Masonry Design and Detailing from an Architect's Perspective

AIA Course: TMSMEW2205

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The Masonry Society

AIA Provider: 505119857

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

This course identifies challenges and opportunities associated with masonry construction systems.

It describes basic masonry wall assembly options, and the pros and cons of each.

The means available to an architect for masonry assemblies to meet building and energy codes are described.

Common masonry detailing problems and solutions are presented, including recent innovative strategies.

Learning Objectives

At the end of this course, participants will be able to:

1 Identify challenges and opportunities associated with masonry construction systems

2 Describe four general masonry wall types, and the pros and cons of each

3 Identify common masonry detailing errors and corrections

4 Understand innovative means to enhance the performance of masonry walls

5 Understand various means available for masonry assemblies to meet building and energy codes

What is Masonry? What are it's virtues and special challenges?

+ •**Many possible solutions**
  - Formal qualities
  - Technical qualities (structure, enclosure, detail, sustainability, etc.)
  - Aesthetic qualities (character, meaning, scale, proportion, etc.)

+ / - •**Designer can (must) weigh many alternatives** then choose a path.
invention vs. selection

+ / - •**Modular coordination** is important.

+ / - •**Lots of new, difficult challenges face the designer and builder; creativity is needed.**
Clay masonry construction is 6,000 years old, but today's masonry walls are new inventions, and are still evolving.

- •**Design development, detailing, and construction administration are all very challenging** in masonry buildings, especially when fees for services are being reduced.
Fewer detail drawings often mean more RFI's during construction.

- •**Quality control is difficult to achieve**
  - variations in mason's training
  - lack of ability to inspect built work
  - absence of designer from construction site

- •**Marketplace demands greater certainty regarding quality, cost and time.**

- •**Initial costs are volatile** due to significant labor component, but life-cycle costs are low.

Wall types - Which is appropriate for a given application?

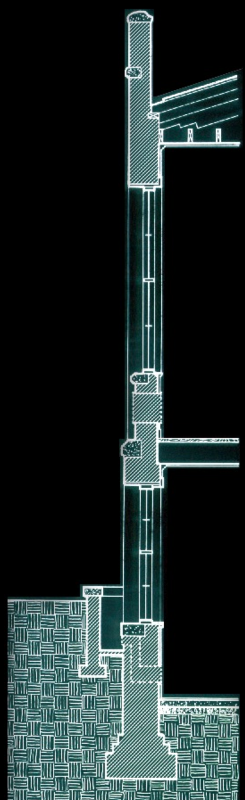
- Barrier walls
  - **Solid**
  - **Reinforced**
- Drainage walls
  - **Cavity or Composite**
  - **Veneer**
    - Rainscreens

What must be done when designing masonry assemblies?

- Check compatibility between varied masonry materials
- Check compatibility with non-masonry materials
- Establish expectations regarding building longevity and maintenance
- Set suitable levels of durability of all elements
- Carefully design joints, perimeters and penetrations
- Adjust the design to meet local environmental conditions
- Establish tolerances for materials, installation and workmanship
- Anticipate the need for submittals, sample panels and site observations
- Anticipate the need for masonry cleaning and maintenance

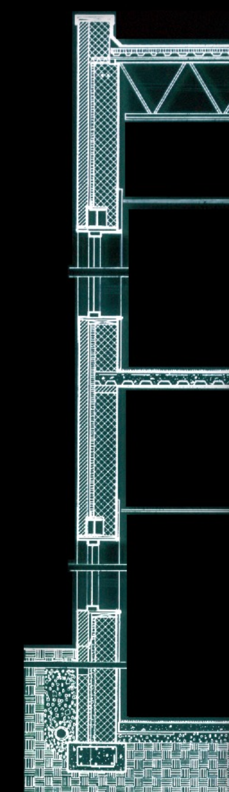
What options are available regarding within masonry assemblies?

Movement joints	Rain control layer (may also be UV control layer)
Ties	Water control layer (WRB or water-resistant barrier)
Anchors	Air control layer
	Thermal control layer
	Vapor control layer
	Flashing
	Cavity dewatering, weep and ventilation products



Holladay Hall / NCSU / 1889

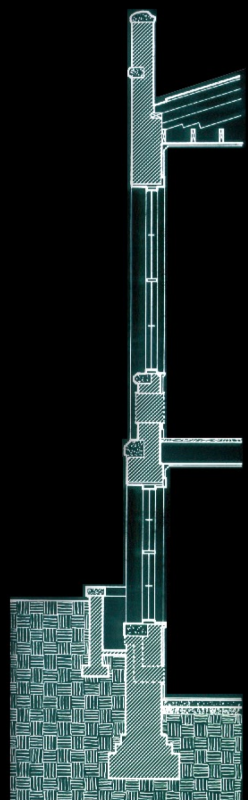
Strategies to Make a Building Wall Moisture Resistant									
Examples	multiwythe brick wall	"dryblock" additive in cmu	painted cmu wall	foundation wall water-proofing & drainage matting	cavity wall or veneer const. with drainage mechanism	ventilate the cavity of the wall to the outside	rainscreen with pressure - equalization chamber	
Material is Barrier			barrier walls		drainage walls			**Assembly is Barrier**
One or two multifunctional materials in a simple additive assembly	Use materials that are intrinsically resistant to moisture	Alter the basic material with modifiers to increase moisture resistance	Apply a sealant to the surface of an intrinsically vulnerable material	Apply layers of sealant and drainage media onto exterior surface	Interupt the path of porous materials within the wall	Convect water vapor from within the wall	Repel moisture with air pressure in compart-mented cavities	**Layers of specialized, sometimes redundant materials in a complex, integrated assembly**



Dining Hall / NCSU / 1985

Principles of masonry design and detailing vary with wall type.

Masonry walls must be designed with the relevant principles for the particular wall type chosen.



