Rehabilitating Metal Stud Masonry

Veneer Cladding Systems

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ABSTRACT

Many residential and office buildings in Canada constructed in the 1970's and early 1980's incorporated steel stud-masonry veneer cladding systems. The steel stud backup and brick veneer were usually connected by means of corrugated strip ties. The brick veneer was designed to transfer the load to the steel stud back-up. A number of such cladding systems are experiencing difficulties mainly due to tie corrosion, lack of ties, frame shortening and deflection of structural members supporting the cladding, such as beams and slabs.

Guidelines and recommendations for retrofitting such distressed cladding systems are presented in this paper.

Keywords: Steel stud, cladding, retrofitting cladding, brick veneer, veneer wall, cladding rehabilitation, masonry cladding, shear connectors

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INTRODUCTION

Over the last 20 years a large number of residential high rise and a large number of commercial structures were constructed in Canada and the United States of America with the cladding system consisting of steel stud and brick veneer. The steel studs were designed for a deflection requirement of L/360, or less, and assumptions in designing the system included composite action between the steel studs and the drywall fastened on both sides of the steel studs by means of drywall screws. The thickness of the steel studs commonly used was between 0.45 mm and 0.91 mm (26 to 20 gauge).

The assembly was usually nested and fastened into a top and bottom track of similar thickness, which was then secured to the main structural elements (slabs, beams) typically by power activated small diameter fasteners. The veneer was designed to transfer all lateral loads to the back-up system by means of corrugated metal strip ties spaced at 400 mm o.c. horizontally and 600 mm o.c. vertically. A number of these types of structures are experiencing distress largely due to frame shortening, tie corrosion, lack of ties, and deflection of supporting elements which caused the back-up assembly (steel studs) to deform. The absence of horizontal control joints to accommodate frame shortening and deflection of main elements has caused loads to be transferred to the veneer which as a result in many cases is under substantial vertical load. This load at times has stabilized the veneer acting as a post-stressing force. Construction tolerances have also contributed to the problem, mainly by causing excessive or undersized cavities to occur for which no allowance was made in the design. During the last few years considerable knowledge has been gained and changes have been introduced to the design philosophies of these assemblies. Such changes are expected to reduce or eliminate the failures encountered in the past.

The overall allowable lateral deflection of the masonry veneer under service load is now generally limited to L/720, there is recognition that there is no composite action between steel studs and gypsum sheathing, and the top connection is designed to accommodate vertical deflection and deformation of the main supporting elements for both the veneer and the back-up steel stud system. The interaction of the ties fastening the veneer to the back-up system is also taken into consideration in the design of these assemblies. Although such changes will improve the design of brick veneer steel stud (BV-SS) wall systems, the repairs and rehabilitation of distressed existing structures have received limited attention.

Retrofitting existing structures or repairing veneer assemblies that are experiencing distress requires the employment of techniques and procedures that can provide verifiable results and at the same time can be shown to satisfy sound engineering principles. This paper provides guidelines and suggests methods for retrofitting steel stud-masonry veneer assemblies that provide for verifiable results and are based on sound and existing engineering principles.

SIGNS OF DISTRESS

Cracking, bulging and spalling of masonry veneer are the most common signs of structural distress of masonry veneer. Complete failure of parts of the veneer has also occurred in a number of cases. (Calgary 1991 and Winnipeg 1990). At times load transferred through the ties to the veneer or deformation of the back-up steel stud system caused by frame shortening or deflection of the slabs or beams supporting the steel studs, has resulted in deformations in the veneer. These deformations and movements may be very noticeable in the vicinity of the steel shelf angle supporting the veneer at floor levels. This is the result of eccentric loading on the veneer caused by deflection of the shelf angle combined with the lack of a control joint below the shelf angle. Small amounts of mortar placed between the shelf angle and the veneer will cause eccentric loading on the assembly further complicating the state of stress within the veneer.

Crushing of interior gypsum sheathing and popping of drywall screws is also a sign of structural distress within the assembly.

Water penetration or an excessive amount of air infiltration or exfiltration may cause structural damage which may be difficult to detect, as it affects the structural components supporting the cladding. Corrosion of ties, fasteners, studs and tracks can be linked to excessive air leakage and the incorrect location of the dew point within the wall system, especially for walls incorporating insulation only within the stud space. For these walls the dew point is within the studs, and thus the possibility of corrosion is much higher than in walls with the dew point on the exterior side of the backup steed stud wall and within the cavity insulation.

