15th Canadian Masonry Symposium
Ottawa, Canada
June 2-5, 2025

Differential Movement – Beware the Backup Structure

Rebecca Herkes[i] and Peter M. Babaian[ii]

Abstract

In the evolving landscape of low-rise multifamily construction, an increasingly popular approach involves multiple stories of wood framing over a concrete podium or slab. Many such buildings feature brick masonry exterior cladding systems to meet zoning ordinances, blend with the neighborhood's character, and reflect a premium design aesthetic. Integrating brick veneer with wood framing can be challenging; without careful attention to detail, this combination can result in significant issues due to differential movement, potentially leading to costly rework. This paper discusses the movement compatibility issues between wood framing and brick masonry, drawing on examples of failure to highlight effective strategies for avoiding these problems in future projects. Additionally, this paper explores how distinctive brick masonry design features can be successfully integrated into wood-framed or concrete podium structures when given the proper design consideration.

Keywords

wood framing, wood shrinkage, differential movement, design, failure

[i] Senior Consulting Engineer, Simpson Gumpertz and Heger, Inc., Chicago, Illinois, USA, Rmherkes@sgh.com
[ii] Senior Principal, Simpson Gumpertz and Heger, Inc., Chicago, Illinois, USA, Pmbabaian@sgh.com

INTRODUCTION

The North American brick cladding systems market is projected to grow in the next five years, reaching a projected revenue of 132.6 billion US dollars (USD) by 2030 [1]. Brick is a popular choice due to its timeless aesthetic appeal, durability, and ability to complement a wide range of architectural styles, making it an enduring option for developers and architects. Additionally, wood framing in commercial construction is increasing due to cost considerations, decreased embodied energy, and ease of construction, which are critical factors for meeting the demands of modern multi-story projects.

With the enduring popularity of both construction materials, it's not uncommon for them to be used together, especially in residential or multi-story mixed-use developments. The primary challenge of using wood-framing and brick masonry veneer together is the opposite and irreversible volume changes that wood and brick undergo throughout their service life. Wood will contract over time, whereas brick will expand.

The consequence of improperly predicting and accommodating the differential movement may result in premature deterioration or failure of these materials or others supported by them. Bound brick masonry veneer can crack making the building more susceptible to detrimental effects including water infiltration, staining, efflorescence, and compromised structural integrity, while also imparting unintended forces on other systems, such as windows. Additionally, the openings through the wood-framed backup wall and brick masonry veneer may become misaligned in a manner that distorts sheet metal flashing, damages sealant joints, creates gaps in the cladding, and binds operable windows and doors within their frames.

The shift in building codes from prescriptive to performance-based standards for managing differential movement in wood-framed structures with brick veneer highlights the need for designers to be familiar with practical solutions. Two critical parts of that are fundamental understanding of cumulative differential movement is critical and establishing design constraints within which detailing for differential movement will be effective.

CALCULATION OF DIFFERENTIAL MOVEMENT

The movement of construction materials can be difficult to predict, since volume change is affected by factors beyond the material properties listed in specifications or submittals. The material's age, storage conditions, orientation, and temperature at installation can impact the amount of volume change.

Wood

As moisture recedes during the natural seasoning process, wood shrinks. Wood shrinkage occurs at different rates depending on the orientation of the wood grain. Shrinkage primarily occurs perpendicular to the wood grain. Longitudinal shrinkage, meaning shrinkage along the wood grain, is typically small enough to be neglected in design [2]. Wood creep and settlement also contribute to the overall shortening of wood through its service life.

Once the wood dries to a point of equilibrium with its environment, it may swell or shrink as its moisture content and temperature varies. This change, unlike the shrinkage during the seasoning process, is reversible.

Brick

Brick masonry undergoes irreversible moisture expansion throughout its service life. A brick unit exists at its smallest volume immediately after exiting the kiln. From that point on, absorption of environmental moisture will result in expansion [2]. The total moisture expansion of brick masonry veneer depends on the kiln temperature during brick production, ratio of brick to mortar face dimension, and the temperature and humidity of the environment.

Building Code History

The International Building Code (IBC) begins Chapter 21, the chapter governing the materials, design, construction, and quality of masonry, by stating that design methods shall comply with the provisions of TMS 402[iii] as well as applicable requirements included in the chapter. References to building code requirements refer to language in the document titled TMS 402 Building Code Requirements for Masonry Structures. The active version of TMS 402 is based on its adoption by IBC.

For the past decade, prior to IBC 2024, which references TMS 402-22, the building code included two primary provisions for the relationship between wood structure and masonry veneer.