Holladay Hall / NCSU / 1889

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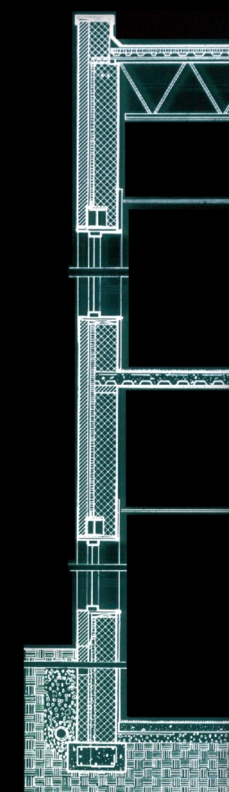
Water **will** be inside the wall assembly:

- penetration at joints,
- through materials, especially mortar
- by condensation of vapor

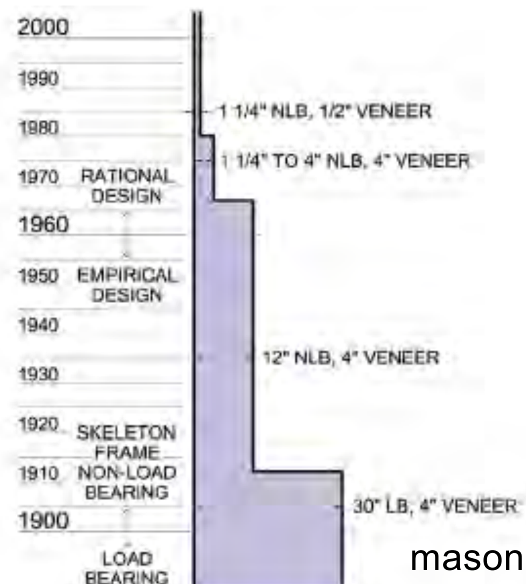
Reduce water penetration

Prevent water from reaching interior



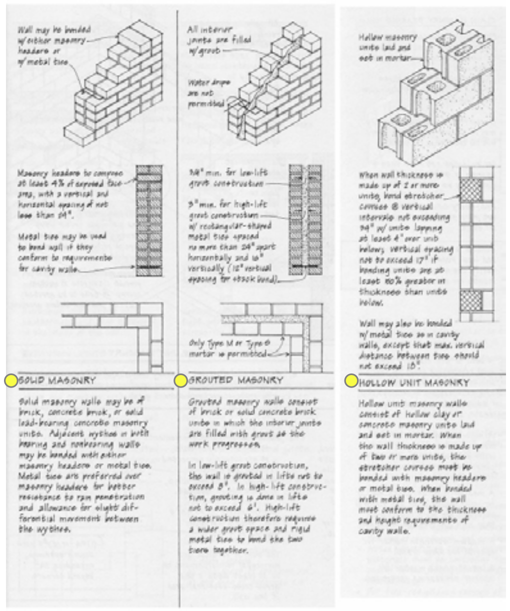
Dining Hall / NCSU / 1985

The Rookery
Burnham and Root
Chicago
1888

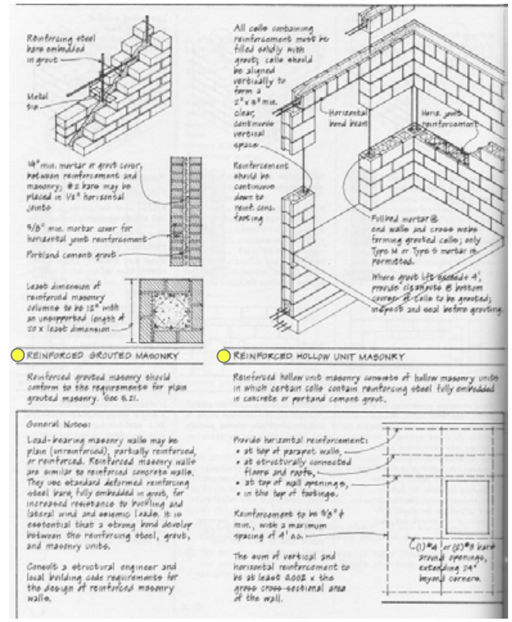


masonry wall thickness 1900 – 2000

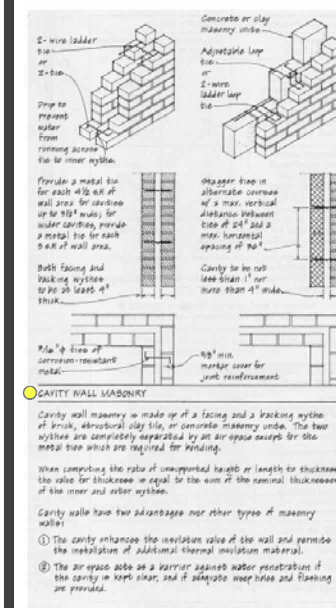
thick loadbearing walls are still available today, but cavity and veneer walls are more common

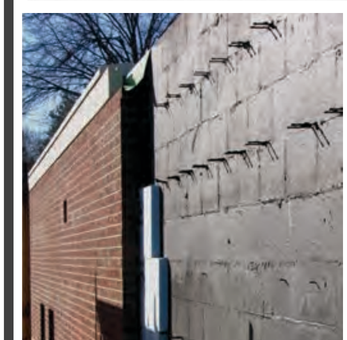


Solid

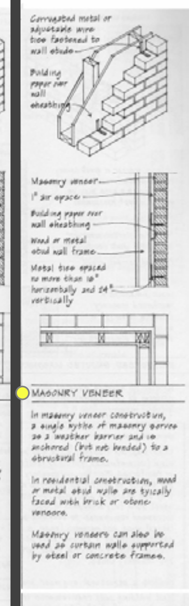


Reinforced





Cavity



Veneer

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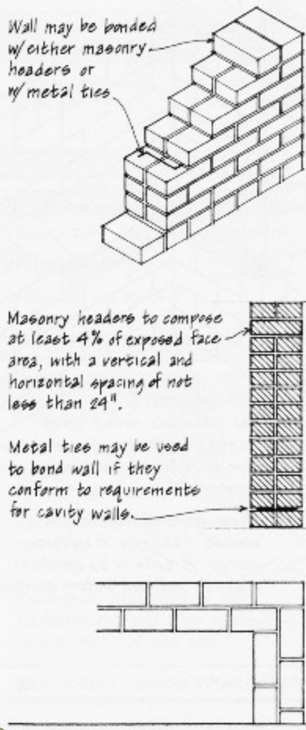
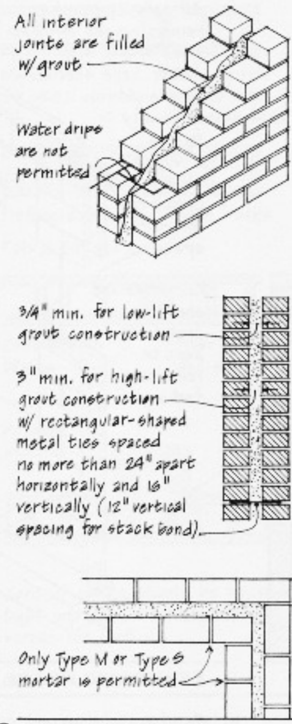
Solid



SOLID MASONRY

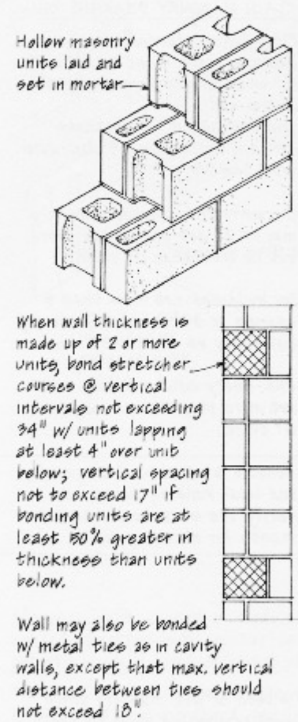
Solid masonry walls may be of brick, concrete brick, or solid load-bearing concrete masonry units. Adjacent wythes in both bearing and nonbearing walls may be bonded with either masonry headers or metal ties. Metal ties are preferred over masonry headers for better resistance to rain penetration and allowance for slight differential movement between the wythes.



