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DIFFERENTIAL MOVEMENTS BETWEEN WOOD-FRAME AND CLAY MASONRY VENEER ON MID-RISE BUILDINGS

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Abstract

With current construction practices in Canada moving to mid-rise wood-frame structures, masonry and wood can complement each other's strengths as they have for centuries in Europe. Like any composite material, there are things to consider when integrating the two materials to ensure lasting performance. This technical aid is for designers who are estimating the differential movement between the wood-framing and clay masonry veneer in low to mid-rise wood-frame buildings.

Table of Contents

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Movements Of Wood-Framing From Moisture

Wood shrinks as it dries. The radial rate of shrinkage of dimension cut timber is approximately -0.002 per 1% reduction in moisture content as per CSA-O86-17 A5.4.6 [1]. The longitudinal is significantly less at -0.00005 per 1% reduction in moisture content. A quick but conservative rule-of-thumb for wood-frame shrinkage is approximately -6.35 mm (-¼") per 3.1 m (10') storey which results from assuming a 13% drop in moisture content. This estimate is validated by the Canadian Wood Council's online shrinkage calculator [2] (Figure 1) and Simpson Strong Tie's online shrinkage calculator [3] (Figure 2 and Figure 3) but will depend on the type of wood product used and the configuration of wall and floor assemblies.

Figure 1: Wood-Framed Wall Shrinkage Estimate Using the Woodworks Online Calculator for One and Two Storey Wood-Frame Walls [2]

