MASONRY TIE

DESIGN & SELECTION

CANADA

I INTRODUCTION

In Canada, requirements for the design and installation of masonry ties are contained in the National Building Code of Canada and in the respective Provincial Building Codes. For structures intended to comply with Part 9, "*Housing and Small Buildings*", tie requirements are prescribed in Section 9.20, "*Above Grade Masonry*". For other than Part 9 structures, CSA S304.1-14 "*Design of Masonry Structures*" is referenced directly by Part 4, "*Structural Design*" of the Building Code, and in turn, S304.1-14 references CSA A370-14, "*Connectors for Masonry*" and CSA A371-14, "*Masonry Construction for Buildings*". CSA A370 is a design standard containing the design requirements for masonry connectors; "*connectors*" is a general term that includes "*anchors*", "*ties*" and "*fasteners*". Because of its scope, A370 is intended principally for use by masonry designers and manufacturers of masonry connectors. It is not specifically intended for use by masonry contractors. CSA A371 is a construction standard and provides the associated installation/execution requirements for connectors. It is intended for use by masonry contractors, however, in order to effect practicable designs, masonry designers should be knowledgeable about its requirements.

Whereas the requirements of Part 4 of the Building Code are used to establish the effects and magnitudes of specified loads incident on the structure, CSA S304.1 and CSA A370 are used, respectively, to determine the forces imposed on the masonry tie by the Part 4 specified loads, and to determine the resistance of the masonry tie. Additionally, CSA S304.1 provides the design requirements for unit masonry veneer systems, wherein masonry ties serve as an integral component.

The references to CSA standards and to the National Building Code of Canada in this Guide neither duplicate nor replace these documents. Therefore, it is recommended that the user of this Guide obtain a copy of the current Provincial Building Code having jurisdiction, as well as CSA S304.1-14, "*Masonry Design for Structures*", CSA A370-14, "*Connectors for Masonry*", and CSA A371-14, "*Masonry Construction for Buildings*", developed and published by the Canadian Standards Association.

II NATIONAL BUILDING CODE OF CANADA 2010

Within the National Building Code of Canada, requirements for, and related to, the design of masonry ties are contained in Part 4, "*Structural Design*", and Part 5, "*Environmental Separation*".

1. Part 4, "Structural Design"

Part 4 of the Building Code contains the fundamental objective-based requirements for the structural design of buildings and their members and connections, including design basis, specified loads and effects, serviceability and deformations, and member strength, stability, and integrity.

The specified loads to which masonry ties are typically subjected include earthquake load, E, wind load, W, and effects due to movement, T. In some applications, for example on sloped masonry veneer, ties may be subjected to dead load, D, to the effects of dead loads, and to variable loads, S, due to snow and ice. The effects of movement are typically accommodated, rather than resisted, by selecting a multi-component tie whose parts slide at junctions rather than restrict movement. However, in some applications and by design, movements are resisted or partially resisted by the tie, for example, in composite masonry walls and multi-wythe masonry walls having filled collar joints, and in masonry walls intended to provide composite action. These resulting loads must be considered in the design of the ties.

Guidance on the application and use of Part 4 requirements is provided in Appendix A of the NBCC, and "*User's Guide – NBC 2010: Structural Commentaries (Part 4 of Division B)*", published by the National Research Council Canada.

For guidance on the application and use of Part 4 for the design of masonry veneer and masonry ties, and the calculation of incident loads due to earthquake, E, and wind, W, see FERO technical document titled, "*Seismic and Wind Loads for Masonry Veneer Ties According to the National Building Code of Canada 2010*".

For additional discussion pertaining to external and internal pressures and suctions, and the considered effect on tie loads, see discussion herein under *"Part 5, Environmental Separation" and "CSA Standard S304.1-14, III.3 Tie Load"*.

2. Part 5, "Environmental Separation"

The scope of Part 5 of the Building Code pertains to the control of condensation in/on and the transfer of heat, air, moisture and sound through building materials, components and assemblies, including masonry. With respect to resistance to loads and deterioration, and pertinent to the use and design of masonry ties, Part 5 requires that the tie:

1. has sufficient capacity and integrity to resist or accommodate all structural and environmental loads, and their effects (NBCC 5.1.4.1.1);
2. transfers structural loads to the building without adverse effects on the performance of other materials, components and assemblies (NBBC 5.1.4.1.5);
3. does not deflect to a degree that adversely affects the performance of other materials, components and assemblies (NBCC 5.1.4.1.5);
4. be designed, and constructed according to the design, to accommodate construction tolerances and the maximum relative structural movement that may reasonably be expected (NBCC 5.1.4.1.1); and,
5. has sufficient resistance to any mechanism of deterioration that may be reasonably expected, and be compatible with adjoining materials (NBCC 5.1.4.2).

