DIFFERENTIAL MOVEMENT BETWEEN WOOD-FRAME & CONCRETE MASONRY VENEER ON MID-RISE BUILDINGS

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Acknowledgments

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 wood-framing and concrete block masonry in low to mid-rise wood-frame buildings.

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Integrating Concrete Block Masonry with Wood Frame Buildings

When concrete block masonry is integrated with wood frame buildings it is typically found at one or more of the following locations:

1.   Stairwells
2.   Two-hour (or greater) firewalls
3.   Elevator shafts
4.   Architectural concrete masonry veneer (concrete brick, split face block, burnished etc.)

Figure 1 depicts concrete block firewalls integrated with wood-frame building in a three-storey townhome. Figure 2 shows architectural concrete masonry veneer on a wood-frame house while Figure 3 displays a concrete block elevator shaft integrated with the wood-framing in a four-storey condo.

Figure 1: Concrete Block Firewalls and Wood Framing During Construction

Figure 2: Charcoal Burnished Architectural Concrete Masonry on Wood-Framing

Figure 3: Elevator Shaft in a Wood-Frame Building Under Construction

Like clay brick masonry veneer, integrating wood framing and concrete masonry elements that are connected to each other requires the differential movement between the two materials to be estimated and managed.

i.)   Movements of Wood-Framing from Moisture:

Wood shrinks when its moisture content falls below the fibre saturation level (typically 28%). The radial rate of shrinkage of dimension cut timber is approximately -0.002 per 1% reduction in moisture content as per CSA-O86-14 A5.4.6 [1]. Wood sill plates and top plates are loaded in the radial direction (perpendicular-to-grain). The longitudinal rate is significantly less at -0.00005 per 1% reduction in moisture content. Wood studs are loaded in the longitudinal direction (parallel-to-grain).

A quick but conservative rule-of-thumb for wood-frame shrinkage is approximately -6.35 mm (-¼") per 3.05 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 4) and Simpson Strong Tie's Online Shrinkage Calculator [3] (Figure 5) but will depend on the type of wood product used and the configuration of wall and floor assemblies.

Figure 4: Wood-Frame Wall Shrinkage Estimate Using Canadian Wood Council's Online Calculator for One and Two Storey Wood-Frame Walls [2]

Figure 5: 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.

Rod System

0.214 in.   0.214 in.

For a 4-storey building, a sample calculation of the cumulative shrinkage can be found in Table 1.

| Table 1: Sample Cumulative Shrinkage Summary For a 4 Storey Wood-Frame Building						
Location	Member	Depth	Shrinkage Coefficient	Moisture Change	Member Shrinkage	Cumulative Shrinkage
Roof System	I joist	N/A	N/A	N/A	N/A	0.997 in.
4th Story Top Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.997 in.
4th Story Stud	Stud	103 in.	0.00005	13%	0.067 in.	0.900 in.
4th Story 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 Story Top Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.736 in.
3rd Story Stud	Stud	103 in.	0.00005	13%	0.067 in.	0.639 in.
3rd Story 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 Story Top Plate	2-2x SPF	3 in.	0.0025	13%	0.097 in.	0.475 in.
2nd Story Stud	Stud	103 in.	0.00005	13%	0.067 in.	0.378 in.
2nd Story 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 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.

ii.)   Movements of Concrete Block Masonry from Moisture:

Concrete masonry products shrink as they lose moisture. This is an advantage because the wood framing and concrete block masonry move in the same direction with moisture reduction but at different rates.

As the concrete masonry units lose moisture they decrease in dimension at an approximate rate between -0.0002 and -0.00045 inch per inch [4]. Assuming a rate of -0.00033 inch per inch, a quick estimate shows -0.04" (-1.01 mm) per 3.05 m (10') storey.

Figure 6 illustrates the expected decrease in the height of concrete masonry walls of different heights due to reductions in moisture content. This applies to concrete masonry veneer walls as well. Therefore, less differential movement is expected between concrete masonry veneer and wood-framing than between clay brick veneer and a wood-framed building.

