# CAVITY WALLS



## Design Guide for Taller Cavity Walls



Masonry Advisory Council

# THE BOTTOM LINE

Aside from the finished product being of considerable beauty and formidable strength, other initial and long-term benefits are gained when cavity wall systems are coupled with the structural entities previously cited.

## INITIAL BENEFITS

- The statement that "Masonry is too expensive" is just a myth. Cavity wall systems are initially lower in cost than many glass curtain walls, metal panel curtain walls, granite panels, marble panels, and architectural precast concrete walls. Add to this a reduction of $26.00 per lineal foot of shelf angle deleted, and additional savings occur.

- Limiting the number of crafts involved promotes rapid construction resulting in savings due to early occupancy.

- All materials required are usually available locally, which eliminates costly shipping charges and untimely postponements.

## LONG TERM BENEFITS

- Cavity walls are energy efficient when considering the life cycle cost of a building. A typical "R" value can be increased if greater energy-efficiency is desired.

- A structure built with the type of systems previously discussed provides a built-in, 2-to-4 hour, fire-rated barrier. Annual fire insurance premiums can be reduced by nearly 1/3, depending upon the type of construction chosen, and its occupancy.

- Masonry construction is very economical with respect to long-term maintenance.

# REFERENCES

1. Technical Note 16, Rev "Fire Resistance", Brick Industry Association, Reissued Oct. 1996.

2. Technical Note 18 series, "Differential Movement, Cause and Effect, Expansion Joints, Flexible Anchorage", Brick Industry Association, Jan. 1991, December 1991.

3. Technical Note 21 series, "Brick Masonry Cavity Walls, Insulated, Detailing, Construction", Brick Industry Association, Aug. 1998, Feb. 1999, Feb. 2002.

4. NCMA TEK 3-12 "Loadbearing Concrete Block in High Rise Buildings" National Concrete Masonry Association, 1998.

5. NCMA TEK 5-2A, 10-1A, & 10-2B "Control of Wall Movement with Concrete Masonry" National Concrete Masonry Association.

6. NCMA TEK 14-10 "Lateral Support of Concrete Masonry Walls" National Concrete Masonry Association, 1994.

7. NCMA TEK 5-6A. "Details" 2001: NCMA TEK 5-7A "Floor and Roof Connections to Walls" 2001.

8. "Manual for the Design of Hollow Core Slabs", Prestressed Concrete Institute, 1985.

9. "Introduction of Cavity Walls - Letters" Chartered Surveyor Weekly, (published in U.K.), vol.10 p.856 March 28, 1985, vol.10 pp. 707, 708 March 14, 1985.

10 "Reinforcing Steel in Masonry", Masonry Institute of America, January 1982.

## INTRODUCTION

Simply stated, a cavity wall is two wythes of masonry, separated by a cavity of varying dimension. The masonry wythes may consist of solid brick, structural clay tile, or concrete masonry units and are bonded together with masonry ties. The cavity (ranging from 2 inches to 4 1/2 inches in width) may or may not contain insulation. See Figure 1. Combining these elements with a sound structural design, appropriate details, quality materials and good workmanship will result in high performance cavity walls.
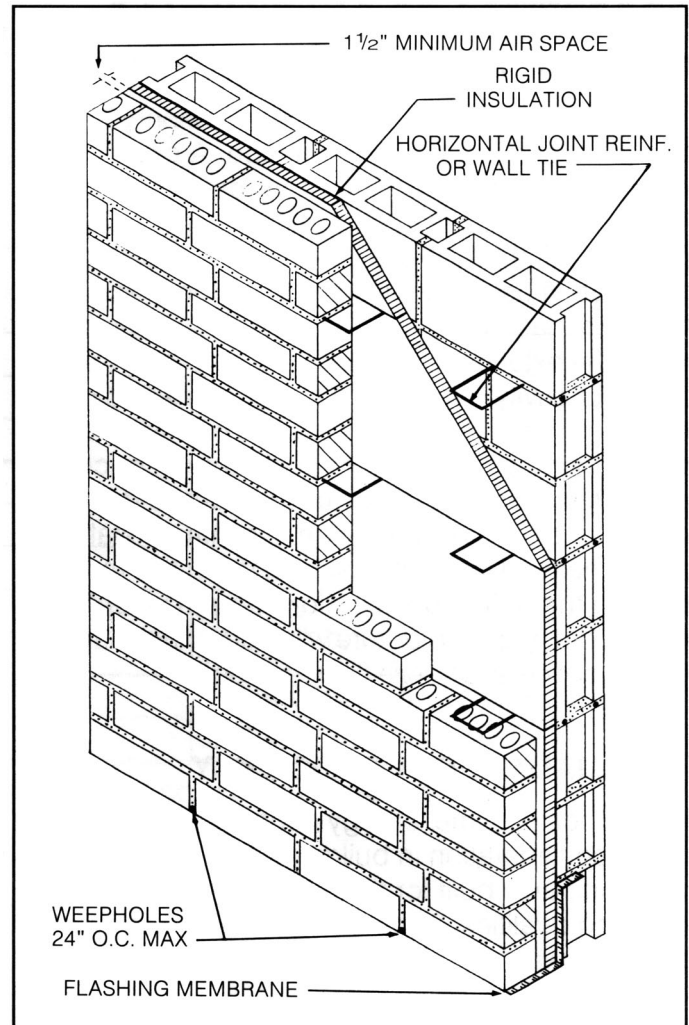
## HISTORY

Cavity walls are not new, they have been observed in ancient Greek and Roman structures. At the Greco Roman town of Pergamum, on the hills overlooking the Turkish town of Bergama, a stone wall of cavity type construction still exists.
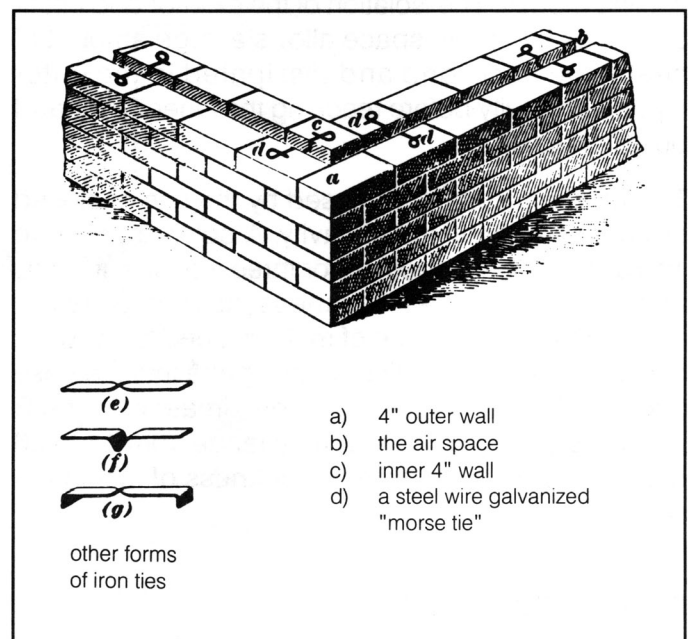
Sometime in the early part of the 19th century, the cavity wall was probably reinvented by the British. Plans dating as early as 1805 suggest a type of construction, featuring two leaves of brickwork, bonded by headers spanning across a 6-inch cavity. An early British publication (dated 1821 ) suggests the use of cavity walls as a means of protection against moisture penetration. The use of metal ties was introduced in Southern England sometime after 1850. These original ties were made of wrought iron.

Cavity walls were first built in the United States late in the 19th century. Figure 2 illustrates an alternate type of cavity wall system originally featured in an 1899 text book assembled for people engaged in the engineering professions and construction trades. However, it was not until 1937 that this type of construction gained official acceptance by any building or construction agency in the United States. Since then, interest in and use of cavity walls in this country has increased rapidly. This has resulted in extensive testing to determine cavity wall properties and performance.

The early use of cavity walls in this country was limited primarily to exterior load-bearing walls in low rise construction. In the 1940s, designers began to recognize the advantages of cavity walls in high-rise buildings. Today, masonry cavity walls are used extensively throughout the United States in all types of buildings. The primary reasons for their popularity are superior resistance to rain penetration, excellent thermal properties, excellent resistance to sound transmission and high resistance to fire.



Typical cavity wall with insulation
FIG. 1



a)    4" outer wall
b)    the air space
c)    inner 4" wall
d)    a steel wire galvanized "morse tie"

other forms of iron ties

A cavity wall type from the publication, "Masonry-Carpentry-Joinery, The Art of Architecture, Engineering and Construction in 1899".

FIG. 2

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# PROPERTIES OF CAVITY WALLS

## RESISTANCE TO MOISTURE PENETRATION

No single unreinforced 4" wythe of masonry is totally impervious to moisture penetration. A cavity wall is designed and built as a moisture-deterrent system. This system takes into account the possible moisture penetration through the outer wythe. Moisture will penetrate masonry walls where hairline cracks exist between masonry unit and mortar. Water which runs down the exterior wall surface will be drawn towards the inner cavity due to wind pressure exerted on the exterior of the wall and the negative pressure present within the cavity. Providing a clean air space will allow this moisture to flow unobstructed down the cavity face of the outer wythe. Flashing installed at recommended locations will then divert this moisture back to the building's exterior through weepholes. Proper drainage of moisture will reduce the chance of efflorescence and freeze-thaw damage.

## THERMAL ENERGY EFFICIENCY

At one point in time, energy conservation was not a major consideration in building design. Cavity walls were primarily built for their structural and moisture diverting qualities. During the mid 1970's, designers became aware of the life cycle cost of buildings so the design of energy efficient walls were initiated. The cavity became an excellent place to insert insulation, minimizing heat loss and heat gain. Both wythes act as a heat reservoir, positively affecting heating and cooling modes. The isolation of the exterior and interior wythes by the air space allows a large amount of heat to be absorbed and dissipated in the outer wythe and cavity before reaching the inner wythe and building interior.

This ability is further increased by the use of closed cell rigid insulation in the cavity. A foil faced, polyisocyanurate insulation is the most beneficial for three reasons: it yields an R value of 8.0 per inch of thickness, its R value is not affected by the presence of moisture, and its foil back enclosure creates a reflective air space that increase the walls overall R value by approximately 2.8. The R value of a typical cavity wall may range from 14 to 26 depending on the type and thickness of insulation selected.

## FIRE RESISTANCE

Results of the ASTM E-119 Fire Resistance Tests and the contents of both the Fire Protection Planning Report (CMIFC)[2] and the Fire Resistance Ratings. Report (AISG)[3] clearly indicate that masonry cavity walls have excellent fire resistance. All cavity walls have a fire rating of 4 hours or greater.

## STRUCTURAL PROPERTIES

Masonry's capacity as a load bearing material is superb, yet its structural potential is often overlooked.

Three principle factors affecting the overall compressive strength of a wall are: the compressive strength of the individual units, the type of mortar, and the quality of workmanship. Tables 2 and 3 lists the assumed compressive strength (f'm) for brick and concrete masonry. For large projects prism testing is preferred since actual values are usually higher than the assumed strengths.

The tables indicate that a standard concrete masonry unit with a type N mortar (1:1:6 by proportion) will yield a minimum f'm of 1500 psi. This strength is sufficient for most mid to low-rise bearing wall structures.

In addition to its excellence capacity as a bearing element, concrete masonry's performance as a back-up system is superb. Each wythe in a cavity wall helps resist wind loads by acting as a separate wall. The cross wire of the horizontal joint reinforcement transfer direct tensile and compressive forces from one masonry wythe to the other. Tests have indicated that joint reinforcement also provides some transfer of shear, approximately 20 to 30 percent, across the wall cavity. For a reference on allowable heights of cavity wall see Table 4.

