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# MASONRY VENEER TIE DESIGN FOR LOW TO MID-RISE WOOD-FRAME BUILDINGS


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## Abstract

Masonry veneer is an excellent addition to any wood-frame building, especially in mid-rise wood-frame building, where current building codes require a non-combustible cladding, like masonry. When designing the ties for the masonry veneer with wood-frame backup walls, there are important considerations. Differential movement between the wood-frame and the masonry veneer and the difference in rigidity between the wood-frame backup wall and the masonry veneer are two very important factors to consider. Differential movement can affect the selection of a corrugated strip tie vs. a slotted tie. Difference in rigidity between the backup and veneer can affect the tie spacing and layout as increased loads are imposed on ties that are supported by less rigid back-up walls according to the CSA-S304-2014 and CSA-A370-2014. The following technical aid provides guidance on design of ties for low to mid-rise wood-frame buildings.

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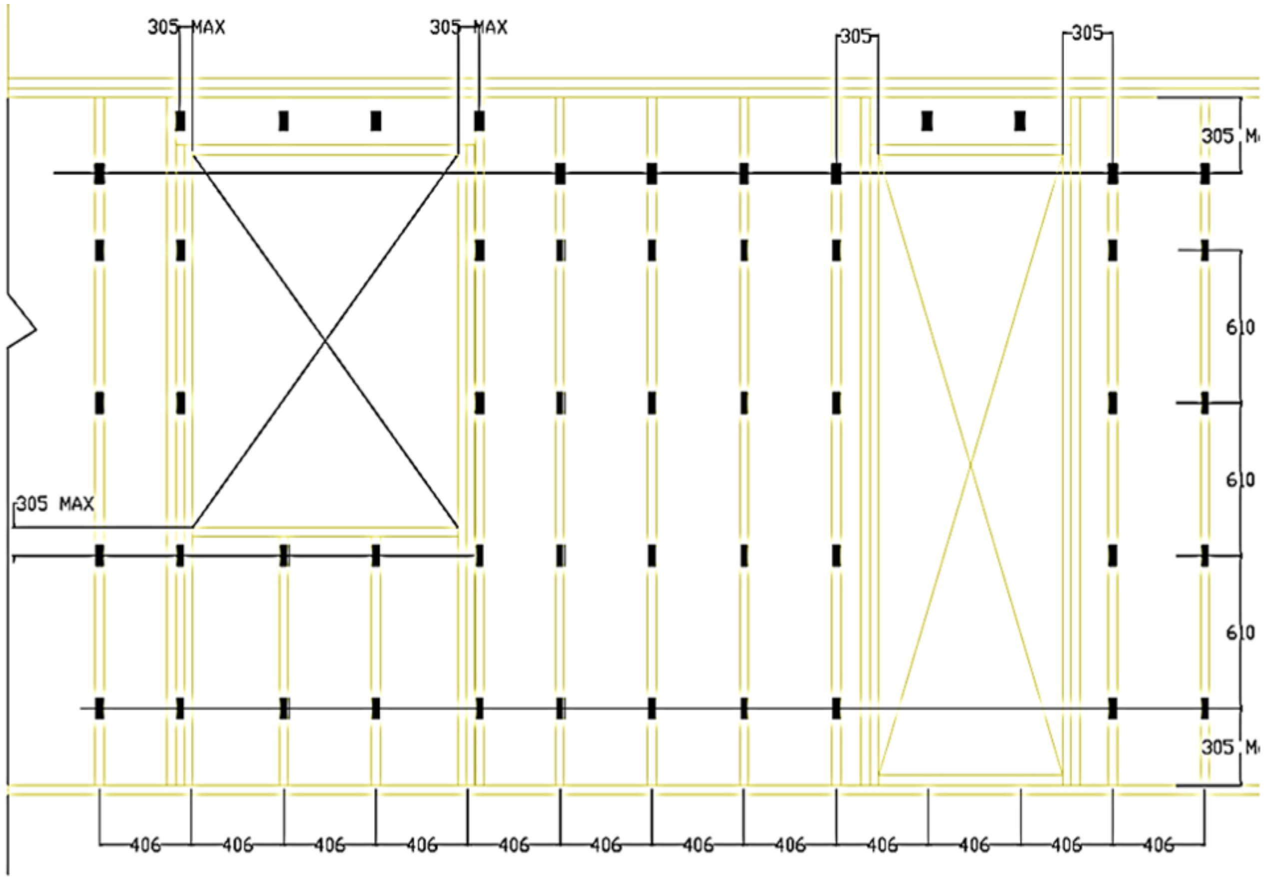
## Figure 1: Typical Tie Layout for SPF Wood Stud Wall with Studs at 406 (16”) O.C.