Figure 6: Concrete Block Masonry Estimated Movement – Shrinkage
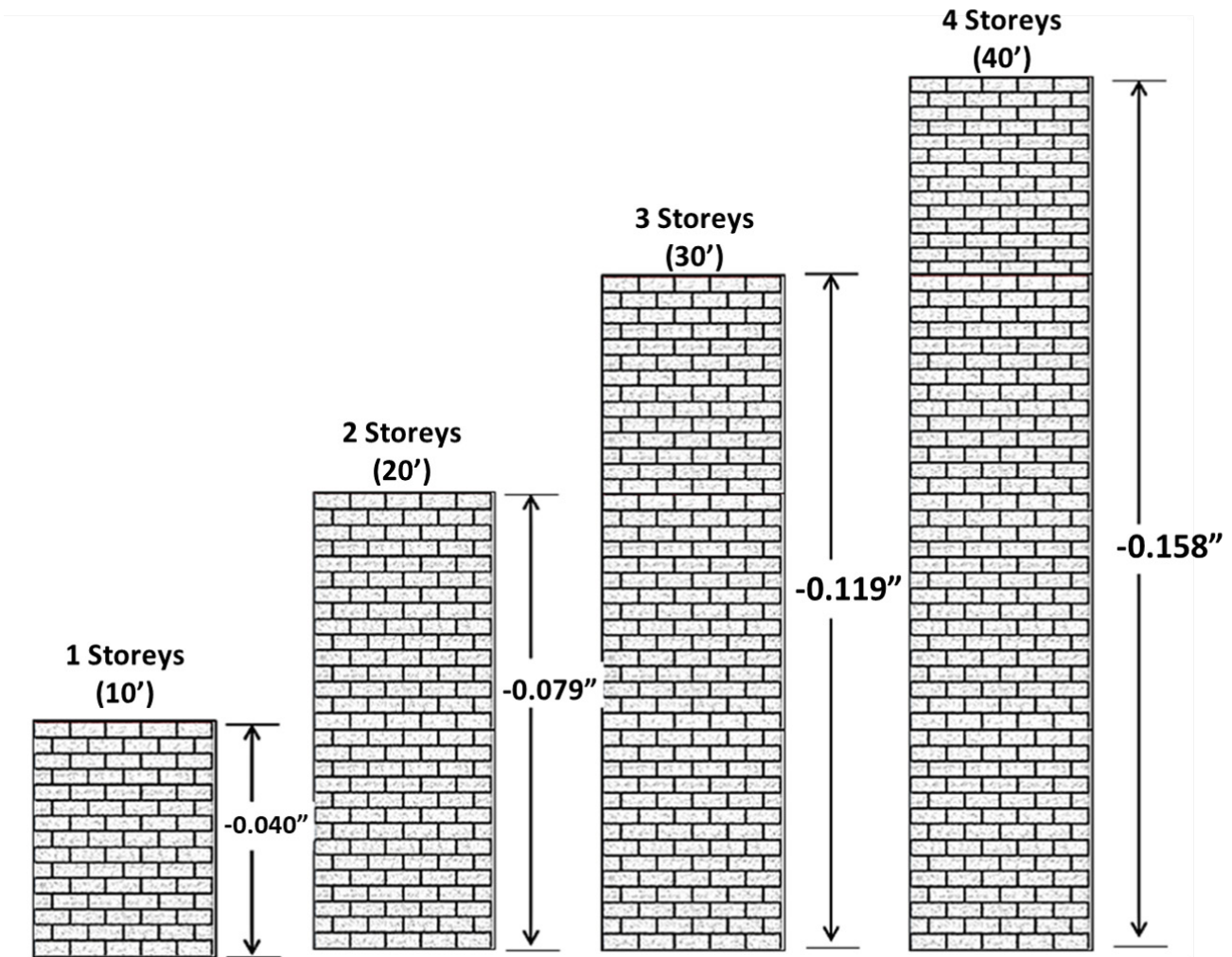
Managing Differential Movement of Concrete Block in Wood-Frame Buildings

The simplest way to manage the differential movement between the wood framing and the concrete block masonry is to isolate the wood-framing from the block masonry. Figure 7 to Figure 10 depicts a concrete block elevator shaft that is isolated from the wood-framing by a ½" (13 mm) gap. This detail can reduce sound transmission through the floors. Figure 12 illustrates an elevator shaft that is under construction before the wood-framing has been installed. The masonry elevator shaft is designed as a self-supporting structure for gravity and lateral loads. Unlike a firewall, it does not require lateral bracing during construction or after a fire.

Alternatively, where concrete block elevator shafts and stairwells are used as shear cores for wood frame buildings or simply for load-bearing walls, the wood framing is connected to the concrete block masonry. In this case, the differential movement between the wood and block due to shrinkage must be managed in the design. (See the next section for details).

Whether connected or disconnected from the wood framing, the rough openings for doors for stairwells and elevator shafts should be oversized by the expected differential movement to permit the doors to function if the predicted differential movement is realized.

Figure 7: Elevator Shaft Permanently Detached from Wood Framing Under Construction - At Top Floor