The need for repairs must be established after careful evaluation of the condition of the entire system. This can only be accomplished by a systematic study of the condition of all components and the factors which contributed to the distress. The remedial action must account for and address the effects of the remedial work on the expected performance of the assembly. If for example, the distress of a brick veneer is attributed to frame shortening, providing a control joint at the floor level may cause distress which manifests itself in the form of over-stressing the steel stud back-up system. If the ties are corroded or inadequate, removing the vertical load acting on the veneer can result in a situation where total collapse may occur. In addition, because of tolerances, the condition of the cavity and its size may vary along the height of the building and the ties may be inadequate once the veneer is released of the unintentional vertical load transferred due to frame shortening.

RETROFITTING OPTIONS

At present no specific guidelines exist in retrofitting BV-SS wall assemblies. A variety of retrofit anchors are available for assemblies where the back-up consists of solid walls such as concrete, concrete blocks, or structural tile.

For such walls, strengthening devices are installed by drilling through the wall and either mechanically (expansion) or chemically (epoxy) affix the tie to the back-up wall, relying on either adhesion or expansion forces to secure the veneer. This method has been reported to provide adequate results for such back-up wall systems. However, this type of strengthening of BV-SS assemblies is limited especially when retrofitted from the exterior of the structure for the following reasons:

a) It is difficult to locate the steel studs when drilling.

b) Removal of a large part of the flange of the stud will reduce its ability to resist loads.

c) The condition of the assembly components can not be verified.

Strengthening the assembly from the interior will result in similar and additional difficulties and costs, within the penetration of the air barrier and the damage to interior finishes being the most important. Factors such as occupancy disruption and making good on retrofitting operations also make the process of repairing from the interior very unattractive.

If severe corrosion of the steel stud assembly is not a factor then the back-up assembly may be deemed structurally adequate, i.e., the back-up wall can carry the lateral loads acting on it, provided that the load is transferred to the back-up system via proper ties or the studs are inadequate and strengthening of the wall system is required.

For inadequate back-up wall strength cases, the assembly can be retrofitted with appropriate ties spaced at 600 mm vertically and 800 mm horizontally overall with the spacing being closer at the top and bottom supports as specified by CSA CAN3-A370 "Connectors for Masonry." During retrofitting the fastenings of the tracks at the top and bottom must be examined and made good if required. Control joints along the length of the wall at the top of veneer panels can be examined, and introduced if required, so as to relieve the stresses arising in the veneer due to frame shortening and deflection of the supporting elements. Placing of a section of membrane between the gypsum sheathing and the retrofit tie (to protect the gypsum sheathing), or utilizing a tie that transfers the load directly to the studs may be considered. Figure 1 shows recommended tie locations for retrofitting steel stud-brick veneer assemblies.

If the back-up system is found to be structurally inadequate to receive the lateral loads from the veneer, i.e. excessive lateral deflection of the steel stud back-up wall is expected, one retrofitting option is the introduction of connectors which can transfer shear across the cavity, allowing the assembly to act as a vertically spanning Vierendeell Truss. There exists two possible methods of attaching ties capable of shear transfer:

1. Ties fastened on the web of the studs as shown in Figure 2. Details of this tie are shown in Figure 3.
2. Ties which can be placed on the flange of the studs as shown in Figure 4. Details of this tie are shown in Figure 5.

The structural performance of the system retrofitted by one of the above methods can be evaluated using a computer frame program. The properties of the components used in this analysis must be carefully chosen to reflect the true system as retrofitted. The interaction of the ties and screws with the components must be based on experimental evaluation of the capacities. The following sections present the methodology and the results of theoretical analysis of brick veneer steel stud assemblies retrofitted with ties capable of causing partial shear connection between the brick veneer and the back-up steel stud framing system.

FRAME MODEL

Figure 6 shows the Vierendeel Truss model schematically. The model is represented by solid lines, while the actual components of the cavity wall are represented by dotted lines. Beam elements are used to model all of the wall components as they are exact elements and can therefore span between points of different material and properties.

The elements in the brick veneer and in the steel stud are assumed to span between connector locations. The model of the shear connector consists of four elements as shown in Figure 6. The first element is the portion of shear connector plate that is connected to the steel stud. A large stiffness is assigned to this element. The second element consists of the portion of the shear connector plate in the cavity. The stiffness of this portion of the plate, as obtained experimentally is $EA = 6 \times 10^6$ N, $EI = 18.5 \times 10^9$ N-mm^2, with $E = 200{,}000$ MPa. The third element is the portion of wire in the cavity which is assumed to be 13 mm long. For this element, the actual properties of the wire are used. The fourth element is the portion of the wire (V-tie) embedded into the mortar bed of the brick veneer, which is assigned a higher stiffness than the portion of wire in the cavity. All the connections between the elements are assumed as fixed, except the connection of V-tie to the shear connector plate which is modeled as hinged. The modulus of elasticity for the brick veneer and the steel studs are 3,000 MPa and 200,000 MPa respectively.