**Table 1**
**R VALUE BRICK AND BLOCK CAVITY WALL**

| | 1/2" | 1" | 1 1/2" | 2" | 2 1/2" | 3" |
|---|---|---|---|---|---|---|
| 4" Clay Brick | | | 0.44 | | | |
| 4" Block (115#.ft³) = 72% solid | | | 1.19 | | | |
| 6" Block (115#.ft³) = 59% solid | | | 1.34 | | | |
| 8" Block (115#.ft³) = 54% solid | | | 1.51 | | | |
| 10" Block (115#.ft³) = 52% solid | | | 1.61 | | | |
| 12" Block (115#.ft³) = 48% solid | | | 1.72 | | | |
| 1/2" Drywall | | | 0.45 | | | |
| Exterior air film (winter) | | | 0.17 | | | |
| Interior air film | | | 0.68 | | | |
| Dead air space (3/4" to 4") (winter) | | | 0.97 | | | |
| * Reflective air space | | | 2.8 | | | |
| Insulation type                thickness (inches) | 1/2" | 1" | 1 1/2" | 2" | 2 1/2" | 3" |
| Polyisocyanurate (foil face) Dow Tuff R™ / Thermax™ | 3.4 | 6.7 | 10.5 | 14.4 | 17.8 | 21.2 |
| Extruded Polystyrene  Dow,  Owens Corning | - | 5 | 7.5 | 10 | 12.5 | 15 |

* Use this value when insulation has a foil backing directly adjacent to air space
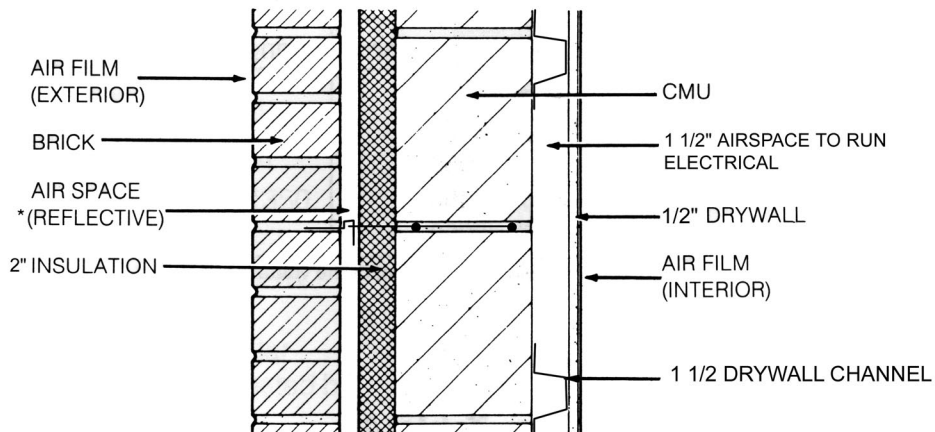


Exterior air film. . . . . . . . . . . . . . . . . . . . . . . . . . . .   0.17

4" Brick . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .   0.44

R of the reflective  air space . . . . . . . . . . . . . . . . . . . .   2.80

R of 2" Dow, Tuff R-C, polyisocyanurate  insulation. . . .   14.4

6" CMU . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .   1.34

1 1/2" air space . . . . . . . . . . . . . . . . . . . . . . . . . . . .   0.97

R of 1/2" drywall . . . . . . . . . . . . . . . . . . . . . . . . . . .   0.45

Inside air film . . . . . . . . . . . . . . . . . . . . . . . . . . . . .   0.68

R of the total wall . . . . . . . . . . . . .. . . . . . . . . . . . . .   21.25

## Table 2
### COMPRESSIVE STRENGTH OF CLAY UNITS AND TYPE OF MORTAR USED IN CONSTRUCTION

| Net area compressive strength of clay masonry units, psi | | Net area compressive strength of masonry, psi |
|---|---|---|
| Type M or S mortar | Type N mortar | |
| 2400 | 3000 | 1000 |
| 4400 | 5500 | 1500 |
| 6400 | 8000 | 2000 |
| 8400 | 10500 | 2500 |
| 10400 | 13000 | 3000 |
| 12400 | — | — |
| 14400 | — | — |

## Table 3
### COMPRESSIVE STRENGTH OF CONCRETE MASONRY UNITS AND TYPE OF MORTAR USED IN CONSTRUCTION

| Net area compressive strength of concrete masonry units, psi | | Net area compressive strength of masonry, psi* |
|---|---|---|
| Type M or S mortar | Type N mortar | |
| 1250 | 1300 | 1000 |
| 1900 | 2150 | 1500 |
| 2800 | 3050 | 2000 |
| 3750 | 4050 | 2500 |
| 4800 | 5250 | 3000 |

*For units of less than 4 in. height, 85 percent of the values listed.

## Table 4
### WALL LATERAL SUPPORT REQUIREMENTS
(unreinforced)

| Construction | Maximum $l/t$ or $h/t$ |
|---|---|
| Bearing walls | |
| Solid or solid grouted | 20 |
| | |
| All other | 18 |
| Nonbearing walls | |
| Exterior | 18 |
| Interior | 36 |

# CAVITY TYPE BEARING WALLS

## GENERAL

When engineered, a cavity wall system can be designed to provide both structure and the enclosing skin. Building this system consists of constructing a series of single story structures, one on top of the other. The structure can be erected at a rate of one floor per week by implementing a tight schedule and sufficient man power. Combining load bearing cavity walls and precast concrete plank floors can make for efficient, economical and speedy construction.

The system relies upon composite reaction between the masonry walls, the precast concrete plank floor, and the roof system. Concrete masonry and precast concrete plank connections transfer wind induced shear stresses through the floor diaphragm to interior masonry shear walls (which may also be utilized as bearing walls). This type of construction is ideal for low and mid-rise construction like the Green Castle apartments shown here.



**FIG. 3 Green Castle (Elmhurst, IL) is constructed of cavity type bearing walls and spans 7 stories high**

## LOAD CAPACITY INVESTIGATION

The following calculations examine the load-bearing capacity of a six story cavity type bearing wall system. The criteria used is as follows:

Brick ..........................4" thickness, 6000 psi min. compressive strength

CMU ..........................6" thickness f'm = 1350, wt ≈ 26 #/ft$^2$

Concrete Plank ..........8" thick, 24'-0" span, wt = 60 #/ft$^2$

Mortar ........................Portland/lime or mortar cement, type designated by physical property

## CALCULATIONS

Floor loads on 6" CMU
     8" Concrete plank = 60 #/ft$^2$
     Partitions & misc. = 20 #/ft$^2$

Dead load = 80#/ft x 24/2 = 960 #/ft
     6" CMU = 8x26 = 210 #/ft
     Live load = 40 #/ft$^2$ x 24/2 = 480 #/ft
     Use Live Load Requirement

Roof Loads:
Let drainage fill + roofing = 20 #/ft$^2$
Dead load = 60 + 20 = 80 #/ft$^2$ x 24/2 = 960 #/ft
Live Load = 30x24/2 = 360 #/ft

Wall Design
Use ACI 530-99/ASCE 5-99/TMS 402-99)
Assume:
• Wall height 8' 0"
• 8" concrete plank bears fully on 6" CMU
• f'm = 1350 psi

# CALCULATIONS - Continued

At Roof >

$$P = .96^{K/1} + .36^{K/1} = 1.32^{K/1}$$
$$e = 5.6 / 2 - 5.6 / 3 = .93" \approx 1"$$
Allow. load. $= 6.64^{K/1} > 1.32$ $\therefore$OK

At 2nd Floor >

$e = .93"$

$$P_1 = 1.32 = 5(.21) = 4(.96) + 4 (.75 \times .48) = 7.65^{K/1}$$
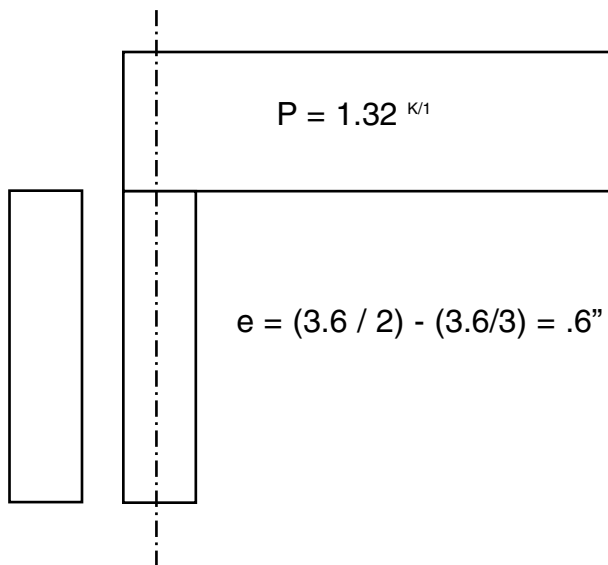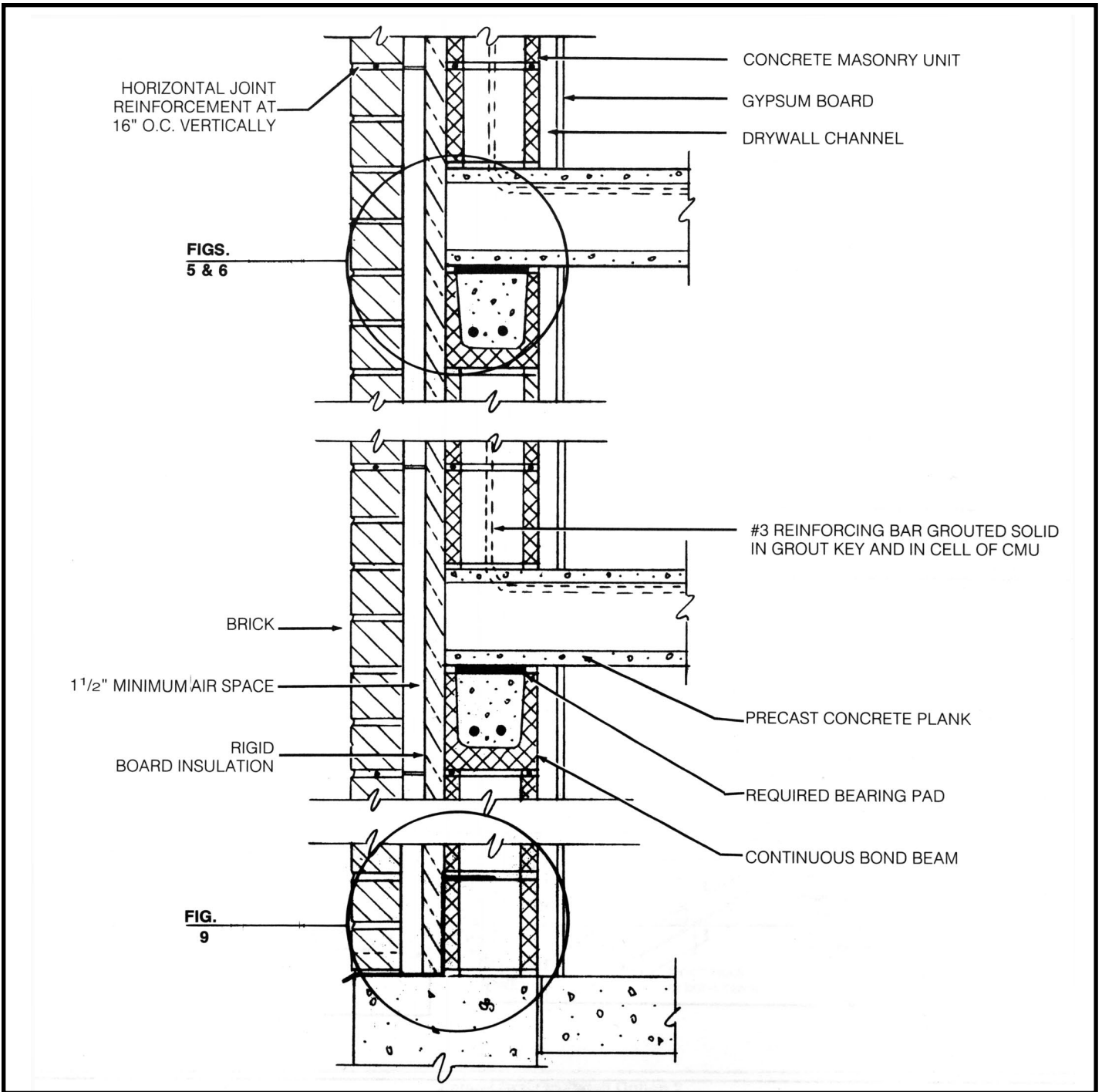$$P_2 = 1.44^{K/1} \times (.93) = 1.34^{K/1}$$
$$P_1 + P_2 = 9.09^{K/1}$$
$$ev = 1.34 / 9.09 = 0.15"$$

$$P_1 + P_2$$

Allow load $= 9.48^{K/1} > 9.09^{K/1}$ $\therefore$OK

Review of cavity bearing wall when distribution moment to both wythes. (ACI 530 / ASCE 5 / TMS 402)



$P = 1.32^{K/1}$

$e = (3.6 / 2) - (3.6/3) = .6"$

4" - 2" - 4" (most extreme condition)

$M = Pe = 1.32 \times .6 = .792$ in.$^{K/1}$

$Mbr = .51 \times .792 = .404$ in.$^{K/ft}$

$f_t = (.404/26.3) = 15.3 < 36$

Review of outer wythe tensile strength only

Brick:

$A = 3.625 \times 12 = 43.5$ in.$^2$

$I = 12 \times (3.625^3/12) = 47.6$ in/$^4$

$S = (47.6 / 1.81) = 26.3$ in.$^3$

CMU:



5.93"

3.625"

1.25" typ.
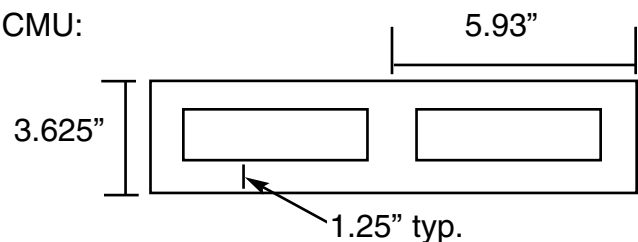
$A = 33.5$ in.$^2$

$I = 46.6$ in.$^4$

$S = 25.7$ in.$^3$

$( I Blk / \sum I) = (47.6/94.2) = .51$

## CONCLUSION:

The calculations indicate that a 6 inch hollow CMU cavity type bearing wall system will support the given loads. The clear height of the wall must not exceed 8' 0" and the concrete planks

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**FIG 4. Typical Bearing Wall Section**

Labels in figure:
- HORIZONTAL JOINT REINFORCEMENT AT 16" O.C. VERTICALLY
- FIGS. 5 & 6
- BRICK
- 1¹/₂" MINIMUM AIR SPACE
- RIGID BOARD INSULATION
- FIG. 9
- CONCRETE MASONRY UNIT
- GYPSUM BOARD
- DRYWALL CHANNEL
- #3 REINFORCING BAR GROUTED SOLID IN GROUT KEY AND IN CELL OF CMU
- PRECAST CONCRETE PLANK
- REQUIRED BEARING PAD
- CONTINUOUS BOND BEAM

## GENERAL

When engineered, a cavity wall system can be designed to provide both structure and the enclosing skin. Building this system consists of constructing a series of single story structures, one on top of the other. The structure can be erected at a rate of one floor per week by implementing a tight schedule and sufficient man power. Combining load bearing cavity walls and precast concrete plank floors can make for efficient, economical and speedy construction, resulting in solid, fire safe buildings. See Figure 4.

After the cavity wall has been designed to meet the structural requirements, connections between the precast concrete plank and the masonry wall must be detailed. Other details, such as flashing, must also be developed.

The wall/floor connections provide the wall with lateral bracing against wind loads. This connection should also assist in the transfer of shear stresses, and in the case of bearing walls, transfer gravity loads to the foundation

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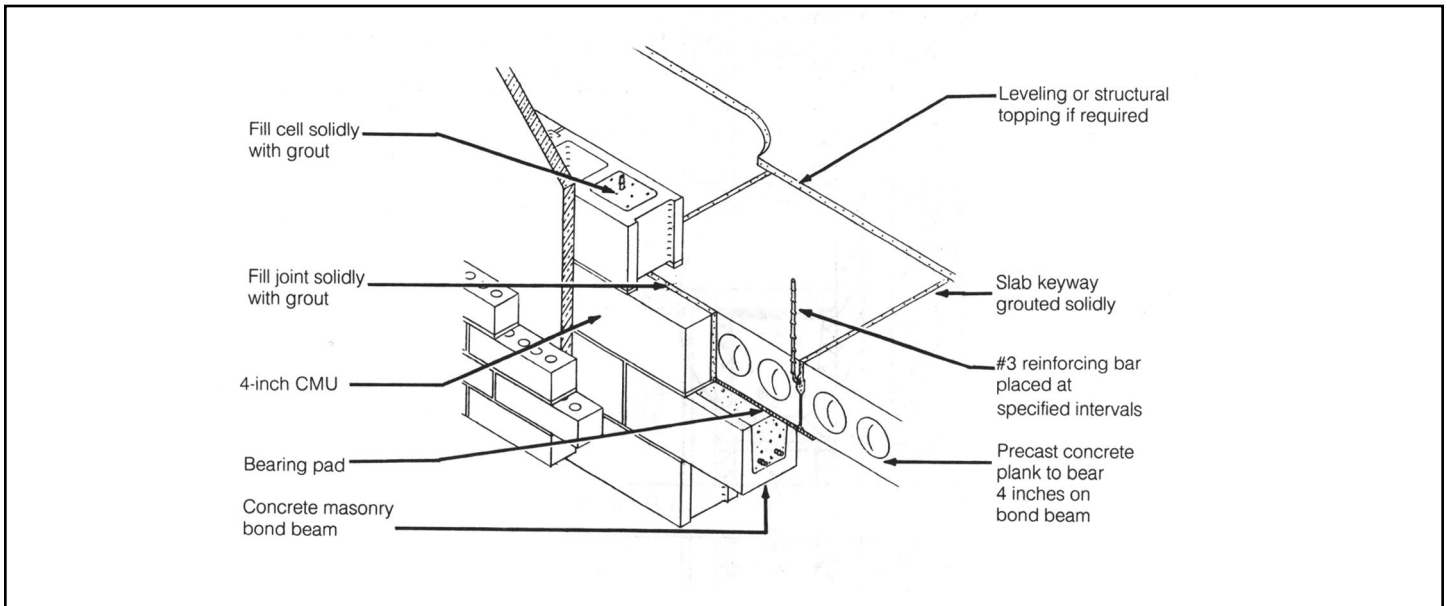
FIG 5 -Bearing Wall Detail Option 1
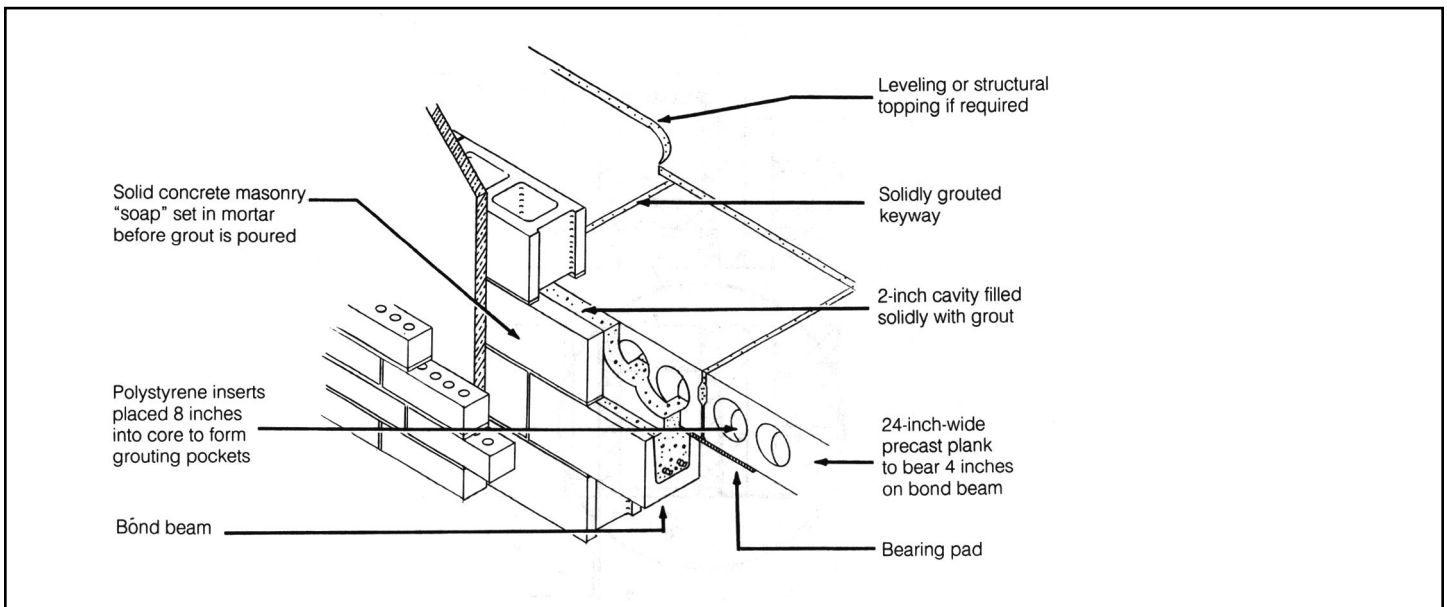


FIG 6 -Bearing Wall Detail Option 2

## CONNECTION FOR LOAD BEARING

One way to anchor precast concrete plank into load bearing concrete masonry is to create a positive tie with reinforcing bars bent at 90 degree angles, see Figure 5. A structural engineer should determine the size and spacing of the reinforcement required.

The reinforcing bar is set into the layway formed between the concrete planks and grouted solid. The exposed portion of the reinforcement fits into the cell of the concrete masonry unit. In the next course, a positive connection is formed when the cell is grouted.

If lateral forces are low, an alternative connection should be considered,see Figure 6. This connection bonds the precast concrete planks to the masonry with a solidly grouted joint. Plugging the cores of the precast concrete planks creates a continuous grout cavity. When the grout is poured it flows into the grout pocket formed at the end of the planks. After the grout cures a positive key connection is formed between the planks and the concrete masonry units. All the precast planks should be in place and the grout fully set before the wall construction continues. Because this detail relies on the bearing pad's frictional resistance to help transfer shear stresses, a structural engineer should determine when this connection is adequate.

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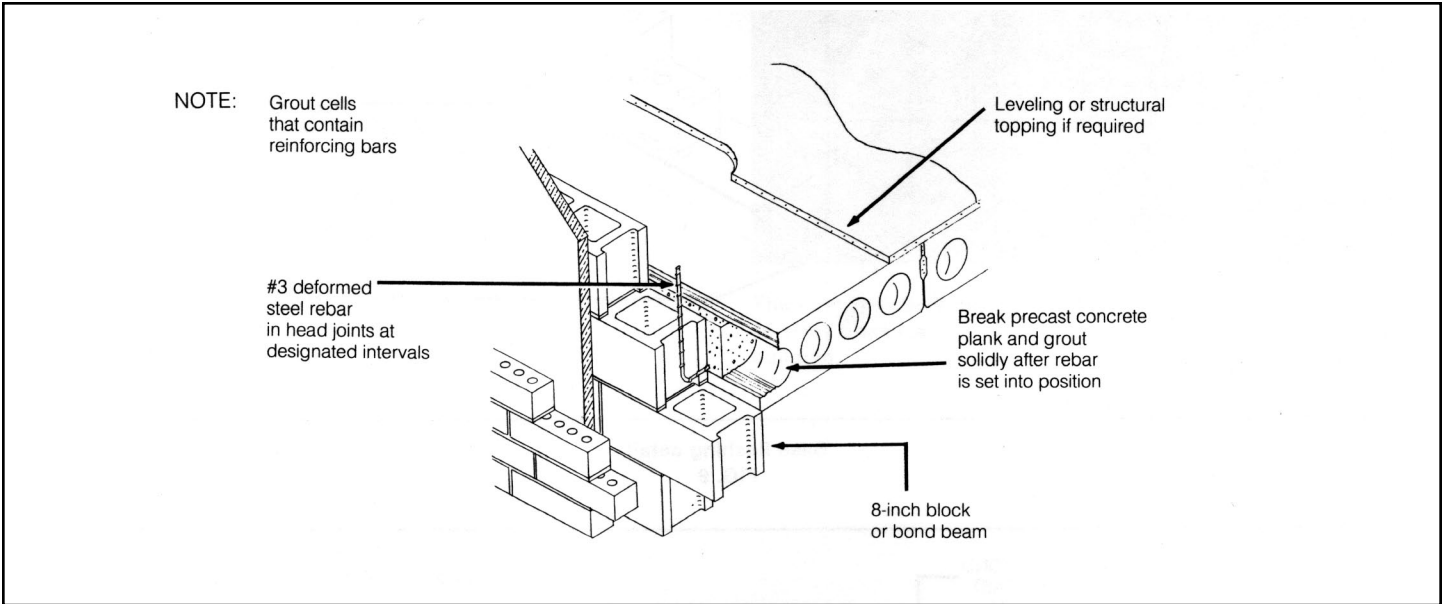
FIG 7 -Lateral Bracing Detail Option 1
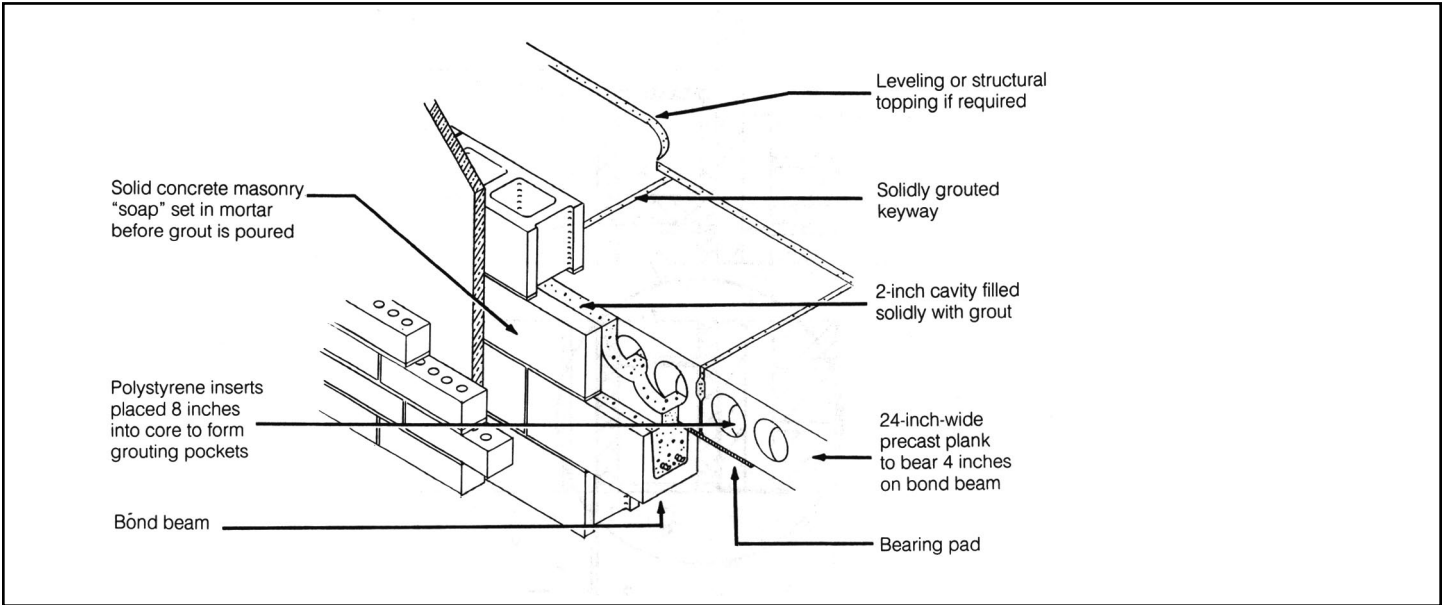