GROUTED MASONRY

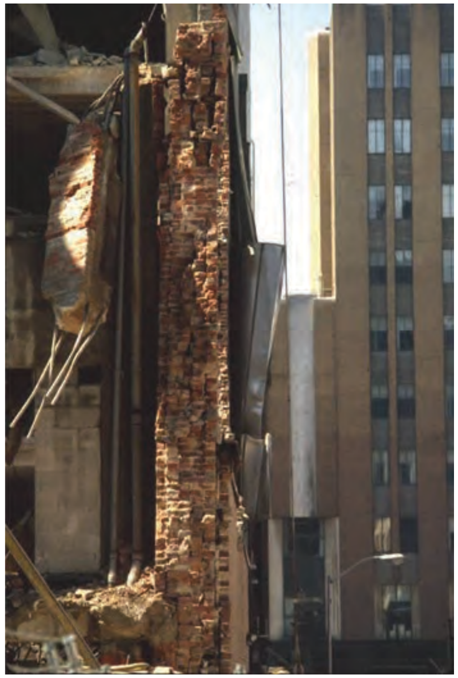
Grouted masonry walls consist of brick or solid concrete brick units in which the interior joints are filled with grout as the work progresses.

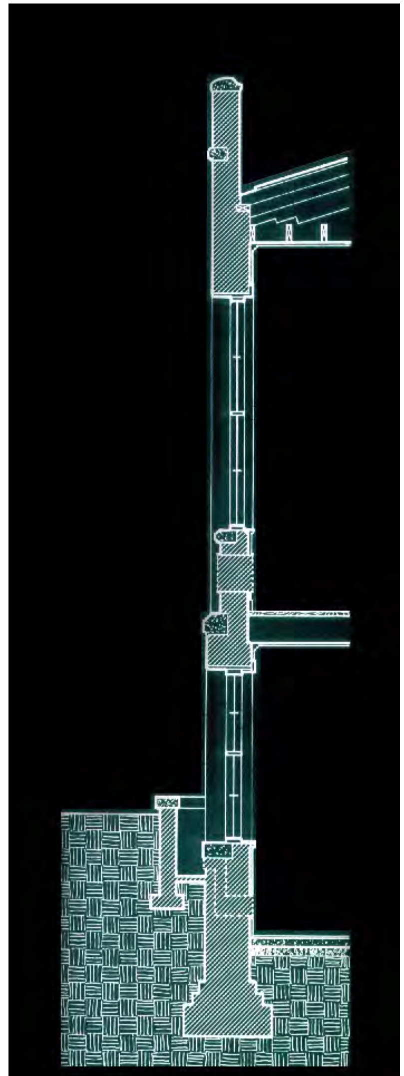
In low-lift grout construction, the wall is grouted in lifts not to exceed 8". In high-lift construction, grouting is done in lifts not to exceed 6'. High-lift construction therefore requires a wider grout space and rigid metal ties to bond the two tiers together.



HOLLOW UNIT MASONRY

Hollow unit masonry walls consist of hollow clay or concrete masonry units laid and set in mortar. When the wall thickness is made up of two or more units, the stretcher courses must be bonded with masonry headers or metal ties. When bonded with metal ties, the wall must conform to the thickness and height requirements of cavity walls.





Holladay Hall / NCSU / 1889

Nearly all masonry buildings built before the 1940's were built with solid masonry walls.

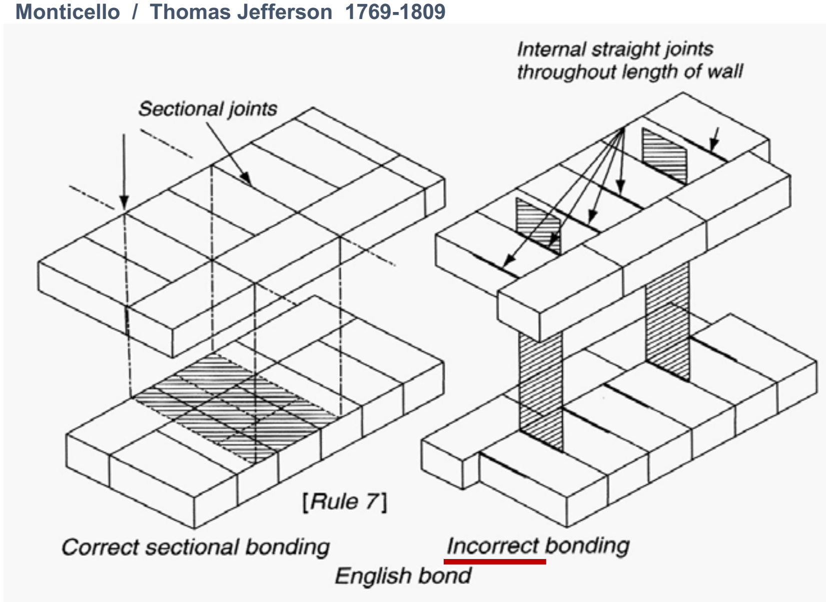
bonding is essential for Solid masonry walls.

