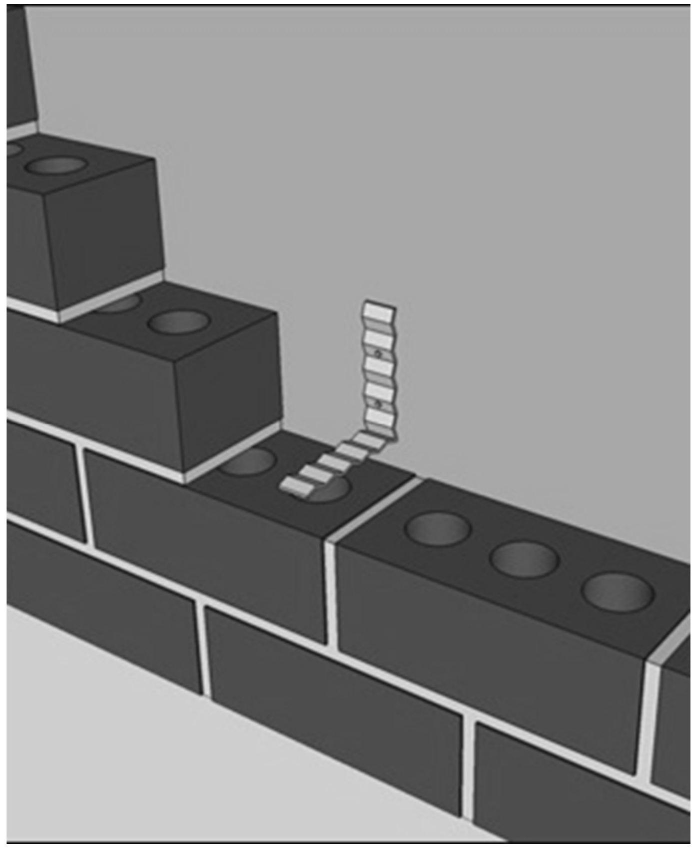
Architecture 504
Masonry Structures

Connectors and Ties

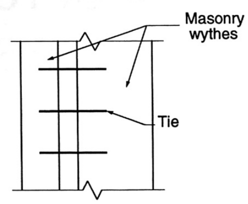


Definitions
Behavior
Support

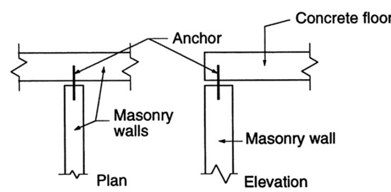
Connectors and Ties

Connectors

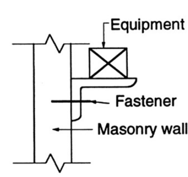
- Wall ties
  - Used to connect 2 wythes of masonry in a cavity wall
  - Or to connect veneer to backup wall
- Anchors
  - Used at intersections of wall
  - To connect wall to roof or floor
  - Spaced along line of support
- Fasteners
  - Attach other items, e.g. equipment
  - Or attach services



(a) Wall Ties



(b) Anchors

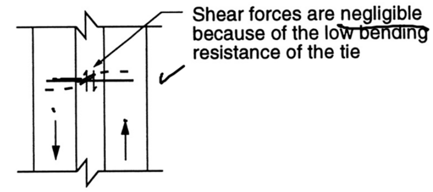


(c) Fasteners

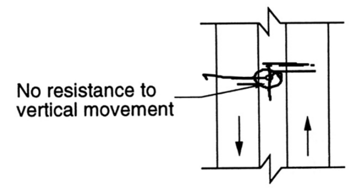
Connectors and Ties

Wall Ties:

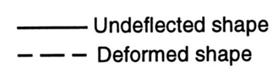
Function
- Transfer force between wythes
- Or veneer to backup wall
- Reduce movement
- Work in tension or compression
- Tie stiffness reduces bending in wall
- Differential vertical movement should be allowed in the tie
  - Flexible (strap)
  - Adjustable (vertically)