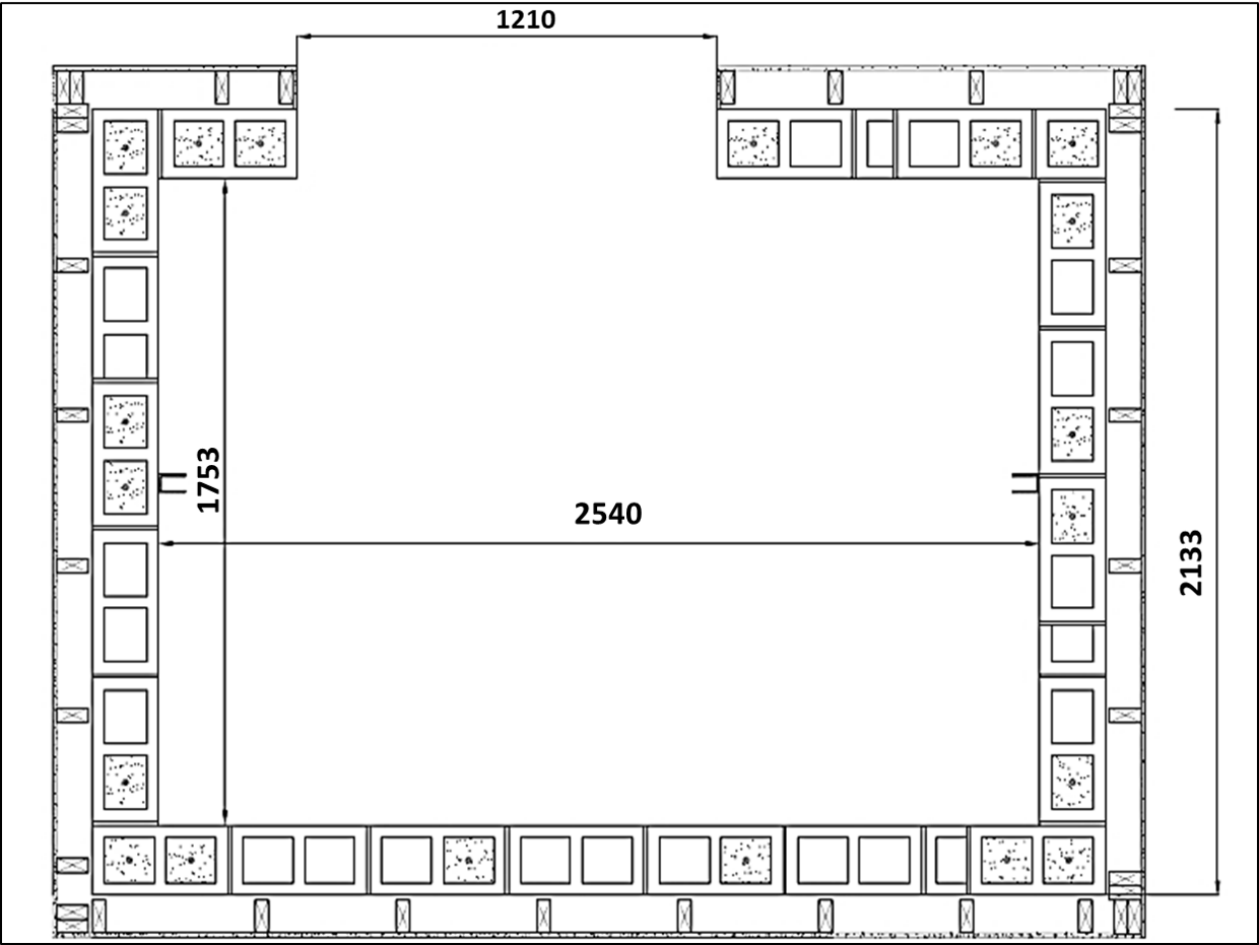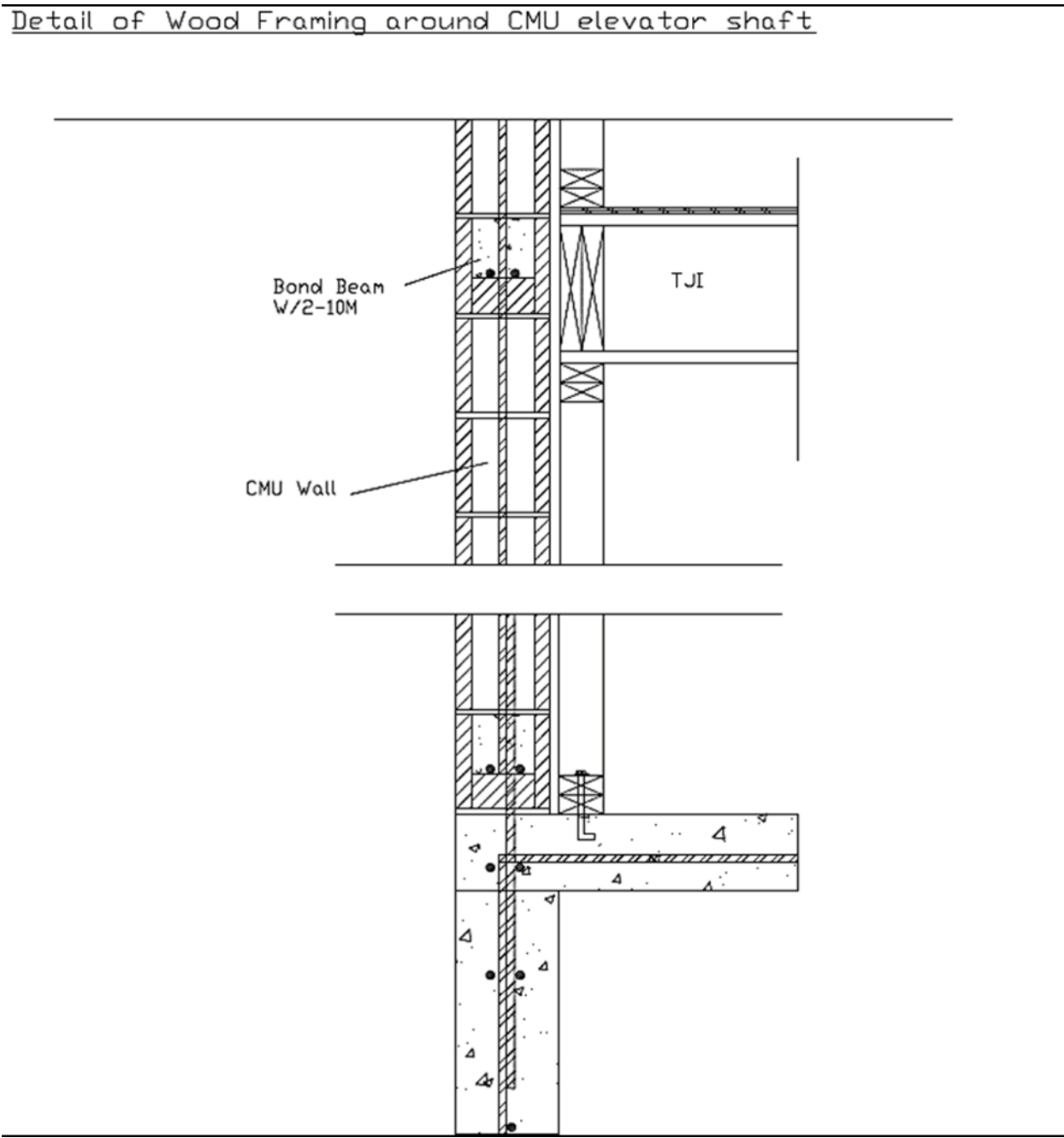**Figure 8: Elevator Shaft Permanently Detached from Wood Framing – Plan Detail**