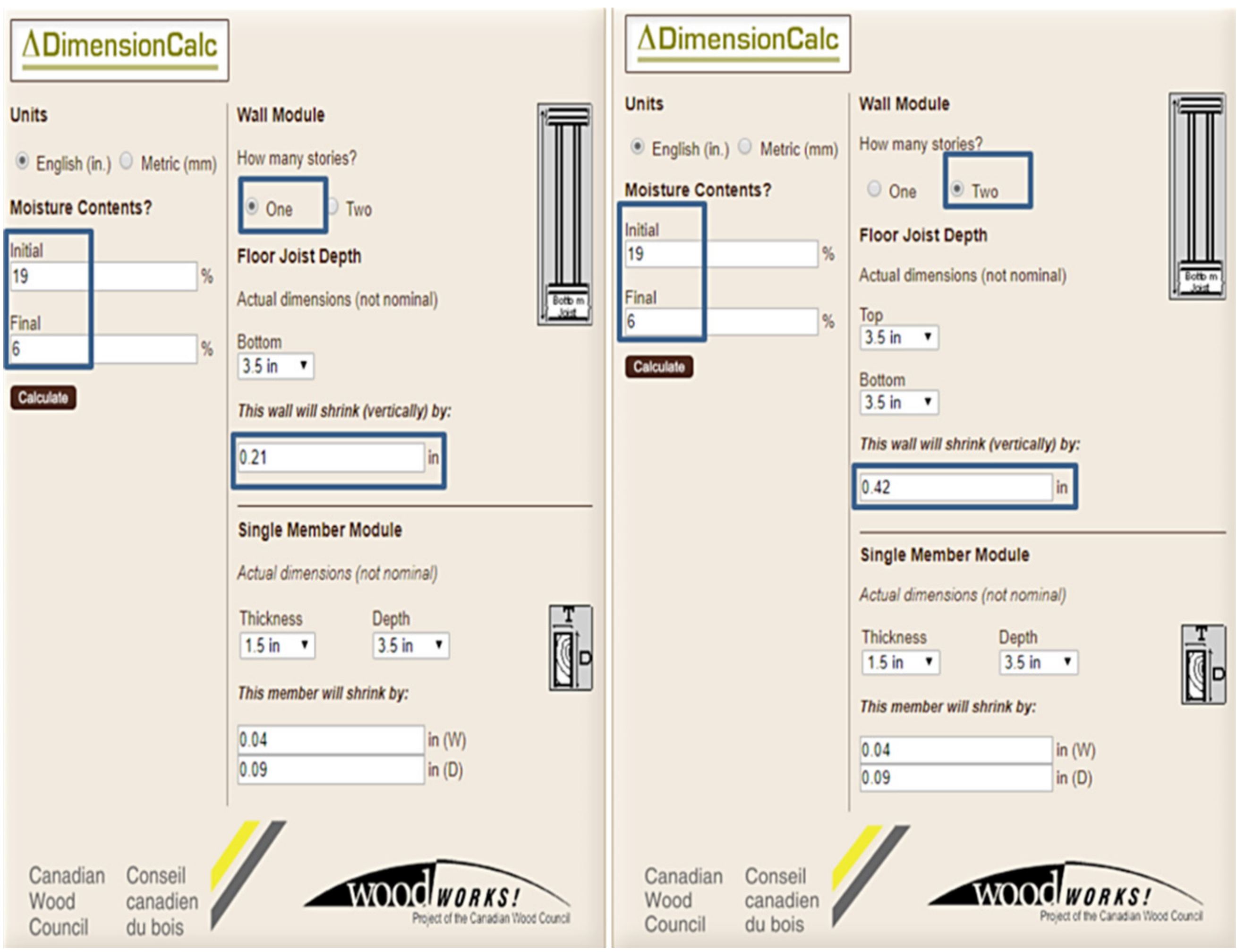


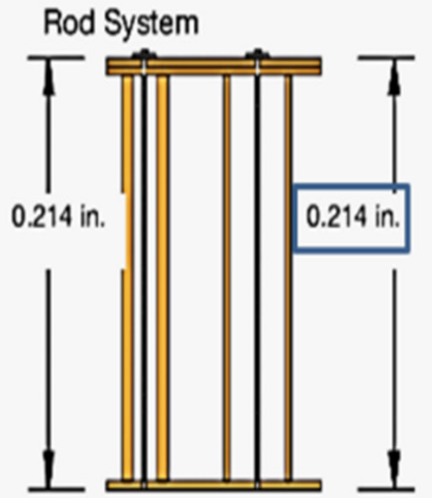
Figure 2: Wood-Framed Wall Shrinkage Estimate Using the Simpson Strong Tie Online Shrinkage Calculator [3] For a One Storey Wall

Holdown/Strap System Shrinkage Summary

Location	Member	Depth	Shrinkage Coefficient	Moisture Change	Member Shrinkage	Incremental Shrinkage
1st Story Sill Plate	2x SPF	1.5 in.	0.0025	13%	0.049 in.	0.049 in.

Continuous Rod System Shrinkage Summary

Location	Member	Depth	Shrinkage Coefficient	Moisture Change	Member Shrinkage	Cumulative Shrinkage
1st Story Top Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.214 in.
1st Story Stud	Stud	104.5 in.	0.00005	13%	0.068 in.	0.117 in.
1st Story Sill Plate	2x SPF	1.5 in.	0.0025	13%	0.049 in.	0.049 in.