FIG 8 -Lateral Bracing Detail Option 2

## CONNECTION FOR NON-BEARING

Non-bearing walls (which span parallel to the floor planks) must also be laterally braced by the concrete plank floor system. One method requires holes to be broken in the top of the plank at designated intervals, see Figure 7. Specify the plank adjacent to the wall to bear on the wall a minimum of 3 inches. The cures of the plank are plugged on both sides of the hole with inserts to form a grout packet. A strap anchor is installed so that one end projects down into the grout pocket and the other end projects up into the cell of a concrete masonry unit. The grout pocket and cell of the concrete masonry unit are grouted solid. This connection transfers sear stresses through the floor diaphragm to interior shear walls while providing lateral support for the exterior wall. An alternative connection requires cutting or breaking the precast concrete plank continuously and butting the plank against the wall,see Figure 8.

Reinforcement is aligned and set into the head joints of the concrete masonry and bent at 90 degrees into the core of the precast plank. The core of the precast plank is then grouted solid when the grout cures it forms a positive connection.

The significance of base flashing can never be over emphasized. The success of any cavity wall system depends on proper flashing details at the base of the

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wall. Figure 9 illustrates a properly flashed cavity wall at the foundation. Weepholes are required at 16" or 24" on center to divert moisture from the cavity to the exterior of the building.

Figure 10 suggests one method of construction for a window-head condition. A bond beam is used in lieu of a steel angle lintel. Flashing should be extended beyond the jamb lines with both ends damne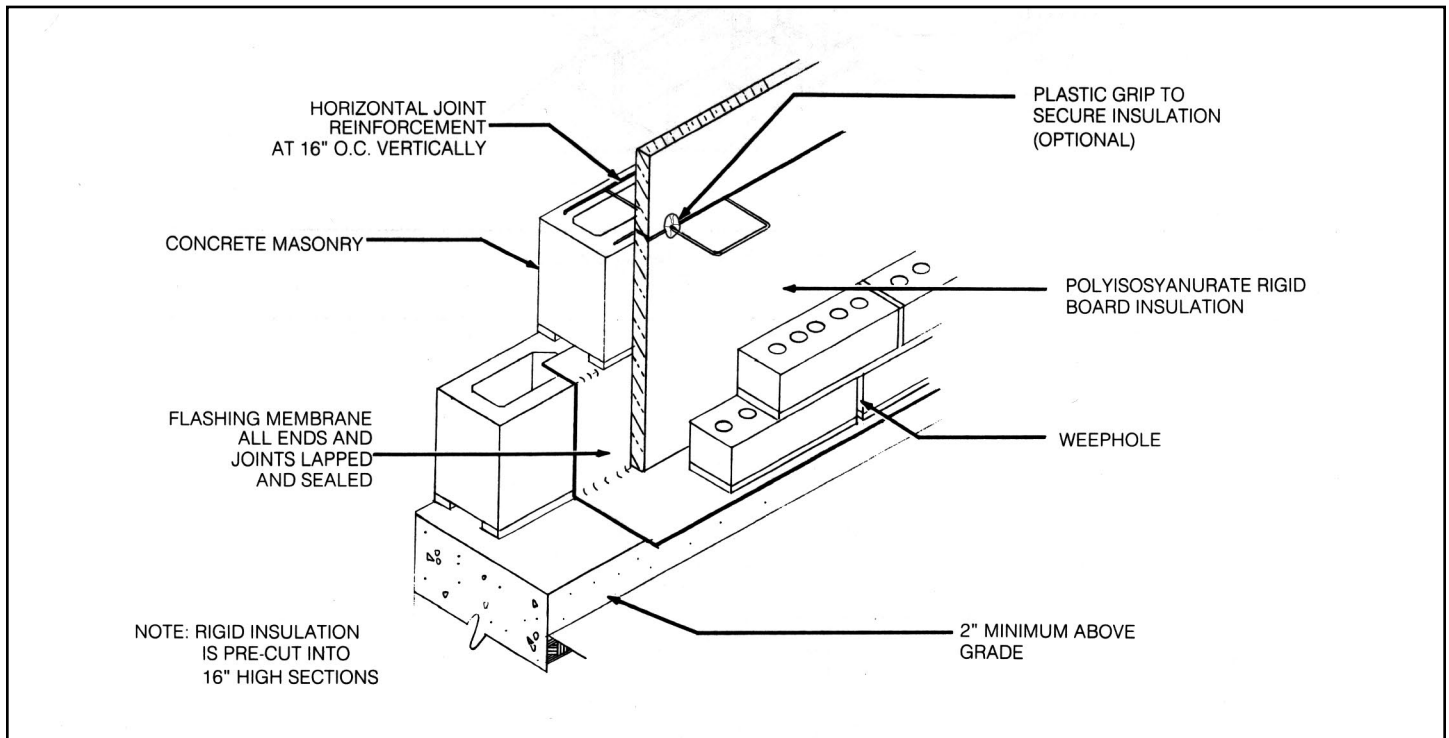d. Sol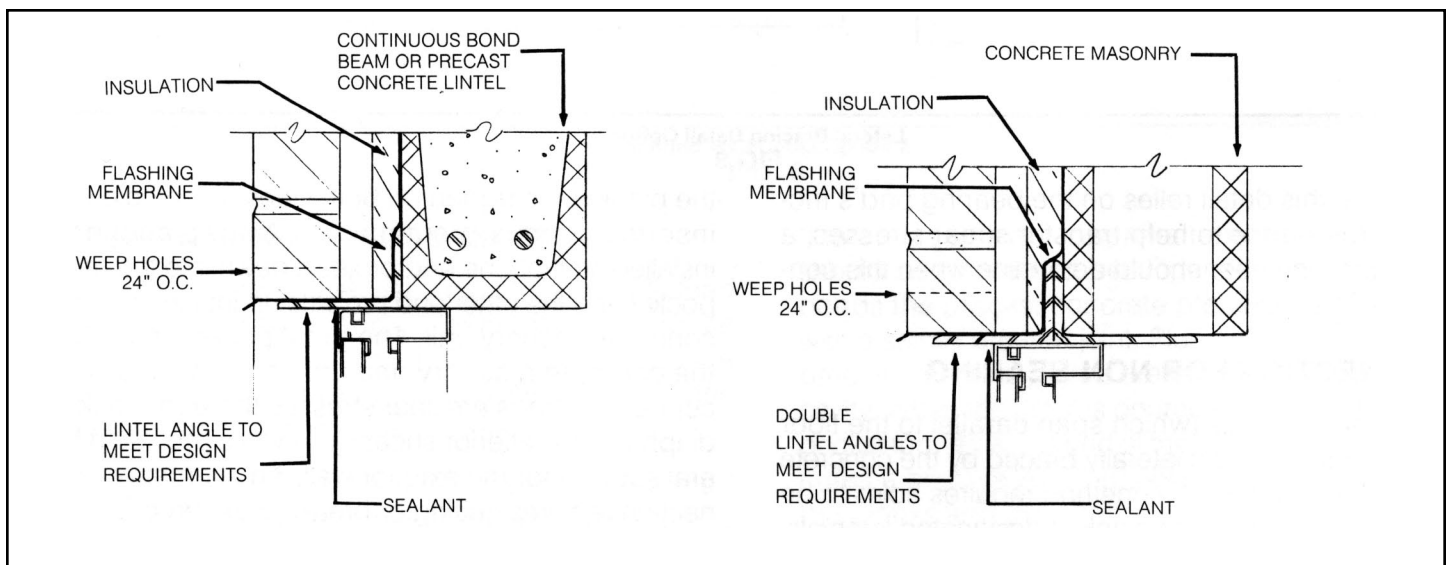id masonry jambs should be avoided. However, for steel windows, the jamb must be partially solid to accept most standard jamb anchors. Stock sizes of windows may be used in cavity walls, although sometimes additional blocking is needed for anchorage. Window spans may be limited for this type of construction.



FIG 9 -Lateral Bracing Detail Option 1



FIG 10 -Lateral Bracing Detail Option 2

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# CAVITY BEARING WALLS

## GENERAL

Cavity walls have been successfully used in mid rise and high rise construction. Buildings in excess of 40 stories have been utilizing cavity walls and a structural reinforced concrete frame.

There are two methods of support for cavity walls cladded to concrete frame structures. One is by means of shelf angles, the other is to bear the wall directly on the outer slab edge. Each system has advantages and disadvantages.

## SHELF ANGLE DESIGN

It is possible to limit shelf angles, to one every 30 vertical feet. First calculations must be developed to check the shear strength of the wedge insert, to determine size and spacing of anchor bolts, and to check angle capacity. The following calculations will determine these structural requirements. Criteria

Brick...........................3 5/8" actual bed depth,
weight = 40 #/ft²

Concrete Slab ............8" depth, f'c = 4000 psi

Shelf Angle .................6" x 4" x 5/16"

Anchor Bolts...............3/4" diameter
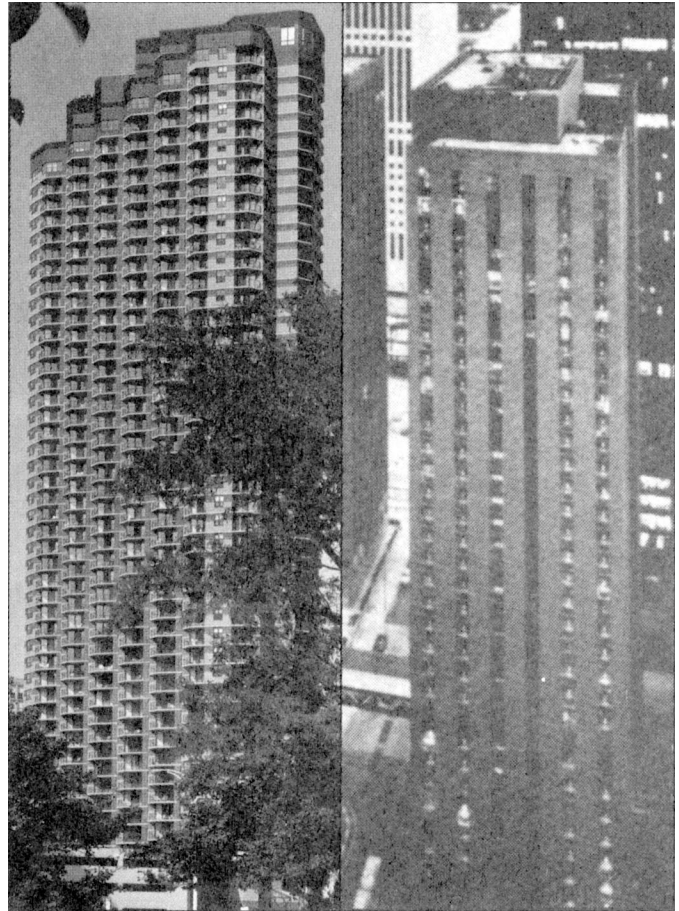


The New York building is a 49 story reinforced concrete frame brick /block cavity wall supported on each floor

The Chicago Hyatt Regency (reinforced concrete frame) supports brick with one shelf angle every third floor.