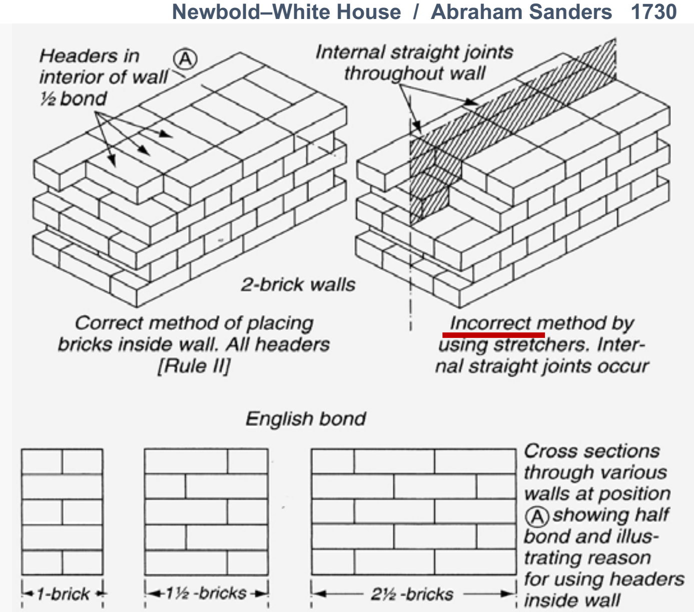
Monticello / Thomas Jefferson 1769-1809

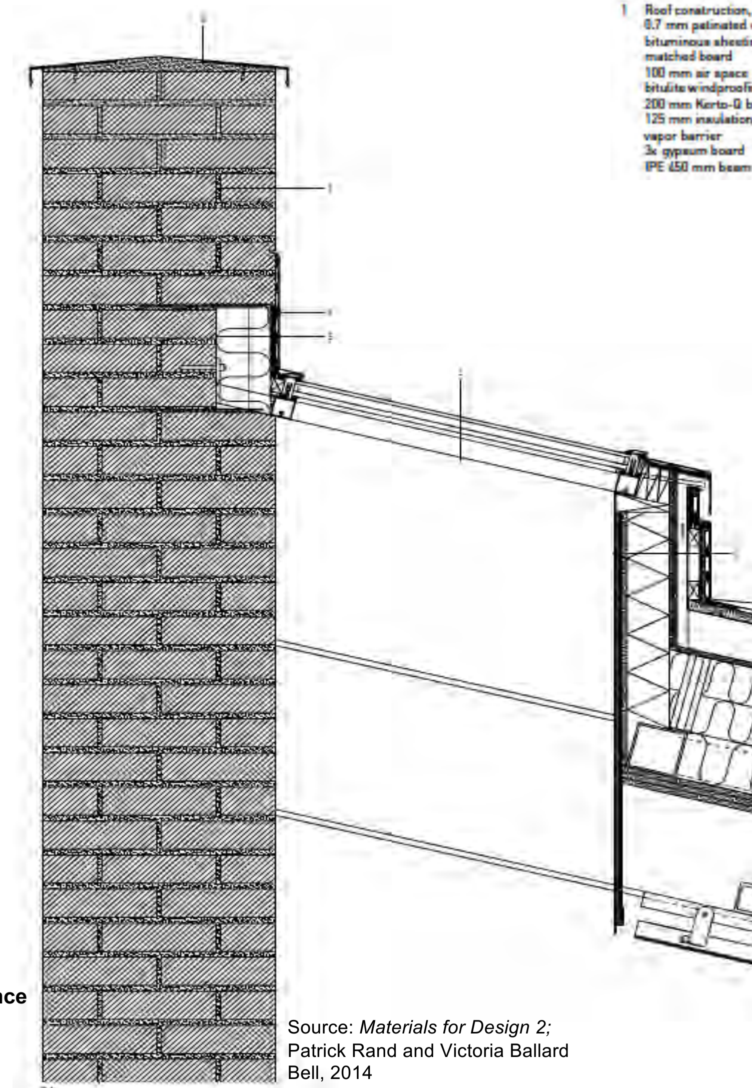
Newbold–White House / Abraham Sanders 1730

Interlocking units bond the courses and wythes together.

Avoid continuous head joints or collar joints in bonded masonry walls.







1 Roof construction, Rw 53dB:
0.7 mm patinated copper
bituminous sheeting
matched board
100 mm air space
bitulite windproofing
200 mm Kerto-Q beams and insulation
125 mm insulation
vapor barrier
3x gypsum board
IPE 450 mm beam

3 Rw 43dB:
0.7 mm patinated copper
bituminous sheeting
plywood
25+25 mm air space
9+9 mm windproofing
100 mm wood structure + insulation
gypsum board
plywood
0.7 mm patinated copper

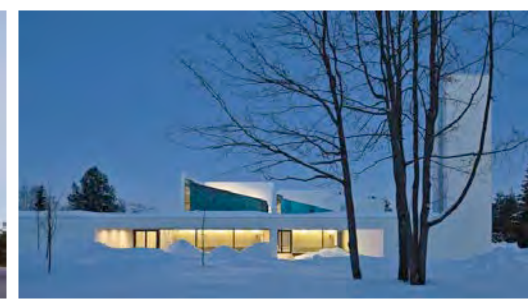
4 Insulating triple glazing, Rw + Ctr 42dB

5 Steel sheeting, painted
bituminous sheeting
plywood
mineral wool insulation

6 L-steel 50 x 50 x 5 mm

7 Massive brick wall, plastered and limed

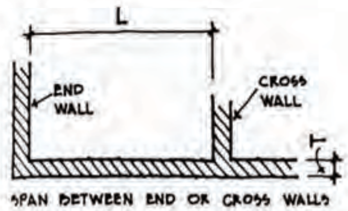
8 Steel sheeting, painted

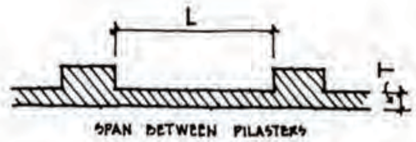


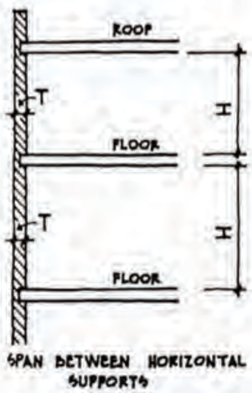
Chapel of St. Lawrence
Avanto Architects
Vantaa, Finland
2010

Source: *Materials for Design 2;* Patrick Rand and Victoria Ballard Bell, 2014

emperical design
“rules of thumb”







MAXIMUM RATIO OF UNSUPPORTED HEIGHT OR LENGTH TO NOMINAL THICKNESS

Construction	*Maximum l/t or h/t*
Bearing walls	
Solid or solidly grouted	20
All others	18
Non-bearing walls	
Exterior	18
Interior	36

Lateral support, height-to-thickness ratios, and minimum thickness requirements for empirically designed masonry walls.

