced |
| Edges | Locate ties within 12 in. (305 mm) of supported and unsupported edges | Locate ties within 16 in. (406 mm) of supported edges and 12 in. (305 mm) of unsupported edges or movement joints, including openings |
| Openings | 24 in. (610 mm) on center around openings and within 12 in. (305 mm) of openings with any dimension > 16 in. (406 mm) for high-wind areas | |

1. When corrugated ties are used, lateral load criteria for method selection is reduced to 75%.

## TABLE 12 (cont.)
## 2016 vs. 2022 TMS 402 Requirements

<table>
<tr><th colspan="3">Veneer Tie Component Minimum Requirements</th></tr>
<tr><th>Subject of Provision</th><th>2016 TMS 402</th><th>2022 TMS 402</th></tr>
<tr><td>Sheet metal</td><td colspan="2">⅞ in. (22.2 mm) wide, base metal thickness 0.06 in. (1.5 mm)</td></tr>
<tr><td>Corrugated sheet metal</td><td colspan="2">⅞ in. (22.2 mm) wide, base metal thickness 0.03 in. (0.8 mm)</td></tr>
<tr><td>Unit wire ties and wire components</td><td colspan="2">W1.7 (MW11) wire; W2.8 (MW18) wire for increased cavity width</td></tr>
<tr><td>Joint reinforcement</td><td colspan="2">W1.7 (MW11) wire; W2.8 (MW18) wire for increased cavity width<br>Cross wires spaced 16 in. (406 mm) on center maximum</td></tr>
<tr><td>Eye and pintle</td><td colspan="2">One or more W2.8 (MW18) wire pintle legs<br>Two or more W2.8 (MW18) wire pintle legs for increased cavity width</td></tr>
<tr><td>Barrel</td><td colspan="2">3/16 in. (4.76 mm) outside barrel diameter</td></tr>
<tr><th colspan="3">Veneer Tie Fastener Minimum Requirements</th></tr>
<tr><th>Subject of Provision</th><th>2016 TMS 402</th><th>2022 TMS 402</th></tr>
<tr><td rowspan="2">Wood</td><td>8d common nail; 8d ring shank nail or No. 10 screw for SDC D or higher</td><td>8d ring shank nail; No. 10 screw with 1⅜ in. (34.9 mm) penetration into framing behind sheathing</td></tr>
<tr><td colspan="2">Locate fastener within ½ in of bend (corrugated tie)</td></tr>
<tr><td>Cold-formed steel</td><td>No. 10 screw</td><td>No. 10 screw extending through with minimum three threads exposed</td></tr>
<tr><td>Masonry</td><td>No fastener requirements listed; assumes use of wire ties, joint reinforcing, joint reinforcing with adjustable eye and pintle ties</td><td rowspan="2">Fasteners meeting minimum pullout resistance of 335 lb (1490 N) design strength or 200 lb (890 N) allowable load</td></tr>
<tr><td>Concrete</td><td>No fastener requirements listed; assumes use of dovetails or proprietary fasteners</td></tr>
<tr><td>Corrosion protection</td><td colspan="2">Fasteners must be corrosion resistant</td></tr>
<tr><th colspan="3">Limiting Height of Veneer</th></tr>
<tr><th>Subject of Provision</th><th>2016 TMS 402</th><th>2022 TMS 402</th></tr>
<tr><td rowspan="2">Wood-framed backing</td><td>30 ft (9.14 m) 38 ft (11.58 m) at gable</td><td>30 ft (9.14 m), 38 ft (11.58 m) at gable (corrugated ties)</td></tr>
<tr><td>Over 30 ft (9.14 m) or 38 ft (11.58 m) at gable; use Alternative Design</td><td>Over 30 ft (9.14 m) or 38 ft (11.58 m) at gable; veneer must be designed and detailed to provide for differential movement</td></tr>
<tr><td>Cold-formed steel framed backing</td><td>30 ft (9.14 m) 38 ft (11.58 m) at gable</td><td>Over 30 ft (9.14 m) or 38 ft (11.58 m) at gable; veneer must be designed and detailed to provide for differential movement</td></tr>
<tr><th colspan="3">General Requirements for Anchored Veneer</th></tr>
<tr><th>Subject of Provision</th><th>2016 TMS 402</th><th>2022 TMS 402</th></tr>
<tr><td>Water penetration resistance</td><td colspan="2">Wood or cold-formed steel framed backings: Water-resistive barrier required<br>Masonry or concrete backings: WRB optional; required air barrier may function as a WRB</td></tr>
<tr><td>Out-of-plane stability</td><td>n/a</td><td>Evaluate out of plane stability when height of backing exceeds typical floor-to-floor heights</td></tr>
<tr><td>Veneer not laid in running bond</td><td>Joint reinforcement of at least one wire W1.7 (MW11) spaced at a maximum of 18 in. (457 mm) on center vertically</td><td>Reinforce with one of the following: knurled wire W1.7 (MW11) minimum; deformed wire D2 (MD13) minimum; joint reinforcement W1.7 (MW11) minimum</td></tr>
<tr><td>Applied loading</td><td>n/a</td><td>Vertical loads on a 5 ft × 5 ft (1.52 m × 1.52 m) area on the face of the masonry: 20 lb (89 N); 180 in · lb (20,340 N · mm) moment</td></tr>
<tr><td rowspan="3">Special inspection</td><td colspan="2">Verification of submittal compliance</td></tr>
<tr><td>n/a</td><td>For veneers over 60 ft above grade, periodic verification of type, size and location of veneer ties and movement joint</td></tr>
<tr><td colspan="2">For Level 2 inspections or engineered veneer, use engineering judgment to determine quality assurance requirements</td></tr>
</table>