Note that the CSA standards S304.1, A370, and A371 (discussion on each is provided subsequently, herein) collectively contain the same, or very similar requirements to those in 5.1.4 of Part 5. Compliance with the CSA masonry standards provides the needed deemed-to-comply solutions to the Part 5 requirements identified above.

Because the scope of Part 5 deals specifically with heat transfer, air leakage and precipitation, ties should be selected and used by the designer mindful of their installed performance with respect to each mechanism, and of their affect on the performance of adjacent materials, components and assemblies, with the intent to control and manage moisture, and to minimize the likelihood of moisture intrusion and its damaging consequent effects. These requirements typically affect the means by which the tie is connected to the structural backing, the number and size of penetrations by a tie through elements intended to control moisture movement, fastener type and size, tie cross-sectional area, and the tie configuration.

Part 4 requires that cladding, including masonry veneer, be designed to resist the net specified pressure due to wind on part or all of a surface of a building, determined as the algebraic difference of the external pressure or suction and the internal pressure or suction. Part 5 clarifies that the specified wind load on materials, components, and assemblies in the environmental separator (including cladding and their ties) is to be 100% of the specified wind load determined under Part 4, except that it may be reduced where it otherwise can be shown by test or analysis (NBCC 5.2.2.2). Part 4 requires that net specified pressure be used to determine wind load on the building surface, considering both internal and external pressures/suctions. However, for claddings and other components forming a "layered" building envelope, this net pressure is actually resisted by each layer according to factors that include the relative stiffness and air leakage rates of the layers, and the volume and compartmentalization of any air spaces present. The algebraic sum of the pressure differentials acting on each layer sum to the computed net pressure acting across the building envelope. The wind pressure/suction acting across a masonry veneer forming part of a modern masonry rainscreen wall having an air barrier system satisfying the requirements of Part 5 of the NBCC will not be subjected to the full net specified pressure acting across the building envelope cross-section.

However, there is no standardized means to determine the pressure distribution across the various layers, and neither S304.1 nor A370-14 states requirements or offers guidance for designers to calculate veneer and tie load reductions. Various sources of literature providing test data are available which help the designer to assess the pressure moderation or pressure equalization effects in masonry veneer systems should the designer wish to consider its effect. In order to reduce the imposed wind load on a masonry veneer and on the ties which connect the veneer to the structural backing, a designer should (a) determine the pressure differential across the masonry cladding by way of test using pressure measurements taken on representative full-scale wall specimens, or (b) make reference to recognized literature for documentation that substantiates a suitable reduction.

III CSA STANDARD S304.1-14, *"DESIGN OF MASONRY STRUCTURES"*

Whereas the Building Code is used to establish the effects and magnitude of specified loads incident on a masonry structure, CSA S304.1 provides the requirements to determine the magnitude of the design loads that must be resisted by masonry ties. The following is a summary of the pertinent design requirements for unit masonry veneer and for masonry ties used to connect unit masonry veneer to its structural backing, within Clause 9 of S304.1-14, "*Veneer*". These requirements are fundamentally related to veneer strength and tie strength.

1. **Unit Masonry Veneer (Clause 9.1.2)** The design requirements for ties within Clause 9 are specific to "unit masonry veneer". Unit masonry veneer is limited to construction using masonry units of clay (shale), calcium silicate (sand-lime), or concrete, with limiting dimensions of not greater than 200 mm high x 400 mm long, and not less than 75 mm wide.
2. **Flexural Bond Strength for Unit Masonry Veneer (Clause 9.1.1).** The flexural bond strength normal to the bed joint between the masonry unit and mortar in unit masonry veneer must be not less than 0.2 MPa when determined using any one of three bond wrench test procedures permitted by S304.1.

3. **Tie Load (Clause 9.1.3.3)**
   a. For flexible structural backing:
      [that is, where stiffness (EI) of the structural backing ≤ 2.5 x stiffness of the uncracked masonry veneer]:
      i. Tie load is the greater of:
         1. 40% of the tributary lateral load on a vertical line of ties; or
         2. double the tributary lateral load on the tie;
   b. For other than flexible structural backing, tie load is:
      i. the tributary lateral load on the tie.

   S304.1-14 does permit lateral load sharing between the masonry veneer and the structural backing, distributed according to their relative stiffness or using rational analysis (Clauses 9.1.3.3 and 6.7.1). With cavity walls, the ties do not have sufficient strength and stiffness to transfer shear between the two wythes, but have sufficient axial strength and stiffness to transfer loads such that the two wythes deflect together. Maximum tie loads occur when only one wythe is considered to resist the full lateral load resulting from net external and internal pressures. For simple and conservative design, tie loading for cavity walls is commonly taken to be that caused by net pressures, that is, the algebraic sum of both internal and external pressures/suctions.