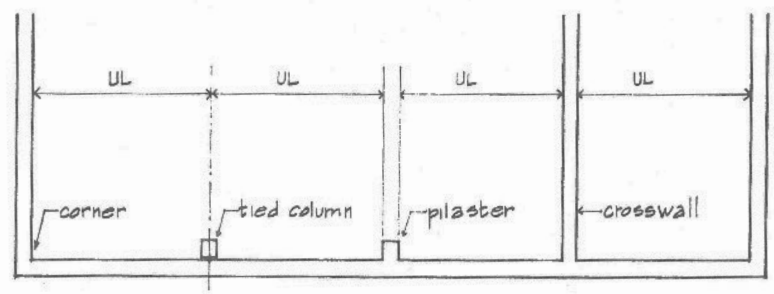
CALCULATED MAXIMUM VERTICAL SPAN

WIND OR SEISMIC LATERAL LOAD (PSF)	WALL WIDTH (IN.) 4	6	8	10	12
UNREINFORCED CONCRETE MASONRY[1]					
10	—	—	13′	16′	18′
15	—	—	10′	12′	15′
20	—	—	9′	11′	12′
25	—	—	8′	10′	11′
CLAY UNIT MASONRY[2]					
10	8′	7′	11′	—	—
15	6′	7′	9′	—	—
20	6′	6′	8′	—	—
25	5′	5′	7′	—	—

LATERAL SUPPORT REQUIREMENTS:

wall type	maximum spacing for UL or UH
solid load bearing	20 x thickness (T)
hollow load bearing (only sum of wythes considered)	18 × T
non-load-bearing	36 × T
* for walls subject to high winds, UL or UH = 10 × T unless walls are adequately braced	

UL = unsupported length
UH = unsupported height



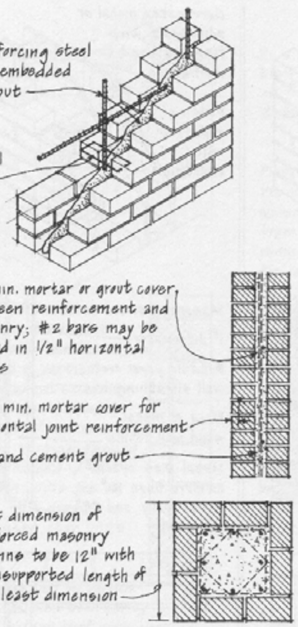
Above: An plane of cmu masonry was blown over by light wind. It had no reinforcement, did not turn a corner or have other stabilizing features such as bracing, as required by OSHA. On the right is shown the bracing used when the wall was rebuilt.

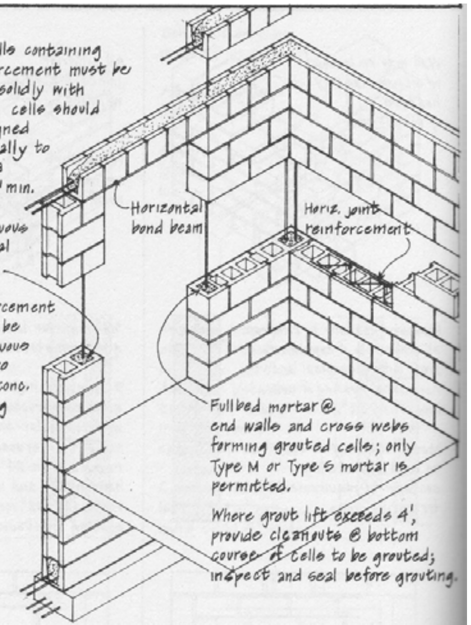
Below: A 5.8 earthquake in Central Virginia in August 2011 sent tremors to Raleigh. This cmu warehouse had at least two 8” walls fail due to out of plane loads. The walls had no keys at movement joints.

Error or workmanship above.

Error of design below.

Reinforced





REINFORCED GROUTED MASONRY

Reinforced grouted masonry should conform to the requirements for plain grouted masonry. See 5.21.

REINFORCED HOLLOW UNIT MASONRY

Reinforced hollow unit masonry consists of hollow masonry units in which certain cells contain reinforcing steel fully embedded in concrete or portand cement grout.

General Notes:

Load-bearing masonry walls may be plain (unreinforced), partially reinforced, or reinforced. Reinforced masonry walls are similar to reinforced concrete walls. They use standard deformed reinforcing steel bars, fully embedded in grout, for increased resistance to buckling and lateral wind and seismic loads. It is essential that a strong bond develop between the reinforcing steel, grout, and masonry units.

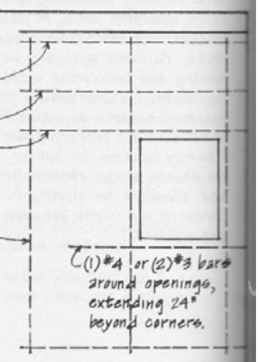
Consult a structural engineer and local building code requirements for the design of reinforced masonry walls.

Provide horizontal reinforcement:

- at top of parapet walls,
- at structurally connected floors and roofs,
- at top of wall openings,
- in the top of footings.

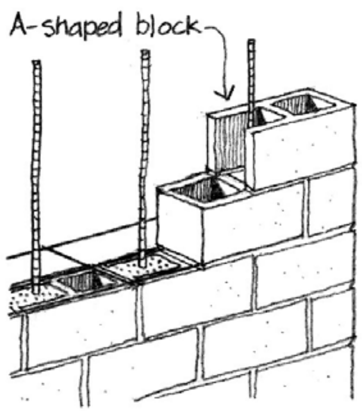
Reinforcement to be 3/8" ϕ min., with a maximum spacing of 4' o.c.

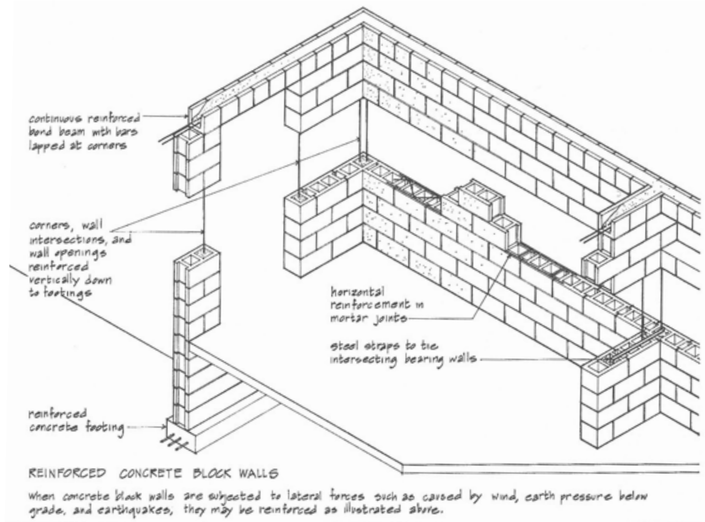
The sum of vertical and horizontal reinforcement to be at least 0.002 x the gross cross-sectional area of the wall.