The boundary conditions for the frame model are as shown in Figure 6. Both the veneer and steel studs are modeled as hinged at the bottom end. The top reaction of the steel studs is simulated by a roller which allows vertical movement of the studs. The brick veneer is modeled as free at the top. To model the partial fixed condition at the bottom ends of the steel studs and the brick veneer, rotational springs are inserted at the bottom hinged ends. The stiffness of spring for the brick veneer is assumed to be 0.65 kN-m (based on rupture modulus, f't of 0.6 MPa) with this same value assumed for the steel stud connection.

Uniform distributed lateral load along the height of the brick veneer is applied to simulate the lateral wind pressure. Self-weight of the brick veneer and steel stud backup wall are also included in the analysis.

EVALUATION OF RETROFITTED ASSEMBLIES

Consider the assembly shown in Figure 7, which is a typical exterior wall of residential structures of the 1970's. Assume that the wall is 2400 mm high and consists of 90 mm veneer, 25 mm airspace, building paper, 13 mm exterior grade drywall, 102 mm wide by 0.91 mm (26 gauge) thick steel studs, 6 mil polyethylene and painted drywall. Assume that the veneer is attached to the studs by means of 28 gauge (0.38 mm) corrugated strip ties, that the corrugated strip ties are found to be severely corroded in the mortar joint as a result of acid used to clean the veneer and that the cavity, as built, is larger than the 25 mm specified in the construction drawings and specifications. This assembly is deemed structurally inadequate and retrofitting is required.

Recognizing that ties at the top and bottom of the walls must resist larger loads prior to cracking of the veneer, the vertical spacing of the retrofit ties is at 200 mm from the shelf angle for the first tie, the second tie is placed at 400 mm above the first tie and the remaining ties are spaced at 600 mm vertically until the pattern is reversed at the top of the wall. The horizontal spacing of the ties is 800 mm and thus every second stud is used in the retrofitting process. The spacing of the ties near openings is reduced based on the guidelines of CSA CAN3-A370, "Connectors for Masonry." Figure 1 shows the vertical locations of the retrofit ties.

Using the properties of the components listed in the previous section with the arrangement of the ties as shown in Figure 1, the wall is analyzed under the action of a 1.0 kPa wind pressure. The maximum tensile stress (secondary) in the brick veneer is 0.18 MPa and the maximum lateral deflection of the assembly is 1.14 mm. Table 1 contains the results of an elastic analysis of 600 mm long sections of walls as shown in Figure 8 for a selection of wall assemblies retrofitted using this method. The method requires the removal of a portion of the exterior sheathing, which needs to be repaired after the tie installation. Fastening ties on two adjacent studs as shown in Figure 8 may be more economical as two ties can be installed per opening.

For assemblies where the steel studs are of sufficient width and thickness and the stud flanges are not corroded, but concerns relate to the excessive width of the as-built cavity (air space), the adequacy of the existing ties, and the ability of the steel studs to carry the lateral load, the use of partial shear connection (such as the one shown in Figure 9) can provide a good solution.

Consider the wall shown in Figure 7, which is to be strengthened by installing ties at every second stud placed at the same vertical locations along the height of the studs as shown in Figure 1. The wall is analyzed using the same properties as for the previous case. Table 2 contains the results of an elastic analysis of an 800 mm wide section of wall as shown in Figure 9 for a selection of combinations of wall assemblies retrofitted with this method. The maximum tensile force in the screws required to develop the computed moments is 411 N (maximum at the first and last connector location), which provides for a factor of safety of 2.8, as obtained by comparing this computed value with experimentally derived values as listed in Table 3.

This partial shear connection retrofit method can provide for a more economical solution, as fewer bricks have to be removed to install this type of connector. It is recommended that the gypsum sheathing supporting the tie be protected by placing a piece of self-adhesive vapour barrier material on the sheathing at the contact location of the connectors.

CONCLUSIONS

Structures with inadequate back-up systems and/or ties can be retrofitted without completely removing the cladding system. The performance can be enhanced by connecting the veneer to the light steel framing with connectors capable of transferring shear, thereby attaining partial shear connection between the brick veneer and the steel studs. Blind restoration of such wall assemblies or the incorporation of relatively large diameter fasteners through the flanges of the studs, cannot be relied upon and may further reduce the ability of the assembly to resist lateral loads by introducing hinges at the location of these penetrations.

REFERENCES

1. CSA Standard, CAN3-A370-M84, "Connectors for Masonry", Canadian Standards Association, Ontario, Canada.

2. CSA Standard, CAN3-S304-M84, "Masonry Design for Buildings," Canadian Standards Association, Ontario, Canada.

3. Papanikolas, P. K., Hatzinikolas, M., Warwaruk, J., Elwi, A. E.; "Experimental and Analytical Results for Shear Connected Cavity Walls"; Proceedings of 5th Canadian Masonry Symposium, June 1989, pp. 251-261.