(a) Flexible Tie



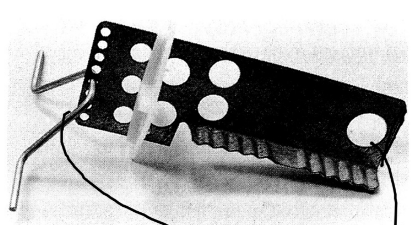
(b) Adjustable Tie

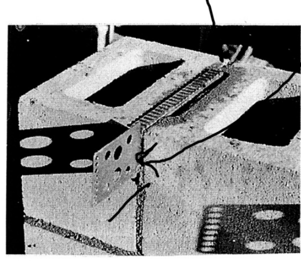


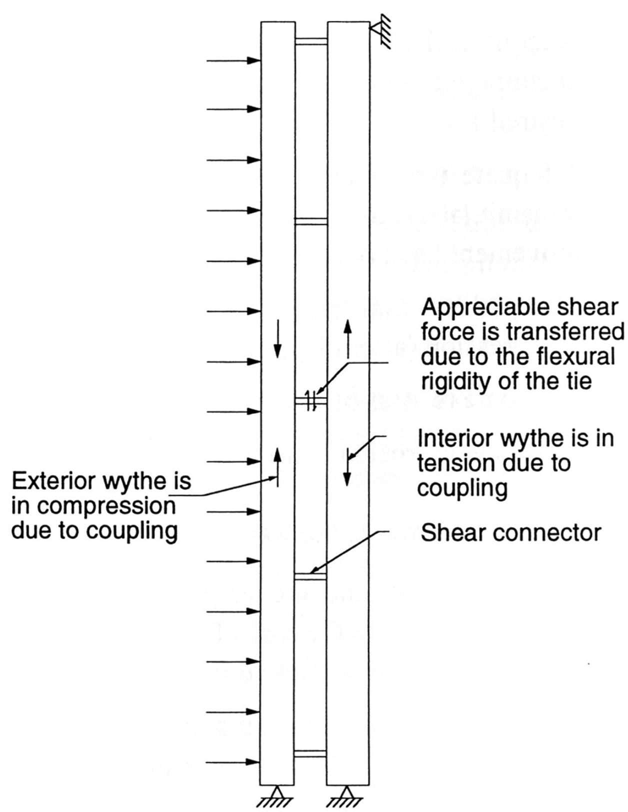
Connectors and Ties

Wall Ties:

Coupled Cavity Wall
- Connector carries shear
- Wythes act together with increased flexural strength
- Heavy load on connector tie


Adjustable rigid tie with wire component for brick wythe

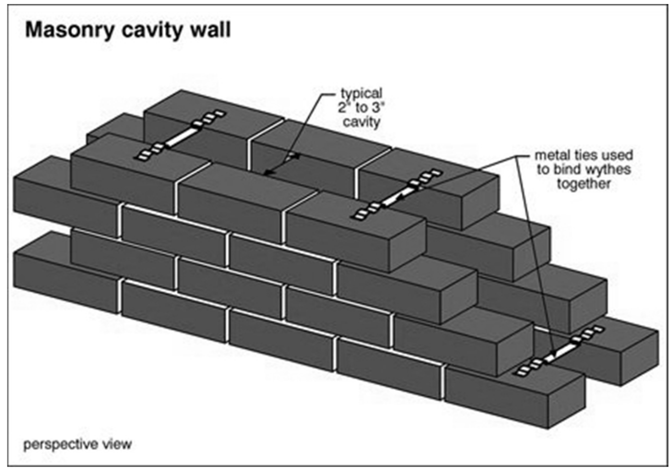

Rigid component in block wythe



Connectors and Ties

Composite (grouted) Walls

- Grout transfers shear forces
- If grout slips, ties reinforce
- Ties carry hydrostatic pressure during grouting
  - Large tensile force during grouting
  - Ties prevent displacement



Connectors and Ties

Performance Summary:

Cavity and Veneer Walls

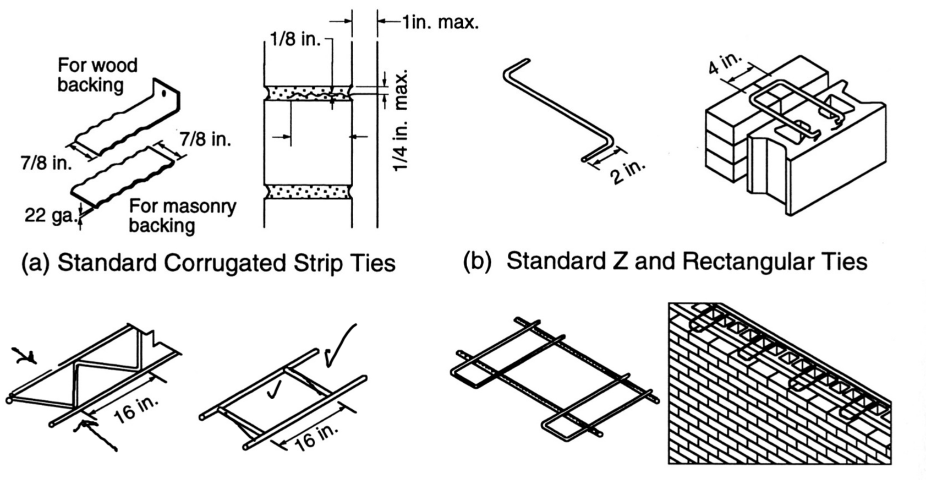
- Adequate flexibility to allow movement
- Adequate tensile and compressive strength to transmit loads between wythes
- Adequate resistance to moisture transfer across wythe
- Adequate corrosion resistance

Composite Walls

- Adequate tensile and anchorage strength to hold wythes together
  - Lateral loads – wind of earthquake
  - Hydrostatic grout pressure
- Adequate shear strength to maintain composite action in bending
- Adequate corrosion resistance

Connectors and Ties

Types of ties:
- Corrugated strip
- Rectangular wire tie
- Z-wire tie
- Continuous ladder of truss tie



(a) Standard Corrugated Strip Ties (b) Standard Z and Rectangular Ties

(c) Standard Continuous Joint Reinforcement (d) Combined Joint Reinforcing and Rectangular Ties

Connectors and Ties

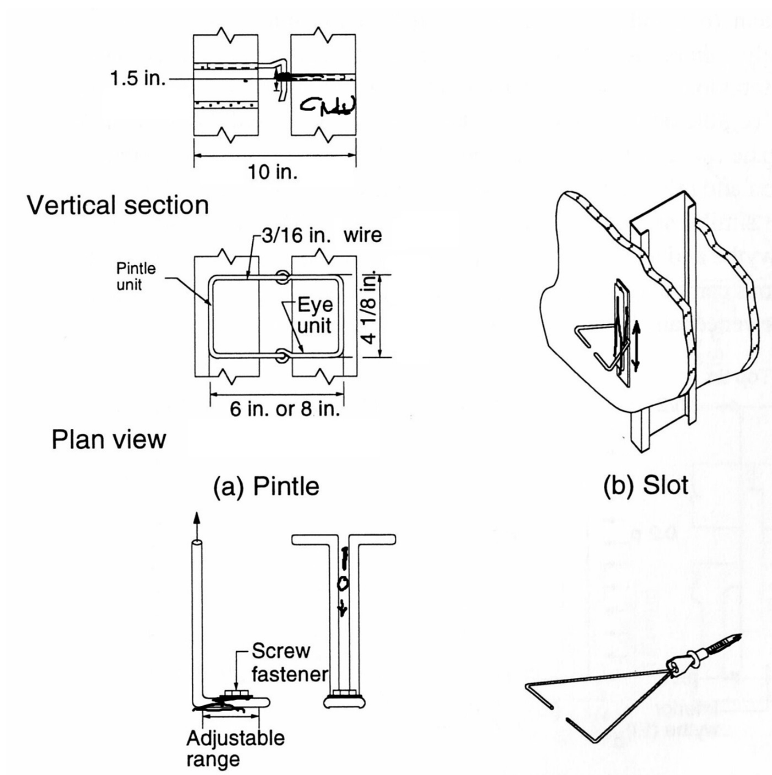
Adjustable Ties:

Pintle
- Pin and Eye

Vertical Slot
- Wire moves vertically in slot

Fastener Adjustment
- Adjustable screw or bolt

Fixed Position
- Not adjustable
- Placed in correct position

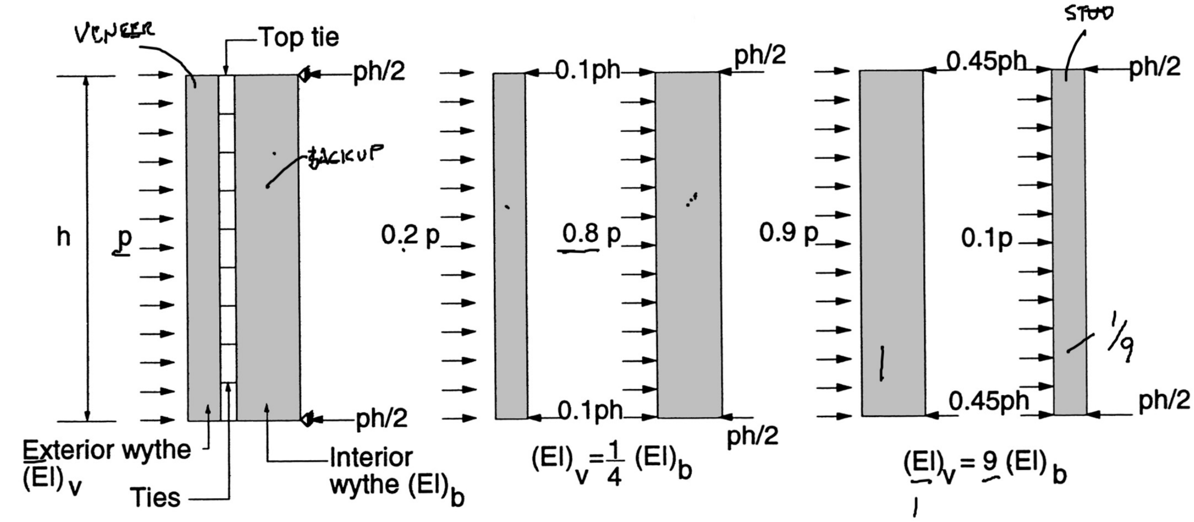


(a) Pintle (b) Slot

(c) Fastener Adjustment (d) Self-Drilling

Connectors and Ties

Lateral load distribution in two-wythe walls transferred by ties



(a) Load Applied to Two-Wythe Wall

(b) Load Distribution for Rigid Backing

(c) Load Distribution for Flexible Backing

Connectors and Ties

Strength performance of different types of ties

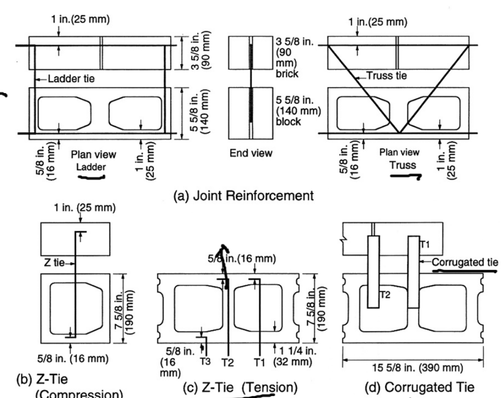


Table 13.1 Capacity of Cavity Wall Ties (from Ref. 13.6)

Specimen type and loading	Cavity width, in. (mm)	Tie placement	Mean failure load, lb (kN)	C.O.V. (%)	Failure mode
Truss reinforcement (compression)	2⅜ (60) 4⅜ (110)	See Fig. 13.8(a)	900 (4.01) 680 (3.03)	10.8 13.0	Buckling of diagonal rod
Ladder reinforcement (compression)	2⅜ (60) 4⅜ (110)	See Fig. 13.8(a)	1,470 (6.56) 1,080 (4.81)	11.0 7.3	Buckling of cross wire
Z-tie compression	2⅜ (60) 4⅜ (110)	See Fig. 13.8(a)	740 (3.28) 660 (2.94)	16.7 8.9	Push through of tie at block
Corrugated tie (compression) See Fig. 13.8(d)	¾ (19) ¾ (19) 2⅜ (60) 4⅜ (110)	tie on web, mortar two sides tie crossing face shell tie on web tie on web	550 (2.43) 610 (2.70) 240 (1.05) 88 (0.39)	21.4 25.5 14.0 14.8	Buckling of tie
Truss reinforcement (tension)	2⅜ (60)	See Fig. 13.8(a)	1,330 (5.92)	10.8	Pull out at brick and wire failure
Ladder reinforcement (tension)	2⅜ (60)	See Fig. 13.8(a)	1,320 (5.89)	16.8	Pull out at block
Z-tie (tension) See Fig. 13.8(c)	N/A	T_1 T_2 T_3	1,170 (5.20) 1,780 (7.90) 950 (1.54)	8.6 16.5 19.0	Pull out of tie at block
Corrugated tie (tension) See Fig. 13.8(d)	N/A	T_1, 4 in. (102 mm) depth T_1, 2 in. (51 mm) depth T_2, tie crossing face shell	1,240 (5.52) 1,170 (5.21) 750 (3.34)	12.3 11.9 13.6	Pull out of tie at block