Figure 9: Elevator Shaft Permanently Detached from Wood Framing – Section Detail

Detail of Wood Framing around CMU elevator shaft

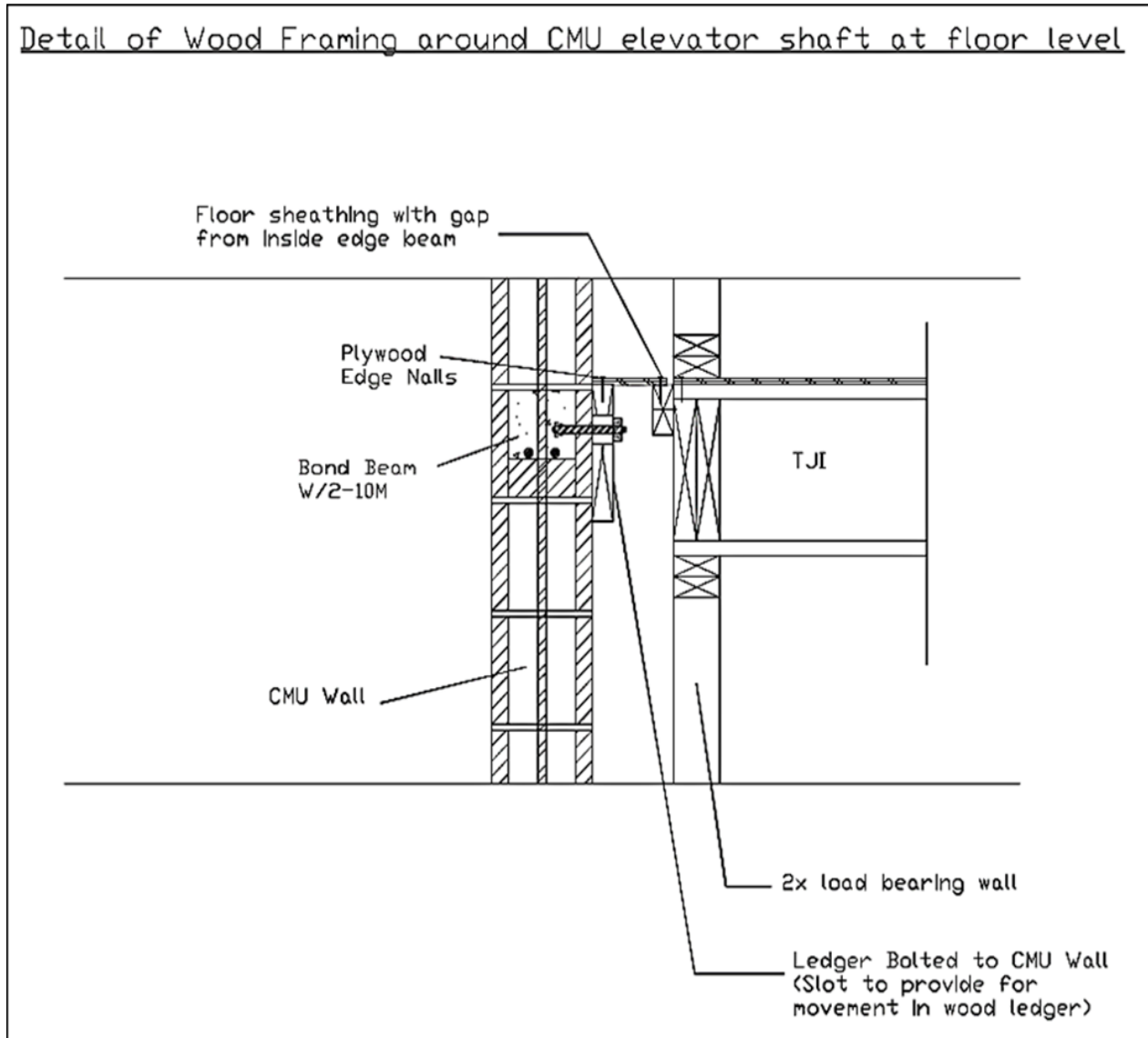Bond Beam
W/2-10M

TJI

CMU Wall

Figure 10: Elevator Shaft Permanently Detached from Wood Framing Under Construction - At Ground Floor

Figure 11: Elevator Shaft Permanently Detached from Wood Framing – Alternate Section Detail

Detail of Wood Framing around CMU elevator shaft at floor level

Floor sheathing with gap from inside edge beam

Plywood Edge Nails

Bond Beam W/2-10M

TJI

CMU Wall

2x load bearing wall

Ledger Bolted to CMU Wall (Slot to provide for movement in wood ledger)

Figure 12: Elevator Shaft Permanently Detached from Wood Framing

With firewalls, it is typically best to anchor the floor framing to the block fire wall to provide lateral support to the firewall (Figure 13). If floors are not connected to the block wall, then the block wall would have to be treated as a vertical cantilever which is not structurally efficient. (A cantilever block wall is severely limited in height by the maximum thickness of typical block units). Non-combustible construction often requires firewalls that utilize break-away connectors manufactured with metals having melting points lower than structural steel (427°C) [5] or slip connections [6] so that, in the event of fire, the connectors on the fireside of the wall will give way before those on the non-fire side of the wall. The advantage of the wood-frame is that it does not require special fire connectors.

The firewall can be considered to be laterally supported after a fire event by the wood framing that remains intact on the non-fire side of the wall as illustrated in Figure 14.

Figure 13: Integrating Wood-Framing and Concrete Block Firewalls

**Figure 14: Block Fire Wall Laterally Supported After a Fire Event by the Wood-Framing**

When connecting the wood-framing to concrete block masonry a special connection detail is recommended which involves a minimum 2" slot to allow for differential movement between the block masonry and the wood-framing. Figure 15 illustrates the differential movement by moving the wood-framing (shown in green) down by the expected shrinkage relative to the block masonry.