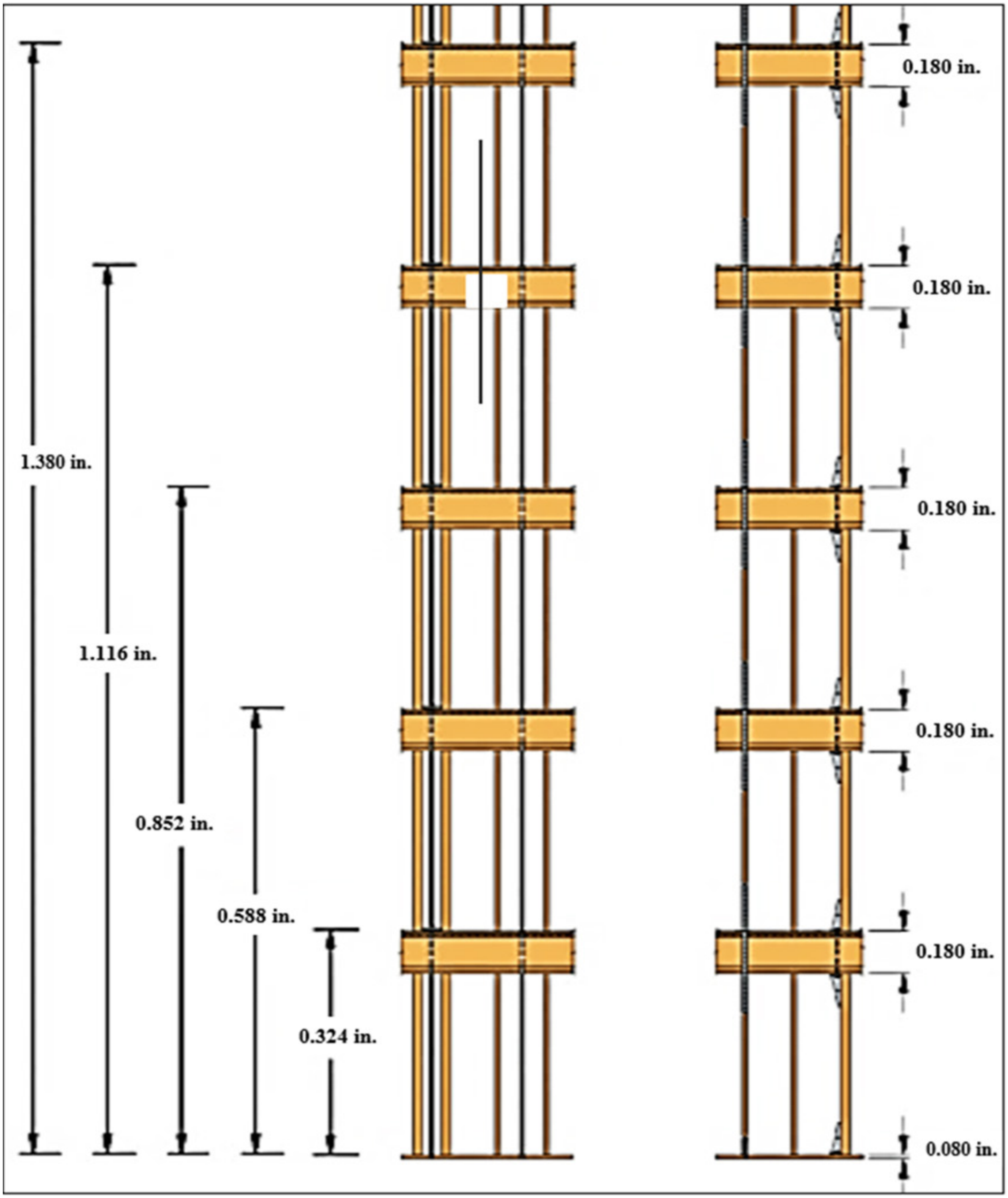


For a 5-storey building a sample calculation of the cumulative shrinkage with a drop from 19% to 6% moisture content can be found in Table 1.

Table 1: Sample Cumulative Shrinkage Summary For 5-Storey Wood-Frame Building

Location	Member	Depth	Shrinkage Coefficient	Moisture Change	Member Shrinkage	Cumulative Shrinkage
5th Storey Top Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	1.258 in.
5th Storey Stud	Stud	103 in.	0.00005	13%	0.067 in.	1.161 in.
5th Storey Sole Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	1.094 in.
5th Floor System	I joist	N/A	N/A	N/A	N/A	0.997 in.
4th Storey Top Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.997 in.
4th Storey Stud	Stud	103 in.	0.00005	13%	0.067 in.	0.900 in.
4th Storey Sole Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.833 in.
4th Floor System	I joist	N/A	N/A	N/A	N/A	0.736 in.
3rd Storey Top Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.736 in.
3rd Storey Stud	Stud	103 in.	0.00005	13%	0.067 in.	0.639 in.
3rd Storey Sole Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.572 in.
3rd Floor System	I joist	N/A	N/A	N/A	N/A	0.475 in.
2nd Storey Top Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.475 in.
2nd Storey Stud	Stud	103 in.	0.00005	13%	0.067 in.	0.378 in.
2nd Storey Sole Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.311 in.
2nd Floor System	I joist	N/A	N/A	N/A	N/A	0.214 in.
1st Storey Top Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.214 in.
1st Storey Stud	Stud	104.5 in.	0.00005	13%	0.068 in.	0.117 in.
1st Storey Sill Plate	2x SPF	1.5 in.	0.0025	13%	0.049 in.	0.049 in.

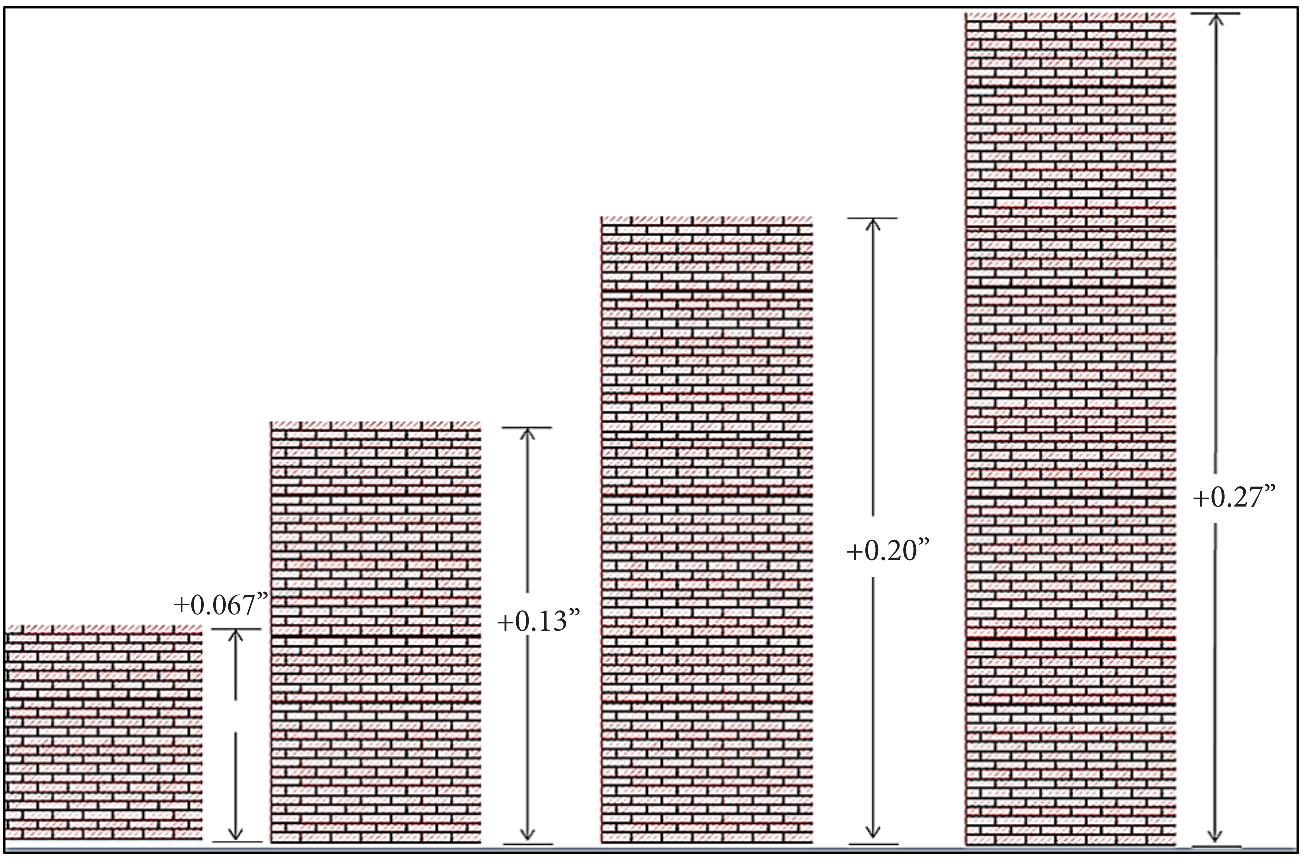
Figure 3: Wood-Framed Wall Shrinkage Estimate Using the Simpson Strong Tie Online Calculator For a Five Storey Wall [3]