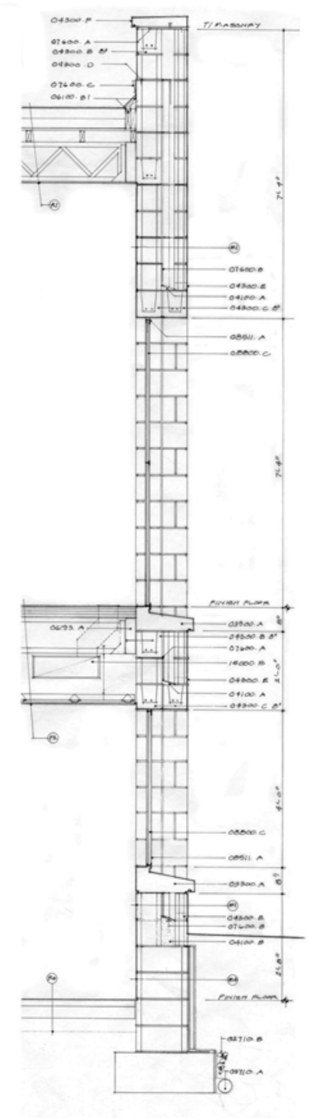


reinforcement can easily go vertically and horizontally in the collar joint.

reinforcement can also easily go vertically in the cores of cmu, and horizontally in lintel block



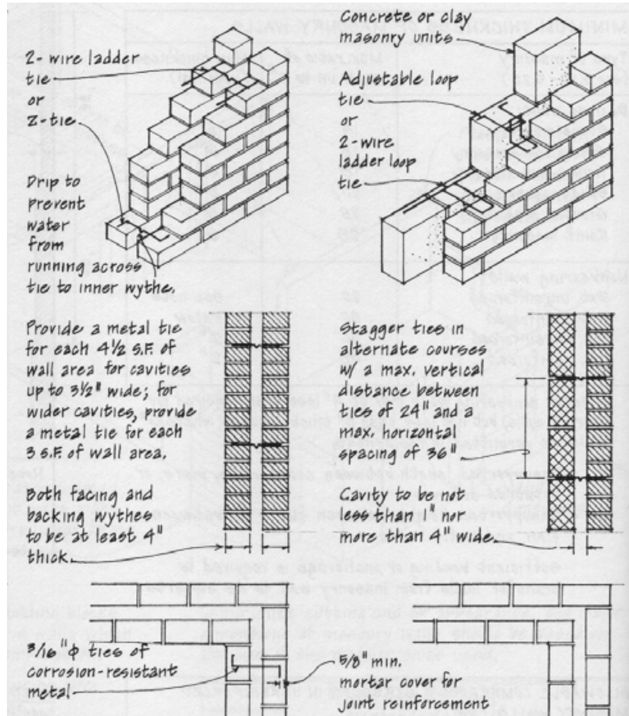




bond beam
using **lintel block**

Cavity

The cavity should be located just inside the outer wythe of masonry. That is where condensation is most likely to occur, and this is also where water that leaks through the veneer can first be directed down and out.



CAVITY WALL MASONRY

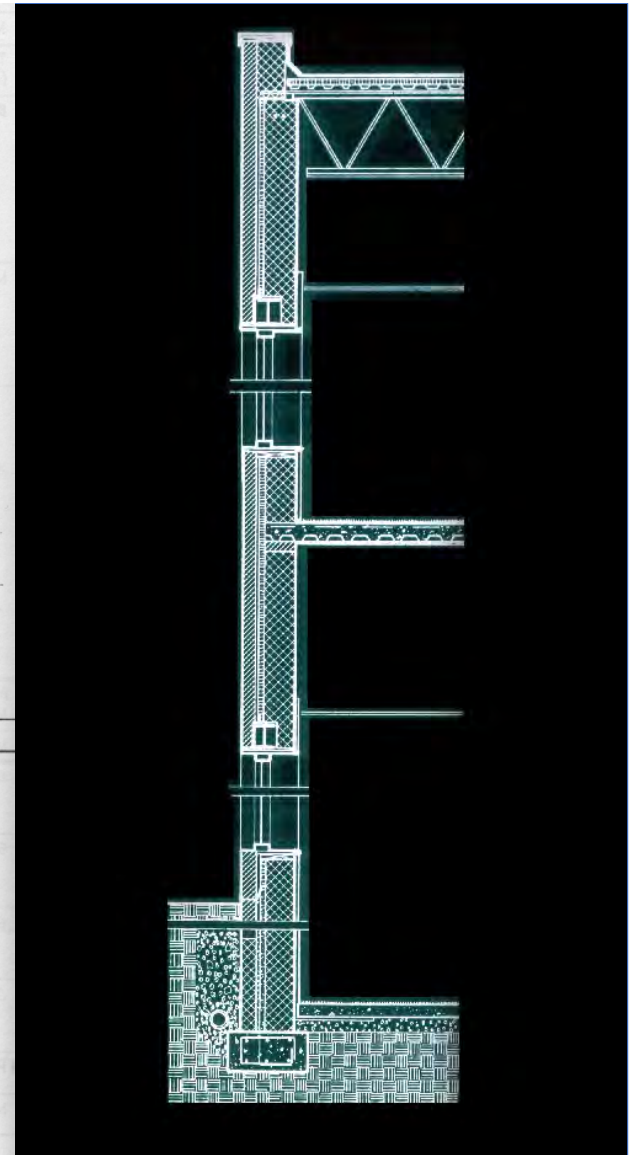
Cavity wall masonry is made up of a facing and a backing wythe of brick, structural clay tile, or concrete masonry units. The two wythes are completely separated by an air space except for the metal ties which are required for bonding.

When computing the ratio of unsupported height or length to thickness, the value for thickness is equal to the sum of the nominal thicknesses of the inner and outer wythes.

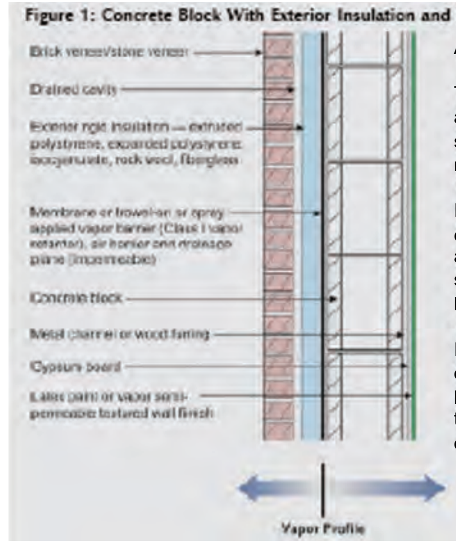
Cavity walls have two advantages over other types of masonry walls:

① The cavity enhances the insulation value of the wall and permits the installation of additional thermal insulation material.