4. "Renovation Strategies for Brick Veneer Steel Stud Task 1: Brick Ties"; Draft of a report prepared for Canadian Mortgage and Housing Corporation.

5. Goyal, A., Rashwan, M. S., Hatzinikolas, M. A. and Zervos, S.; "Structural Performance Of Cavity Walls Constructed With Units Containing Sawdust And Shear Connected To The Brick Veneer" Submitted for publication to the Canadian Journal of Civil Engineering, to be published in August 1994.

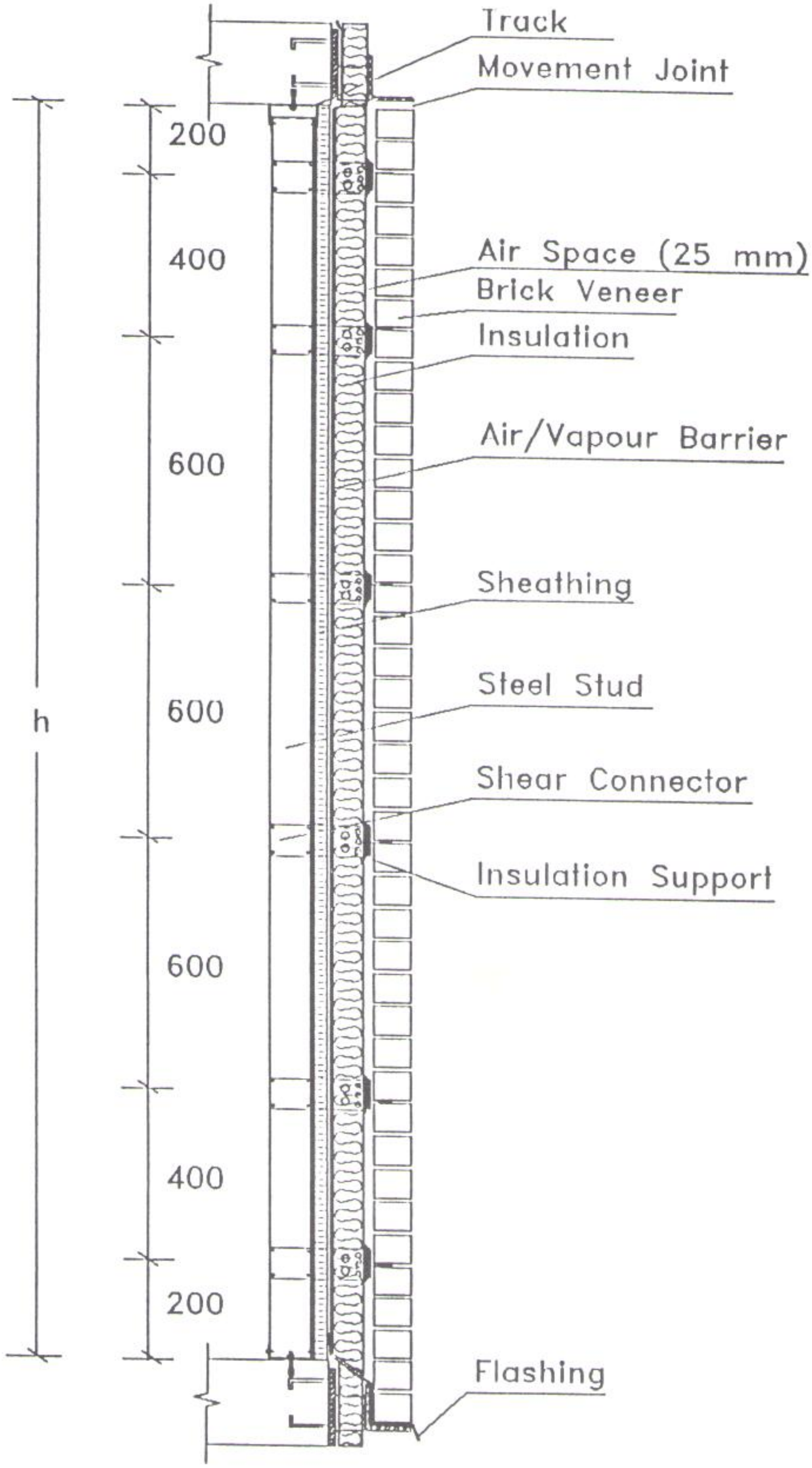

Figure 1. Typical Location of Retrofitted Ties in Brick Veneer Steel Stud Wall System

