CHAPTER 4
MASONRY VENEER/STEEL STUD WALLS
(NONBEARING CONSTRUCTION)

1. INTRODUCTION. This document defines the criteria to be used when designing curtain wall masonry veneer on steel studs. These walls are to be designed to resist out-of-plane lateral loads due to wind and seismic forces. Also, the wall system must collect, direct and remove water from the wall cavity to properly control moisture, prevent efflorescence, and control corrosion of the steel system. These curtain wall steel stud systems will not carry building dead or live loads, nor provide lateral resistance to the building system.

2. GENERAL DESCRIPTION OF WALL SYSTEM. This wall system consists of a masonry veneer exterior wythe connected by anchors to a steel stud backup wall. The steel studs will be mechanically braced until the sheathing and wallboard are placed on the studs. Sheathing is placed on the cavity face of the stud and the wallboard material is placed on the inside face of the studs. A cavity space is provided between the masonry veneer and the steel stud wall to allow moisture to migrate down the inside face of the cavity, brace the masonry veneer laterally and transfer the horizontally applied loads to the steel studs. The masonry wythe will be isolated on three sides to assure that it will only carry its own weight.

3. REQUIREMENTS FOR WALL COMPONENTS AND DETAILS. See Appendix G for typical Masonry Veneer / Steel Stud details.

a. Masonry Wythe.

(1) Masonry Units. Dimensional and physical requirements of the masonry units are given in TM 5-809-3/NAVFAC DM-2.09/AFM 88-3, Chapter 3. Masonry units used in veneer walls will be solid.

(2) Mortar. Four types of mortar are specified in ASTM C270, they are M, S, N, and O. While Types S and N may be used for masonry veneer systems; Type S mortar has higher strength and good workability and can be used above and below grade, Type N has a lower strength, better workability is more water tight and can only be used above grade. The lower strength of Type N mortar allows cracking in the masonry wythe at relatively low load levels. Masonry cracking will result in more uniformly distributed anchor forces. Conversely, vertical beam action of the uncracked masonry wythe causes nonuniform distribution of loads to the wall anchors. Those wall anchors near the top of the uncracked masonry wythe have much higher loads than those in the lower half of the wythe. Type S mortar is recommended for the design of masonry veneer steel stud systems. Two strength properties of mortars are measurable: the bond strength in accordance with ASTM C 1072 and the compressive strength in accordance with ASTM C 780. Of these two strengths bond is more important in veneer walls and compression is more important in bearing walls. Type S mortar has the highest compressive and bond strengths and can be achieved with either portland cement-lime or masonry cement. However, since masonry cements include premixed workability and air-content additives the bond strengths are reduced. In order to achieve good bond strengths the maximum air-content of the cement must be limited to 12 %. Since every manufacturer of masonry cement uses different additives and a different air-content, care should be used when specifying masonry cements for veneer walls. To assure a bond strength comparable to a portland cement lime mortar, a comparative bond strength test between the masonry cement proposed for the job and a corresponding type of portland cement mortar needs to be completed to demonstrate equivalent or better bond and compressive strengths for the masonry cement mortars. The contractor will be required to perform the ASTM C 1072 and C 780 tests on their proposed mortars. Masonry units for the bond strength test will be the same as proposed for the project.

(3) Masonry Base Details. The base of the masonry wythe must be placed on a shelf angle or a foundation ledge that is lower than the base channel of the steel stud wall by at least 102 mm (4 “). The width of this shelf angle or a foundation ledge will include the width of the masonry wythe and the cavity. This width will not be less than two thirds of the unit thickness plus the minimum air space. Masonry units set on shelf angles may use a formed lip to reduce the depth of the horizontal joint that is created at the shelf angle line.

b. Steel Studs and Framing. Designers specifying cold-formed studs and framing will use a minimum base metal thickness of 1.21 mm (0.0478 “) and not refer to the metal thickness as 1.146 mm (0.0451”). While the base metal thickness is to be specified to match the design, designers can use table 1-1 as a guide to selecting commonly referred base metal thickness. Designers should be aware that the minimum delivered thickness specified for steel studs will be no less than shown in table 1-1 when materials are specified to the minimum design thickness and delivered in accordance with AISI. The minimum depth of members will be 89 mm (3-1/2 “) and the minimum flange width of 35 mm (1-3/8 “) will have a minimum return lip of 6.4 mm (1/4 “). Shop drawing submittals will need to present the calculations that show the effective flange, with the return lip provided. The actual required stud depth, thickness and spacing will be determined prior to completion of the contract documents. In some cases, the use of a minimum stud depth of 152 mm (6”) yield a more efficient design. Steel studs and framing will be hot-dipped galvanized metal with a minimum ASTM A 653, G60 coating.