   For masonry veneer walls with structural backing of concrete masonry or steel stud, and where full or partial composite action is considered by the design, the masonry ties must have sufficient strength and stiffness to resist both shear and axial loading. Shear connection increases the lateral load resistance of the wall system, or conversely, for the same load resistance, it provides design opportunity to reduce the "size" of the structural backing. For the design of shear connected masonry veneer using concrete masonry or steel stud structural backing with FERO Shear™ Connectors, FERO provides the needed software to simplify tie design. The assembly is analyzed as a vierendeel truss. The program *"Composite Wall Design Software"* is available as a complimentary download from www.ferocorp.com with an included user manual.

4. **Tie Pattern and Tie Spacing in Unit Masonry Veneer (Clause 9.1.3)**
   a. Tie Spacing:
      i. Maximum tie spacing: 820 mm horiz. x 600 mm vert.;
      ii. Top of veneer panel to the uppermost row of horizontal ties is the lesser of:
         1. 300 mm; or
         2. ½ the required vertical spacing in the field of the veneer;
      iii. Base of veneer panel to the lowermost row of horizontal ties is the lesser of:
         1. 400 mm; or
         2. the required vertical spacing in the field of the veneer;
      iv. At openings:
         1. 600 mm max. around openings;
         2. 300 mm max. from edge of openings;
   b. Tie Pattern for Flexible (Steel Stud) Structural Backing (See 3b, above):
      i. Ties may be staggered where the horizontal stud spacing does not exceed 410 mm;
      ii. Where the horizontal tie spacing exceeds the stud spacing, the ties must be positioned so that all studs are loaded;
      iii. Where a staggered tie pattern is used, ties must be provided at the top of each stud (along the uppermost row at the top of the veneer panel);
   c. Tie Pattern for Other than Flexible Structural Backing (See 3a, 3b, above):
      i. No specific requirements are stated.

5. **Seismic Requirements (Clauses 4.6 and 4.6.2)** CSA S304.1 contains no special seismic requirements for unit masonry veneer systems or unit masonry tie systems. In contrast, ACI 530/ASCE 5/TMS 402, which contains masonry design requirements for use in the United States, requires that horizontal joint reinforced be placed in masonry veneer in the higher seismic design categories, and further, that this joint reinforcement be mechanically attached to the masonry tie in the highest seismic design categories.

6. **Stack Pattern Unit Masonry Veneer (Clause 9.1.3.4)** To help ensure integrity, robustness, and strength of the veneer, and to provide crack control, unit masonry veneer constructed in stack pattern (stack bond) requires bed joint reinforcement. This reinforcement need not be mechanically attached to the masonry ties. CSA S304.1 references CSA A371 for size, configuration and placement of the reinforcement. Clause 8.1 of A371 requires rod reinforcement having 3 to 5 mm diameter [typically, 3.65 mm dia. (9 gauge) is used], with vertical spacing not more than 400 mm, and (a) for solid units, a single-rod reinforcement placed along the centerline of the veneer within a tolerance of ±13 mm, and (b) for hollow, semi-solid, and cored units, two-rod reinforcement with a minimum mortar cover of not less than 10 mm on the inner and outer faces of the veneer.

   Note that joint reinforcement is not required for unit masonry veneer constructed in running pattern (running bond).

7. **Deflection Limit on Structural Backing (Clause 9.1.4.3)** Wind load deflection of structural backing systems must not exceed the span of the structural backing/360, using Importance Factor for wind loads, $I_w = 0.75$.

S304.1-14 also contains serviceability requirements which indirectly affect unit masonry veneer design, and the design and selection of the supporting masonry tie. Requirements include:

8. **Tie Serviceability (Clause 4.10.1)**

   Structural Considerations (Clause 4.10.1.2): Consideration must be given to the structural effects of differential movements between a masonry member and adjacent structural member caused by elastic deformation, creep, moisture, and temperature changes. The designer must consider the effects of both short- and long-term differential movements (Clause 4.10.1.3) in veneer (walls), composite walls, and cavity walls. S304.1-14 provides guidance to the designer for the calculation of in-situ movements in concrete masonry and unit masonry veneer (Notes to Clause 4.10.1.2). These notes direct the designer to (a) carefully consider the design and use of movement joints to prevent or relieve stress, and (b) for the calculation of expected movements, to information provided in *"Effects of Deformation in Building Components" within the "User's Guide – NBC 2010: Structural Commentaries (Part 4 of Division B)"* and to the masonry material and assembly movement properties provided in Tables 1 and 2 of S304.1.