Figure 16 illustrates the expected movement at the 4th floor (identified by the blue rectangular outline in Figure 15). Figure 16 illustrates the expected differential movement at this location is [-0.639" – (-0.119")] = -0.52" (13.2 mm). A slotted connection can accommodate this movement. Figure 17 provides a section detail of the slotted connection.
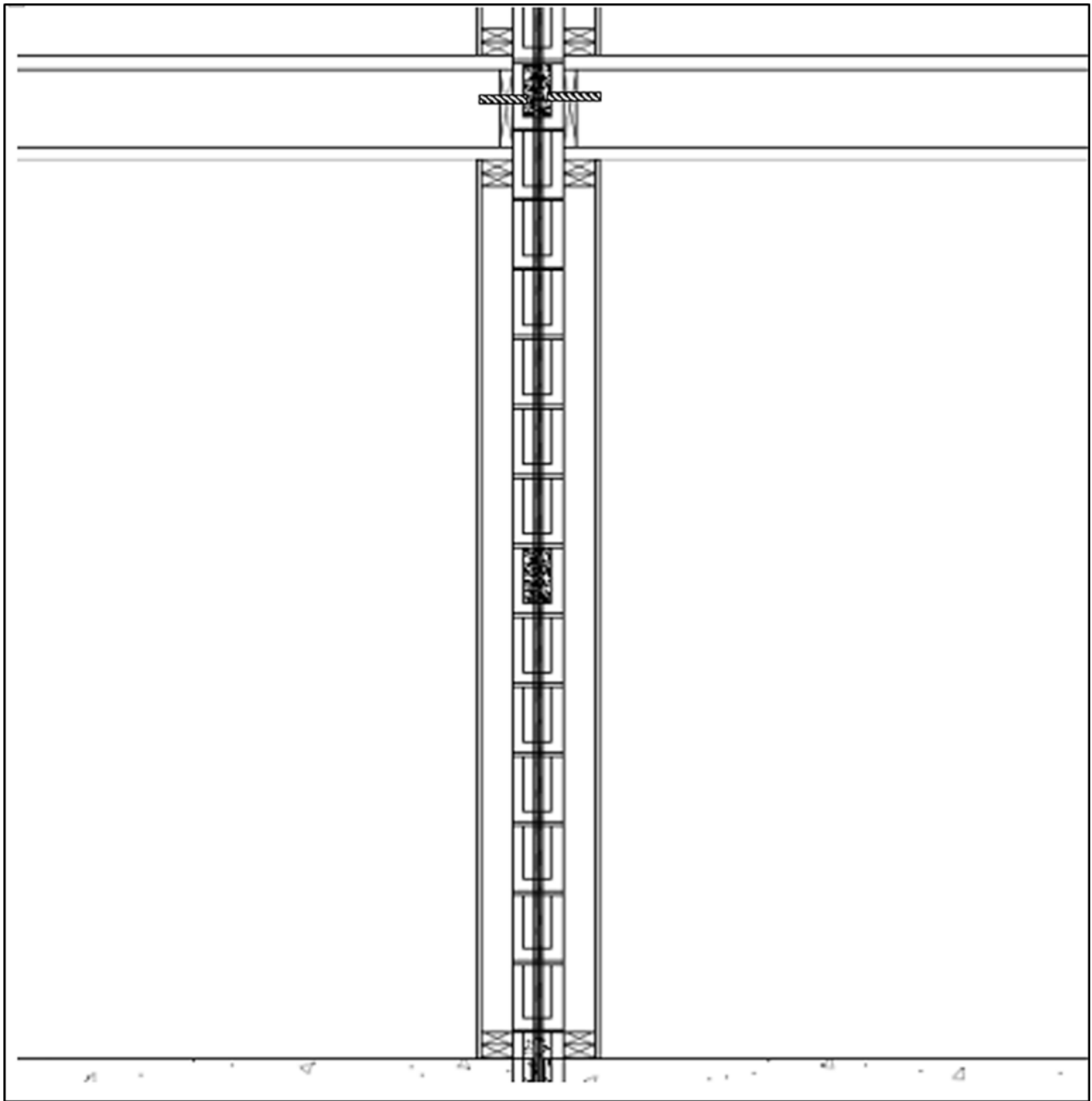