Movements of Clay Brick Veneer From Moisture

At the time of manufacture, clay masonry products are typically extremely dry from the kiln firing during the manufacturing process. Clay bricks typically absorb moisture from the environment until they reach equilibrium. This moisture absorption causes the veneer to swell and increase in dimension. As Clay bricks swell with moisture, it increases in dimension at an approximate rate of +0.00056 inch per inch. A quick estimate at +1.7 mm (+1/15") per 3.1 m (10') storey. Figure 4 illustrates the expected increase in the height of the brick veneer with moisture.

Figure 4: Clay Brick Veneer Estimated Movement - Swell



Managing Differential Movements of Clay Masonry Veneer & Wood-Framing

As discussed in the previous sections, clay masonry typically increases in dimension during its service while the wood-frame decreases in dimension during service. To manage the differential movement between the two materials, the appropriate location and size of horizontal movement joints (shelf angles), as well as accommodation for movements at openings, and appropriate selection of masonry veneer ties must be determined. The location of masonry movement joints shall be noted in the construction documents according to Section 6.3 of the CSA-A371-2014 – Masonry Construction for buildings [4]:

6.3 Movement joints

Movement joints shall allow free movement of masonry to prevent or relieve stress due to differential movement. For veneers, movement joints shall be kept clear of all materials other than those specified in the contract documents. The location and details of movement joints shall be as specified in the contract documents.

Note: *Movement joints accommodate expansion, contraction, and other movements in one or more directions.*

Movement joint location and spacing recommendations can be found in literature from the Brick Industry Association (BIA) [5] and the National Concrete Masonry association [6]. Excerpts from these sources are below:

Figure 5: Movement Joint Locations as Recommended by BIA and NCMA [5],[6]

Possible Joint Locations:

- Wall openings
- At given spacings in a continuous wall
- Changes in wall height
- Foundation or support structure joints
- Changes in support conditions (foundation vs. framing)
- Proximity to wall corners or intersections

Typical Maximum Vertical Control Joint Spacings

Wall Type	Material	Movement joint spacing (23’ – 32.5’)
Veneer	Clay	7m – 10m (16’ – 23’)
	Concrete	5m – 7m

Multi-component tie systems are able to accommodate differential movement (Figure 6) because they have a 30 mm (1- ¼”) slot to accommodate differential movement with some slots as large as 51 mm (2”). These ties are ideal when the designer wishes to support 6.1 m (20’) to 11 m (36’) of masonry veneer on the foundation with a wood-frame building as the slot can more easily accommodate the cumulative differential movement between the veneer and the wood frame. Corrugated strip ties (Figure 7) can be used as well. However, CSA-A370-2014 – Connectors for masonry [7] Clause 10.5.1.2e, limits the use of corrugated strip ties to masonry veneer not higher than 11 m (36’) above local grade.

Although not standardized in CSA-A370-2014, it is recommended that corrugated strip ties only be used if masonry veneer is supported on shelf angles at every floor with wood-frame construction, where differential movement is isolated to one floor by the presence of the shelf angle at each floor. In this case, differential movement is expected to be significantly less and therefore can typically be managed by a strip tie. CSA-A370-2014 can also provide additional information on masonry tie selection for adequate corrosion protection depending on the location of the building.