# CALCULATIONS



Shelf Angle Detail

3⁵/₈"  2⁷/₈" max.

ev = 4.69"

1¹/₄"

2³/₄"

W

P

8"

¹/₂" max.

1¹/₂" min.
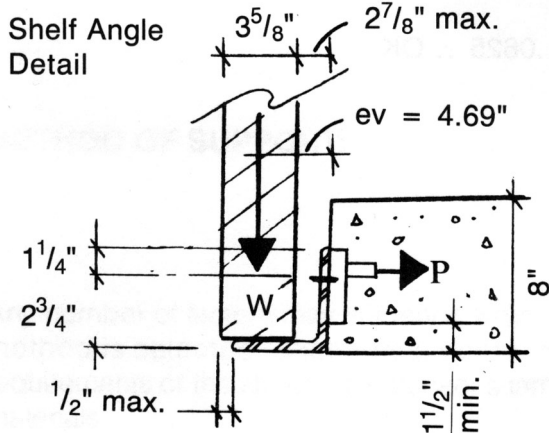
Wedge Insert Spacing

$V_a = 4.7^k$ @ 2.125" from face

$e_v = 4.69$

$V_a = (2.125 \times 4.7) / 4.49 = 3.23^k$

$W = 40 \times 30 = 1200^{lb/ft}$ or $1.2^k$

insert space = 2.13 / 1.2 = 1.78 ft.

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Check 3/4" dia. bolt with root area = 0.334 in2

$v$ / bolt = 1.75 x 1.2 = 2.1$^k$ < 2.13$^k$

$f_v$ = 2.1 / .334 = 6.29 ksi < 10   ∴ OK

T = 2.1 X (4.69 / 2.75) = 3.58$^k$

$F_t$ = 26 - 1.8(6.29) = 14.68 ksi

$f_t$ = 3.58 / .334 = 10.72 < 14.68

span M = 1.2 x (1.752 / 8) = .46

fb = (.46x12) / 1.35 = 4.1 ksi  ∴  OK


NEGLECT BENDING DEFLECTION

Check Rotation of 6 x 4 x 5/16 angle
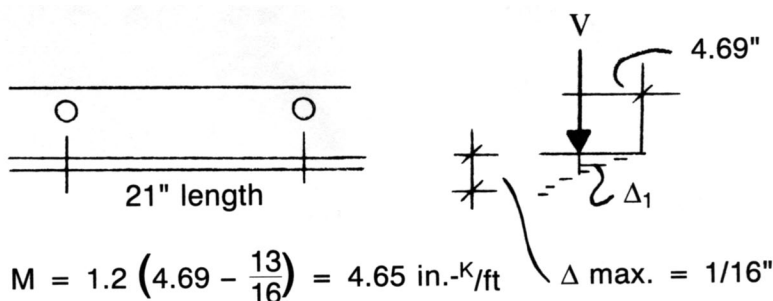


$M = 1.2 \left(4.69 - \frac{13}{16}\right) = 4.65$ in.-$^K$/ft    Δ max. = 1/16"

$I = 21 \times \frac{(5/16)^3}{12} = .0534$ in.$^4$

$S = \frac{.0534}{.1563} = .342$ in.$^3$

$fb = \frac{4.65}{.342} = 13.6$ ksi

$\Delta_1 = \frac{2.1(3.88)^3}{3\,(29 \times 10^3)(.0534)} = .026"\ < .0625$ ∴ OK


## CONCLUSION

These calculations conclude that a 6 x 4 x 5/16 shelf angle would adequately support the brick if installed every third floor.  Three-quarter inch bolts are required every 21 inches on center and concrete must obtain a minimum strength of 4000 p.s.i.
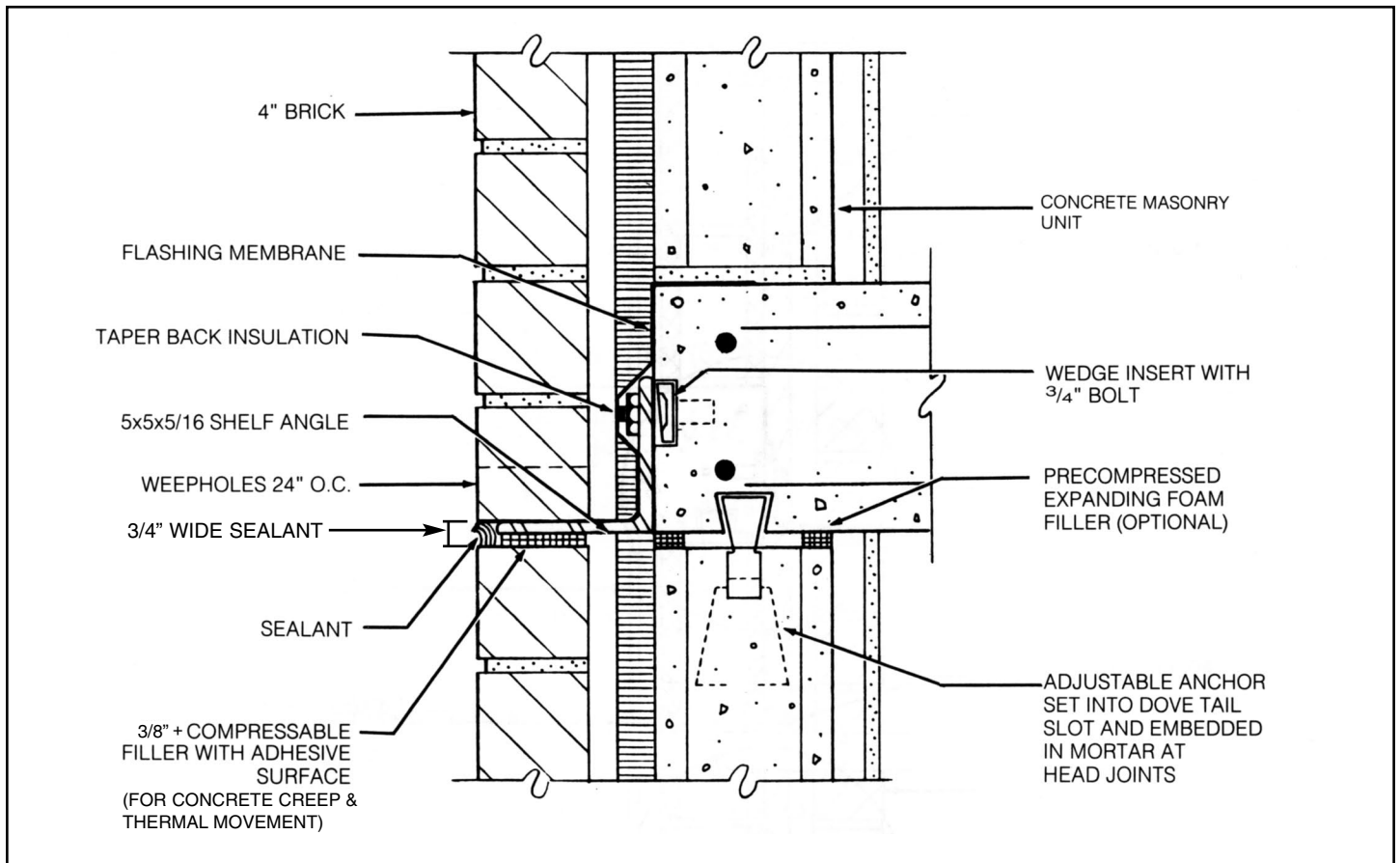
**HORIZONAL JOINT REINFORCEMENT AT 16" O.C. VERTICALLY**

**1½" MINIMUM AIR SPACE**

**FIG. 13**

**POLYISOSYANURATE RIGID BOARD INSULATION**

**BRICK**

**FIG. 14**

**CONCRETE MASONRY UNIT**

**CONCRETE SLAB**

**DRYWALL**

**DRYWALL CHANNEL TO PROVIDE ADEQUATE SPACE FOR ELECTRICAL ROUGH-IN**
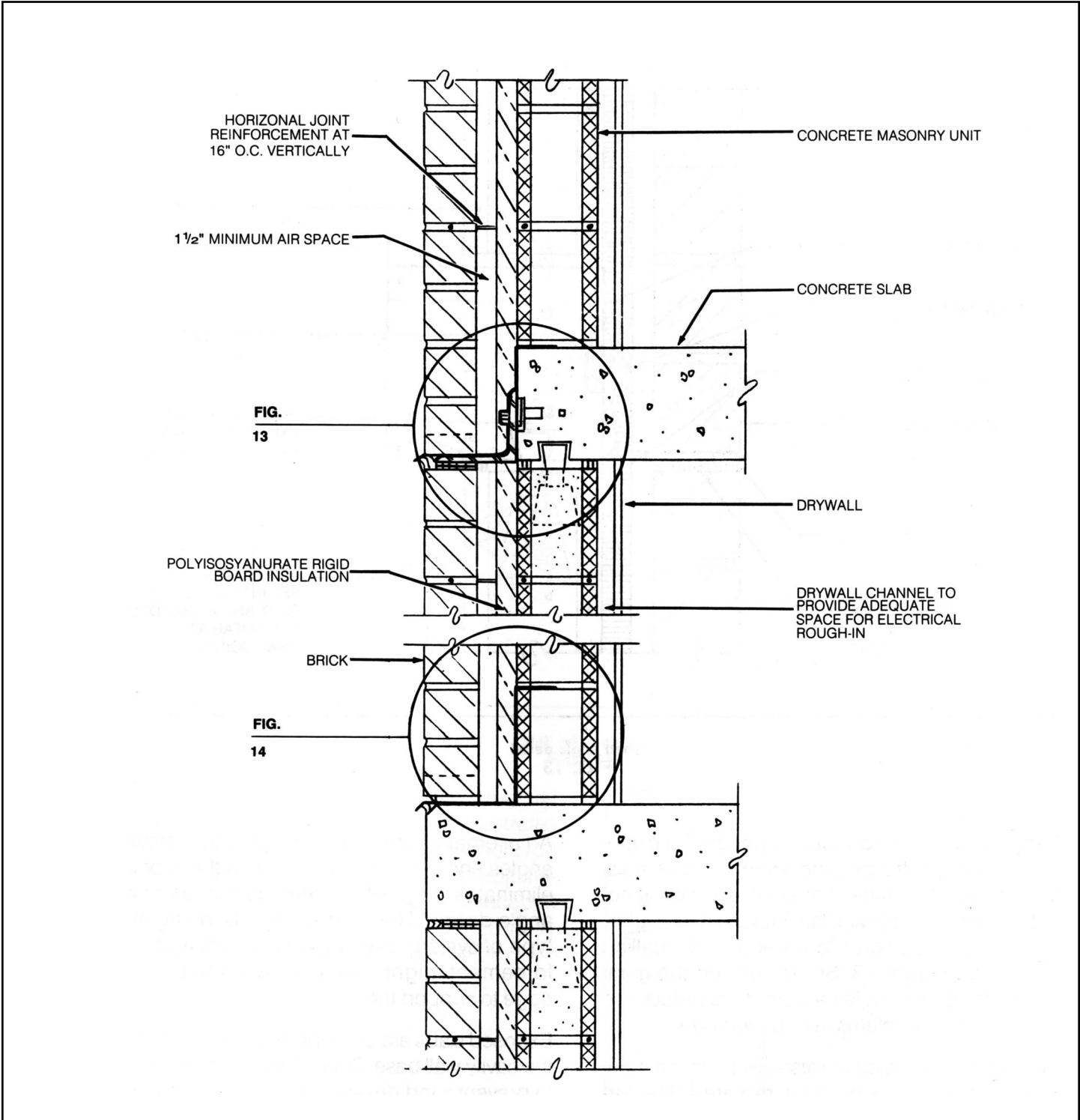
FIG 12 - Wall section

## METHOD OF SUPPORT:

Any number of factors may influence which support method is selected: aesthetics, economy, code requirements or the structural engineer's familiarity of materials.