Figure 15: Differential Movement Between Wood-Framing and Concrete Block Wall Due to Moisture
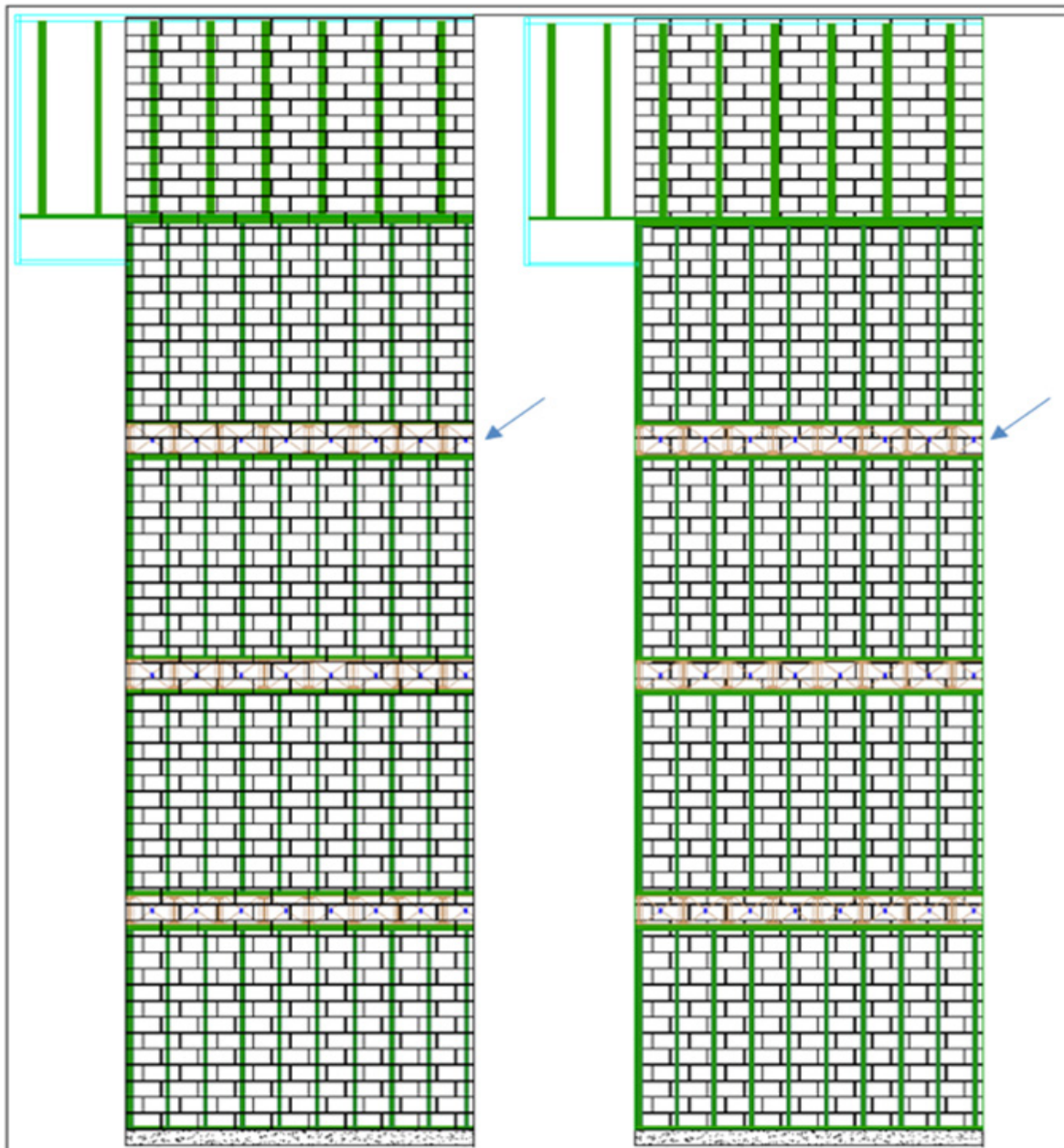
Figure 16: Differential Movement Between Wood-Framing and Concrete Block Wall Due to Moisture at the 4th Floor
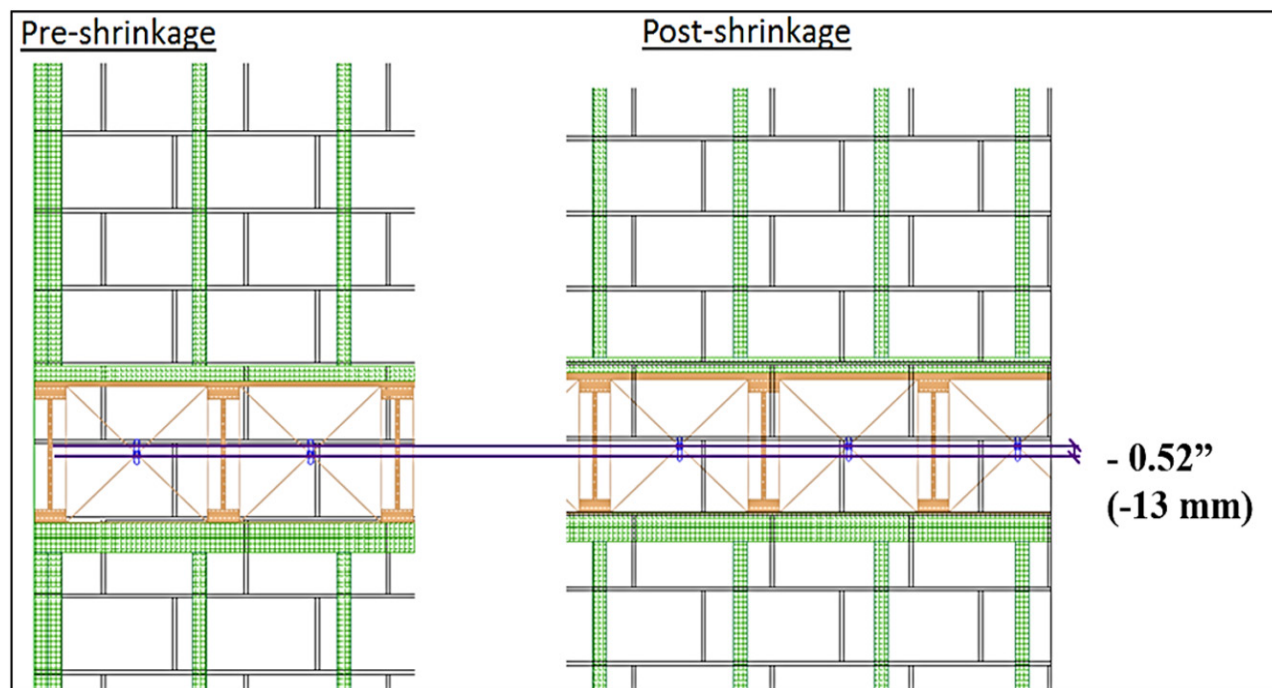
Figure 17: Section and Plan Detail to Integrate Wood-Framing and Concrete Block Firewalls