# SUMMARY

The 2022 version of TMS 402/602 was substantially rewritten to reorganize the provisions and add new content regarding the design of anchored veneer. This *Technical Note* summarizes these changes in prescriptive and engineered design methods and provisions to aid designers in providing safe, aesthetic and functional anchored veneer assemblies for all commercial and residential projects.



# REFERENCES

1. Annual Book of ASTM Standards, ASTM International, West Conshohocken, Pennsylvania, 2024:

**Volume 1.03**

| | |
|---|---|
| A240/A240M | *Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications* |
| A480/A480M | *Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip* |
| A580/A580M | *Standard Specification for Stainless Steel Wire* |
| A1008/A1008M | *Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Required Hardness, Solution Hardened, and Bake Hardenable* |

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| | |
|---|---|
| A951/A951M | *Standard Specification for Steel Wire for Masonry Joint Reinforcement* |
| A1064/A1064M | *Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete* |

**Volume 4.05**

| | |
|---|---|
| C62 | *Standard Specification for Building Brick (Solid Masonry Units Made from Clay or Shale)* |
| C126 | *Standard Specification for Ceramic Glazed Structural Clay Facing Tile, Facing Brick, and Solid Masonry Units* |
| C212 | *Standard Specification for Structural Clay Facing Tile* |
| C216 | *Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale)* |
| C270 | *Standard Specification for Mortar for Unit Masonry* |
| C476 | *Standard Specification for Grout for Masonry* |
| C652 | *Standard Specification for Hollow Brick (Hollow Masonry Units Made from Clay or Shale)* |
| C1019 | *Standard Test Method for Sampling and Testing Grout for Masonry* |
| C1405 | *Standard Specification for Glazed Brick (Single Fired, Brick Units)* |
| C1714 | *Standard Specification for Preblended Dry Mortar Mix for Unit Masonry* |

2. ANSI/ASHRAE/IES Standard 90.1-2022, *Energy Standard for Sites and Buildings Except Low-Rise Residential Buildings* (I-P Edition), Peachtree Corners, Georgia, 2022.

3. ASCE/SEI 7-22 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, American Society of Civil Engineers, Reston, Virginia, 2022.

4. Clark C., Danforth L., Bryja J., “Designing Anchored Brick Veneer Above 30 Feet with a Backing of Wood Framing,” *12th North American Masonry Conference*, Denver, Colorado, 2015.

5. Hochwalt J., Bennett R., Thompson J., Dalrymple A., Clark C., and Trimble B., “Proposed Changes to the TMS 402 Anchored Veneer Provisions,” *13th North American Masonry Conference*, Salt Lake City, Utah, 2019.
6. 2024 *International Building Code*, International Code Council, Country Club Hills, Illinois, 2024.
7. 2024 *International Energy Conservation Code*, International Code Council, Country Club Hills, Illinois, 2024.
8. 2024 *International Residential Code*, International Code Council, Country Club Hills, Illinois, 2024.
9. TMS 402/602 *Building Code Requirements and Specification for Masonry Structures*, The Masonry Society, Longmont, Colorado, 2016.
10. TMS 402/602 *Building Code Requirements and Specification for Masonry Structures*, The Masonry Society, Longmont, Colorado, 2022.
11. TMS *Masonry Designers’ Guide*, The Masonry Society, Longmont, Colorado, 2022.