After the method of masonry support has been determined details must be developed. Figure 12 illustrates a typical wall section for cavity wall/concrete frame system with varying support method. Maintaining a 8 inch thick concrete slab will produce modular masonry coursing. Standard horizontal joint reinforcement should be spaced at 16 inch vertical intervals. Avoid placing reinforcement at the slab level and directly below the slab.

4" BRICK

FLASHING MEMBRANE

TAPER BACK INSULATION

5x5x5/16 SHELF ANGLE

WEEPHOLES 24" O.C.

3/4" WIDE SEALANT

SEALANT

3/8" + COMPRESSABLE FILLER WITH ADHESIVE SURFACE (FOR CONCRETE CREEP & THERMAL MOVEMENT)

CONCRETE MASONRY UNIT

WEDGE INSERT WITH 3/4" BOLT

PRECOMPRESSED EXPANDING FOAM FILLER (OPTIONAL)

ADJUSTABLE ANCHOR SET INTO DOVE TAIL SLOT AND EMBEDDED IN MORTAR AT HEAD JOINTS

Steel Shelf angle detail @ 30' or every third typical floor.

Shelf angles create a continuous horizontal break within the cavity, obstructing the vertical flow of moisture through the air space. If special attention is not given to the detailing and installation of shelf angles, moisture infiltration, efflorescence and brick spalling can occur. A reduction of shelf angles will also eliminate the number of horizontal expansion joints required. The further apart the expansion joints are spaced, the wider the joint needs to be. Most horizontal expansion joints need to be 3/4 inch to 1 inch wide. After differential movement occurs, the joint will compress to approximately 5/8" - 3/4".

An alternative method of design is to remove all shelf angles and bear the cavity wall on the floor slab. This eliminates the potential problems inherent with shelf angle design. However, thermal bridging makes this type of system less energy efficient and dated.

Exposed slabs are susceptible to moisture infiltration at the cavity wall base. Special details must be developed to prevent wind driven rain from penetrating beneath the flashing and into the building. Flashing must be set in a continuous bed of mastic or a self adhering flashing with stainless steel drip edges, must be used to prevent wind driven rain from penetrating beneath the flashing.

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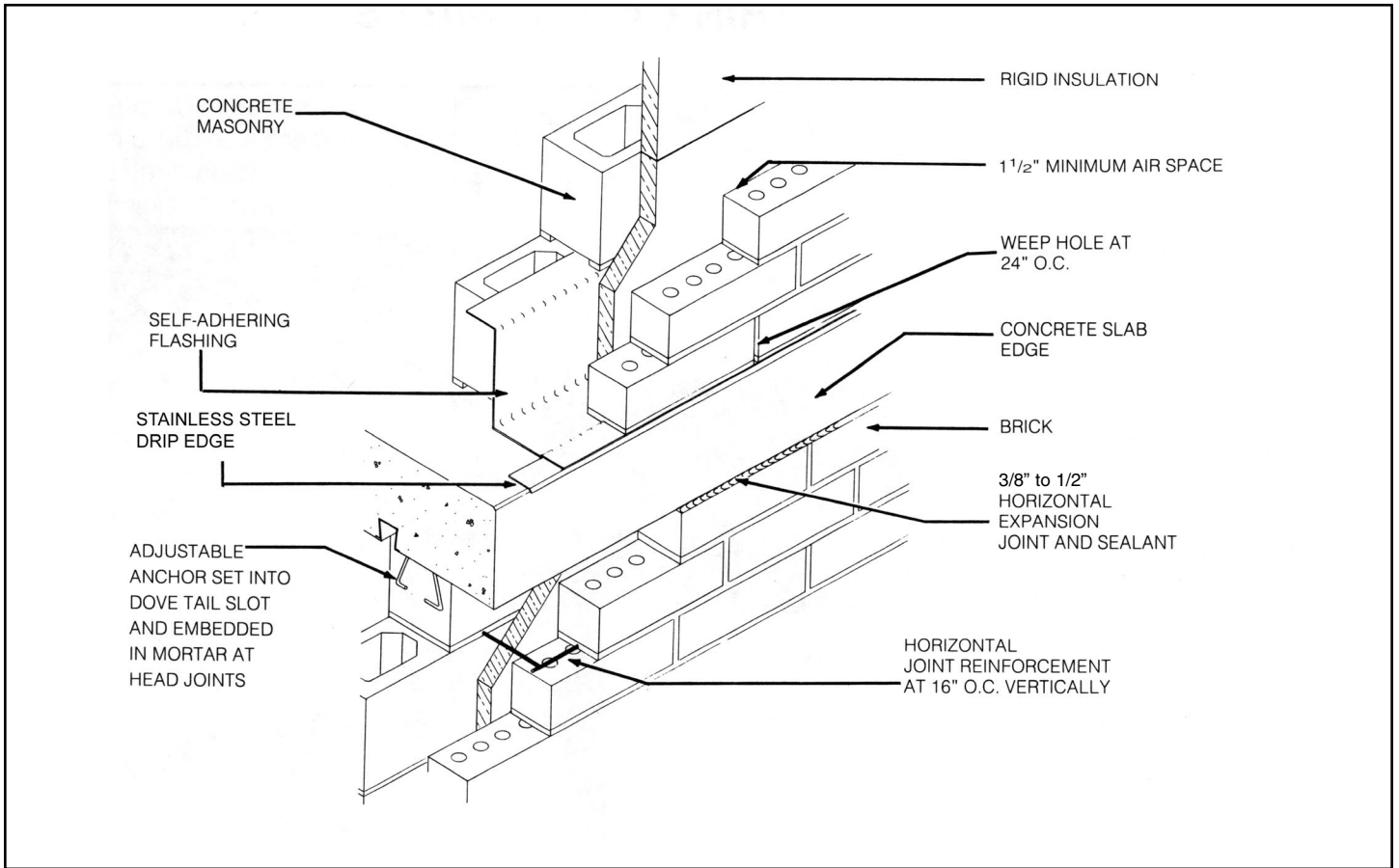
Old, Exposed Slab edge detail

Concrete masonry must be anchored to the structural frame to laterally brace the wall. Figure 15 illustrates one common method of attachment. The anchor type used should provide vertical and horizontal adjustability. Anchors placed vertically should be spaced at 16 inches on center. Anchors placed horizontally should be spaced at 32 inches on center.
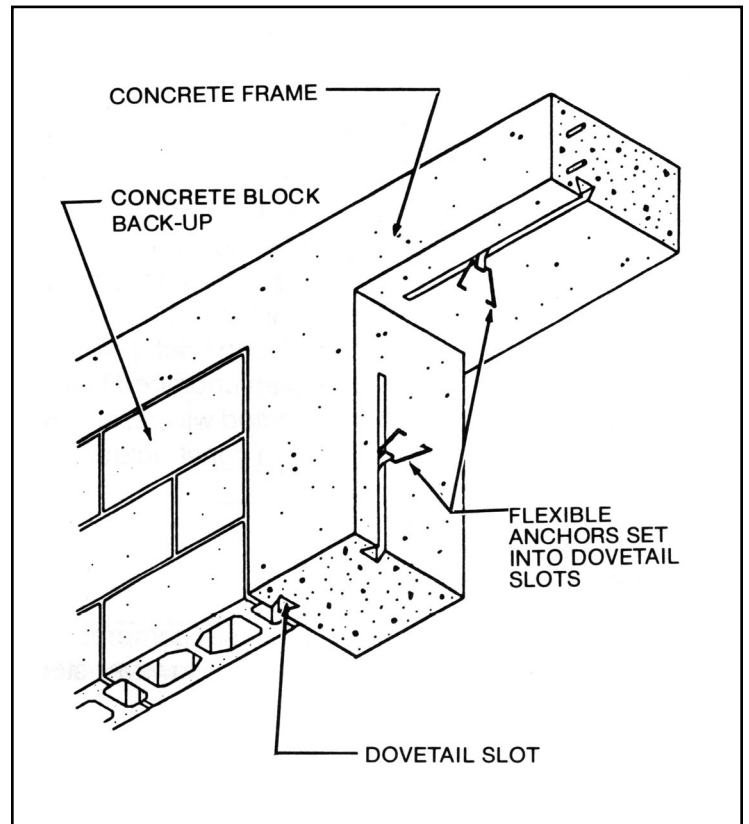


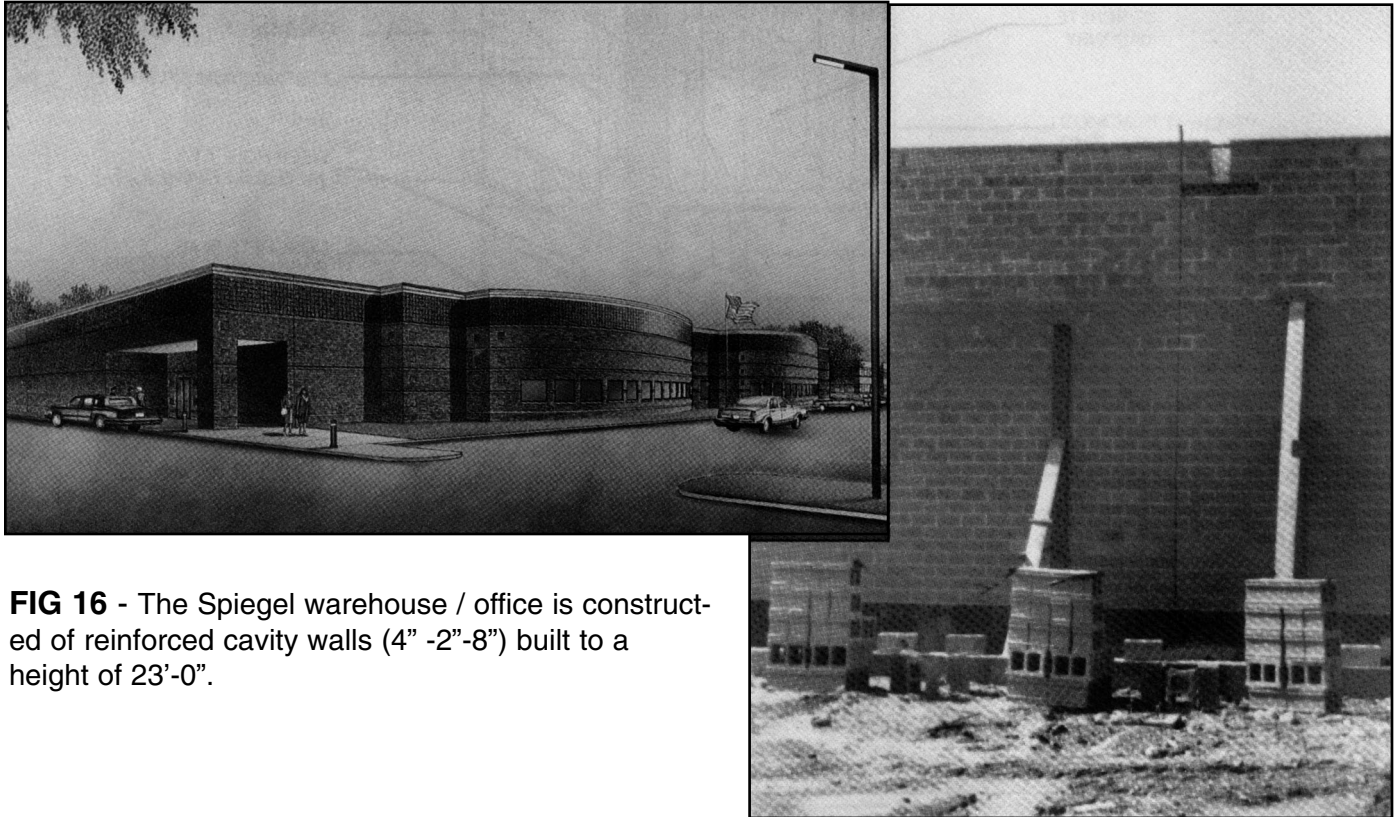**FIG 15** - Lateral support anchors

# TALL THIN CAVITY WALLS



**FIG 16** - The Spiegel warehouse / office is constructed of reinforced cavity walls (4" -2"-8") built to a height of 23'-0".

## GENERAL

There are two methods for determining the maximum unbraced wall height, empirical design or rational (engineered) design. The empirical design method is discussed in Chapter 5 of the Building Code requirements for Masonry Structures (ACI 530-99/ASCE 5 99). The code establishes 18x the nominal wall thickness as a limiting factor for the distance between lateral supports. For cavity walls the maximum unbraced height is determined by the sum of the nominal thickness of the masonry wythes multiplied by 18 (excluding the width of the cavity). Therefore, a cavity wall consisting of a 4 inch brick and an 8 inch CMU can be constructed to a height of 18'-0". If this same wall has reinforcing steel, cavity walls in excess of 36' can be constructed. See Figure 16 for an example.