Managing Differential Movement of Concrete Masonry Veneer in Wood-Frame Buildings

Concrete masonry veneer has less expected differential movement than clay brick veneer relative to wood framing. This is because when clay brick veneers are exposed to moisture, they tend to expand while the wood, protected from moisture, tends to shrink. With concrete masonry veneers, the concrete veneers also tend to shrink like wood does.

The effect of the differential movement between concrete masonry veneer and wood framing for a 4-storey wood-framed building with the first 3 storeys of veneer bearing on the foundation is illustrated in Figure 18 below. The relative shrinkage of the wood framing can be seen in the figure in green and overlaid on a white concrete brick masonry veneer. Using the concrete brick masonry as the reference point, the location of the wood-frame was shifted down by 0.675" (17.1 mm) to account for the cumulative shrinkage (0.833" - 0.158").

In Figure 18, the original location of the window rough opening can be seen in the blue outline and the final location after differential movement has been accounted for in the red outline.

For more information on managing differential movement between masonry veneers and wood-framing refer to the technical aid published by the Alberta Masonry Council, Canadian Wood Council titled "Differential Movements between Wood-Frame and Clay Masonry Veneer on Mid-Rise Building".

Figure 18: Concrete Brick Masonry Veneer Bearing Off Foundation with Shelf Angle - Expected Differential Movement at the Bottom of 4th Floor and at 3rd Floor Window Rough Opening
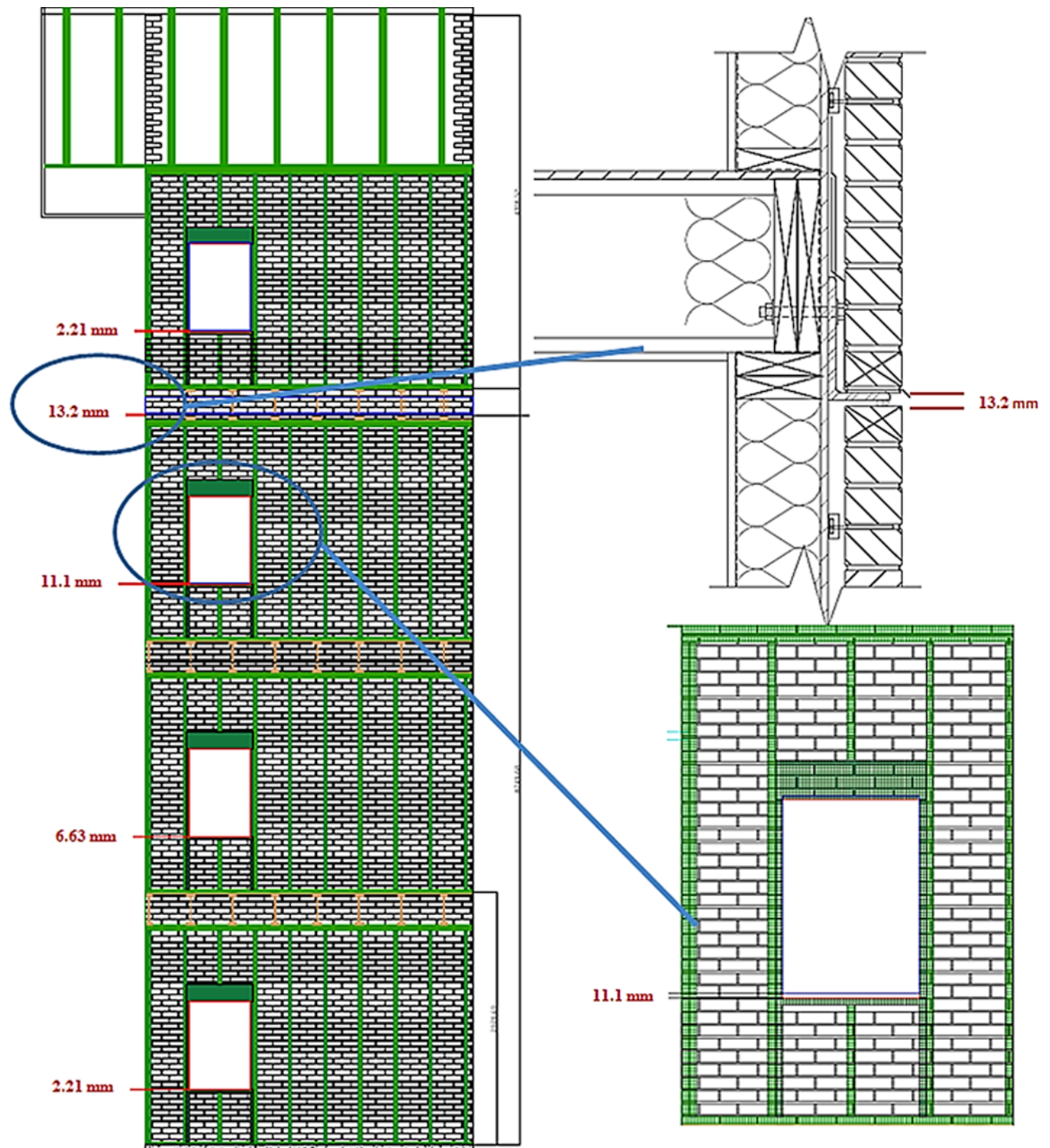
References

[1] Canadian Standards Association, CSA O86- Engineering design in wood, including Update 1 (May 2016) and Update 2 (June 2017)

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

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

[4] FPInnovations, Chun Ni editor, "Mid-Rise Wood Frame Construction Handbook – 1st edition", 2015

[5] http://ncma-br.org/pdfs/104/TEK%2010-04.pdf (NCMA TEK5-8B)

[6] http://www.ncma-br.org/pdfs/5/TEK%2005-08B.pdf   (NCMA TEK5-8B)

[7] http://www.ferocorp.com/pages/firewall_connector/firewall_connector.html

i Canadian Wood Council, Introduction to Wood Design (2011 Edition).