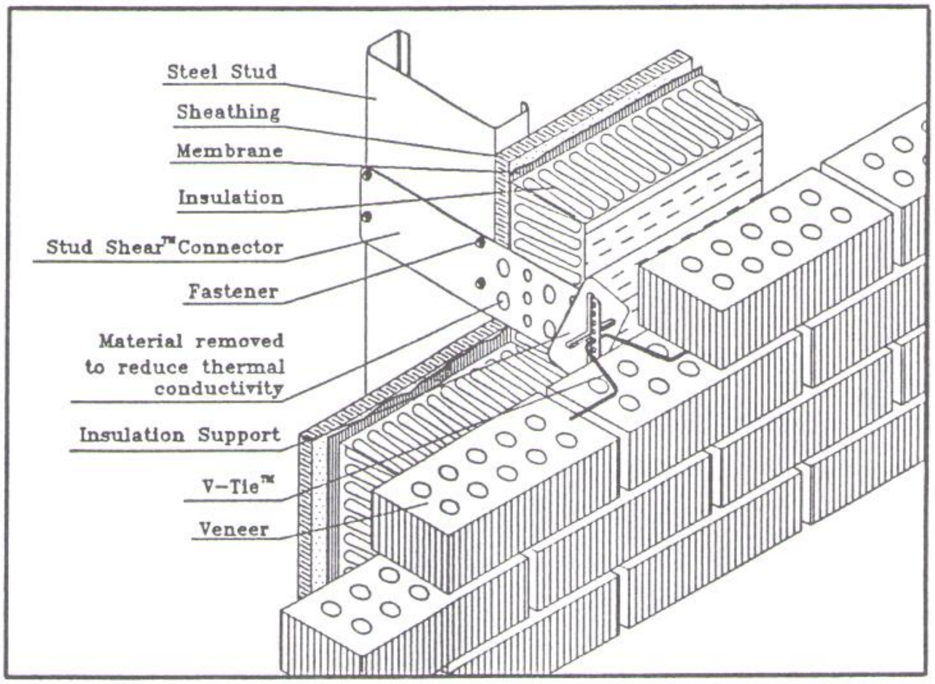

Figure 2. Shear Connector Attached to the Web of the Steel Stud

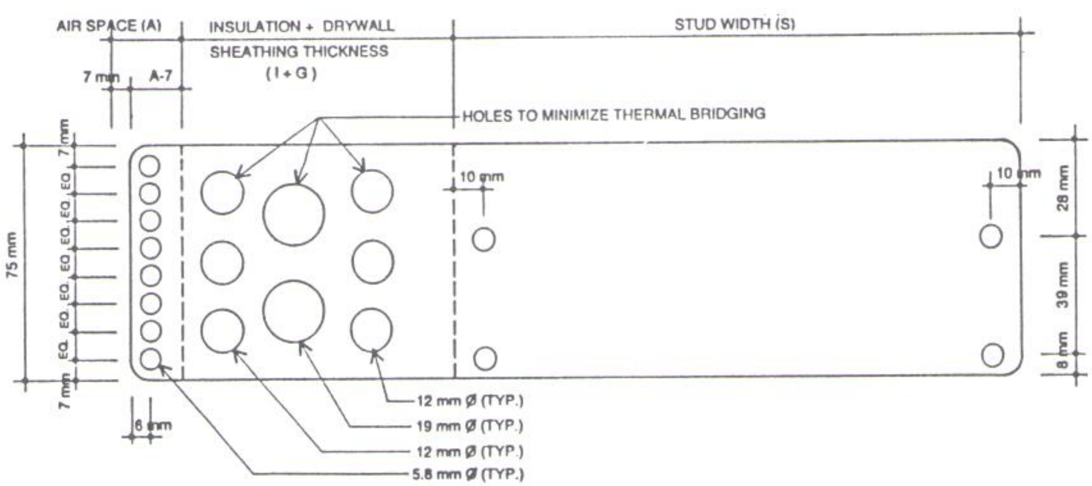

Figure 3. Dimensions of Shear Connector Plate used to attach the Web of the Steel Stud