   Veneer and Cavity Walls: These wall types, by their definition in S304.1-14, are intended by design to provide no structural composite action. To ensure that the masonry veneer remains nonloadbearing and that unintended and potentially large shear loads are not imposed on masonry ties connecting the veneer to the structural backing, masonry ties must not offer resistance to structural movements parallel to the wall. Typically, this is achieved by using multi-component ties that are structurally "released", offering free movement at the junction between adjacent parts both horizontally and vertically. For example, the vertical slot in a FERO L-Plate allows unobstructed vertical movement between the L-Plate and the inserted V-Tie™; and the "flattened" inboard end of the V-Tie™ freely slides horizontally through the L-Plate to allow unobstructed horizontal movement. The designer should ensure that the anticipated differential movement between the masonry veneer and the structural backing is suitably accommodated by the length of free movement offered by the tie. Typically, the "throw" offered by the FERO multi-component masonry ties is sufficient for conventional unit masonry veneer designs.

   Walls Providing Composite Action (Clauses 7.7.2 and 10.7.1): For these wall types, masonry ties provide full or partial shear transfer between masonry wythes, or between the exterior masonry wythe and the non-masonry structural backing. To achieve shear transfer/resistance using multi-component masonry ties, movement between the components must be prevented or limited. The FERO Stud Shear™ Connector and Block Shear™ Connector offer the structural benefits of composite action. Whereas FERO shear connectors resist movement parallel to the wall in the vertical direction, they provide free unobstructed movement in the horizontal direction. For additional information about FERO ties and composite action, see *"CSA Standard S304.1-14, III.3 Tie Load"*.

IV CSA STANDARD A370-14, *"CONNECTORS FOR MASONRY"*

CSA A370 provides the design requirements for masonry ties, including requirements for materials, manufacturing, identification, corrosion protection, configuration, spacing, ultimate strength, minimum strength, tie resistance, and serviceability and testing. The following is a summary of requirements particular to masonry tie design.

1. **Limit States Design (Clause 9.4.2.1.1)** Although the 1994 edition of CSA A370 permitted the use of both Working Stress Design and Limit States Design, the 2004 edition permits only Limit States Design.

   Masonry ties are designed to have sufficient strength and stability so that the factored resistance, ΦR, of the tie is greater than or equal to the effect of factored loads.

2. **Tie Ultimate Strength (Clause 9.2)** The ultimate strength of a masonry tie, P_{ult}, may be established by engineering analysis or by testing, or by a combination of the two approaches, and must take into account all possible modes of failure. Normally, P_{ult}, for each of main body, bucking, and pullout/pushthrough failure modes is determined by direct testing conducted by the manufacturer of the tie in accordance with the test procedures of CSA A370 (Clause 12), and with applied statistical reduction to account for variation (Clause 12.1.5.2). When determining ultimate strength in tension and compression, CSA A370 also places a limit of 4 mm on acceptable deformation of the assembly (Clause 9.2.2.2.1). Most often, ultimate loads for fasteners in various substrates are obtained by a designer directly from technical literature published by the manufacturers and suppliers of fasteners. Further discussion about ultimate strengths, and their relation to tie factored resistance, is provided under *"IV.3 Tie Factored Resistance"*.

   The ultimate strength of a masonry tie, P_{ult}, is limited to not less than 1000 N (224 lbs.) (Clause 8.1).

3. Tie Factored Resistance (Clause 9.4.2)

The factored resistance of a masonry tie is taken as the least resistance, ΦP_{ult}, where:

P_{ult} = the ultimate strength of the masonry tie

Φ= 0.9 for material failure of the metal components of the tie

= 0.6 for embedment failure, failure of the fastener, or buckling failure of the tie

It is important to clarify that the factored resistance of a tie is the least resistance, ΦP_{ult}, resulting from the various combinations of P_{ult} and Φ, both of which are failure mode dependent. Factored resistance for ties reported in FERO literature is the least ΦP_{ult} for all failure modes and combinations with the exception of fastener failure. Fastener resistance, $\Phi P_{ult\ fast}$, is typically determined by the designer when selecting the fastener type, and (in addition to the ΦP_{ult} reported by FERO for the particular tie under consideration) must be compared against the effects of factored loads to establish suitability. Additionally, factored resistance reported in FERO literature is specific to the test specimen cross-section described in the literature, with stated limitations on cavity width (within FERO literature, this is typically provided as Note (i) to tabled "Design Data"). Where the cavity width of the design assembly is greater than the cavity width reported for the test specimen, it may be necessary to reduce the published ΦP_{ult}; either an analytical adjustment must be made by the designer, or simple laboratory tests must be undertaken to confirm ΦP_{ult} for the design configuration. Where masonry ties are required for large cavities/air spaces, FERO provides the needed technical support to designers.