(1) Welding. Welding of steel studs requires the use of qualified welders experienced in the welding of cold-formed steel. When welding is used, the contractor needs to provide Qualification documents for each welder working on the project. Welded connections to steel framing members will be touched-up with zinc-rich paint after welding. Normally welded connections are not required in curtain-wall construction but may be used for attachments.

(2) Connections. Connections of studs to runners and other framing members will be made with screws or welds. When the thickness of the thinner connected parts is less than 4.8 mm (3/16 “) the capacity of the connected parts will be in accordance with AISI. For bolted connections when the thickness of the thinner material is equal to or greater than 4.8 mm (3/16 “) use AISC. Normally the minimum top and bottom channel connections in curtain-wall construction will require a single #10-16 self-drilling, self-tapping screw in each flange of the bottom runner for either system and the top channel of the double track system. Welding of studs may be used in lieu of screws or bolts. Slide clip connections will be used when parapets extend above the roof line of the structure. These slide clips connectors need to be welded to a structural element and the details and the capacity of the manufacturers system will need to be included in the shop drawing review. The minimum edge distance of shot-in anchors for top and bottom runners to concrete is 76 mm (3 “) and the minimum fastener spacing is 102 mm (4 “). Contract plans will show anchorage details of the steel studs and other framing members to the building structural system, and the extra steel stud wall framing members required around openings. The required strength capacities of framing weld and screw connectors will be in accordance with ML/SFA 540-87 and ML/SFA 920-91.

(3) Openings. Window and door frames will be attached to the steel stud system, not the masonry veneer.

(4) Top Track and Bottom Runner. A single track or double track top (slip joint) connection will be used at the top of stud walls to permit the vertical movement of the structural framing system to prevent the loading of the steel studs. Both flanges of the steel stud will be attached to the inside top channel for the double track system and the bottom runner of either system. Mechanical bracing of the single track systems should

be installed in addition to support for all studs. This brace will be placed 305 to 457 mm (12 to 18 ") from the bottom of the top channel track.

(5) Parapets. When parapet walls extend above the roof line a slip clip connection will be used to allow for structural deflections without loading the steel stud system.

c. Sheathing. Fire and eater resistant gypsum board sheathing encased in water-repellent paper on both sides and on the long edges will meet the requirements of ASTM C 79. Other materials may be used as sheathing when supported by satisfactory performance data. All gaps in the sheathing resulting from cuts, corners, joints and machine end cuts of the sheathing and all joints at the interface of the sheathing with dissimilar materials such as floor slabs, doors, windows, and other locations where the water-resistant membrane terminates will be taped or filled with an exterior rubber-based caulk. The base detail of the exterior sheathing will be designed to resist water infiltration and the caulking will be applied to form joints that are complete and continuous. Enough connections of the sheathing to the steel studs to provide lateral support for the studs in the direction parallel to the plane of the wall will be required. All screw attachments through the exterior sheathing must resist air and water infiltration.

d. Veneer Anchors. Veneer anchors will be attached through the sheathing to the steel studs. All steel components of anchors will be stainless steel or hot-dipped galvanized steel. Anchor wires will be a minimum of 4.8 mm (3/16 ") diameter. There will be one anchor for each 0.19 m^2 (2 ft^2) of wall area and anchors will be spaced no further apart than 610 mm (24 "). The load-deflection stiffness criteria of each veneer anchor, applies to direct loads in both tension and compression, and will be not less than 350 N/mm (2000 lbs/in). The design load of the anchor will be the controlling wind load on the stud tributary width times one-half the vertical span of the stud. The controlling wind load will be the lesser of the design wind load or the wind load that causes masonry cracking. This load will then be used to calculate the required anchor capacity. Anchors will have a maximum "play" or not more than 1.59 mm (1/16 "). Synthetic rubber washers will be used under tie connector plates. A clutch torque slip screw gun will be used to eliminate stripping of threads. Additional anchors will be installed within 305 mm (12 ") of the free edges of veneer panels and at the edges of wall openings at the normal spacing. Additional anchors required around openings will be detailed on the contract drawings.