Connectors and Ties

Strength performance of crimped (water drip) ties

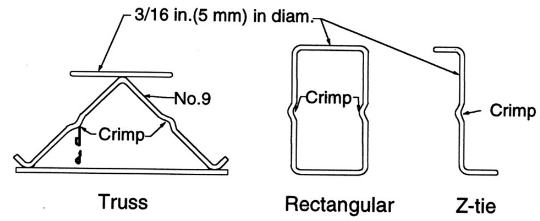


Table 13.2 Effect of Crimp on Tie Capacity (from Ref. 13.7)

Type of Tie	Yield Loads, lb (kN)	
	Compression (P)	Shear (V)
Straight ties (no crimp)		
3/16 in. (4.76 mm) Z	1,970 (8.77)	45 (0.20)
3/16 in. (4.76 mm) rectangular	3,640 (16.2)	100 (0.45)
3/16 in. (4.76 mm) truss	2,310 (10.3)	1,830 (8.14)
No. 8 gage truss	1,370 (6.10)	–
No. 9 gage truss	1,080 (4.81)	890 (3.96)
Crimped ties		
3/16 in (4.76 mm) Z	920 (4.10)	38 (0.17)
3/16 in. (4.76 mm) rectangular	1,830 (8.14)	98 (0.44)
3/16 in. (4.76 mm) truss	1,250 (5.56)	1230 (5.47)
No. 8 gage truss	810 (3.60)	–
No. 9 gage truss	510 (2.27)	450 (2.00)

Connectors and Ties

Comparative Strength of Adjustable Ties

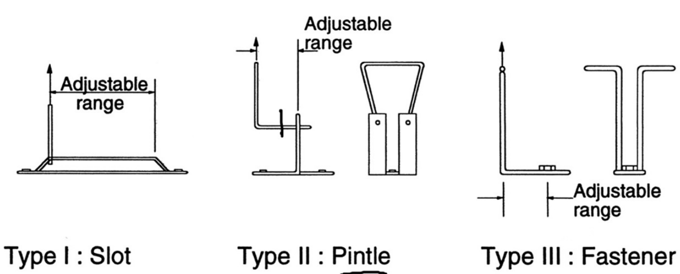
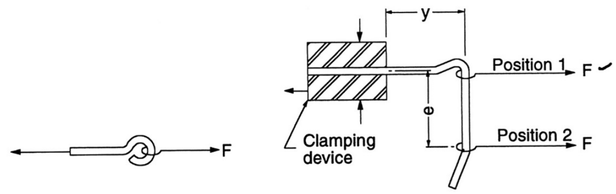


Table 13.3 Strength and Stiffness of Adjustable Ties in Brick Veneer/Steel Stud Systems (from Ref. 13.10)

Tie type	Adjusted position	Ultimate load, lb (kN)	C.O.V. (%)	Load @ 0.05 in. (1.2 mm), lb (kN)
I	Middle Quarter End	590 (2.64) 610 (2.73) 780 (3.45)	4.6	190 (0.83) 240 (1.06) 290 (1.28)
II	Minimum 15 mm 35 mm	380 (1.70) 260 (1.14) 130 (0.57)	10.9	98 (0.44) 53 (0.24) 18 (0.08)
III	15 mm 25 mm 30 mm	290 (1.29) 270 (1.20) 250 (1.10)	4.6	110 (0.48) 115 (0.50) 64 (0.28)

Connectors and Ties

Comparative Strength of Adjustable Pintle Ties



(a) Test of Single Eye (b) Test of Single Pintle

Figure 13.12 Effect of adjustability on capacity of pintle ties (from Ref. 13.11).

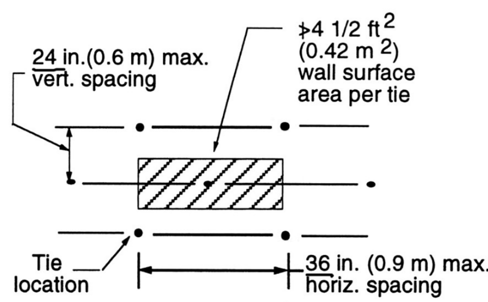
Table 13.4 Effect of Eccentricity on Capacity of Pintle Tiles (from Ref. 13.11)

Unit (3/16 in. dia. wire)	Load position	*y* (Exposed shank), in (mm)	*e* (Eccentricity) in (mm)	Yield load, lb (kN)
Single eye	-	-	-	550 (2.45)
Single pintle	1	1 3/4 (45)	0	490 (2.18)
Single pintle	2	1 (25)	1 1/2 (38)	50 (0.22)
Single pintle	2	1 3/4 (45)	1 1/2 (38)	40 (0.18)

Note: For distances *y* and *e*, refer to Fig. 13.12.