4. Serviceability (Clause 9.3)

a. <u>Free Play (Clause 9.3.3.2)</u>: The total mechanical free play of multi-component ties is limited to not more than 1.2 mm, and includes any mechanical free play between a tie component and the structural backing.

b. <u>Displacement + Free Play (Clause 9.3.3.3)</u>: When subjected to a 0.45 kN (100 lb.) load, tie displacement + mechanical free play is limited to not more than 2.0 mm. Tie displacement includes all secondary deformations. The tie must satisfy this condition at all positions of adjustment (9.3.4.2.2).

c. <u>Positive Restraint (Clause 9.3.4.2.1)</u>: Adjustable ties must provide positive restraint at all positions of adjustment, including at maximum adjustment, to prevent disengagement during construction and in service.

Normally, displacement, and displacement + free play are determined by direct testing conducted by the manufacturer of the tie in accordance with the test procedures of CSA A370 (Clause 12), and with applied statistical reduction to account for variation (Clause 12.1.5.2). It is important to highlight that a multi-component adjustable tie must satisfy the A370-14 requirements for displacement + freeplay, and for positive restraint, at all positions of adjustment.

5. Structural Integrity (Clauses 9.5, and 9.2.2.3)

In order to ensure positive load transfer from the masonry tie to the structural backing and to limit the magnitude of secondary deformations in the system, CSA A370 requires that a masonry tie be fastened directly to the structural components that resist wind, seismic, and gravity loads, or to secondary components that are capable of conveying the loads to these primary structural members. These secondary components must have adequate strength, stiffness, bearing and deformation characteristics to convey the tie loads. The suitability of secondary components is assessed by the designer.

Where masonry ties are secured to or bear against materials whose strength and deformational characteristics can be diminished by the effects of moisture, with attendant risk of unacceptable loss of on-going performance, suitable design measures must be taken to either protect the material from the harmful effects of moisture, or to prevent moisture from reaching them. Where masonry ties are surface mounted to a structural sheathing, the sheathing becomes an intervening component/material between the masonry tie and the structural backing members. In this case, the designer should assess the suitability of the sheathing (and the sheathing membrane if used) giving due consideration to building science and the water management strategies used to control moisture originating both from the exterior and the interior of the assembly. As an alternative to surface mounting, FERO offers proprietary masonry ties that are intended by design to penetrate intervening components and materials, and to transfer loads directly to the structural backing members.

For masonry veneer supported by steel stud structural backing, the 1994 edition of the A370 standard recommended that not less than 18 ga. steel stud members be used. This requirement has been removed from the standard. The 2004 edition is generic in its approach, and notes that the size of screw fasteners should be carefully matched to the tie and backing material thickness to prevent stripping of threads or base material (Clause 9.2.2.3, Note 3).

6. Tie Spacing (Clause 7.1)

In CSA A370-14, tie spacing requirements for unit masonry veneer reiterate those also provided in CSA S304.1-14, and include requirements for maximum tie spacing, spacing at openings, spacing at wall top, and spacing at wall base. For a summary, see "*III.4 Tie Pattern and Tie Spacing in Unit Masonry Veneer (Clause 9.1.3)*", under CSA S304.1, herein.

7. Corrosion Protection (Clauses 4.2.1.2, 4.2.4.2., and 5)

CSA A370-14 provides comprehensive requirements for tie corrosion protection. These are identified and briefly summarized as follows:

a. <u>Required Materials (Clause 4.1) and Required Zinc Coating (Table 5.2):</u>

   i. Requirements for base materials and zinc coating mass for corrosion protection are specified in Table 4.1 and Table 5.2, respectively;

   ii. Other materials and coatings are permitted for use where equivalent performance can be demonstrated with respect to service life, strength, and stiffness.

b. <u>Tie Fabrication After Hot-dip Galvanizing (Clause 4.2.1.2)</u>: A tie cannot be modified after hot-dip galvanizing if the modification adversely affects corrosion performance.

c. <u>Material Compatibility (Clause 5.2.5)</u>: Where there is a potential for electrochemical corrosion, compatible materials must be chosen, or the materials must be electrically separated using electrical insulating materials.

d. <u>Tie Service Life (Clause 5.1)</u>: Notwithstanding any minimum requirements for corrosion protection prescribed by A370-14, a masonry tie must have sufficient corrosion resistance/protection to maintain acceptable performance throughout the design service life of the masonry veneer it supports.

e. <u>Prescribed Minimum Levels of Corrosion Protection (Clause 5.2)</u>:

   i. Three levels of corrosion protection are identified:

      1. <u>Level 3</u> (Clause 5.2.2): ties fabricated from Types 304 or 316 stainless steel, in accordance with the applicable standards identified in Table 4.1 of the standard;