Figure 6: Multi-Component Masonry Tie

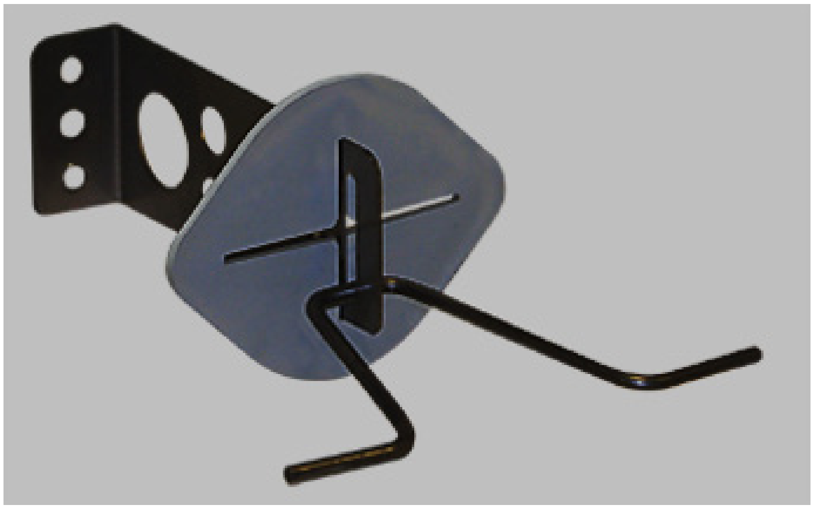


Figure 7: Pre-Bent Corrugated Strip Tie

The effect of the differential movement between the clay brick veneer expansion and the wood frame shrinkage for brick veneer on a 4-storey wood-framed building is illustrated in Figure 8 and Figure 9 below. The relative shrinkage of the wood framing in green was overlaid on a white clay brick veneer in AutoCAD (Figure 8). Using the clay brick as the reference point the location of the wood-frame was shifted down by the cumulative shrinkage of (18.7 mm +4.3mm) = 23 mm or 0.906" (Figure 8). In Figure 9, the original location of the window rough opening can be seen in the blue outline and the final location after the differential movement has been accounted for in the red outline.

Figure 9 demonstrates that a 1" over-sized rough opening that is backer rod and caulked would account for the expected differential movement and prevent cracking of the brick veneer from differential movement between the frame and veneer on a 4-storey brick veneer supported on a foundation. Of course, this design would require the use of multi-component ties and typically it is recommended to install at most 9.144 m (30') even though greater heights are possible.

Figure 8: Differential Movement Between Wood-Framing and Clay Brick Veneer Due to Moisture