e. Fasteners. Screw connectors for stainless steel anchors will be stainless steel. Screws for galvanized anchors will be hot-dipped galvanized.

f. Moisture Barrier. A water-resistant membrane will be placed over the exterior sheathing. The membrane will be 67 N (15 lbs) roofing felt or similar material, such as: "Tyvek" building wrap by Dupont or "Barricade" building wrap by Simplex. The barrier material will be shingled with each sheet lapping over the sheet below with a minimum 152 mm (6") lap. Sheets will be lapped a minimum of 152 mm (6") at vertical joints. The moisture barrier must not be a vapor barrier that will trap water in the stud space of the wall.

g. Vapor Retarder. A 0.15 mm (6-mil) vapor retarder as required in the ROUGH CARPENTRY guide specification will be provided on the warm side of the insulation. In most geographical areas the vapor retarder will be located between the interior wall board material and the face of the steel studs. In hot humid areas of the United States including the Gulf coast, Florida, coastal Georgia, North Carolina, South Carolina and Virginia, the vapor retarder should be located between the exterior sheathing and the steel studs. Check local practice and the recommendations for the installation of insulation and vapor retarders at the project location. The building designers should perform a condensation analysis of the wall system used to determine the dew point location within the wall were condensation might be expected occur.

h. Flashing. Copper or stainless steel through-wall flashing as required in the SHEET METALWORK, General guide specification will be used. Flashing must be designed, detailed and constructed so that all water entering the cavity is directed out through weep holes. Ends and sill flashing must be lapped and sealed at joints. Ends will be turned up at sills and heads. Flashing must also be turned up behind the moisture barrier a minimum of 152 mm (6") and will be attached to the sheathing. Flashing must extend to the exterior face of the masonry wall. Weep holes as described herein will be provided.

i. Shelf Angles. Shelf angles will be hot-dipped galvanized structural steel members. Angles will be provided in segments, approximately 3.1 m (10 ') in length, with gaps between segments. Shelf angles will be detailed to allow enough gaps for thermal expansion and contraction of the steel in angle runs and at building corners. Corners of buildings will have corner pieces with each leg no less than four 1.2 m (4 ') in length where possible. Any areas that are welded will be touched-up with a zinc-rich paint.

j. Cavity. A cavity space of 51 to 102 mm (2 to 4 ") will be provided between the masonry veneer and the exterior sheathing or, if insulation is used over the sheathing, between the masonry veneer and the insulation. In all situations a 51 mm (2 ") minimum wide air space is required and needs to be coordinated with the standard dimensions of lintels and shelf angles. The cavity provides water drainage and prevents moisture migration from the masonry wythe to the steel stud backup wall. The cavity should be kept clean of mortar droppings. To keep mortar droppings from plugging the weep holes place a course gravel or drainage material behind the weep holes in the cavity to a minimum depth of 102 mm (4").

k. Masonry Crack Control. Crack control will be in accordance with the Masonry Manual for anchored veneer.

l. Weep Holes. Head joint weep holes that extend through the masonry wythe will be provided immediately above the mortar bed joint containing the horizontal leg of the through wall metal flashing and near the top of the wall at the same spacing. Details along with the required spacing will be shown on a wall section on the contract drawings. Weep holes need to be kept free of debris during construction and need to be functional at the end of the construction period.

m. Head Joint Vents. Head joint vents will be placed near the top of the veneer wythe at the same spacing as the weep holes. These vents will help maintain a dry cavity.