**Back-up Wall Stiffness**

The backup wall is considered flexible if its stiffness is less than 2.5 the stiffness of the un-cracked veneer.

Veneer stiffness = $E_m \cdot I_{veneer}$

Backup wall stiffness = $E_{stud} * I_{backup}$

Example: 90 mm brick and 2x6 SPF wood stud backup wall with studs at 406mm o.c. (ignore exterior plywood sheathing) with tie spacing 406mm (16”) horizontal o.c. by 610mm (24”) vertical o.c.

**Veneer:** $E_{brick} = 850x13MPa = \mathbf{11{,}050MPa}$

$$I_{veneer} = \frac{b \cdot h^3}{12} = \frac{(1000mm/m)\cdot(90mm)^3}{12} = \mathbf{6.075x10^7 mm^4}$$

$$E_{brick} \cdot I_{veneer} = \mathbf{6.713x\ 10^{11}\ N\text{-}mm}$$

**2x6 backup:** $E_{stud} = 8{,}550$ MPa

$$I_{backup} = \frac{b \cdot h^3}{12}\left(\frac{1000mm/m}{406.4mm}\right) = \frac{(38.1mm)\cdot(139.7mm)^3}{12}\left(\frac{1000mm/m}{406.4mm}\right) = 2.13 \times 10^7 mm^4$$

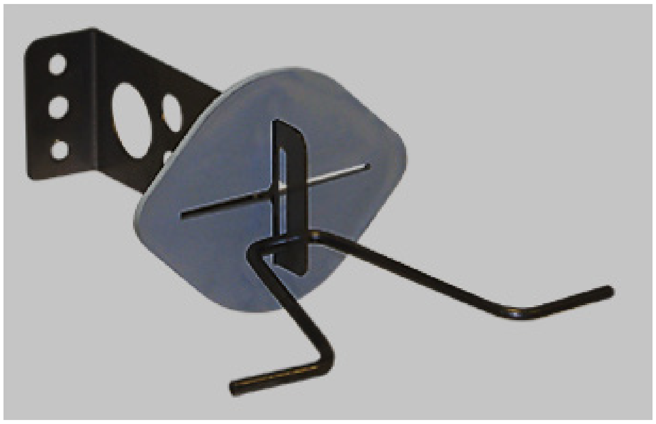
$$E_{stud} \cdot I_{backup} = \boldsymbol{1.821 \times 10^{11}} \textbf{ N-mm}$$

$$E_{stud} \cdot I_{backup} / E_{brick} \cdot I_{veneer} = 1.821 \times 10^{11} / 6.713 \times 10^{11} = 0.27 < 2.5 \Rightarrow \textbf{flexible backing}$$