## REINFORCED MASONRY

Masonry is an excellent material to resist compressive forces, but is relatively weak in tension. However, steel is subjected to buckling under compressive loads but is excellent when used to resist tension forces. Combining these two materials will produce a homogeneous structure capable of resisting substantial lateral and vertical forces.

Reinforced masonry performs because the materials work together. Reinforcing steel placed within a masonry system must be capable of being stressed. The mechanism used to provide this capability is grout. Solidly grouting a cell of a concrete masonry unit which contains reinforcing steel, creates a bond between the interface of steel, grout and concrete masonry. When a wall is laterally loaded, it deflects producing compression in the masonry. The forces are transferred through the masonry and into the grout and by bond into the reinforcing steel, thus the steel is stressed in tension.

Structural engineers are now encouraged to use the ultimate strength design method designated by BOCA Research Report 86-51, when designing masonry walls. This report expands the limit on deflection to 0.007h. A masonry wall can now be designed to limit lateral deflection under service loads. This limit on lateral deflection insures that the steel will be stressed below yield strength conditions. The wall will rebound to its normal vertical conditions when the lateral load is removed because the stress in the steel is within its elastic limits. Designing a cavity wall with this method would enable the builder/owner to construct a cost effective system.

## DETAILS

Details for reinforced cavity walls are similar to non reinforced walls. Flashing is required at all typical locations (e.g; over openings, under openings, at the top and at the base of the wall). Special provisions are required for flashing walls which are grouted. When flashing extends into the cells of CMU that are reinforced, the ends must be trimmed. (See Figure 17 below). This will allow grout to flow freely through the cells when it is poured. If the flashing is allowed to obstruct grout flow, problems such as grout hangups, honeycombing or cold joints will develop. Disrupting the continuity of the grouted cell will affect its structural effectiveness.

## CONNECTIONS

Special consideration should be given to connection details. For bearing walls, pockets should be formed to house steel beams. There should be some adjustability for the method of attachment, to accommodate for construction tolerances. See Figure 18.
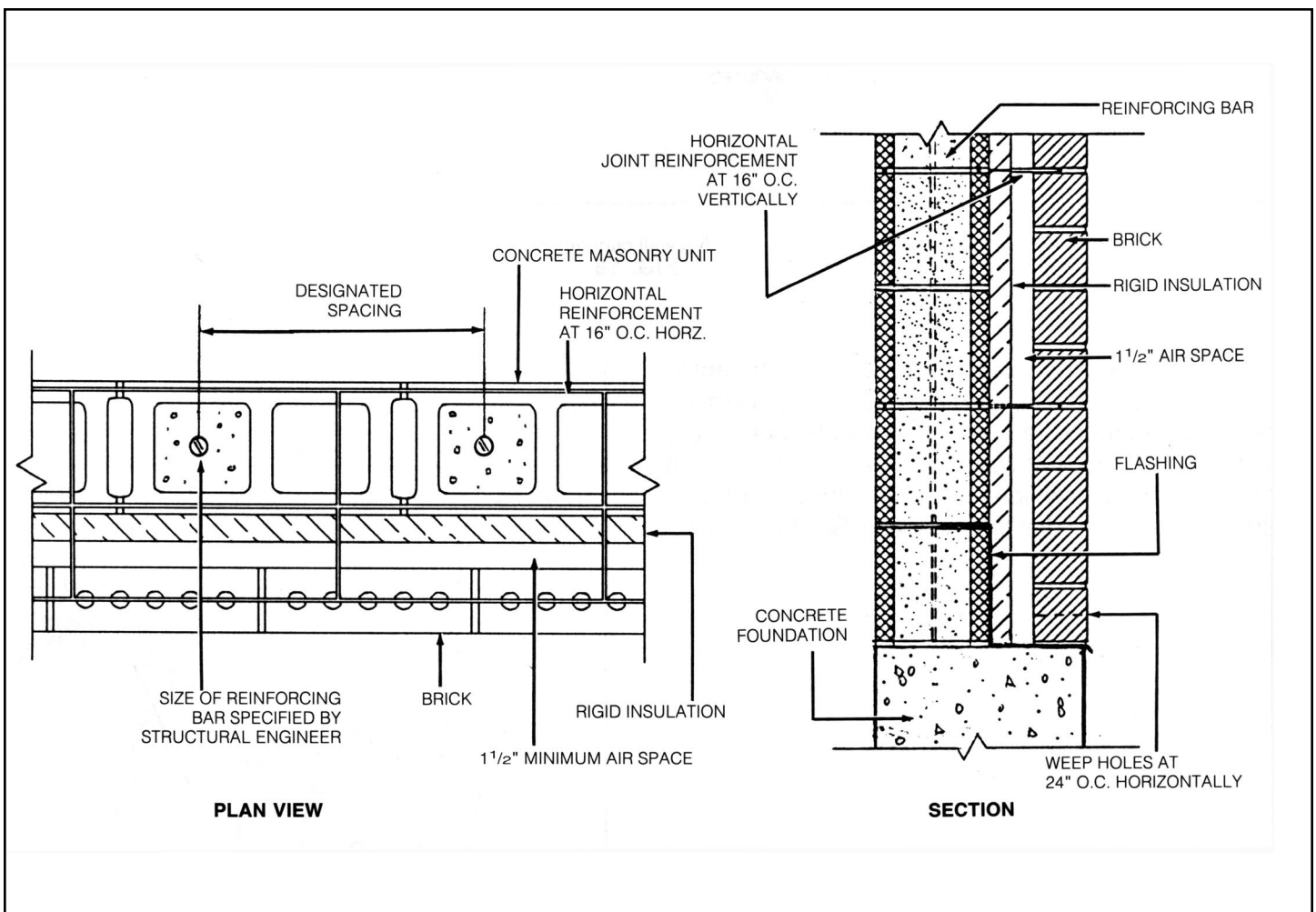


**FIG 17** - Base flashing for reinforced cavity wall
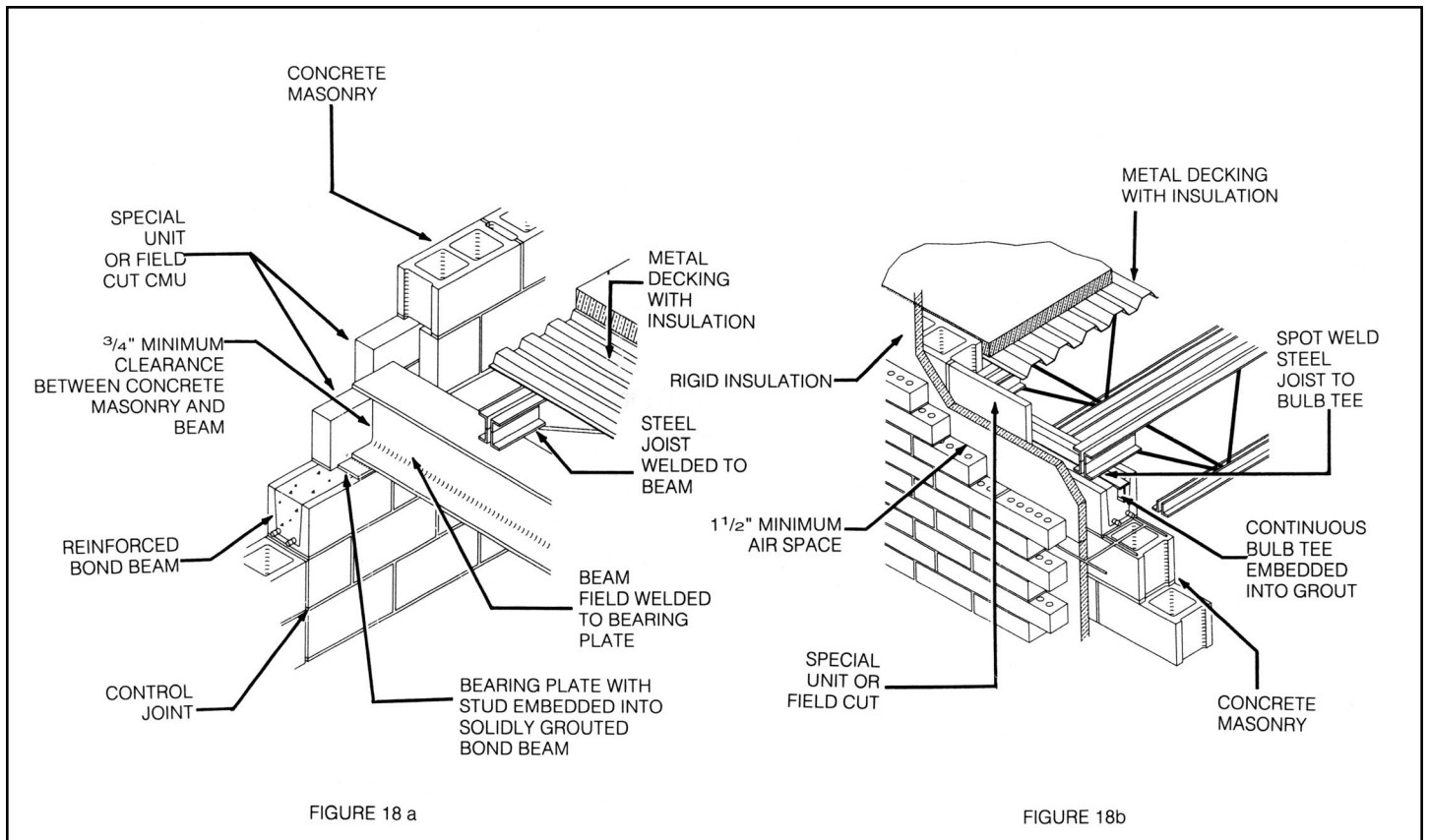
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**FIG 18** - Bearing wall connections

If steel joists bear on the masonry wall, attachment to the joists could be welded to a continuous steel member which is embedded into a bond beam. See Figure 18b above and to the right. For non-bearing walls, a method of attachment must be detailed which adequately braces the wall against movement due to wind loads. See Figure 19 on the right.
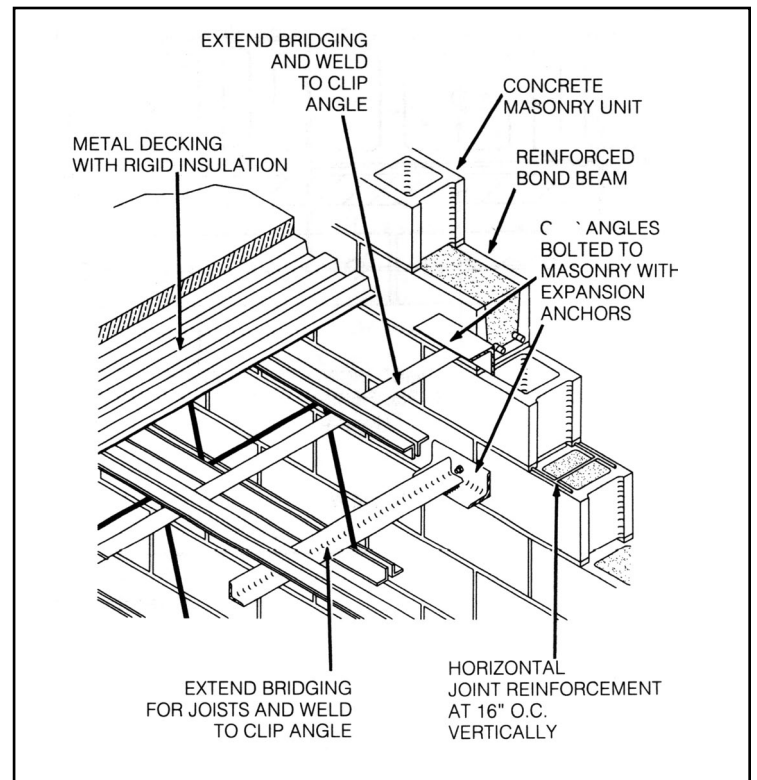


**FIG 19** - Laterally braced wall

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# DETAILS COMMON TO ALL SYSTEMS

## PARAPET DETAIL

Detailing the parapet can be difficult. Designers have tried different ways to detail parapets to minimize cracking, leaking and displacement. Figures 20 and 21 illustrates two parapets coping details.