# Appendix A: Design Examples

**EXAMPLE 1**

## Prescriptive Basic Design Method for Wood-Framed Single-Family Home Located in Climate Zone 2

For a two-story, 24 ft tall, wood-framed single-family home located in Climate Zone 2:

- Seismic Design Category B as determined by applicable *International Building Code* (IBC) or ASCE/SEI 7. Generally, veneer for a single-family home is specified in accordance with the *International Residential Code* (IRC). However, for educational purposes, this example uses IBC for designers using TMS 402/602 for large custom homes or where required by the authority having jurisdiction.
- Use $p_{veneer}$ = 28.6 psf for wind load governing over seismic load
- 2 × 4 in. framing at 16 in. on center with oriented strand board (OSB) sheathing and fiberglass batt insulation between studs
- 12 ft floor-to-floor height
- Builder desires to use corrugated veneer ties

Determine the following:

(a) Allowable deflection for backing stability and veneer height limits
(b) Permitted design method
(c) Maximum tributary area for veneer tie spacing
(d) Maximum specified cavity width
(e) Permitted veneer tie type
(f) Fastener requirements for veneer tie connection to backing

### (a) Check allowable deflection for backing stability and veneer height limits.

For 4 in. nominal modular brick, the specified thickness is 3.625 in.

$h_b / t_{sp}$ = (12 × 12 in./ft) / 3.625 in. = 39.7

*Note: TMS does not indicate that linear interpolation is allowed. Therefore, use $h_b / t_{sp}$ = 67 and Wind: $\delta_{service} = h_b / 240$ from Table 10.*

*where:*
$h_b$ = unsupported height of backing
$t_{sp}$ = specified thickness of veneer

Wind: $\delta_{service} = h_b / 240$ = 144 in. / 240 = 0.6 in. maximum out-of-plane deflection before the veneer becomes unstable.

*Note: The calculated maximum deflection for stability is different from maximum deflection for serviceability. Serviceability requirements are typically L/360 to L/600.*

Limiting height of veneer for use of corrugated veneer ties with wood framing is 30 ft or 38 ft at gable.

Therefore, corrugated veneer ties may be used if maximum cavity specified width is 1 in. See item (d).

### (b) Select the permitted design method from Table 1.

In Table 1, $p_{veneer}$ refers to the strength level out-of-plane loading due to wind or seismic loads that will be applied to the veneer. For wind, $p_{veneer}$ is found using the components and cladding calculation and not the main wind force resisting system procedures.

For SDC B and $p_{veneer} \leq$ 37.5 psf, corrugated metal veneer ties can be used with the Prescriptive Basic design method.

### (c) Find the maximum veneer tie tributary area and spacing from Table 2.

Based on the Prescriptive Basic design method, the maximum tie spacing is 24 in. and maximum tributary tie area is 2.67 ft². Assuming a veneer tie is placed on each stud (16 in. horizontal), the vertical spacing is:

> $2.67\ \text{ft}^2 \times 144\ \text{in}^2/\text{ft}^2 / 16\ \text{in.} = 24\ \text{in.} \leq$ maximum spacing 24 in.
> Use 16 × 24 in. spacing

### (d) Determine minimum/maximum specified cavity width.

The 2024 *International Energy Conservation Code* (IECC) [Ref. 7] for Climate Zone 2 requires minimum R-13 insulation within the wall framing or R-10 continuous insulation in the wall cavity. Generally, R-13 batt insulation fits within nominal 4 in. deep wall framing. Therefore, the option for insulation within the wall framing is used, with no continuous insulation required.

Per 2022 TMS 402, drainage space must be 1 in. minimum and cavity size is limited to 1 in. due to the use of corrugated ties. Therefore, maximum specified cavity width is 1 in.*

* The specified OSB sheathing meets the 100 psi bearing strength requirement and need not be included in the cavity width dimension.

### (e) Determine permitted veneer tie types for maximum cavity specified width.

Corrugated veneer ties are acceptable with 1 in. maximum specified cavity width.

When a veneer tie is selected, check its manufacturer's data for conformance with prescriptive requirements. Reference *Technical Note* 44B for tables showing minimum sizes and thicknesses in accordance with 2022 TMS 402 prescriptive veneer tie component requirements.

### (f) Determine permitted fastener requirements for veneer tie connection to the wood-framed backing.

From Table 5, "Prescriptive Fastening Requirements by Backing and Veneer Tie Type":

Use No. 10 screws located within ½ in. of the 90° bend of the corrugated sheet metal veneer tie. Minimum ⅝ in. penetration into the framing member, not including thickness of sheathing.

*or*

2.5 × 0.131 in. long ring-shank nails located within ½ in. of the 90° bend of the corrugated sheet metal veneer tie. Minimum 1⅜ in. penetration into the framing member, not including thickness of sheathing.