- The height of exterior masonry veneer connected to wood-framed structure was limited to 9.14 m (30 ft) above the foundation, with an additional 2.4 m (8 ft) permitted at gables [3][4] (TMS 402-13/ACI 530-13/ASCE 5-13, sec. 12.2.2.3.1.2 and TMS 402-16, sec. 12.2.2.6.1).

- Exterior brick masonry veneer having an installed weight of 195 kg/m^2 (40 psf) or less was permitted to be supported on wood construction up to 3.7 m (12 ft) high. Commentary in TMS 402-13/ACI 530-13/ASCE 5-13 and TMS402-16 stated that the height limit of 3.7 m (12 ft) was considered to be the maximum single story height [3][4] (TMS 402-13/ACI 530-13/ASCE 5-13, sec. 12.2.2.3.1.5 and TMS 402-16, sec. 12.2.2.3.1.2).

Interpretation of these requirements has evolved in response to the potential ambiguity and apparent contradiction between the height restrictions of 9.14 m (30 ft) and 3.7 m (12 ft). The brick masonry veneer height of 9.14 m (30 ft) was considered to dictate the maximum vertical distance from the non-combustible foundation to the next support, while the single-story height limit of 3.7 m (12 ft) was considered to go into effect only when the support was anchored directly to the wood construction. Since the type of support, foundation or relieving angle, does not affect the extent of wood shrinkage relative to the brick masonry veneer, the 9.14 m (30 ft) limit was generally understood to govern differential movement, and the 3.7 m (12 ft) limit was intended to moderate fire safety risk.

In addition to its interpretative ambiguity, the code's height limitations do not preempt issues and non-performance stemming from differential movement. The amount of differential movement that could accumulate over 9.14 m (30 ft) could exceed 3 cm (1.18 in.) [5]. For designers that relied on the prescriptive limits of the building code, the issues that often accompany wood framed construction with brick masonry veneer were not necessarily circumvented.

Current Code

In IBC 2024, referencing TMS 402-22, the provisions for differential movement between wood structure and masonry veneer appear to be more performance-driven than previous prescriptive version. The height limitations no longer exist and the building code states: "Exterior veneer connected to wood light frame construction – When veneer with a backing of wood exceeds 30 ft (9.1 m), or 38 ft (11.58 m) at a gable, in height, design and detailing for differential movement between the wood light frame backing and masonry veneer is critical to the performance of the masonry veneer [6]." The commentary states: "Alternative

[iii] The Masonry Society (TMS) produces TMS 402 Building Code Requirements for Masonry Structures and TMS 602 Specification for Masonry Structures as a single document titled TMS 402/602 Building Code Requirements and Specification for Masonry Structures. In late 2013, ACI (American Concrete Institute) and ASCE (American Society of Civil Engineers) relinquished sponsorship of the TMS 402/602 standards. The 2015 version of IBC (IBC 2015), referencing the 2013 version of that document, states that masonry shall comply with the provisions of TMS 402/ACI 530/ASCE 5 or TMS 403. 2018 IBC and subsequent versions state that masonry shall comply with the provisions of TMS 402, TMS 403, or TMS 404.

framing, such as balloon framing instead of platform framing, is one option to limit the shrinkage of the wood framing. Information on conducting an analysis for heights exceeding 30 ft. (9.1 m) and proper detailing are given in Silvester et al. (2014) and Clark et al. (2015)[iv] [5]."

The emphasis on proper detailing with consideration for differential movement is a vital addition, however revised prescriptive parameters that could help to safeguard against excessive differential movement are absent.

The evolution of building code from prescriptive to performance-based standards for addressing differential movement in wood-framed structures with brick veneer underscores the need for practical solutions. Fundamental understanding of cumulative differential movement remains essential, but equally so are design constraints within which established methods of accommodating differential movement will be effective.

Resources such as The Brick Industry Association (BIA) Technical Notes on Brick Construction (Tech Notes) 18 [2] and 18A [7], and the code-referenced papers by Silvester et al. (2014) and Clark et al. (2015) [5], provide valuable information and calculation tables to properly design brick masonry veneer with a wood-framed structure. To supplement these sources, we include considerations for a practical approach below.

FRAMING METHOD

The commentary of the standard referenced in IBC states that using balloon framing instead of platform framing may limit the cumulative shrinkage of the wood framing. In balloon framing, uninterrupted vertical studs extend from the foundation to the roof. In platform framing, each story of the structure is built independently, with horizontal floor platforms constructed first and walls built on top. The increased relative amount of shortening in platform framing results from the floor joists and rim joist at each floor line, since they undergo shrinkage perpendicular to the wood grain and create additional construction joints where settlement may occur.