The cavity should be continuous up to the top of the parapet, and expansion joints should extend up and completely through the parapet. In addition, the parapet wall should be doweled to the structural deck. Vertical reinforcing is required when the height of the parapet exceeds three times its thickness. Parapet copings should be of stone, hard-fired clay or precast concrete caps. The coping should be sloped and should provide a drip on both sides of the wall. Place a continuous (through the wall) flashing membrane under the mortar bed immediately beneath the coping. to avoid displacement, the coping is secured to the wall by using an anchor and dowel rod connection. Fill and seal alternate coping head joints with foam backer rods and a sealant (keep joint totally void of mortar). The back of the parapet should be constructed of durable materials.
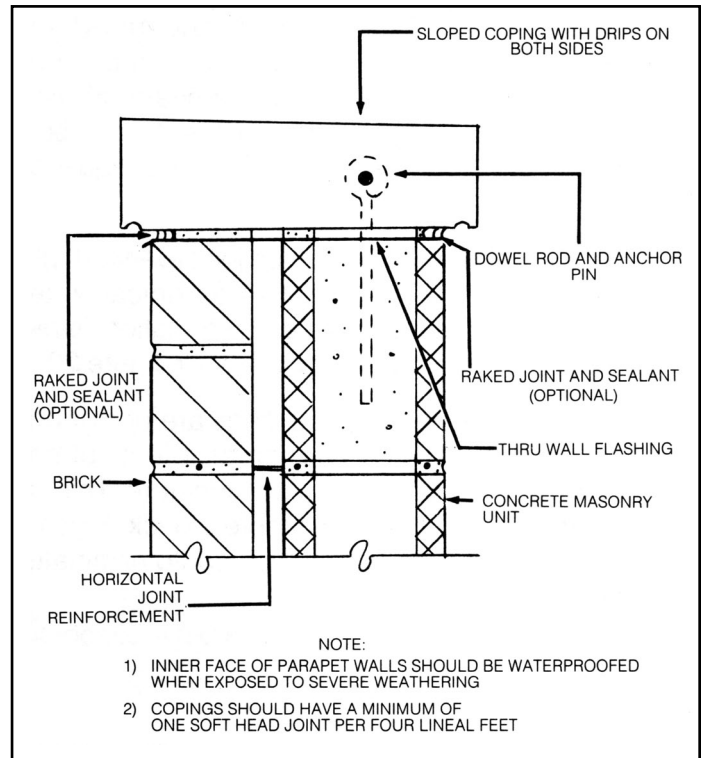


**FIG 20 - Coping detail for low parapet**

## MOVEMENT JOINTS

There is a common misconception in the construction community. Many designers, builders, and contractors do not know the distinction between control joints and expansion joints. Control joints are placed in concrete or concrete masonry walls. They control cracking by reducing restraint and accommodating wall movement resulting from shrinkage to initial drying. Locate vertical control joints a maximum of 20'-0" on center horizontally. Other provisions which dictate the placement of control joints are discussed in NCMA TEK 5-2A,10-1 & 10-2B.

There are several ways to form a control joint. The most practical method of forming a control joint is to rake back a vertical mortar joint creating a plane of weakness. The joint should be raked back to a minimum depth of 3/4 inch and extended continuously up the wall surface. Apply sealant where required.

Since shrinkage, due to drying is not found in clay masonry construction, control joints are not necessary for brick masonry walls. Brick expands when subjected to moisture gain. Brick also expands and contracts when experiencing temperature variation. So expansion joints are required for brick.
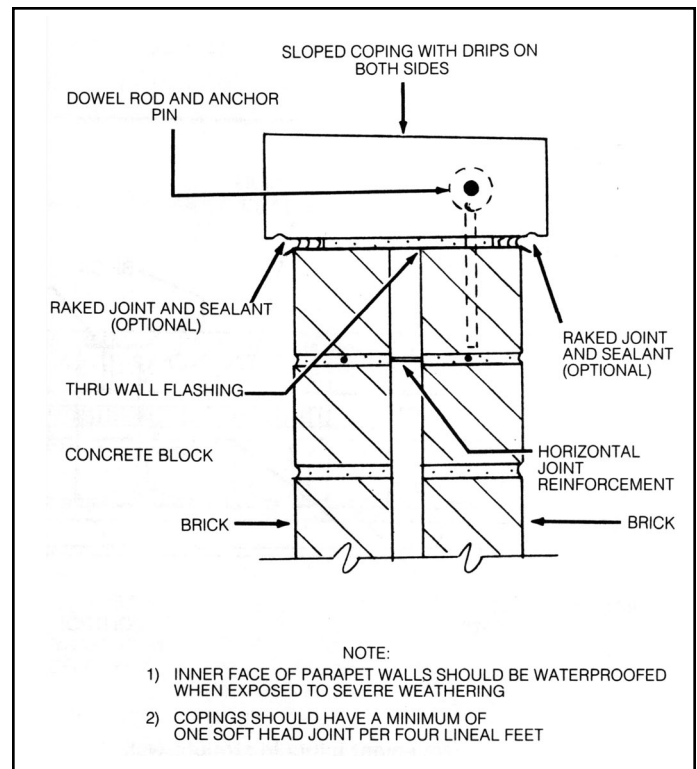


**FIG 21 - Coping detail for high parapet**

An expansion joint is a continuous break in the exterior wythe of masonry. The break is in the form of a soft joint which is totally void of any mortar or material capable of resisting movement. This joint will accommodate movement due to temperature variations, moisture expansion or differential structural movement. An expansion joint is usually placed in the vertical direction although horizontal expansion joints are required under shelf angles.

Construct a minimum of one-1/2 inch expansion joint every 30'-0" on center horizontally. Consult BIA Technical Note #18A for more accurate placement information. Typical details of movement joints are shown in Figure 22.

Many mid rise and high rise buildings are designed with balconies. Water penetration problems often occur at the sliding door/cavity wall juncture. This is due in part, to the pitch of the concrete deck. Figure 23 illustrates a flashing detail which could eliminate this moisture problem, using a prefabricated end dam with self adhering flashing.
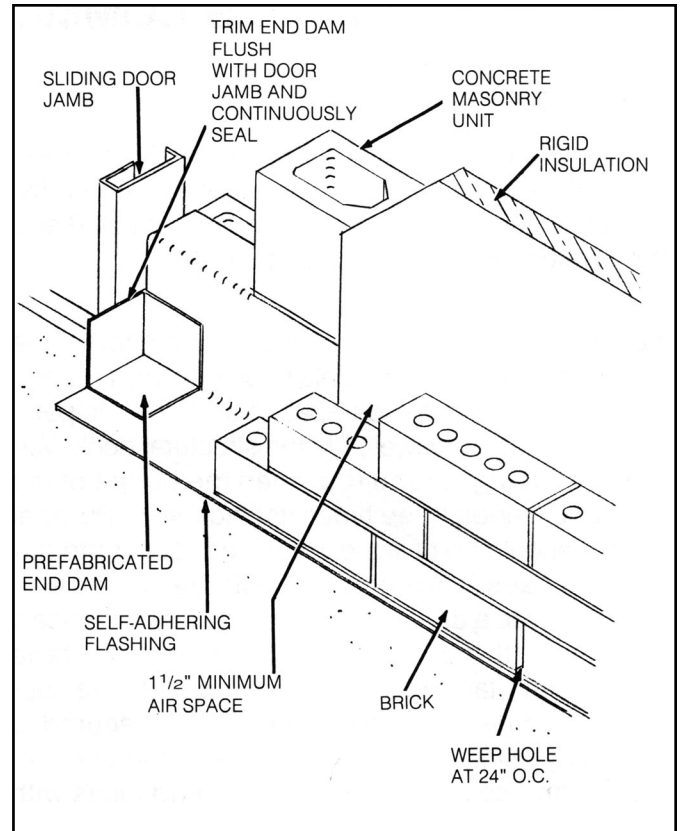


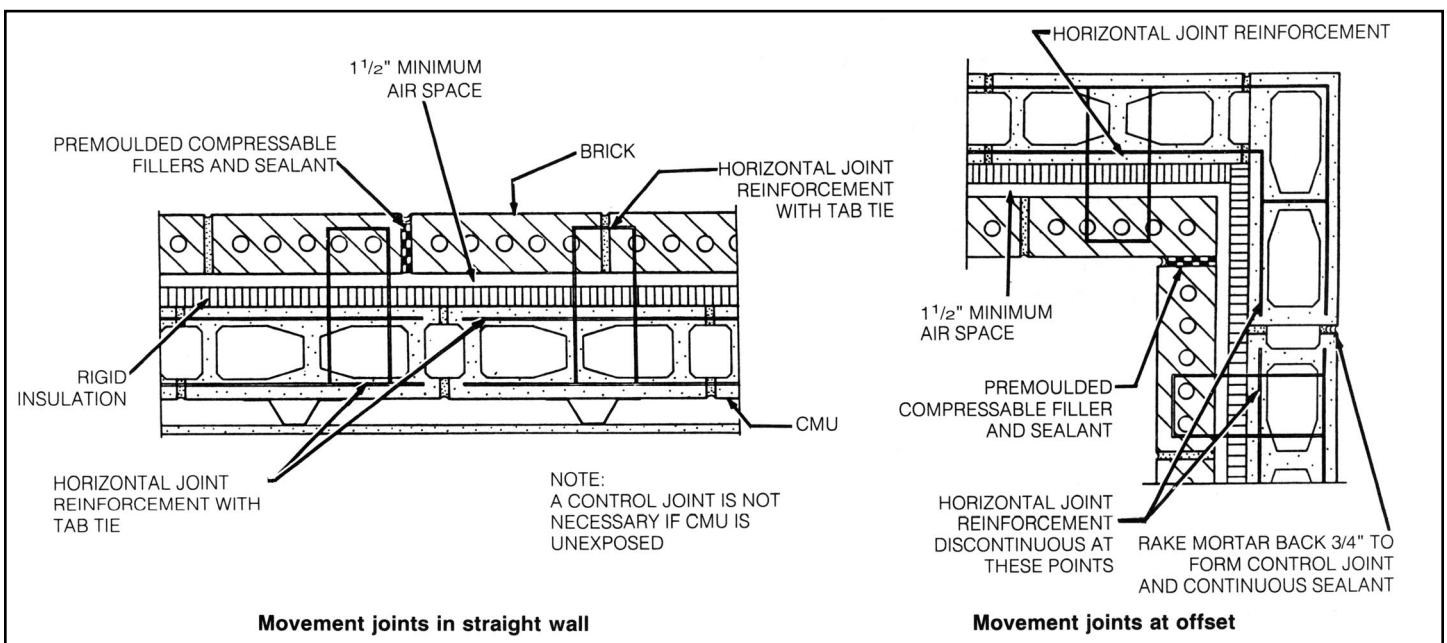**FIG 23 - Flashing cavity wall at sliding door**



**FIG 22 - Expansion and control joints**

# MASONRY ADVISORY COUNCIL

The Masonry Advisory Council would like to thank
the following organizations for their assistance.

- Beer, Gorski and Graff, Ltd.
  Structural Engineers
  Chicago, IL

- Brick Industry Association
  Reston Virginia

- Building Research Station
  Garston, Watford, England

- Dayton Superior Corporation
  Miamisburg, Ohio

- National Concrete Masonry Association
  Herndon, Virginia

- Prestressed Concrete Institute
  Chicago, IL

- Walter Laska
  Masonry Technologies, Inc.
  Downers Grove, IL

## FOOT NOTES:

1.  The minimum dimensions of a cavity without insulation is 2 inches.  If rigid insulation is placed inside  a conventional cavity, an airspace with a minimum dimension of 1 1/2 inch must be maintained.  In a hybrid cavity with continuous drainage mat, a 0 - 3/8" tolerance between the mat and the inside face of the outer wythe is desired.

2. The Concrete and Masonry Industry Fire Safety Çommittee produces a series of publications know as the "Fire Protection Planning Reports".  These reports contain a variety of pertinent fire-related information.

3.  The American Insurance Services Group, Inc. publishes a guide called the "Fire Resistance Ratings".  This publication presents information concerning the construction of building assemblies which provide fire resistance ratings of up to four hours.  Also "Standard Method for Determining Fire Resistance of Concrete and Masonry Assemblies" ACI 216.1-97 / TMS 0216.1-97.  American Concrete Institute and The Masonry Society, 1997.

4.  The information contained in this table was obtained from ACI 530-99/ASCE5-99/TMS 402-99.

5.  Primary forms of differential movement occur through: concrete frame shrinkage or "creep", thermal expansion and contraction of brick, and irreversible moisture expansion of brick.  An actual dimension should be calculated and determined by a structural engineer.

## DISCLAIMER NOTICE