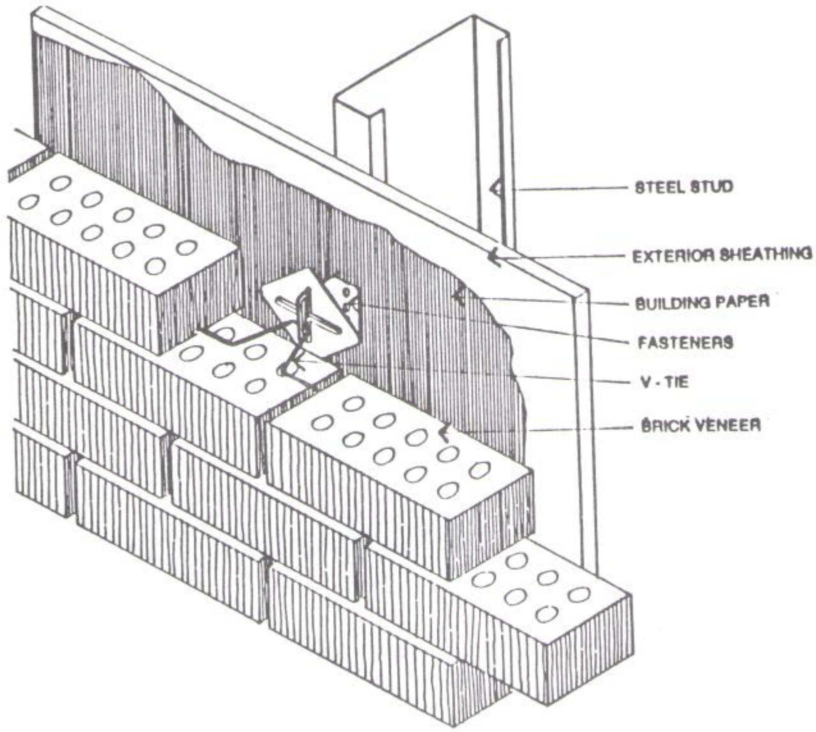

Figure 4. Shear Connector Attached to the Flange of the Steel Stud

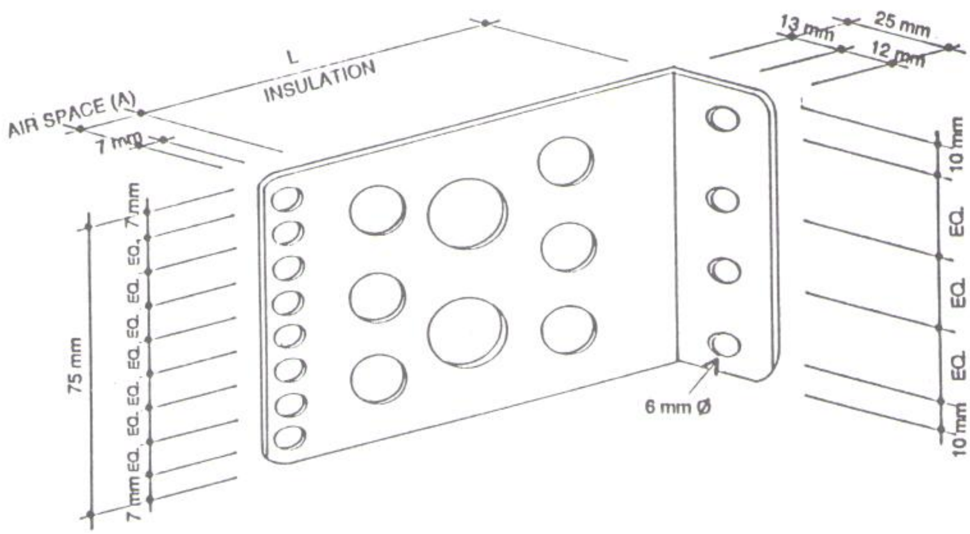

Figure 5. Dimensions of Shear Connector Plate used to attach to the Flange of the Steel Stud