However, platform framing is significantly more popular in modern construction, especially for mid-rise multi-family construction. Platform framing involves shorter studs which are easier to source and can be prefabricated into modular framing or backup wall panels. The construction process benefits from sequentially installing floor platforms from which contractors can safely work. Additionally, the platforms act as horizontal fire stops at each floor and often align better with fire code requirements, an important consideration for combustible construction. The advantages of platform framing could reasonably outweigh the consequences of increased differential movement between wood and brick. In developing a practical approach for accommodating differential movement in brick masonry veneer with wood-framing structure, consideration of modern construction methods favors platform framing as a basis.

Based on the platform-framed wood structure calculations included in the articles by Silvester et al. (2014) and Clark et al. (2015) [5] and the brick expansion equation included in the BIA Tech Note 18 (2019) [2], the anticipated amount of differential movement for five stories of platform framing is provided in Table 1.

[iv] The paper referred to as Silvester et al. (2014) and Clark et al. (2015) was updated and reproduced by Civil + Structural Engineer Media as Nicastro et al. (2020) [5]

Table 1: Cumulative Differential Movement of Platform Framing with Brick Masonry Veneer

Story	Wood			Brick			Total Cumulative Differential Movement cm (in.)
	Shrinkage cm (in.)	Creep cm (in.)	Cumulative cm (in.)	Moisture Expansion cm (in.)	Thermal Expansion cm (in.)	Cumulative cm (in.)	
5th	-0.66 (-0.26)	-0.05 (-0.02)	-4.11 (-1.62)	0.15 (0.06)	0.12 (0.05)	1.37 (0.54)	5.49 (2.16)
4th	-0.66 (-0.26)	-0.10 (-0.04)	-3.40 (-1.34)	0.15 (0.06)	0.12 (0.05)	1.10 (0.43)	4.50 (1.77)
3rd	-0.66 (-0.26)	-0.18 (-0.07)	-2.64 (-1.04)	0.15 (0.06)	0.12 (0.05)	0.82 (0.32)	3.47 (1.36)
2nd	-0.66 (-0.26)	-0.23 (-0.09)	-1.80 (-0.71)	0.15 (0.06)	0.12 (0.05)	0.55 (0.22)	2.35 (0.93)
1st	-0.66 (-0.26)	-0.28 (-0.11)	-0.94 (-0.37)	0.15 (0.06)	0.12 (0.05)	0.27 (0.11)	1.21 (0.48)

DESIGN CONSIDERATIONS

Anchors and Ties

One fundamental anchored brick masonry veneer detail is the anchor or wall tie. The anchors must provide out-of-plane support while allowing in-plane movement, such as that resulting from differential volume change. The IBC 2024 does not allow corrugated metal veneer ties for anchored masonry veneer over 9.1 m (30 ft) tall, with an additional 2.4 m (8 ft) allowed at gable ends [6]. As shown in Table 1, given the amount of cumulative differential movement for three stories, corrugated metal veneer ties should not be used at any height. Adjustable wire anchors, such as base and vee anchors or eye and pintle anchors, are required for taller structures and recommended for all applications. The success of these anchors in accommodating in-plane movement requires that they be installed with appropriate clearance for the relative upward movement of the brick masonry veneer. A wire vee tie or pintle at maximum upward extension relative to its anchor plate will introduce movement restraint that could result in anchor failure or stress and cracking.