      2. <u>Level 2</u> (Clause 5.2.3): ties fabricated from carbon steel that is hot-dip galvanized after fabrication, having minimum mass identified in Table 5.2 for the stated tie material and thickness;

      3. <u>Level 3</u> (Clause 5.2.4): ties fabricated from unprotected carbon steel, or steel with zinc coating having less than the required mass for Level 2 protection identified in Table 5.2.

   ii. Minimum level of corrosion protection is prescribed by Table 5.1 as a function of connector use (height above grade at which the masonry veneer is constructed) and severity of the exposure environment [the annual Driving Rain Index (aDRI) for the geographical location in which a structure is built] (Clause 5.2.1):

      1. For exterior applications:

         a. Level 2 corrosion protection is required for ties and fasteners supporting masonry veneer:

            i. constructed < 13 m above grade, regardless of aDRI;

            ii. constructed ≥ 13 m above grade, where aDRI < 2.75;

         b. Level 3 corrosion protection is required for ties and fasteners supporting masonry veneer:

            i. constructed ≥ 13 m above grade, where aDRI ≥ 2.75;

      2. By way of various notes to Table 5.1, the designer must give special consideration to aggressive exposure environments and where masonry ties are used as stone anchors;

      3. Values for the aDRI for selected locations in Canada are provided in Annex E of A370-14.

V CSA STANDARD A371-14, *"MASONRY CONSTRUCTION FOR BUILDINGS"*

CSA A371-14 provides the minimum material and construction requirements for masonry in buildings other than those that fall under the scope of Part 9 of the Building Code. This standard is intended to contain only construction requirements with which a masonry contractor would be expected to be familiar and be able to comply. As such, the requirements within A371 are prescriptive in nature. The following is a summary of requirements particular to masonry tie construction and installation in unit masonry veneer. The discussion is limited to other than (deemed to comply) "Prescriptive Ties" as defined by the A371 standard, and does not consider continuous wire ties.

1. Fasteners (Clauses 9.3.5 and 10.2.3.2)

Fasteners are to be installed in accordance with the manufacturer's specifications. Fasteners that rely on preload should not be over-torqued.

2. Straightness and Perpendicularity (Clause 9.3.7)

Ties are not to be angled or bent across the cavity.

3. Tie Installation (Clauses 9.3.6, 9.4.2.7, and 10.2.3.1)

Ties are to be installed in accordance with the requirements of the project contract documents. Note that the FERO V-Tie™ is intended to be installed along the centreline of a unit masonry veneer within a reasonable tolerance. Clause 12.2.2 limits the permissible variation in the width of the constructed air space for unit masonry to ± 13 mm. Implicit in this is a requirement to embed a wire tie, including the FERO V- Tie™, along the centre of the unit masonry veneer within a tolerance of ± 13 mm.

MASONRY TIE DESIGN AND SELECTION (CANADA)

FERO System		Serviceability			Strength
		Free Play mm (in.)	Displacement [@ 45kN (100lbs.)] mm (in.)		Factored Resistance[ΦP_{ult}] kN (lbs)
			w/o Free Play	with Free Play	
Block Shear Connector		0.80 (0.031″)	0.15 (0.006″)	0.95 (0.037″)	3.3 (735)
Stud Shear Connector		0.80 (0.031″)	0.05 (0.002″)	0.85 (0.033″)	2.5 (560)
Side Mounting Rap-Tie		0.80 (0.031″)	0.11 (0.0043″)	0.91 (0.036″)	3.7 (825)
Rap-Tie	Mounted Directly on Steel Stud	0.80 (0.031″)	0.47 (0.019)	1.27 (0.05″)	1.5 (340)
	Mounted to Surface of Protected Exterior Gypsum Sheathing	0.80 (0.031″)	0.50 (0.02″)	1.30 (0.051″)	1.5 (340)
Heavy Duty Rap-Tie	Mounted Directly on Steel Stud	0.80 (0.031″)	0.47 (0.019″)	1.27 (0.05″)	1.5 (340)
	Mounted to Surface of Protected Exterior Gypsum Sheathing	0.80 (0.031″)	0.50 (0.02″)	1.30 (0.051″)	1.5 (340)
Slotted Block Tie (Type I)		1.04 (0.041″)	0.07 (0.003″)	1.11 (0.044″)	1.5 (340)
Slotted Block Tie (Type II)		0.50 (0.02″)	0.10 (0.004″)	0.60 (0.024″)	3.0 (675)
Slotted Stud Tie (Type I)		1.04 (0.041″)	0.07 (0.003″)	1.11 (0.044″)	1.5 (340)
Slotted Stud Tie (Type II)		0.50 (0.02″)	0.10 (0.004″)	0.60 (0.024″)	2.5 (560)
Slotted Side Mounting Rap-Tie		1.04 (0.041″)	0.16 (0.0063″)	1.2 (0.047″)	2.1 (475)
Slotted Rap -Tie	Mounted Directly on Steel Stud	1.04 (0.041″)	0.63 (0.025″)	1.67 (0.066″)	1.5 (340)
	Mounted to Surface of Protected Exterior Gypsum Sheathing	1.04 (0.041″)	0.66 (0.026″)	1.7 (0.067″)	1.5 (340)
Slotted Heavy Duty Rap-Tie	Mounted Directly on Steel Stud	1.04 (0.041″)	0.63 (0.025″)	1.67 (0.066″)	1.5 (340)
	Mounted to Surface of Protected Exterior Gypsum Sheathing	1.04 (0.041″)	0.66 (0.026″)	1.7 (0.067″)	1.5 (340)
Adjustable BVTS		0.74 (0.029″)	0.45 (0.018″)	1.19 (0.047″)	1.3 (300)
Pac-Tie	Mounted Directly on Steel Stud	0.74 (0.029″)	0.45 (0.018″)	1.19 (0.047″)	1.3 (300)
	Mounted to Surface of Protected Exterior Gypsum Sheathing	0.74 (0.029″)	1.13 (0.044″)	1.87 (0.074″)	1.3 (300)
Cat-Tie		0.74 (0.029″)	0.45 (0.018″)	1.19 (0.047″)	1.3 (300)
BVTS		0.00 (0.00″)	0.95 (0.037″)	1.01 (0.04″)	0.72 (160)
Lateral Tie Clip		0.00 (0.00″)	1.01 (0.04″)	1.01 (0.04″)	0.73 (165)
ICF Masonry Veneer Tie System		0.08 (0.031″)	0.47 (0.019″)	1.27 (0.05″)	1.5 (340)