**EXAMPLE 2**

## Prescriptive Enhanced Design Method for Wood-Framed Multifamily Residential Construction Located in Climate Zone 4

For a four-story, 48 ft tall wood-framed, multifamily residential building located in Climate Zone 4:

- Seismic Design Category C as determined by applicable *International Building Code* (IBC) or ASCE/SEI 7
- $p_{veneer}$ = 58 psf for wind load governing over seismic load
- 2 × 4 in. framing at 16 in. on center with OSB sheathing and fiberglass batt insulation between studs
- 12 ft floor-to-floor height
- Builder desires to use corrugated veneer ties

Determine the following:

(a) Allowable deflection for backing stability and veneer height limits
(b) Permitted design method
(c) Maximum tributary area for veneer tie spacing
(d) Maximum specified cavity width
(e) Permitted veneer tie type
(f) Fastener requirements for veneer tie connection to backing

### (a) Check allowable deflection for backing stability and veneer height limits.

For 4 in. modular brick, the specified thickness is 3.625 in.

$h_b / t_{sp}$ = (12 ft × 12 in./ft) / 3.625 in. = 39.7
Use $h_b / t_{sp}$ = 67 and Wind: $\delta_{service} = h_b / 240$ from Table 10

$\delta_{service} = h_b / 240$ = 144 in. / 240 = 0.6 in. maximum out-of-plane deflection before the veneer becomes unstable.

*Note: The calculated maximum deflection for stability is different from maximum deflection for serviceability. Serviceability requirements are typically L/360 to L/600.*

Limiting height of veneer for use of corrugated veneer ties with wood framing is 30 ft or 38 ft at gable.

Therefore, corrugated veneer ties cannot be used because the veneer is 48 ft tall.

### (b) Select the permitted design method from Table 1.

In Table 1, $p_{veneer}$ refers to the strength level out-of-plane loading due to wind or seismic loads that will be applied to the veneer. For wind, $p_{veneer}$ is found using the components and cladding calculation and not the main wind force resisting system procedures.

For SDC C and $50 < p_{veneer} \leq 75$ psf, Prescriptive Enhanced or engineered design methods are permitted. The designer has chosen to comply with Prescriptive Enhanced requirements.

### (c) Find the maximum veneer tie tributary area and spacing from Table 2.

Based on the Prescriptive Enhanced design method, the maximum tie spacing is 16 in. and maximum tributary tie area is 1.78 ft². Using the maximum 16 in. spacing for the horizontal direction, the vertical spacing is:

1.78 ft² × 144 in² / ft² / 16 in. = 16 in. ≤ maximum spacing 16 in.
Use 16 × 16 in. spacing

### (d) Determine minimum/maximum specified cavity width.

2022 ASHRAE 90.1 [Ref. 2] Table 5.5-4, “Building Envelope Requirements for Climate Zone 4,” requires minimum insulation R-value R-13 + R-3.8 continuous insulation or R-20. Generally, R-13 batt insulation fits within nominal 4 in. deep wall framing. Using R-20 would require deeper framing. Therefore, the designer will add extruded polystyrene (XPS) continuous insulation in the cavity. Using an XPS manufacturer–provided R-value, 1 in. minimum continuous insulation is required in the cavity.

Per 2022 TMS 402, 1 in. minimum drainage space is required. BIA recommends 2 in. minimum drainage space. However, this building is adjacent to the property line. Therefore, the design team will use the minimum required drainage space.

1 in. insulation + 1 in. drainage space = 2 in. maximum specified cavity width*

* The specified OSB sheathing meets the 100 psi bearing strength requirement and need not be included in the cavity width dimension.

### (e) Determine permitted veneer tie types for maximum specified cavity width.

Even though nonadjustable veneer ties are permitted, BIA recommends adjustable veneer tie types with wood-framed construction due to the differential movement between the brick and the wood backing. Reference *Technical Note* 28 for more information on wood-framed backing and differential movement.

The designer initially chose an eye and pintle adjustable veneer tie. However, wood framing has the potential for shrinkage [Ref. 4]. Therefore, the designer decided to use a strap and vee veneer tie type for more vertical movement capability and more restraint of the adjustable part.

When a veneer tie is selected, check its manufacturer’s data for conformance with prescriptive requirements. Reference *Technical Note* 44B for tables showing minimum sizes and thicknesses in accordance with 2022 TMS 402 prescriptive veneer tie component requirements.

### (g) Determine permitted fastener requirements for veneer tie connection to the wood-framed backing.

From Table 5, “Prescriptive Fastening Requirements by Backing and Veneer Tie Type”:

Use No. 10 screws with 1⅜ in. minimum penetration into the framing member, not including thickness of sheathing.