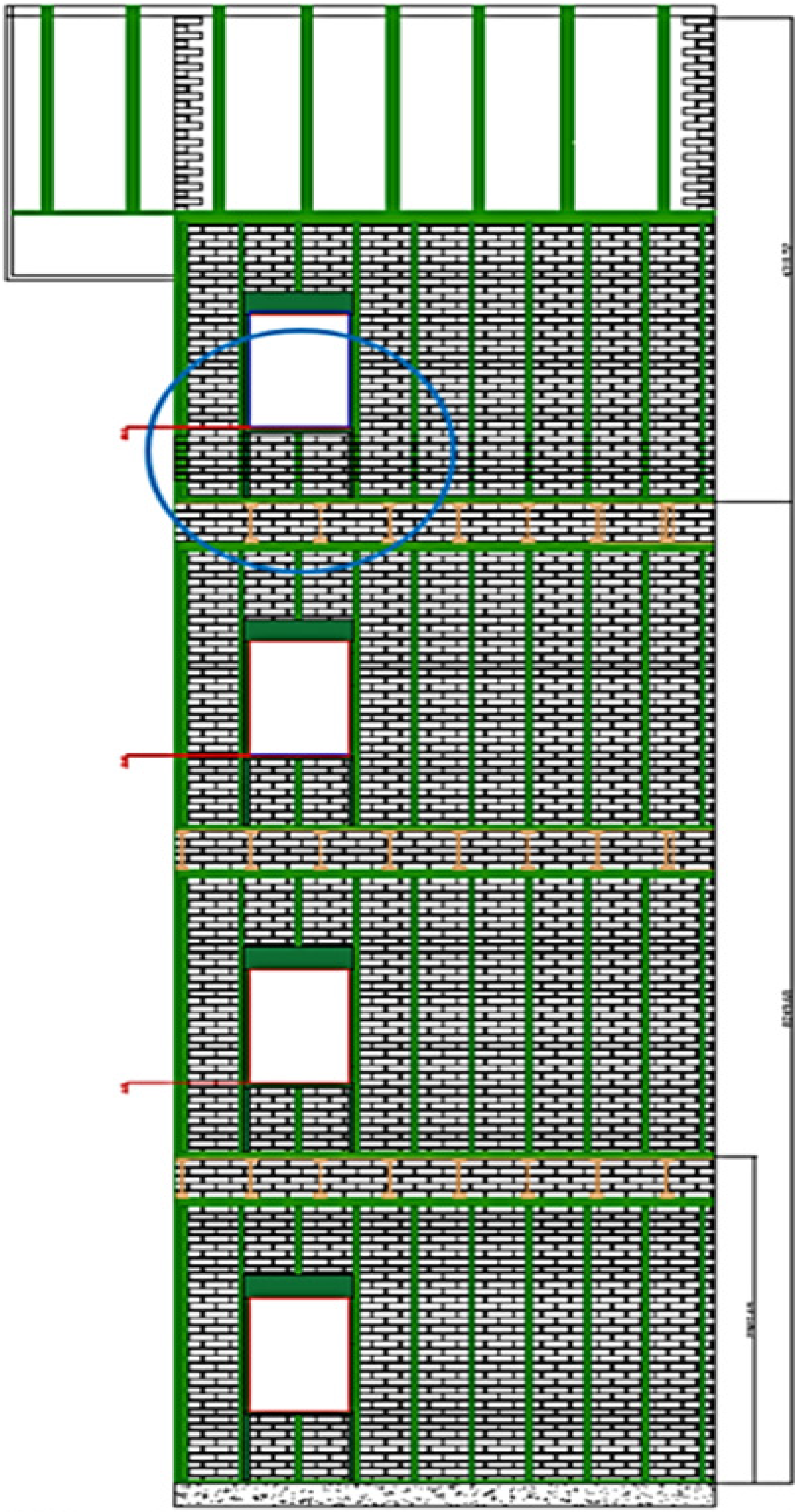


Figure 9: Differential Movement Between Wood-Framing and Clay Brick Veneer Due to Moisture at the 4th Storey Window

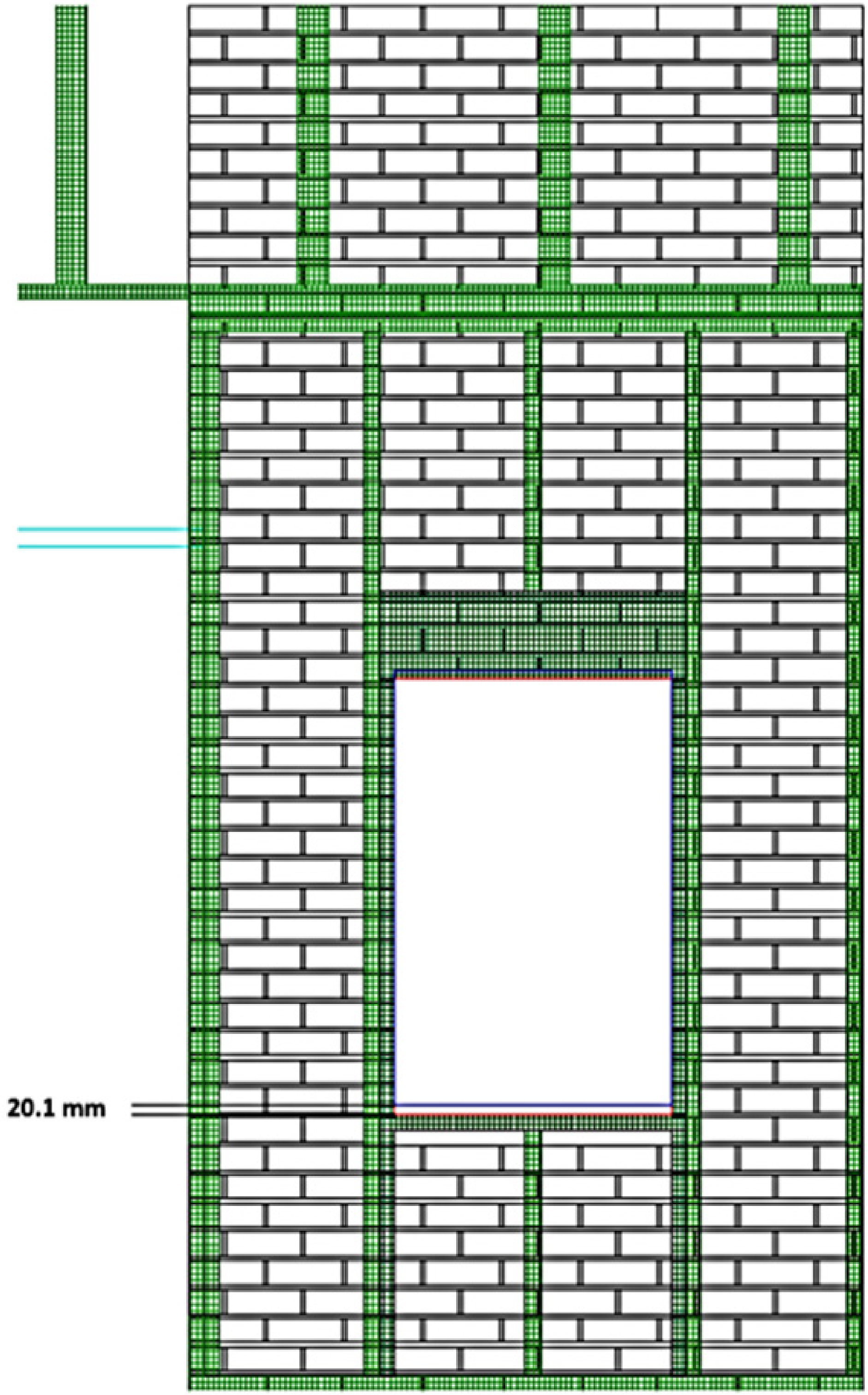


Figure 10 to Figure 13 provides possible masonry support layouts in a sample building and how the differential movements can be managed for these two configurations.