Notes

1. These design data are based on connector testing in accordance with CSA A370-14, *Connectors for Masonry*, with no surcharge, and with test samples having the following configuration:
   a. Block Shear Connector: 114 mm [4.5″] cavity (with configuration for 25 mm [1″] air space); standard FERO V-Tie™; and V-Tie™ engaged into Shear Connector Plate at position of maximum vertical adjustment; no insulation present.
   b. Stud Shear Connector: 127 mm [5″] cavity (with configuration for 25 mm [1″] air space); standard FERO V-Tie™; and V-Tie™ engaged into Shear Connector Plate at position of maximum vertical adjustment; no insulation or gypsum sheathing present.
   c. Side Mounting Rap-Tie: 76 mm [3″] cavity (with configuration for 25 mm [1″] air space); standard FERO V-Tie™; and V-Tie™ engaged into Plate at position of maximum vertical adjustment; no insulation or gypsum sheathing present.
   d. Rap Tie: 5″ [127 mm] cavity; 4″ [102 mm] L-Plate; 1″ [25 mm] air space; one (1) fastener located in the centre hole of the L-Plate; standard FERO V-Tie™; and V-Tie™ engaged into L-Plate at position of maximum vertical adjustment.
   e. Heavy Duty Rap-Tie: 127 mm [5″] cavity; 102 mm [4″] Heavy Duty L-Plate; 25 mm [1″] air space; one (1) fastener located in the centre hole of the L-Plate; standard FERO V-Tie™; and V-Tie™ engaged into L-Plate at position of maximum vertical adjustment.
   f. Slotted Block Tie (Type I): 127 mm [5″] cavity; Slotted Block Tie (Type I) having (I) of 102 mm [4″]; 25 mm [1″] air space; standard FERO V-Tie™; and V-Tie™ engaged into Block Plate at centreline of vertical adjustment.
   g. Slotted Block Tie (Type II): 127 mm [5″] cavity; Slotted Block Tie (Type II) having (I) of 102 mm [4″]; 25 mm [1″] air space; standard FERO V-Tie™; and V-Tie™ engaged into Block Plate at centreline of vertical adjustment.
   h. Slotted Stud Tie (Type I): 127 mm [5″] cavity; Slotted Stud Tie (Type I) having (IG) of 102 mm [4″]; 25 mm [1″] air space; two (2) fasteners connecting Stud Plate and steel stud; standard FERO V-Tie™; and V-Tie™ engaged into Stud Plate at centreline of vertical adjustment.
   i. Slotted Stud Tie (Type II): 127 mm [5″] cavity; Slotted Stud Tie (Type II) having (IG) of 102 mm [4″]; 25 mm [1″] air space; two (2) fasteners connecting Stud Plate and steel stud; standard FERO V-Tie™; and V-Tie™ engaged into Stud Plate at centreline of vertical adjustment.
   j. Slotted Side Mounting Rap-Tie: 140 mm [5.5″] cavity (with configuration for 25 mm [1″] air space); standard FERO V-Tie™; and V-Tie™ engaged into Plate at position of maximum vertical adjustment; no insulation or gypsum sheathing present.
   k. Slotted Rap-Tie: 127 mm [5″] cavity; 102 mm [4″] Slotted L-Plate; 25 mm [1″] air space; one (1) fastener located in the centre hole of the L-Plate; standard FERO V-Tie™; and V-Tie™ engaged into L-Plate at position of maximum vertical adjustment.
   l. Slotted Heavy Duty Rap-Tie: 127 mm [5″] cavity; 102 mm [4″] Slotted Heavy Duty L-Plate; 25 mm [1″] air space; one (1) fastener located in the centre hole of the L-Plate; standard FERO V-Tie™; and V-Tie™ engaged into L-Plate at position of maximum vertical adjustment.
   m. Adjustable BVTS: 100 mm [4″] cavity and 78 mm [3.07″] BVTS; no insulation or gypsum sheathing present.
   n. Pac-Tie: 102 mm [4″] cavity; no insulation; standard AB-Clip, Backer Plate, and Fero V-Tie™ two (2) fasteners connecting the Pac-Tie System to the structural backing; and V-Tie™ positioned at the AB-Clip centreline.