**EXAMPLE 3**

## Engineered Modeling Analysis Design Method for Cold-Formed Steel Framed Energy-Efficient Housing in Climate Zone 5

For a four-story, 48 ft tall cold-formed steel framed, multifamily residential building located in Climate Zone 5:

- Seismic Design Category C as determined by applicable *International Building Code* (IBC) or ASCE/SEI 7
- $p_{veneer}$ = 58 psf for wind load governing over seismic load
- 4 in. deep wall framing at 16 in. on center with exterior-grade gypsum sheathing and fiberglass batt insulation between studs
- 12 ft floor-to-floor height
- Project required to comply with enhanced energy efficiency goals
- Veneer uses cement-lime Type N mortar; modulus of rupture, $f_r$, from 2022 TMS 402 is 100 psi and $f'_m$ is 2500 psi

Determine the following:

(a) Allowable deflection for backing stability and veneer height limits
(b) Permitted design method
(c) Maximum tributary area for veneer tie spacing
(d) Maximum cavity specified width
(e) Permitted veneer tie type
(f) Fastener requirements for veneer tie connection to backing

### (a) Check allowable deflection for backing stability and veneer height limits.

For 4 in. modular brick, the specified thickness is 3.625 in.

$h_b / t_{sp}$ = (12 ft × 12 in./ft) / 3.625 in. = 39.7
Use $h_b / t_{sp}$ = 67 and Wind: $\delta_{service} = h_b / 240$ from Table 10

$\delta_{service} = h_b / 240$ = 144 in. / 240 = 0.6 in maximum out-of-plane deflection before the veneer becomes unstable.

*Note: The calculated maximum deflection for stability is different from maximum deflection for serviceability. Serviceability requirements are typically L/360 to L/600.*

2016 TMS 402 limited the height of veneer used in conjunction with cold-formed steel backing to 30 ft. The 2022 version of TMS 402 eliminated this restriction.

### (b) Select the permitted design method from Table 1.

In Table 1, $p_{veneer}$ refers to the strength level out-of-plane loading due to wind or seismic loads that will be applied to the veneer. For wind, $p_{veneer}$ is found using the components and cladding calculation and not the main wind force resisting system procedures.

For SDC C and $50 < p_{veneer} \leq 75$ psf, Prescriptive Enhanced or engineered design methods are permitted. The designer will check if Prescriptive Enhanced requirements can be met.

### (c) Find the maximum veneer tie tributary area and spacing from Table 2.

Based on the Prescriptive Enhanced design method, the maximum tie spacing is 16 in. and maximum tributary tie area is 1.78 ft². Using the maximum 16 in. spacing for the horizontal direction, the vertical spacing is:

1.78 ft² × 144 in²/ft² / 16 in. = 16 in. ≤ maximum spacing 16 in.
Use 16 × 16 in. spacing

## (d) Determine minimum/maximum specified cavity width.

2022 ASHRAE 90.1 Table 5.5-5, "Building Envelope Requirements for Climate Zone 5," requires minimum insulation R-value R-13 + R10 continuous insulation. Generally, R-13 batt insulation fits within nominal 4 in. deep wall framing. The designer will add mineral wool insulation in the cavity. Using the manufacturer-provided mineral wool R-value of R4.2 per inch, 2.5 in. minimum continuous insulation is required in the cavity. However, to meet the enhanced energy-efficiency goals of the project, 4 in. continuous insulation is placed within the cavity.

Per 2022 TMS 402, 1 in. minimum drainage space is required. BIA recommends 2 in. minimum drainage space.

4 in. insulation + 2 in. drainage space + ⅝ in. sheathing* = 6⅝ in. maximum specified cavity width

* The exterior-grade specified gypsum sheathing does not meet the 100 psi bearing strength requirement and must be included in the cavity width dimension. As a result, the selected veneer tie must transfer the lateral load directly to the backing. See item (e) for further discussion.

This exceeds the maximum specified cavity width for Prescriptive Enhanced design. The veneer wall assembly must follow one of the engineered design methods. The Tributary Area method utilizes test data for cavity widths within the prescriptive limit. Whereas some veneer tie manufacturers may be able to provide test data demonstrating performance beyond the prescriptive cavity width limit, the structural engineer has decided to use the Modeling Analysis design method.

## (e) Determine permitted veneer tie types for maximum specified cavity width.

The structural engineer has chosen to use an adjustable eye and pintle veneer tie. Since the wall system is being engineered, any tie type except for corrugated veneer ties is permitted. However, only adjustable ties are recommended for use with cold-formed steel framing. In order to transfer the lateral load directly to the steel framing, an adjustable veneer tie with prongs is selected.

## (f) Determine permitted component sizes and thicknesses.

Calculate the stiffness (EI) of the veneer wall. Note that because the veneer is stiff, distribution of forces will be more nonlinear. Expect to see this in the model results.