Figure 10: Example of Brick Veneer Bearing on the Foundation with Shelf Angle at the Top of the 3rd Floor

In the example in Figure 10, 3 storeys (approximately 9.14 m) of brick veneer bears on the foundation on either a brick ledge or a shelf angle. Figure 11 illustrates the expected differential movement at the location of the shelf angle at the top of the 3rd floor and the expected differential movement of the brick veneer around the windows. An oversized rough opening that is filled with backer rod and caulking can be used to accommodate this movement. The absence of a movement joint may lead to step cracking at the corners of the window. Multi-component ties would be required to manage the differential movement between the brick veneer and wood framing.

Figure 11: Brick Veneer Bearing Off Foundation with Shelf Angle at the Top of the 3rd Floor Detail

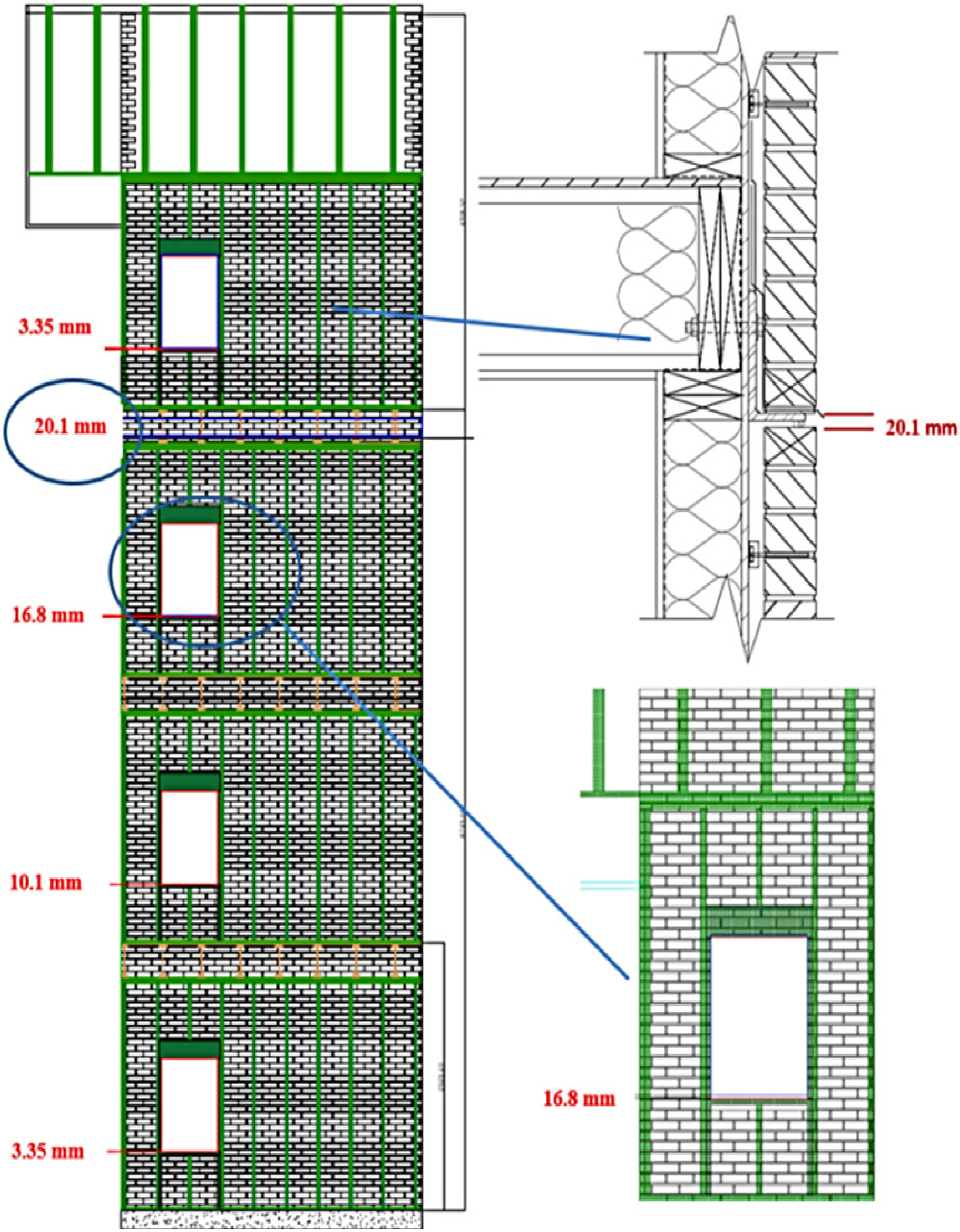
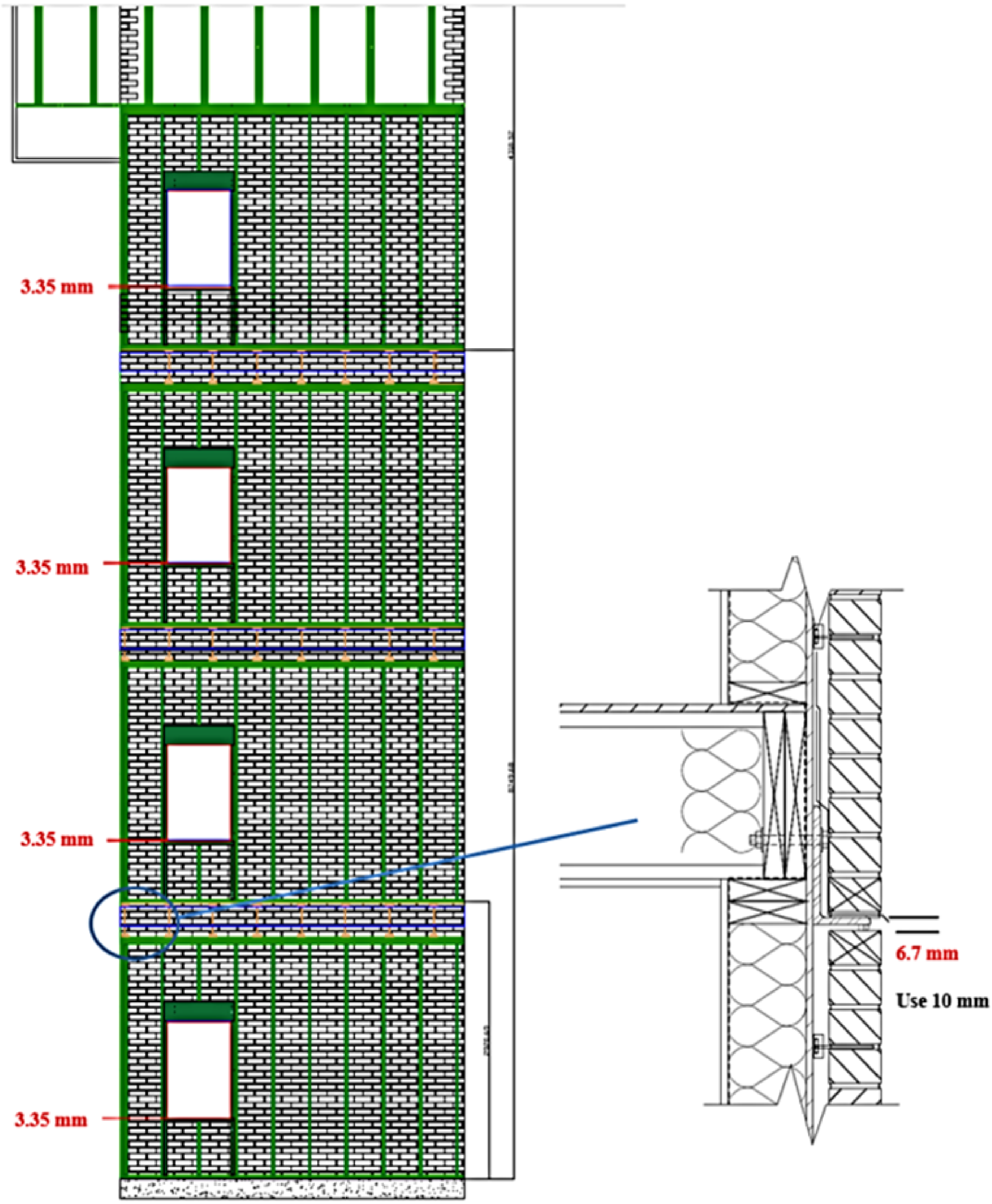