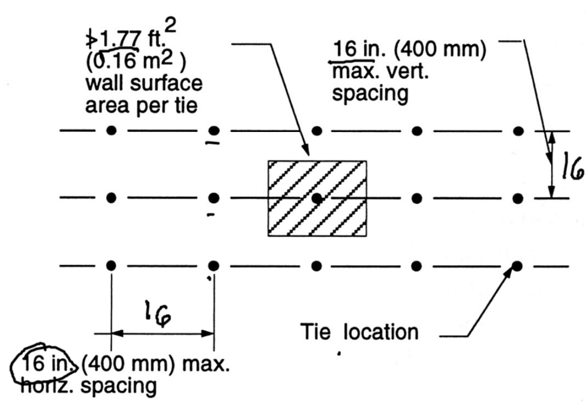
Connectors and Ties

BIA recommendations for non-adjustable ties:
- Use one 3/16" tie
- For each 4.5 ft^2 wall area
- Spaced not more than 24" vertically
- Spaced not more than 36" horizontally
- For cavity width 3.5" or less



Spacing and staggering of wall ties (3/16 in. (5 mm) dia.)

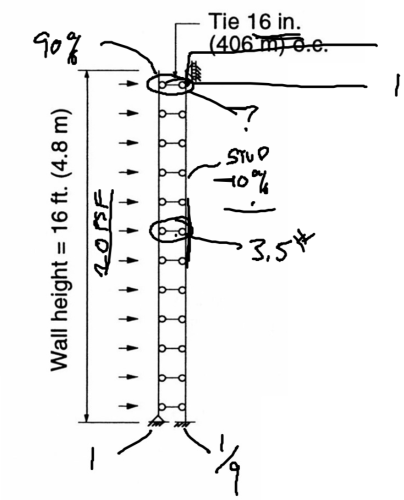
Recommendations for Pintle type ties:
- For each 1.77 ft^2 wall area
- Spaced not more than 16" vertically
- Spaced not more than 16" horizontally



Connectors and Ties

Example:

Estimate of tie forces in a cavity wall. Assume the veneer carries 90% of the 20 psf wind load and 10% is carried by a steel stud backup wall. The top of the veneer is not attached to the slab.



(a) Wall Configuration

$$p_v = p\,\frac{(EI)_{veneer}}{(EI)_{backup} + (EI)_{veneer}}$$

and

$$p_b = p - p_v$$

where

$(EI)_{veneer}$ = flexural rigidity of the veneer
$(EI)_{backup}$ = flexural rigidity of the backup wall
p = total applied pressure
p_v = net pressure carried by the veneer
p_b = net pressure carried by the backup wall

$$p_v = 20\text{ PSF}\,\frac{1}{1/9 + 1} = \frac{1}{1\tfrac{1}{9}} = 0.9$$

$(EI)_{veneer} = 9\,(EI)_{steel\ stud}$

$p_v = 0.9p$ and $p_{ss} = 0.1p$.

For $p = 20$ lb/ft² (1.0 kN/m²), applied on the veneer, and assuming that the ties are rigid, the tie force due to a tributary area of 1.77 ft² (0.16 m²) can be approximated as

Tie force = (0.1)(20)(1.77) = 3.5 lb (0.016 kN)

Connectors and Ties

Estimate the force in the top tie:

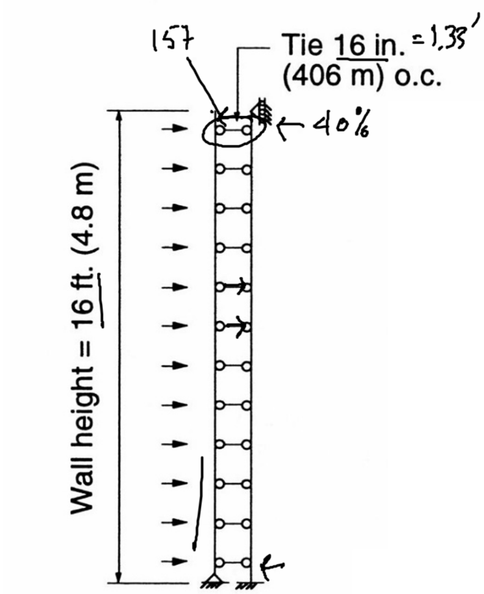
For a 16" wide strip (on one tie) on the veneer wall which carries 90% of the load the total load would be:

$$0.9(20\text{ lb/ft}^2)(1.33\text{ ft} \times 16\text{ ft}) = 384\text{ lb}$$

The load carried by the top tie is estimated as 40% of the total load assuming the other ties carry some of the load.

$$\text{Top tie force} = 3.5\text{ lb} + 0.4(384) = 157.5\text{ lb}$$

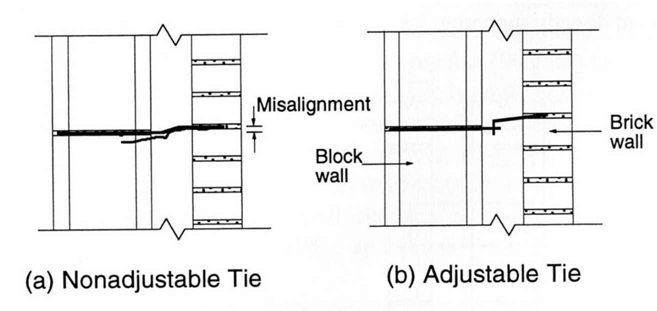
The top tie would carry the one tie force (like all the ties) plus 40% of the load on the wall:
= 157.5 lbs.

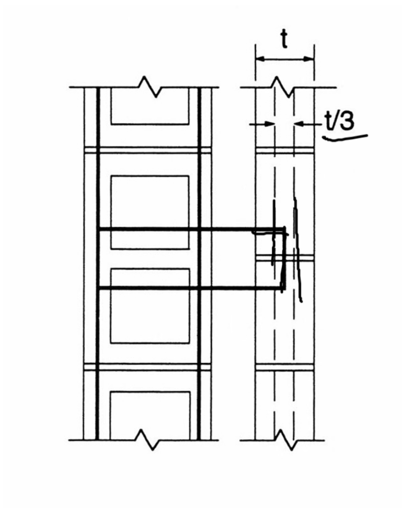


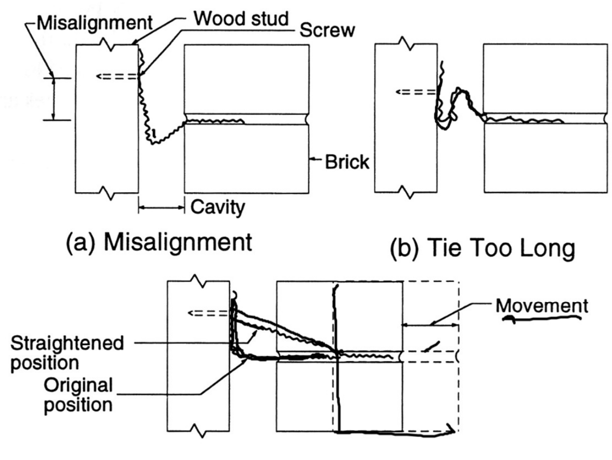
(a) Wall Configuration

Connectors and Ties

Considerations with tie installation
- Alignment is critical
- Strap ties must be straight
- Anchor portion of tie should be in the middle 1/3 of the mortar







(c) Movement is Required to Straighten up Slack

Connectors and Ties

Corrosion Resistance:
- All ties must have some corrosion resistance
- Hot dipped galvanized
- Stainless steel
- Galvanizing requirements given below

Table 13.5 MSJC Specifications for Corrosion Resistance of Ties (from Ref. 13.1)

Type	Application	Classification
Wires	Joint reinforcement, wire ties, or anchors in exterior walls or interior walls exposed to moist environments (for example, swimming pools and food processing)	ASTM A 153 Class B2 (1.50 oz/ft^2)
Sheet metal	Sheet metal ties or anchors in exterior walls or interior walls exposed to moist environments	ASTM A 153 Class B2 (1.50 oz/ft^2)
	Sheet metal ties or anchors in interior walls	ASTM A 525 Class G60 (0.60 oz/ft^2)

Note: 1 oz/ft^2 = 300 g/m^2