$E_m = 700\, f'_m = 700\,(2500 \text{ psi}) = 1{,}750{,}000 \text{ psi}$
$I = \frac{1}{12} bh^3 = \frac{1}{12} \times 16 \text{ in.} \times (3.625 \text{ in.})^3 = 63.5 \text{ in.}^4$
[assumes 16 in. veneer tie horizontal spacing]
Modulus of rupture from 2022 TMS 402

Model the veneer and backing as multi-span beams linked together with the veneer ties as supports as shown in Figure 2. Contact manufacturers for eye and pintle veneer tie types and their stiffnesses, or begin with the stiffness value from Table 6. Calculate the stiffness of the cold-formed steel framing or obtain the value from manufacturer catalog data.

**Iteration 1.** Where the bending stress in the veneer exceeds the modulus of rupture, $f_r$, add a hinge in the veneer beam at the location of the maximum bending stress and rerun the model. This is where the first crack occurs in the veneer, and the stresses will redistribute.

**Iteration 2.** Where the bending stress in the veneer exceeds the modulus of rupture, $f_r$, add a second hinge at the maximum bending stress and rerun the model. Repeat until no bending stress exceeds the modulus of rupture.

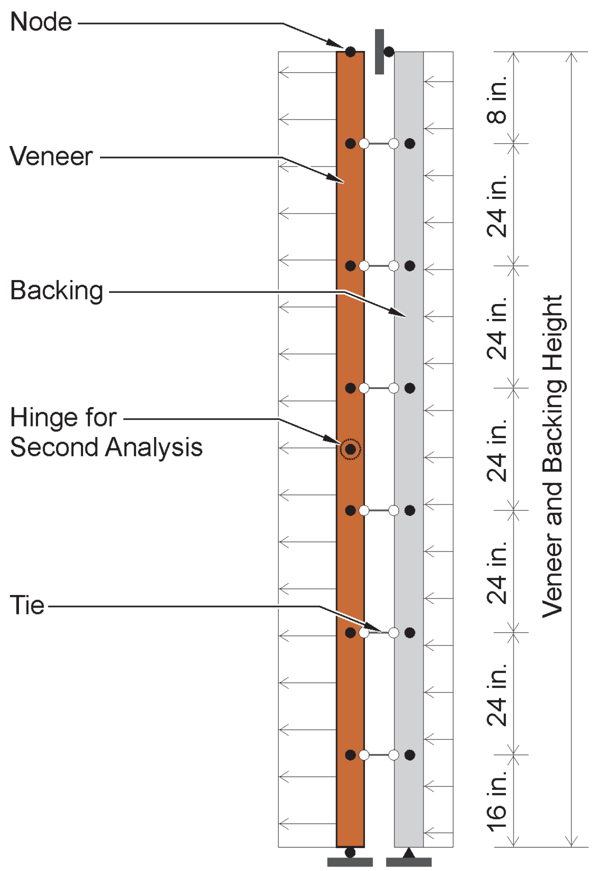


**Figure 2**
**Modeling Veneer Wall for Analysis**

**Iteration 3.** When no bending stress exceeds the modulus of rupture, use the maximum force in the links to select a veneer tie from manufacturer data.

Refer to the 2022 version of TMS *Masonry Designers' Guide* Example 16.2-7 [Ref. 11] for more detailed discussion of model iterations and stiffness value, net section modulus, and cracking moment calculations.

### (g) Determine permitted fastener requirements for veneer tie connection to the wood-framed backing.

Use maximum veneer tie force to design and detail the attachment of the veneer tie to the backing.

Refer to fastener catalog for capacity values of proprietary fasteners when used with cold-formed steel framing, or calculate capacity in accordance with the cold-formed steel code requirements.

**EXAMPLE 4**

## Prescriptive Enhanced Design Method for CMU Multifamily Residential Construction Located in Climate Zone 5

For a four-story, 48 ft tall CMU-backed, multifamily residential building located in Climate Zone 5:

- Seismic Design Category B as determined by applicable *International Building Code* (IBC) or ASCE/SEI 7
- $p_{veneer}$ = 58 psf for wind load governing over seismic load
- 12 ft floor-to-floor height with slab-supported CMU backing at each floor level

Determine the following:

(a) Allowable deflection for backing stability and veneer height limits
(b) Permitted design method
(c) Maximum tributary area for veneer tie spacing
(d) Maximum specified cavity width
(e) Permitted veneer tie type
(f) Fastener requirements for veneer tie connection to backing

### (a) Check allowable deflection for backing stability and veneer height limits.

For 4 in. modular brick, the specified thickness is 3.625 in.