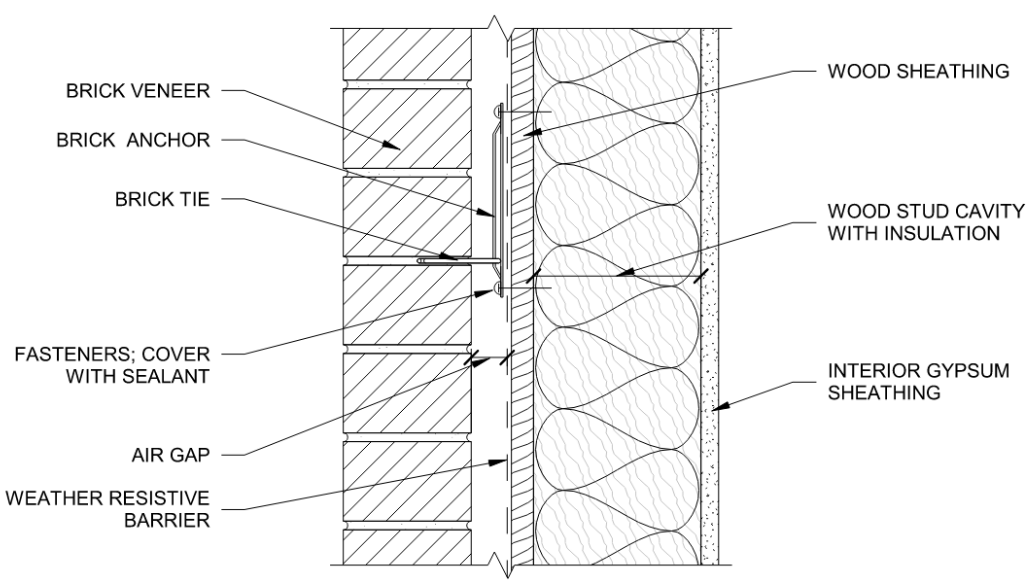

Figure 1: Brick Tie with Upward Clearance

Expansion Joints

Expansion joints are the industry-standard solution to differential movement, so it's important to examine to what extent they can be used to accommodate the movement between brick and wood.

In the case of brick masonry veneer with wood framing, the predominant direction of movement across the joint will be compression. The compression capacity of the sealant can be determined by its class rating according to ASTM C920 Standard Specification for Elastomeric Joint Sealants. Class 50 and Class 100/50 compress by 50 percent of the initial joint width and are generally recommended. For these sealants, the movement joint width in brick masonry veneer should generally be two times the anticipated compression.

For differential movement of 1.25 cm (0.5 in.), the sealant joint should be 2.5 cm (1.0 in.) wide. Sealant manufacturers generally recommend that expansion joints fall within a range of 0.64 cm to 2.5 cm (¼ in. to 1 in.) width to achieve the optimal profile. Joints exceeding 2.5 cm (1 in.) may require specific direction or approval from the sealant manufacturer.

Therefore, based on the predicted differential movement calculated in Table 1 and the practical limits of sealant movement joints, the best option is to support brick masonry veneer with a platform-framed backup wall at every story. In this way, the relative cumulative effects of differential movement will be limited to one story only.

Although subject to some variability due to the conditions assumed in the calculations, a 2.5 cm (1 in.) wide movement joint at every floor line in the brick masonry veneer of a platformed framed structure is a universally practical solution. While technically feasible, the aesthetic prominence requires compromise on the design. Factors that may reduce the movement joint include:

Install brick in warm conditions. The calculated amount of brick expansion assumes 311C (100 F) degree increase from the time of installation. This calculation was performed in accordance with BIA Tech Note 18, but it conservatively assumes that brick was installed at a low baseline temperature such that its thermal movement is entirely expansion.

Brick selection. The majority of the brick units' expansion will occur in the first month after exiting the kiln. As such, it's important to be aware of the production dates for brick units. This may be particularly relevant to custom brick orders that will be transported to the project site promptly after production. Additionally, the size of the brick units affects their expansion. Brick units with a larger face area will cause greater expansion of the brick masonry veneer than smaller bricks.

Prefabricated framing panels. In general, wood members will experience a longer drying time before the masonry is installed if they are not shipped directly to the site.

For all types of backup wall systems, vertical expansion joints are also critical for the longevity and performance of the brick masonry veneer system. In general, their design and placement does not vary between wood framing and other backup wall systems, as the effect of wood shrinkage is not cumulative in the horizontal (ie. non dead load bearing) direction. However, it is important to understand the benefit of vertical expansion joints at locations where the brick masonry veneer's height above the support varies. For example, if relieving angles are used as lintels above door and window openings, the brick masonry veneer directly above the lintel will experience less cumulative vertical expansion over the service life of the building than the brick masonry veneer directly adjacent to the opening. In this manner, location of expansion joints for wood framed structures does not vary from the recommendations in BIA Tech Note 18A for brick veneer in general [7].

Penetrations

To a much greater extent than other framing systems, the detailing of openings and penetrations that bridge from the wood framing through the brick masonry veneer must consider the differential movement.

For penetrations with discretionary location, it may be advantageous to locate the penetration a lesser distance above the relieving angle where the cumulative movement is at a minimum and the sealant joint width does not have to match the horizontal movement joint width. Sheet metal sleeves with exterior picture-frame flanges may also be successfully used to accommodate movement of penetrations relative to the brick masonry veneer.