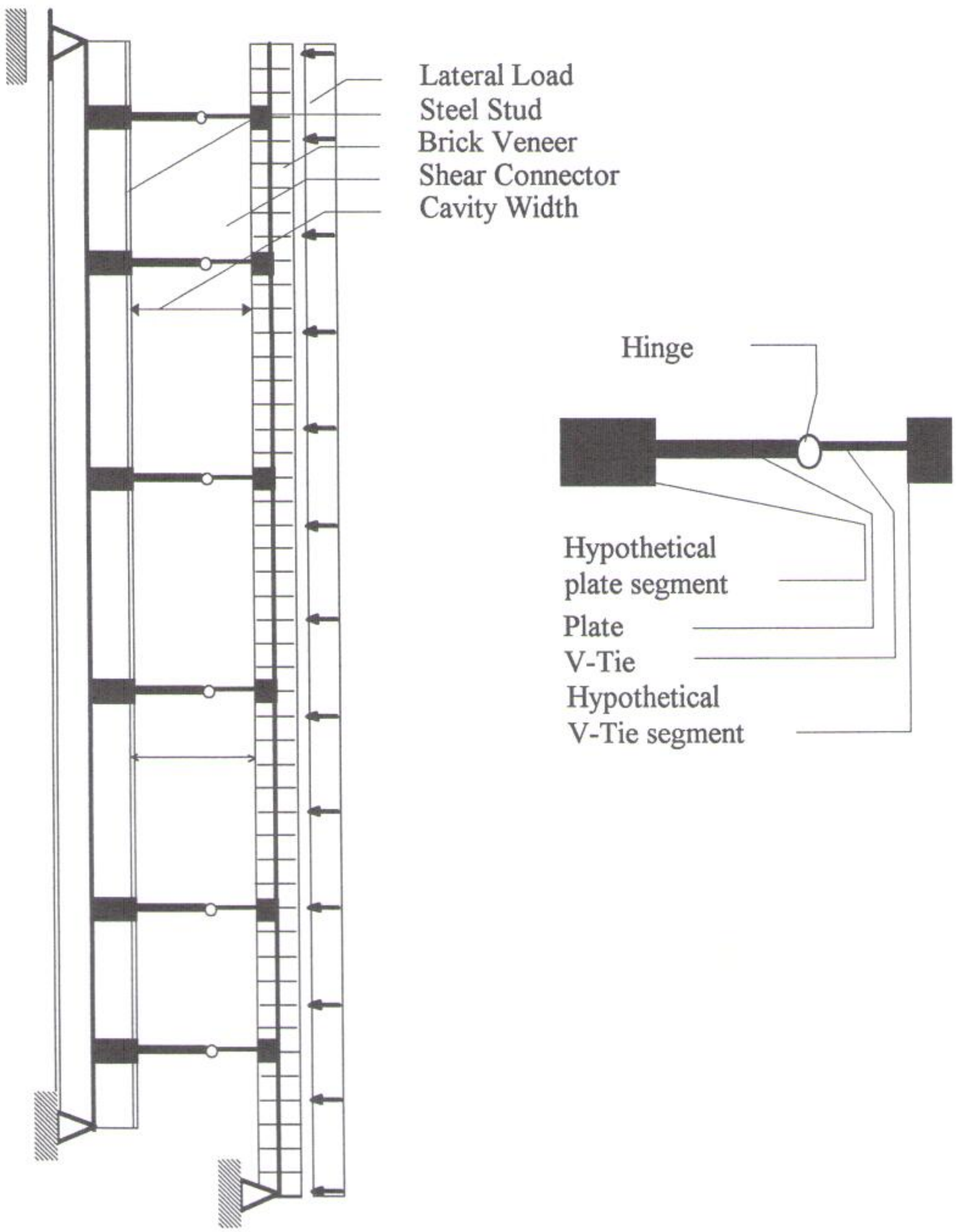

Figure 6 Frame Model

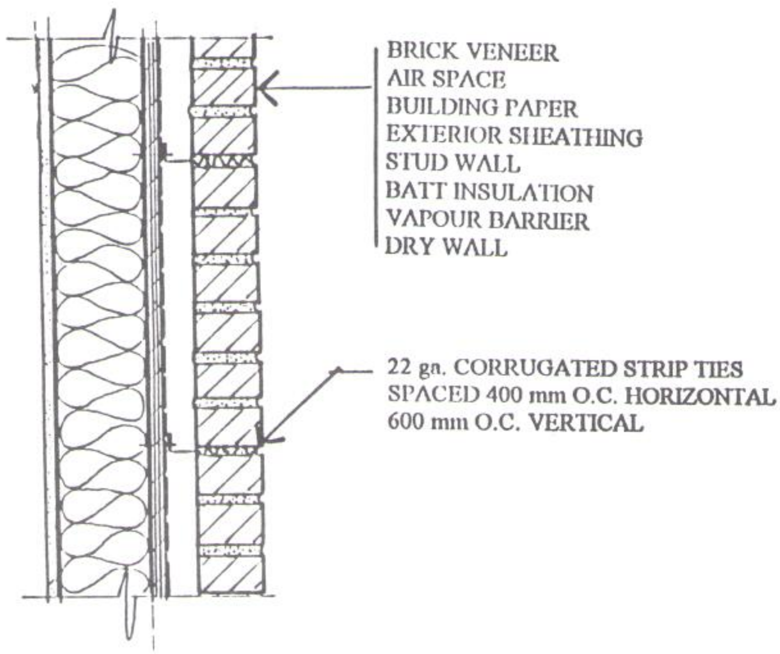

Figure 7. Typical Cross Section of Brick Veneer Steel Stud Wall Assembly of the 1970's and Early 1980's