4. WALL SYSTEM DESIGN REQUIREMENTS. This exterior wall system will be designed assuming that all out-of-plane lateral loads are resisted entirely by the steel stud backup wall. The veneer anchors will be designed to transfer those lateral loads to the steel studs. All in-plane loads will be isolated from the stud wall system. All vertical masonry loads will be carried by a shelf angle or the foundation wall. Veneer anchorage will provide sufficient movement to account for the story drift displacements around window and door openings.

a. Steel Studs. Studs will be sized and spaced to resist wind or seismic loads. Wind loads on steel studs and framing will be in accordance with EI 01S901 and seismic loads will be in accordance with TI 809-04. Supplemental framing will be added at the heads, jambs and sills of openings, as required by design, to resist the tributary loads from the opening closures (doors, windows, etc.). The stud system selected for lateral loading will be checked for deflection, which normally controls panel wall design. Material thickness for the top and bottom runners will be designed for allowable stress and deflection and will be equal to or thicker than the steel stud used in the wall. The minimum delivered material thickness for steel studs is shown in table 1-1.

(1) Section properties. All section properties needed for the design of the steel studs and framing will be in accordance with AISI.

(2) Allowable stresses. All allowable stresses used for the design of the steel studs and framing will be in accordance with AISI.

(3) Deflection limits. The allowable steel stud horizontal deflection, Δ due to the controlling lateral load is defined as follows:

$$\Delta \leq \frac{L}{600} \quad \text{(Eq 4-1)}$$

Where:

L = The vertical span of the steel studs in mm (in).

(4) Selection of top and bottom runners. The base metal thickness for the steel stud runners is equal to or greater then for the steel stud. The thickness of the top runner, t will be sized as follows:

$$t = \left[\frac{7.5338(P)(e)}{F_y(b_{eff})}\right]^{1/2} \quad \text{(Eq 4-2)}$$

Where:

P = the top end wind load reaction (lbs).

e = the gap between the inner top track and the outer top track as shown in figure 4-1, (in).

F_y = the yield strength of the top runner metal (psi).

b_{eff} = the effective width of the top channel flange for analysis (in).

For double track systems, b_{eff} is equal to the stud spacing. With single track systems, b_{eff} is equal to:

$$b_{eff} = W_{stud} + 2\left[\frac{e + D}{\tan(30)}\right] \quad \text{(Eq 4-3)}$$

Where:

W_{stud} = the width of the stud flange (in).

D = depth of track overlap in a slip track connection, 32 mm (1.25 in).

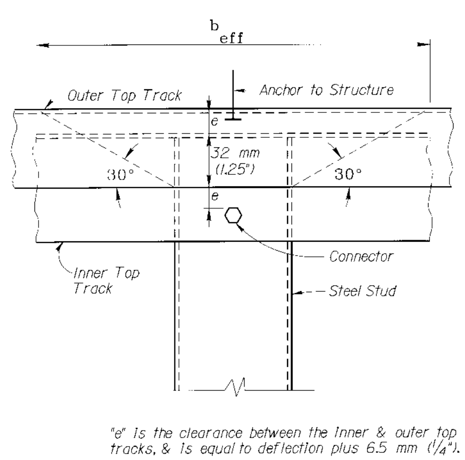

Figure 4-1: Double Track Slip Joint

b. Veneer Anchors. Anchors will be structurally adequate to transfer the lateral loads to the steel stud wall in both tension and compression. Capacity will be based on test results of the anchor provided. The following design procedure to determine the required anchor capacity.

Step 1: Calculate the maximum static out-of-plane distributed load at first cracking.

$$W_{cr} = C1\left[\frac{t_n}{L}\right]^2 \qquad \text{(Eq 4-4)}$$

Where:

W_{cr} = the cracking distributed load for the masonry KPa (psf),
t_n = the nominal thickness of the masonry wall mm (in),
L = the stud span m (ft),
C1 = constant =0.001644 – metric, (240 – English).

Step 2: Calculate the total static out-of-plane distributed load corresponding to the cracking wind load.

$$W_{tot} = W_{cr}\left[\frac{E_bI_b + E_sI_s}{E_bI_b}\right] \qquad \text{(Eq 4-5)}$$

Where:

W_{tot} = the total static out-of-plane wind distributed load corresponding to the cracking wind load KPa (psf),
E_bI_b =the rigidity of the masonry veneer for the stud spacing N-mm^2 (Kip-in^2),
E_sI_s = the rigidity of a steel stud N-mm^2 (Kip-in^2).