② The air space acts as a barrier against water penetration if the cavity is kept clear, and if adequate weep holes and flashing are provided.



air and water barrier

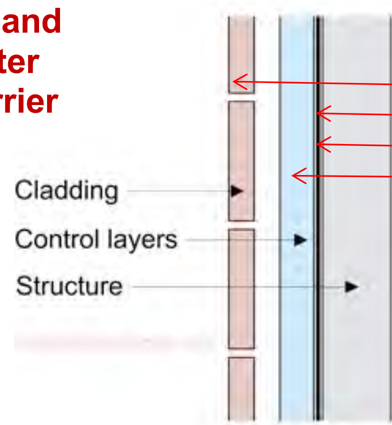


Applicability – all hygro-thermal regions

This is arguably the most durable wall assembly available to architects and engineers. It is constructed from non-water sensitive materials and due to the block construction has a large moisture storage (or hygric buffer) capacity.

It can be constructed virtually anywhere. In cold climates condensation is limited on the interior side of the vapor barrier as a result of installing all of the thermal insulation on the exterior side of the vapor barrier (which is also the drainage plane and air barrier in this assembly).

In hot climates any moisture that condenses on the exterior side of the vapor barrier will be drained to the exterior since the vapor barrier is also a drainage plane. This wall assembly will dry from the vapor barrier inwards and will dry from the vapor barrier outwards.