   o. Cat-Tie: 25 mm [1″] cavity; standard AB-Clip and Fero V-Tie™; two (2) fasteners connecting the Cat-Tie System to the structural backing; and V-Tie™ positioned at the AB-Clip centreline.
   p. BVTS: 100 mm [4″] cavity and 78 mm [3.07″] BVTS; 22 gauge corrugated masonry strip tie; no insulation or gypsum sheathing present.
   q. Lateral Tie Clip: using the FERO V-Tie™ with two Lateral Tie-Clips (one per V-Tie™ leg).
   r. ICF Masonry Veneer Tie System: 127 mm [5″] cavity; 102 mm [4″] Plate; 25 mm [1″] air space; standard FERO V-Tie™; and V-Tie™ engaged into ICF Plate at centreline of vertical adjustment.
2. Smaller cavity widths and/or the addition of insulations providing lateral support to the tie L-Plate will increase the tabled factored resistance of the tie and reduce tie deflection.
3. "Protected gypsum sheathing" consists of Perma-Barrier (W.R. Grace) adhered to 12.7 mm (0.5″) exterior gypsum board.
4. These design data reflect both the windward (compression) and leeward (tension) capacities of the Slotted Rap-Tie system, with the governing values listed.
5. The ultimate strength of a FERO tie system, P_{ult}, is determined in accordance with CSA A370-14 and is calculated by multiplying the average tie strength established by testing by (1 – 1.64 cov). The factored resistance of the tie system, ΦP_{ult}, is calculated using the Limit States Design procedures of CSA A370-14.
6. For the FERO tie systems that use the FERO V-Tie™, the factored resistance of the mortar pull-out or push-through for the V-Tie™ embedded at the centreline of 90 mm (3.5″) brick veneer utilizing Type S or N mortar exceeds or equals the tabled factored resistance, ΦP_{ult},. that is, failure by pull-out/push-through of the mortar joint does not govern.
7. The factored resistance of the mortar pull-out or push-out for 22 gauge corrugated strip ties (used with the BVTS tie system) embedded not less than 50 mm (2″) into 90 mm (3.5″) masonry veneer utilizing Type S or N mortar equals or exceeds the the tabled factored resistance, ΦP_{ult}; that is, failure by pull-out/push-through of the mortar joint does not govern.
8. The tabled Stud and Block Shear™ Connector factored resistance, ΦP_{ult}, pertain to "conventional tie use", where the tie is intended by design to resist lateral loads only. To provide composite action between the masonry veneer and the structural backing, where the tie is required to resist shear loads, engineering analysis is required to determine factored resistances, deflections, and connector spacing. Contact FERO Corporation for technical assistance and the availability design tools to facilitate structural analysis.
9. The tabled factored resistance for the Lateral Tie-Clip is based on tests using the FERO V-Tie™ with two Lateral Tie-Clips (one per V-Tie™ leg). No mortar was used. Hence, where the tabled strength design data is used, two (2) lateral Tie-Clips per V-Tie™ should be used (one per V-Tie™ leg). With the addition of mortar providing confinement, increased factored resistance may be realized.
10. The stated tie factored resistance does not consider fastener resistance. A compatible fastener (or fasteners) having an adequate factored resistance must be selected (by design in accordance with CSA A370-14).
11. All FERO Ties satisfy the limiting requirements for serviceability (tie displacement and mechanical free play) in CSA A370-14. Tabled mechanical free play is for stainless steel components. The mechanical free play for hot-dip galvanized components is less.

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