Through Wall Flashing

For many buildings that feature brick as one of many cladding types, brick masonry veneer may transition to another cladding material above it. At these interfaces, through wall flashing overlapping the top of the brick masonry system is common practice. The sheet metal flashing must feature an exterior downturned leg to conceal the clearance space at the top of the brick masonry veneer. The downturned leg should overlap the brick by approximately 1 inch at the time of construction to prevent the ingress of bulk water, birds, and insects. The designer must ensure that the upward movement of the brick is not restricted by the through wall flashing. If appropriate clearance is not provided, the flashing may be distorted, or the brick may crack.

Figure 2: Distorted Through Wall Flashing Above Brick Masonry Veneer

Soffits

Assuming that the brick is supported at each floor line, the differential movement will be greatest at the top of each story. As such, soffits at roofs, balconies, and projections require clearance for the brick to move upwards. This could be achieved with an appropriately sized sealant joint or sheet metal flashing similar to the through-wall flashing.

Window and Door Openings

Openings through the backup wall, such as windows and doors, will be supported by the backup structure, but they often have components such as sealant, panning, and thresholds that bridge from the window or door unit to the veneer. The window or door unit will move downward in conjunction with the wood framing, while the brick expands upward from its support. The upward movement must be accommodated at the window perimeter and, critically, the window and door frames cannot span between the backup structure and the brick masonry veneer as it will result in binding and potentially cracking of the unit.

Although the distance from the brick support will impact the amount of anticipated movement, conservative design practice would be to match the movement joint width. Construction tolerances at openings require greater buffer for accommodation of movement. If the movement is accommodated by a sealant joint, the sealant joint should not be wept.

In many instances, it may be practical to accommodate movement at the head and sill with sheet metal flashing or trim rather than sealant. At the sill, the brick expansion must be provided clearance behind metal cap flashing with a downturned vertical leg. If not integrated with the window frame, the attachment of the metal cap flashing should be carefully considered to allow the window flashing to effectively drain water into the brick masonry veneer cavity.

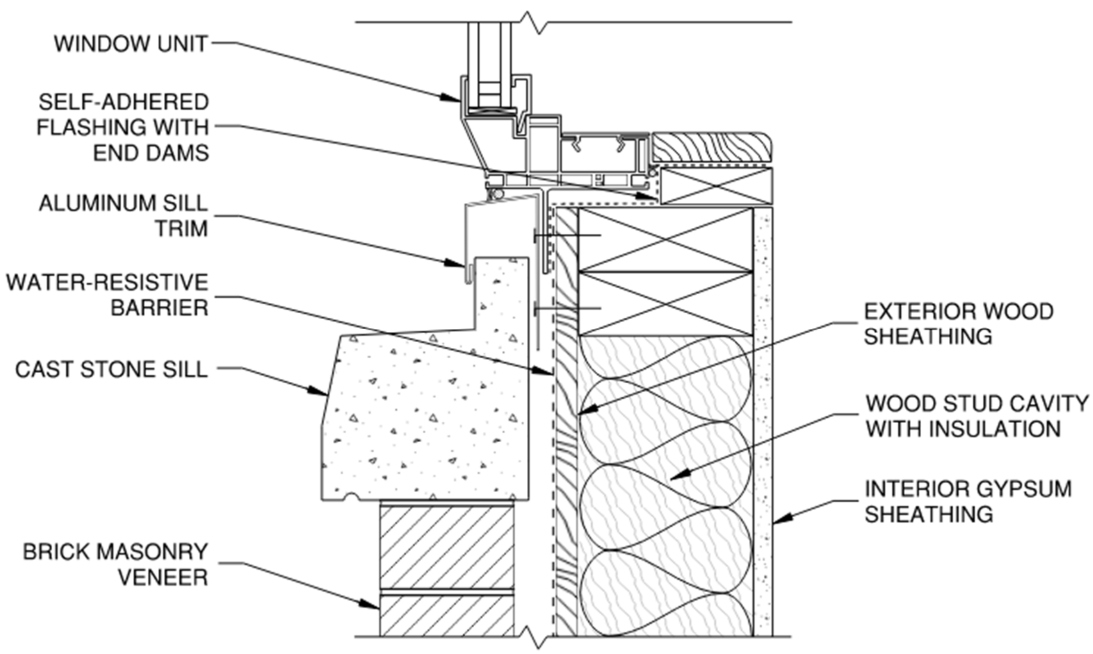

Figure 3: Window Sill Detailing to Accommodate Differential Movement

The detailing of window jambs must not constrain differential shearing movement between the backup wall and the brick masonry veneer. Shear forces can induce a combination of tension and compression within the sealant, potentially stressing it differently compared to pure expansion or compression. To avoid sealing the window directly to the brick masonry, L-shaped metal closure flashing can span the cavity between the backup wall and the brick. The metal closure flashing will be sealed to the window and integrated with the water resistive barrier. The closure flashing and the brick masonry will be in contact but unsealed to deflect bulk water without restricting movement.