## Masonry Tie Type Selection

With respect to the masonry veneer, if the veneer is clay brick, the brick swells and increases in dimension while the wood-frame shrinks and decreases in dimension. With concrete masonry veneer product (such as concrete brick, or split face architectural concrete block) the veneer shrinks but by a less pronounced amount than the wood-framing. The use of an appropriate masonry veneer tie must then be determined when integrating masonry veneer and wood-framed buildings. Corrugated strip ties (Figure 2a) can be used, however, according to CSA-A370-2014 – Connectors for masonry Clause 10.5.1.2e), corrugated strip ties are limited to use on masonry veneer not higher than 11 m (36') above local grade. Although not standardized in CSA-A370-2014, corrugated strip ties should only be used if masonry veneer is supported on shelf angles at every floor 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 approximately 6 mm (¼") or less and can be managed by a strip tie. Adjustable tie systems accommodate differential movement much better than corrugated strip ties (Figure 2b) because they typically have a 30 mm (1.2") to 50 mm (2") long slot to accommodate differential movement. Adjustable ties are ideal when the designer wishes to support 6.1 (20') to 11 m (36') of masonry veneer on the foundation with a wood-frame building as the slot can accommodate the cumulative differential movement between the veneer and the wood frame. CSA-A370-2014 also provides additional information on masonry tie selection for adequate corrosion protection depending on the location of the building.

### Figure 2a): Adjustable Masonry Tie b) Pre-Bent Corrugated Strip Tie



## Masonry Tie Design

### I) Tie Loads

Seismic Load: $q_f = V_p = 0.3F_aS_a(0.2)I_ES_pW_p = 1.18$ kPa

Wind Load: $p = I_w\, q\, C_e\, C_g\, C_p = 0.96$kPa => $q_f = 1.5\cdot 0.96$kPa = 1.44 kPa => **Wind load governs**

If *the back wall stiffness* is > 2.5 · $(EI)_{veneer}$ then **non-flexible backing** => tributary area (TA) is:

i) TA = Area acting on the tie (typically 406mm x 610mm or 16"x24")

**Else Flexible Backing**

ii) TA = greater of ($TA_1 = 2\cdot$ TA per tie, $TA_2 = 0.4\cdot$ TA on a vertical line of ties

$C_f / T_f = 2 \times (1.44\ \text{kN/m}^2)\cdot(0.406\ \text{m})\cdot(0.610\ \text{m}) = \mathbf{0.71\ kN}$

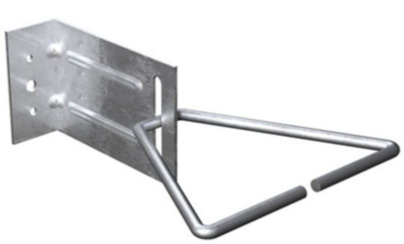
OR

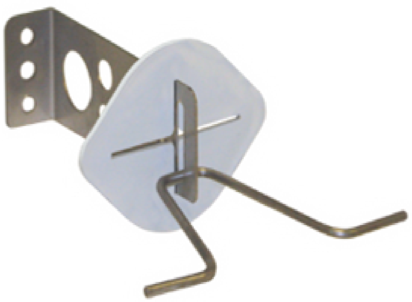
$T_f / C_f = 0.4 \times (1.44\ \text{kN/m}^2)\cdot(0.406\ \text{m})\cdot(3.048\ \text{m}) = \mathbf{0.71\ kN}$

### II) Tie Resistance

### a) For a Slotted Adjustable V-Tie

### Figure 2a): Adjustable BLOK-LOK V-tie b) Adjustable FERO V-tie





**According to CSA-A370-2014 Ties must have a minimum** $P_{ult} = 1.0$ **kN** => $P_r = \phi\, P_{ult}$.

P*ult* is typically the limit of the development length of the mortar (substrate) and the tie. The actual steel tie has significantly larger strength when calculated according to the CSA-S16-2009 as the minimum acceptable diameter for the wire is 3.65 mm ± 0.15mm and there are 2 legs that engage the mortar (Figure 2a and Figure 2b).