Figure 12: Example of Brick Veneer Bearing on A Shelf Angle at Every Floor

In the example in Figure 10, the first storey of brick veneer bears on the foundation on either a brick ledge or a shelf angle while a shelf angle supports 1 storey of brick for the remaining storeys. Figure 11 illustrates the expected differential movement at the location of the shelf angle at the top of the 1st floor which is the expected movement for subsequent floors as well. Although multi-component ties are recommended, prescriptive corrugated strip ties could be used with the building in Figure 12 because the height of the brick veneer is less than or are equal to 11m (36’) above local grade (CSA-A370-2014[7] Clause 10.5.1.2) and the shelf angles at each floor reduce the differential movement between the brick veneer and wood framing to 6.7 mm per storey.

Figure 13 illustrates the expected differential movement at the location of the shelf angles and around the windows. In Figure 13, the shelf angle detail specifies the use of a 10 mm joint even though the expected movement is only 6.7 mm. The use of a 10 mm joint is consistent with typical mortar joint size for brick masonry veneer and would better facilitate coursing of the brick to match the horizontal movement joints at the shelf angles.

Figure 13: Brick Veneer Bearing Off Foundation with Shelf Angle at The Top of the 3rd Floor Detail



References

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[2] http://cwc.ca/dimensioncalc/

[3] https://www2.strongtie.com/webapps/woodshrinkage/

[4] Canadian Standards Association, CSA A371- Masonry Construction for Buildings, Canadian Standards Association, Mississauga, Ontario, Canada, June 2014

[5] http://www.gobrick.com/Portals/25/docs/Technical%20Notes/TN18A.pdf

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[7] CSA-A370 – Connectors for Masonry, Canadian Standards Association, Mississauga, Ontario, Canada, March 2014