The detailing of window heads requires consideration of the load path. If the brick at the window head is supported by a loose lintel, the upward movement of the brick may result in a gap between the lintel and the window. To prevent exposure of the water resistive barrier or window head flashing, an aesthetic trim piece should be installed behind the lintel. If the brick masonry is supported by the backup wall via a relieving angle, the movement differential between the window and the brick masonry veneer at the head will be negligible. However, as described previously, vertical expansion joints at the ends of the relieving angle may be needed to accommodate the difference in cumulative vertical expansion between the differentially supported brick.

CREATIVE SOLUTIONS

Designing for movement accommodation does not preclude creative solutions or architectural innovation. Vertical expansion joints, often required at window head corners, may conflict with the traditional horizontal emphasis of running bond patterns. To address this, stack bond can effectively conceal vertical expansion joints at window corners, offering a more contemporary aesthetic. Alternating stack bond vertically between windows with running bond in other areas can simulate brick piers, preserving a traditional visual reference.

For horizontal movement joints at floor lines, incorporating a projecting sill creates a deliberate horizontal feature. The West Michigan headquarters of a health company in Grand Rapids, Michigan, exemplifies these strategies, blending functional requirements with thoughtful design.

Figure 4: Brick Masonry Veneer at West Michigan Building

CONCLUSION

The responsibility to ensure proper accommodation of differential movement in wood-framed structures with brick veneer ultimately falls on the designer. To reiterate some key design considerations:

- Coordinate the placement of brick ties relative to their base plate to accommodate relative upward movement of the brick masonry veneers.

- Support brick masonry veneer with a platform-framed backup wall at every story with a 2.5 cm (1 in.) wide movement joint at every floor line.
- Ensure that upward movement of the brick masonry veneer is not restricted by through wall flashing, soffits, or penetrations.
- As an alternative to sealant joints, consider sheet metal flashing or trim at door and window perimeters to provide more clearance for relative downward movement of the opening.

While the transition from prescriptive to performance-based building codes eliminates ambiguity, it demands a thorough understanding of movement dynamics and a commitment to effective detailing. Designers and builders must avoid interpreting the removal of prescriptive limits as a reprieve from the consequence of differential movement, as the risks of structural damage, water infiltration, and aesthetic compromise are too significant to ignore. A robust framework of proven methods and innovative detailing must become standard practice to address these challenges. With diligence and thoughtful application, brick veneer over wood framing can be constructed without sacrificing design intent or performance.

REFERENCES

[1] "North America Brick Cladding Systems Market Size & Outlook." *Grand View Research*, 2023, https://www.grandviewresearch.com/horizon/outlook/brick-cladding-systems-market/north-america.

[2] "Volume Changes - Analysis and Effects of Movement." *Technical Notes on Brick Construction 18*, Brick Industry Association, May 2019.

[3] *TMS 402-13/ACI 530-13/ASCE 5-13: Building Code Requirements for Masonry Structures and Specification for Masonry Structures (TMS 602-13/ACI 530.1-13/ASCE 6-13). The Masonry Society, 2013.*

[4] *TMS 402-16: Building Code Requirements for Masonry Structures and Specification for Masonry Structures (TMS 602-13). The Masonry Society, 2016.*

[5] Nicastro, Anthony J., et al. "Brick Cladding over Wood-Framed Structures." *Civil + Structural Engineer Magazine*, 13 May 2020, https://csengineermag.com/brick-cladding-over-wood-framed-structures/.

[6] *TMS 402-22: Building Code Requirements for Masonry Structures and Specification for Masonry Structures (TMS 602-13). The Masonry Society, 2022.* 13.1.2.2.2 Wood Light Frame Backing

[7] "Accommodating Expansion of Brickwork." *Technical Notes on Brick Construction 18A*, Brick Industry Association, Aug. 2018, https://www.gobrick.com/content/userfiles/files/tn18a-Accommodating-Expansion-of-Brickwork.pdf.

[8] International Code Council. *International Building Code 2024*. International Code Council, 2024.