## i.) Tie Withdrawal / Push Resistance Through Mortar

From CSA S370-2014 Clause 9.4.2.1.2 - $\phi = 0.90$

$T_r = \phi \cdot P_{ult} = 0.90 \cdot 1.00$ kN = **0.90 kN / per fastener > 0.71** **OK**

$C_r = \phi \cdot P_{ult} = 0.90 \cdot 1.00$ kN = **0.90 kN per fastener > 0.71** **OK**

## ii.) Tension / Compression Resistance of the Steel Tie According to CSA-S16-2009

$$T_r = C_r = \phi \cdot F_y \cdot A_g \, x10^{-3}$$

Where:
$\phi = 0.90$
$F_y = 345\text{MPa}$
$A_g = 22 \text{ mm x } 0.80 \text{ mm} = 17.6 \text{ mm}^2$

$T_r = C_r = 0.90 \cdot 345 \text{ MPa} \cdot 17.6 \text{ mm}^2 =$ **5.46 kN** > 0.71 kN

**b) For a Corrugated Strip Tie**

**According to CSA-A370-2014 Ties must have a minimum $P_{ult} = 1.0$ kN => $P_r = \phi \, P_{ult}$.**

$P_{ult}$ is typically the limit of the development length of the mortar (substrate) and the tie. The actual steel tie has significantly larger strength when calculated according to the CSA-S16-2009 as the minimum acceptable dimensions for a strip tie is 22 mm wide by 0.80 mm thick.

## i.) Tie Withdrawal / Push Resistance Through Mortar

From CSA S370-2014 Clause 9.4.2.1.2 - $\phi = 0.90$

$T_r = \phi \cdot P_{ult} = 0.90 \cdot 1.00$ kN = **0.90 kN / per fastener > 0.71** **OK**

$C_r = \phi \cdot P_{ult} = 0.90 \cdot 1.00$ kN = **0.90 kN per fastener > 0.71** **OK**

## ii.) Tension / Compression Resistance of Tie

$P_{rw} = (\phi\, y_w) \cdot L_{pt} \cdot K_{SF} \cdot K_T \cdot K_D \cdot n_F \times 10^{-3}$

$\phi\, y_w =$ 28 N/mm (From Table 7.4 of 2015 Wood Design Manual)
$L_{pt} = {}^2/_3 \cdot 44.5$ mm = 29.7 mm (2/3 recommended in CSA-O86-2014)
$K_{SF} = 1.0$
$K_T = 1.0$
$K_D = 1.15$
$n_F =$ 1 wood screw

$P_{rw} = 28\ N/mm \cdot 29.7\ mm \cdot 1.0 \cdot 1.0 \cdot 1.15 \times 10^{-3} =$ **0.96 kN** $> (T_f)_{fastener} = 0.71$ kN **OK**

## III) Tie Connection Design

(Tf / Cf) fastener = **0.71 kN**

**Assumptions:**

- SPF wood stud
- 19 gauge (0.91 mm) light gauge steel plate
- 1 - No. 10 wood screw 1-3/4” (44.5 mm) in length, per tie

### Fastener Withdrawal:

$P_{rw} = (\phi\, y_w) \cdot L_{pt} \cdot K_{SF} \cdot K_T \cdot K_D \cdot n_F \times 10^{-3}$

$\phi\, y_w =$ 28 N/mm (From Table 7.4 of 2015 Wood Design Manual)
$L_{pt} = {}^2/_3 \cdot 44.5$ mm = 29.7 mm (2/3 recommended in CSA-O86-2014)
$K_{SF} = 1.0$
$K_T = 1.0$
$K_D = 1.15$
$n_F =$ 1 wood screw

$P_{rw} = 28\ N/mm \cdot 29.7\ mm \cdot 1.0 \cdot 1.0 \cdot 1.15 \times 10^{-3} =$ **0.96 kN** $> (T_f)_{fastener} = 0.71$ kN **OK**

### Fastener Pull Through:

$P_{pt} = 1{,}460$ N (From Table 7.5 of 2015 Wood Design Manual with 0.91mm plate)

$P_{pt} = 1{,}460\ N \times 10^{-3} =$ **1.46 kN** $> (C_f / T_f)_{fastener} = 0.71$ kN **OK**