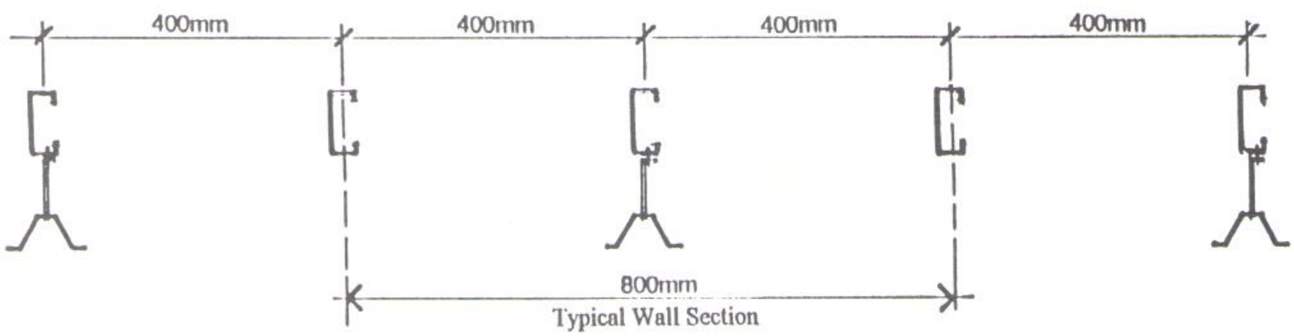

Figure 8. Horizontal Spacing of Shear Connectors Attached to the Webs of the Steel Studs

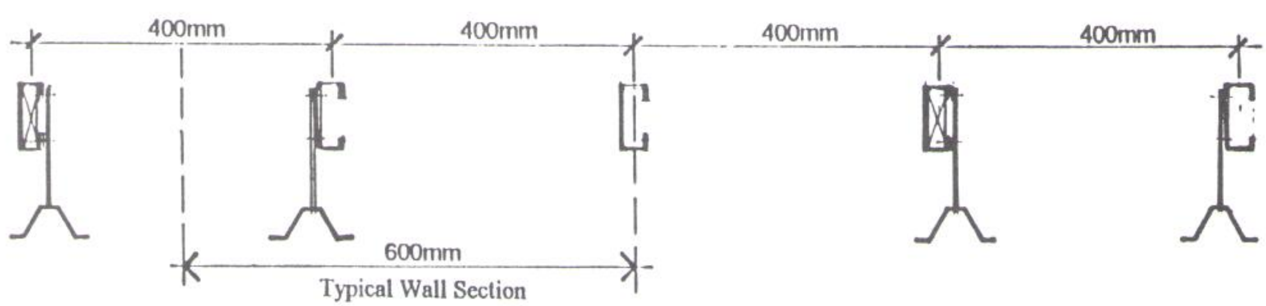

Figure 9. Horizontal Spacing of Shear Connectors Attached to the Flanges of the Steel Studs

Table 1 Maximum Tensile Stresses in the Brick Veneer and the Midheight Deflection of Wall Retrofitted with Shear Connectors attached to the Web of the Steel Studs Subjected to a 1.0 kPa Wind Load.

Stud Thickness	Steel Stud Unsupported Height							
	2400 mm		2600 mm		2800 mm		3000 mm	
(gauge)	f't (MPa)	Δ (mm)	f't (MPa)	Δ (mm)	f't (MPa)	Δ (mm)	f't (MPa)	Δ (mm)
18	0.13	0.86	0.15	0.10	0.16	1.37	0.17	1.71
20	0.15	0.97	0.16	1.25	0.18	1.40	0.19	1.83
22	0.16	0.99	0.17	1.30	0.19	1.55	0.20	1.92
24	0.17	1.04	0.19	1.33	0.20	1.65	0.22	2.02
26	0.18	1.14	0.21	1.46	0.23	1.80	0.24	2.25

Note: f't denotes maximum tensile stress in brick veneer and Δ denotes midheight lateral wall deflection.

Table 2 Maximum Tensile Stresses in the Brick Veneer and the Midheight Lateral Deflection of Wall Retrofitted with Shear Connectors attached to the Flanges of the Steel Studs Subjected to a 1.0 kPa Wind Load.

Stud Thickness	Steel Stud Unsupported Height							
	2400 mm		2600 mm		2800 mm		3000 mm	
(gauge)	f't (MPa)	Δ (mm)	f't (MPa)	Δ (mm)	f't (MPa)	Δ (mm)	f't (MPa)	Δ (mm)
18	0.17	1.02	0.17	1.31	0.21	1.64	0.23	2.04
20	0.19	1.16	0.20	1.48	0.23	1.70	0.26	2.29
22	0.20	1.19	0.23	1.51	0.24	1.84	0.27	2.31
24	0.21	1.23	0.24	1.58	0.25	1.99	0.28	2.44
26	0.23	1.34	0.26	1.72	0.28	2.14	0.31	2.66

Table 3 Self Tapping Sheet Metal Screw Ultimate Tensile Pullout Loads

Self Tapping Sheet Metal Screw Size	Thickness of Steel Stud			
	14 ga. (1.73 mm)	16 ga. (1.44 mm)	20 ga. (0.94 mm)	26 ga. (0.45 mm)
# 8	4185 N	3150 N	1290 N	N/A
# 10	4425 N	3135 N	1245 N	740 N
# 12	4290 N	2835 N	1800 N	N/A
# 14	5010 N	3180 N	1575 N	1150 N

Note: Loads have been modified (reduced) by applying correction factors as per CSA CAN3-A370.