$h_b / t_{sp}$ = (12 ft × 12 in./ft) / 3.625 in. = 39.7
Use $h_b / t_{sp}$ = 67 and Wind: $\delta_{service} = h_b / 240$ from Table 10

$\delta_{service} = h_b / 240$ = 144 in. / 240 = 0.6 in maximum out-of-plane deflection before the veneer becomes unstable.

*Note: The calculated maximum deflection for stability is different from maximum deflection for serviceability. Serviceability requirements are typically L/360 to L/600.*

There is no limiting height for brick veneer constructed with CMU backing.

### (b) Select the permitted design method from Table 1.

In Table 1, $p_{veneer}$ refers to the strength level out-of-plane loading due to wind or seismic loads that will be applied to the veneer. For wind, $p_{veneer}$ is found using the components and cladding calculation and not the main wind force resisting system procedures.

For SDC B and 50 < $p_{veneer}$ ≤ 75 psf, Prescriptive Enhanced or engineered design methods are permitted. The designer has chosen to comply with Prescriptive Enhanced requirements.

### (c) Find the maximum veneer tie tributary area and spacing from Table 2.

Based on the Prescriptive Enhanced design method, the maximum tie spacing is 16 in. and maximum tributary tie area is 1.78 ft². Using the maximum 16 in. spacing for the horizontal direction, the vertical spacing is:

> 1.78 ft² × 144 in.²/ft² / 16 in. = 16 in. ≤ maximum spacing 16 in.
> Use 16 × 16 in. spacing

### (d) Determine minimum/maximum specified cavity width.

2022 ASHRAE 90.1 Table 5.5-5, "Building Envelope Requirements for Climate Zone 5," requires minimum insulation R-value R-13.3 continuous insulation for mass walls such as CMU. Therefore, the designer will add polyisocyanurate (polyiso) continuous insulation in the cavity. Using a polyiso manufacturer-provided R-value of R6 per in., 2.5 in. minimum continuous insulation is required in the cavity.

Per 2022 TMS 402, 1 in. minimum drainage space is required. BIA recommends 2 in. minimum drainage space.

> 2.5 in. insulation + 2 in. drainage space + 0 in. sheathing* = 4½ in. maximum specified cavity width

* No sheathing is used with CMU backing. However, where sheathing does not meet the 100 psi bearing strength requirement and the veneer ties are not directly connected to the backing, the sheathing thickness must be included in the cavity width dimension.

### (e) Determine permitted veneer tie types for maximum specified cavity width.

Joint reinforcement is required for the construction of CMU walls. Ladder-type, truss-type or tab-type joint reinforcement is permitted for use in assemblies to transfer loads from the veneer to the CMU wall backing. Truss-type joint reinforcement across the cavity is not permitted.

Because BIA recommends joint reinforcement with adjustable ties rather than rigid multi-wire joint reinforcement, the designer has selected eye and pintle wire ties with ladder joint reinforcement.

### (f) Determine permitted component sizes and thicknesses.

Because the cavity width exceeds 4 in., the larger wire size, W2.8, is required. Drips are not permitted in cross wires or tabs.

From Table 3 and Table 4:

**Ladder joint reinforcement:**
Longitudinal wires: Minimum W2.8 size.
Cross wires: Minimum W2.8 wire and spaced at maximum of 16 in. on center

**Eye and pintle wire ties:**
Two or more pintle legs of minimum W2.8
Have two wires embedded in the veneer

### (g) Determine permitted fastener requirements for veneer tie connection to CMU backing.

Joint reinforcement is embedded in CMU mortar joints to connect the veneer to the backing.

**EXAMPLE 5**

## Engineered Tributary Area Design Method for Cold-Formed Steel Framed Police Station in High Seismic Area

For a two-story, 24 ft tall, cold-formed steel framed police station located in Charleston, South Carolina, in Climate Zone 2:

- Seismic Design Category D as determined by applicable *International Building Code* (IBC) or ASCE/SEI 7
- To determine $p_{veneer}$ for seismic loading, the structural engineer used Default Site Class D, Risk Category IV and additional criteria listed in item (b)
- 4 in. deep framing at 16 in. on center with gypsum sheathing and fiberglass batt insulation between studs
- 12 ft floor-to-floor height

- ASTM C216 units, nominal 4 in. thickness
- No corbelling or sloped brickwork

Determine the following:

(a) Allowable deflection for backing stability and veneer height limits
(b) Permitted design method
(c) Maximum tributary area for veneer tie spacing
(d) Maximum cavity specified width
(e) Permitted veneer tie type
(f) Assumptions for design method
(g) Fastener requirements for veneer tie connection to backing

## (a) Check allowable deflection for backing stability and veneer height limits.

For 4 in. modular brick, the specified thickness is 3.625 in.