Step 3: Compare W_{tot} to W_d (the design wind load) to calculate the maximum anchor force (A_{max}).

$$\text{if} \ldots W_{tot} \le W_d \ldots \text{then} \ldots A_{max} = \frac{W_{cr}L}{2}\left[\frac{\text{Stud .Spacing}}{C2}\right] \qquad \text{(Eq 4-6)}$$

or

$$\text{if} \ldots W_{tot} \rangle W_d \ldots \text{then} \ldots A_{max} = \frac{W_dL}{2}\left[\frac{E_bI_b}{E_bI_b + E_sI_s}\right]\left[\frac{\text{Stud.Spacing}}{C2}\right] \qquad \text{(Eq 4-7)}$$

Where:

Stud Spacing is in mm (in)
C2 = constant = 1000 – metric, (12 – English)

Step 4: Compare A_{max} to the seismic criteria.

$$\text{if} \ldots A_{max} \ge A_{seis} \ldots \text{then} \ldots A_{des} = A_{max} \qquad \text{(Eq 4-8)}$$

$$\text{if} \ldots A_{max} \langle A_{seis} \ldots \text{then} \ldots A_{des} = A_{seis} \qquad \text{(Eq 4-9)}$$

$$A_{seis} = C3(S_{DS})(V_w A_r) \qquad \text{(Eq 4-10)}$$

Where:

A_{max} = the maximum anchor load N (lbs),
A_{des} = the design wind anchor load N (lbs),
A_{seis} = the seismic anchor load N (lbs),
V_w = the veneer unit weight KPa (psf),
A_r = the area per anchor m^2 (ft^2),
C3 = constant =2,000,000 – metric, (2 – English).
S_{DS} = the design spectral response acceleration as per Eq C-3

Step 5: Choose the anchor capacity.

if K<= 350 N/mm (2 kips/in) then A_{cap} = 1.25 A_{des} (Eq 4-11)
if K> 350 mm (2 Kips/in) then A_{cap} = 2 A_{des} (Eq 4-12)

Where:

K = the anchor stiffness with the load in N/mm (kips/in) of deflection,
A_{cap} = the specified load capacity of the anchor to be selected N (lbs).

This design procedure was derived from Western States Clay Products Association test data.

c. Shelf Angles. The angle size and the attachment details of the angle to the building structure to provide vertical support of the masonry wythe must be determined by the designer. The deflection of the shelf angle under gravity loading due to the masonry will be limited to not more than 1.6 mm (1/16 “) at the end of the horizontal leg. Rotation of the shelf angle support will be included in the 1.6 mm (1/16 ”) deflection limit for the horizontal leg displacement calculation.

5. WORKMANSHIP. The success of this wall system is dependent upon good detailing and good workmanship. Careful, quality workmanship is essential to produce a satisfactory masonry veneer steel stud wall system. Special attention needs to be given to the masonry veneer construction to provide quality mortar, full head joints, bed joints, clean cavities, proper flashing and weep holes, and to provide mortar free brick expansion joints. It is essential that the design and detailing requirements in this document and references contained herein are clearly provided in contract plans and specifications.

6. DESIGN EXAMPLE.

a. Given:

(1) Wall System: An exterior non-loadbearing brick veneer steel stud wall system is required. The wall section consists of a nominal 102 mm (4 “) face brick wythe, a 60 mm (2-3/8 “) cavity, and a backup wall of 152 mm (6 “) steel studs with a 13 mm (1/2“) gypsum sheathing fastened to each side of the studs. The wall has a vertical span of 3.66 m (12 ‘) and is simply supported.

(2) Design lateral Loading: The design wind pressure for the wall is 1.34KPa (28 psf) acting inward or outward on the wall. The structure is in seismic zone zero.

b. Problem: Check the design of the wall system described above. Check the allowable flexural stress and the allowable deflection of the steel studs due to that loading.

c. Solution:

(1) Member loading requirements: Since the steel studs are to be designed to resist the total lateral (wind) loading, the anchors need to be selected to transfer the lateral loading from the brick wythe to the steel studs.