$h_b / t_{sp}$ = (12 ft × 12 in./ft) / 3.625 in. = 39.7
Use $h_b / t_{sp}$ = 67 and Seismic: $\delta_{seismic} = h_b / 100$ from Table 10

$\delta_{seismic} = h_b / 100$ = 144 in. / 100 = 1.44 in. maximum out-of-plane deflection before the veneer becomes unstable.

*Note: The calculated maximum deflection for stability is different from maximum deflection for serviceability. Serviceability requirements are typically L/360 to L/600.*

## (b) Select the permitted design method from Table 1.

Seismic design calculations for $p_{veneer}$ provided by the structural engineer:

ASCE/SEI 7 criteria
$S_s$ = 1.5g
$S_1$ = 0.5g.
$a_p$ = 1.0
$R_p$ = 1.5
$\Omega_o$ = 2.0 (for anchorage into masonry)
$W_p$ = 40 psf (single wythe brick weight)
$I_p$ = 1.5 for Category IV structure (fallen veneer could impede use of building)
$p_{veneer} = F_p$ = 96 psf at top of wall, 32 psf at base of wall

For SDC D and $p_{veneer}$ > 75 psf; only engineered design methods are permitted. The architect has chosen to use the Tributary Area design method.

## (c) Find the maximum veneer tie tributary area and spacing.

The architect has chosen to use an adjustable slotted veneer tie. Since the wall system is being engineered, any tie type except for corrugated veneer ties is permitted. However, only adjustable ties are recommended for use with cold-formed steel framing.

The tie stiffness can be selected from Table 6 or values provided by veneer tie manufacturers.

| | | | |
|---|---|---|---|
| Adjustable – slotted | 330 lb<br>(1468 N) | 200 lb<br>(890 N) | 3000 lb/in.<br>(525 N/mm) |

Select equation for determining the force in the veneer tie from Table 7 using tie stiffness from Table 6:

| | |
|---|---|
| 5000 lb/in. (876 N/mm) ≥ $k_{tie}$ > 2500 lb/in. (350 N/mm) | 2.5 $pA_t$ |

For p = $p_{veneer}$ and F = 330 lb from Table 6:

$A_t$ = 330 lb / (2.5 × 96 psf) = 1.375 ft²
$A_t$ ≤ 1.375 ft² = 14 × 14 in. maximum tributary area. Use 16 × 8 in. to match stud spacing.

Table 9 could also be used to determine $A_t$ for selected forces in the ties and $p_{veneer}$.

The architect was notified that the wall was built with a 16 × 24 in. tie spacing. In a situation where the ties have been misplaced, Table 7 equations can be used to calculate the maximum force in the veneer tie to confirm that it is less than the capacity given by the veneer tie manufacturer as shown below. As an alternative, Table 8 calculates the tie force for the as-built tributary area:

For $p_{veneer}$ = 95 psf and $A_t$ = 16 × 24 in., the force in the tie is approximately 95 psf × [(16 in. × 24 in.) / (144 in.² / ft²)] × 2.5 = 633.3 lb.

### (d) Determine minimum/maximum specified cavity width.

2022 ASHRAE 90.1 Table 5.5-2, "Building Envelope Requirements for Climate Zone 2," requires minimum insulation R-value R-13 + R-7.5 continuous insulation. Generally, R-13 batt insulation fits within nominal 4 in. deep wall framing. Therefore, the designer will add extruded polystyrene (XPS) continuous insulation in the cavity. Using an XPS manufacturer–provided R-value, 2 in. minimum continuous insulation is required in the cavity.

Per 2022 TMS 402, 1 in. minimum drainage space is required. BIA recommends 2 in. minimum drainage space.

2 in. insulation + 2 in. drainage space = 4 in. maximum specified cavity width*

* The specified gypsum sheathing meets the 100 psi bearing strength requirement and need not be included in the cavity width dimension.

### (e) Determine permitted veneer tie types for maximum specified cavity width.

The structural engineer has chosen to use an adjustable slotted veneer tie. Since the wall system is being engineered, any tie type except for corrugated veneer ties is permitted. However, only adjustable ties are recommended for use with cold-formed steel framing.

### (f) Verify assumptions for design method.

Because nominal 4 in. thick ASTM C216 units are being used in a vertical application, the brickwork meets the requirements for using the Tributary Area method.

### (g) Determine permitted fastener requirements for veneer tie connection to the cold-formed steel framed backing.

Use No. 10 corrosion-resistant screws extending through 0.043 in. minimum thickness cold-formed steel framing by at least three full-profile, untapered exposed threads.