(2) Assumptions:

(a) Studs: The minimum stud to be checked is: a 152 mm (6 “) stud; 1.438 mm (0.0566 “) thickness, 41 mm (1-5/8 “) flange width and with a 13 mm (1/2 “) return. Studs will be spaced on 406 mm (16 “) centers.

(b) Anchors: The brick wythe is attached to the steel studs backup wall with 4.8 mm (3/16 “) diameter corrosion resisting veneer anchors spaced 406 mm (16 “) on center both vertically and horizontally.

(3) Check stud strength:

(a) Section Properties: From the American Iron and Steel Institute (AISI, Specification for the Design of Cold-Formed Steel Structural Members, Part V, “Charts and Tables”.

Thickness of sheet (t) = 1.438 mm (0.0566 “),
Depth of section (D_{stud}) = 152 mm (6.00 “),
Width of flange (B) = 41 mm (1.625 “),
Return of flange (C) = 15 mm (0.60 “),
Section Modulus (S_x) = 17,649 mm^3 (1.077 in^3),
Moment of inertia (I_x) = 1,318,205 mm^4 (3.167 in^4),
Area of section (A_{stud}) = 15.6 mm (0.616 “).

(b) Steel Properties:

Modulus of elasticity (E_s) = 200,000 MPa (29,000,000 psi),
Yield strength (F_y) = 228 MPa (33,000 psi).

(c) Design check: The uniform wind load normal to the wall, w, in N/m (lbs/ft) of wall, is:

$$w = (1.34KPa)\left[\frac{406mm}{C4}\right] = 544N/mm...(37.3plf) \qquad \text{(Eq 4-13)}$$

Where:
C4 = constant = 1 - metric, (12 – English)

The moment in steel stud due to wind load, M_s, is:

$$M_s = \frac{wL^2}{8} = \frac{544\ N/m..(3.66\ m)^2}{8} = 911\ .N - m...(672\ ft - lbs) \qquad \text{(Eq 4-14)}$$

Where:

L = the span of the steel studs in m (ft).

The allowable moment in steel stud with a 1/3 increase is stress for wind, M_a, is:

$$M_a = \frac{1.33 F_y S_x}{\Omega_f} = \frac{1.33(228\text{MPa})(17{,}649\text{mm}^3)}{1.67(C5)} = 3{,}198.\text{N} - \text{m}...(2{,}359\text{ft} - \text{lb}) \quad \text{(Eq 4-15)}$$

Where:

Ω_f = the required factor of safety for bending ad given in the AISI specification,
C5 = constant =1,000,000 – metric, (12 – English).

$$M_a = 3{,}198.\text{N} - \text{m}..(2{,}359\text{ft} - \text{lbs})..\rangle\rangle..M_s 911.\text{N} - \text{m}..(672\text{ft} - \text{lbs}) \quad \text{(Eq 4-16)}$$

(4) Check stud deflection: The deflection, Δ, in the steel stud due to the wind load is:

$$\Delta = \frac{5wL^4 C6}{384 E_s I_x} \quad \text{(Eq 4-17)}$$

$$\Delta = \frac{5(544.\text{N/m})(3.66.\text{m})^4(10^9)}{384(200{,}000\text{ MPa})(1{,}318{,}204.\text{mm}^4)} = 4.8.\text{mm}...(0.189\text{ in}) \quad \text{(Eq 4-18)}$$

Where:

C6 = constant = 10^9 – metric, (1728 – English)

The allowable deflection in the steel stud, is given by:

$$\Delta \le \frac{L}{600} = \frac{3.66.\text{m}(C7)}{600} = 6.1.\text{mm}...(0.240\text{in}) \quad \text{(Eq 4-19)}$$

$$4.8.\text{mm}...(0.189\text{in})\ldots\langle\ldots 6.1.\text{mm}...(0.240\text{in})\ldots\text{OK} \quad \text{(Eq 4-20)}$$

d. Summary:

(1) A 152 mm (6 “), 1.438 mm (0.0566 ”) thick steel stud with a 41 mm (1-5/8 “) flange and a 15 mm (0.6 “) return, spaced at 406 mm (16 “) centers is satisfactory.

(2) Use a 4.8 mm (3/16 “) diameter wire anchor spaced on 406 mm (16 “) centers vertically and horizontally.