wet | dry

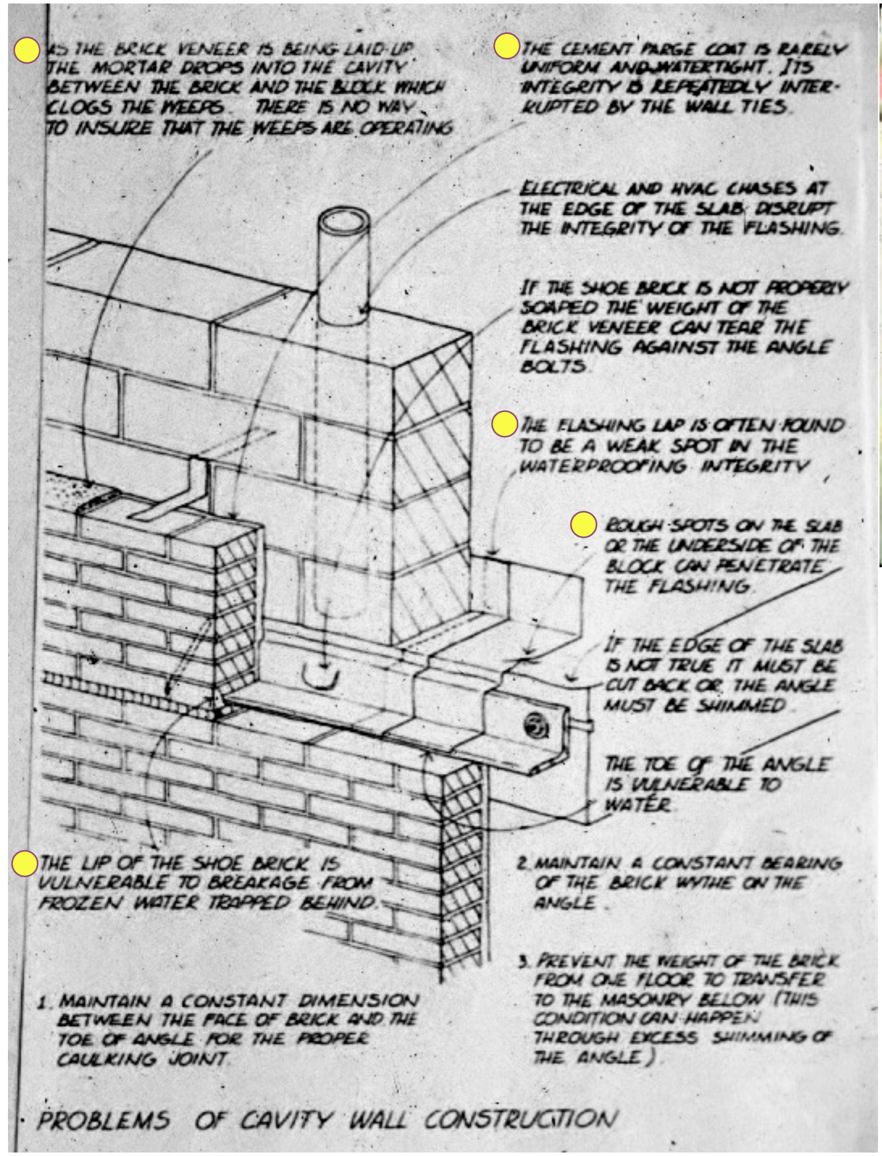
moisture tolerant

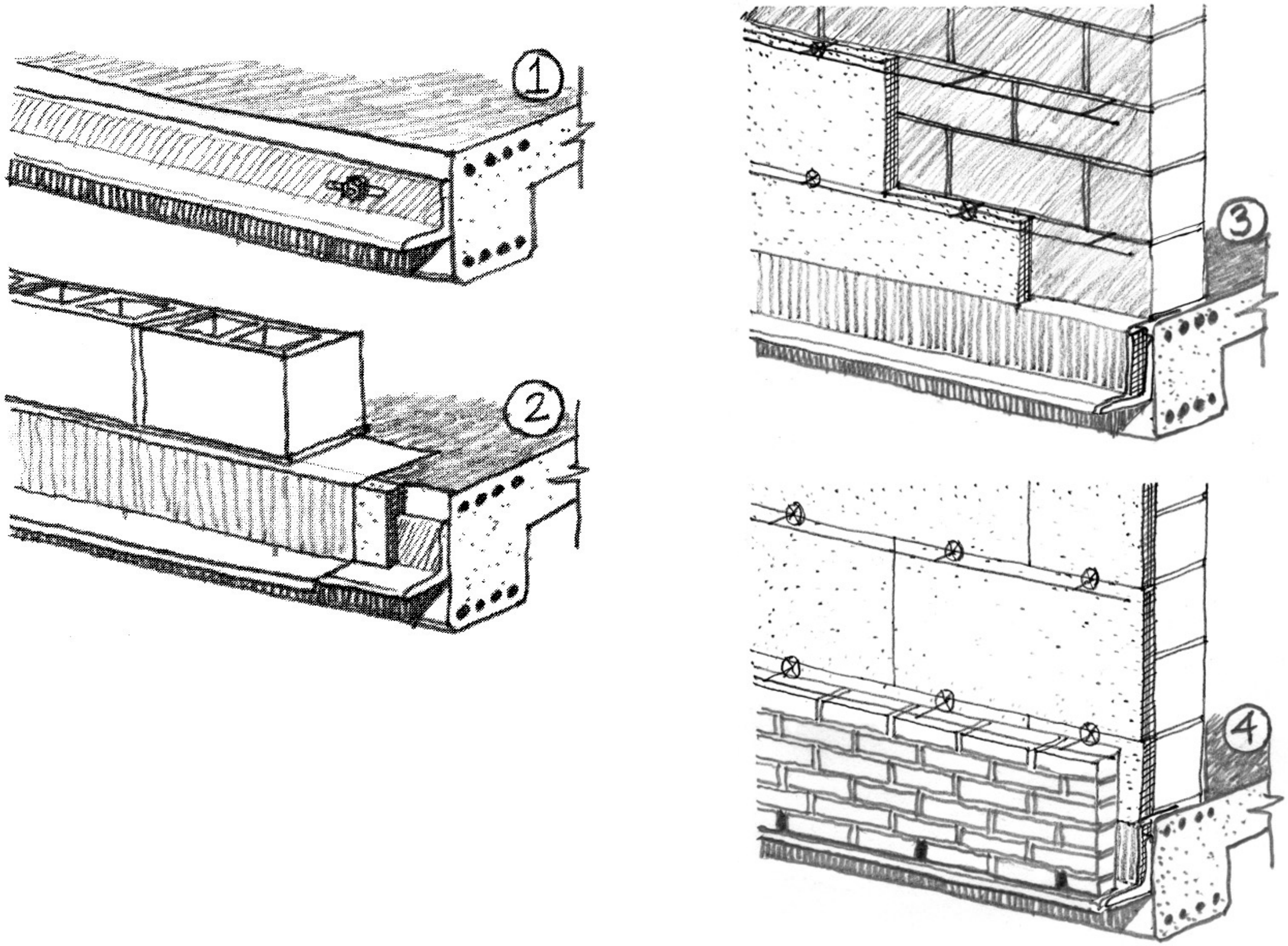
The Perfect Wall

Today walls need four principal control layers.
They are presented in order of importance:

1 a rain control layer (also may be uv control layer)
2 an air control layer
3 a vapor and/or water control layer
4 a thermal control layer

Joseph Lstiburek, Ph.D., P.Eng.
Building Science Corporation
http://www.buildingscience.com/documents/insights/bsi-001-the-perfect-wall


AS THE BRICK VENEER IS BEING LAID UP THE MORTAR DROPS INTO THE CAVITY BETWEEN THE BRICK AND THE BLOCK WHICH CLOGS THE WEEPS. THERE IS NO WAY TO INSURE THAT THE WEEPS ARE OPERATING
THE CEMENT PARGE COAT IS RARELY UNIFORM AND WATERTIGHT. ITS INTEGRITY IS REPEATEDLY INTERRUPTED BY THE WALL TIES.
ELECTRICAL AND HVAC CHASES AT THE EDGE OF THE SLAB DISRUPT THE INTEGRITY OF THE FLASHING.
IF THE SHOE BRICK IS NOT PROPERLY SOAPED THE WEIGHT OF THE BRICK VENEER CAN TEAR THE FLASHING AGAINST THE ANGLE BOLTS.
THE FLASHING LAP IS OFTEN FOUND TO BE A WEAK SPOT IN THE WATERPROOFING INTEGRITY
ROUGH SPOTS ON THE SLAB OR THE UNDERSIDE OF THE BLOCK CAN PENETRATE THE FLASHING.
IF THE EDGE OF THE SLAB IS NOT TRUE IT MUST BE CUT BACK OR THE ANGLE MUST BE SHIMMED.
THE TOE OF THE ANGLE IS VULNERABLE TO WATER
THE LIP OF THE SHOE BRICK IS VULNERABLE TO BREAKAGE FROM FROZEN WATER TRAPPED BEHIND.
1. MAINTAIN A CONSTANT DIMENSION BETWEEN THE FACE OF BRICK AND THE TOE OF ANGLE FOR THE PROPER CAULKING JOINT.
2. MAINTAIN A CONSTANT BEARING OF THE BRICK WYTHE ON THE ANGLE.
3. PREVENT THE WEIGHT OF THE BRICK FROM ONE FLOOR TO TRANSFER TO THE MASONRY BELOW (THIS CONDITION CAN HAPPEN THROUGH EXCESS SHIMMING OF THE ANGLE.)
PROBLEMS OF CAVITY WALL CONSTRUCTION



Source: *Architectural Detailing; Function, Constructibility Aesthetics;*
Edward Allen and Patrick Rand, 2016

See **NCMA TEK 6-2B**, R-Values and U-Factors of Single Wythe Concrete Masonry Walls

Rebirth of Single Wythe Masonry

Evolving Technology Responds to Tighter Energy Codes

Brendan Quinn,
and Ed Weinmann, LEED Green Associate

Rise of Energy Codes Increased focus on energy efficient buildings has led to building envelope performance coming under scrutiny. Public awareness of the effects of greenhouse gas emissions (GHG) and climate change grew rapidly toward the end of the 20th Century. The first versions of the International Energy Conservation Code (IECC) and LEED were published in 2000. Canada's National Energy Code for Buildings 2011 replaced the original Model National Energy Code for Buildings from 1997. Each presented new ways of thinking about the role of the built environment, both its materials aspects and minimum performance expectations. Today, 39 states and Washington DC have adopted a version of the IECC from 2009, or later.

Table 2 – Summary of Mass Wall Min R-value or Max U-factor

2009 IECC		
Climate Zones	Rmin insulation	Umax assembly
1	NR	.580
2	5.7 ci[1]	.151
3	7.6 ci	.123
4	9.5 ci	.104
5	11.4 ci	.090
6	13.3 ci	.080
7	15.2 ci	.071

Exterior Face: Exposed — Interior Face: 1.5-inch Insulation[3]

Calculated Rci (U-factor)	Climate Zones: Rmin 1	Rmin 2	Rmin 3	Rmin 4	Rmin 5	Rmin 6	Rmin 7	Umax 1	Umax 2	Umax 3	Umax 4	Umax 5	Umax 6	Umax 7
7.5 (0.082)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	N	N
7.5 (0.079)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
7.5 (0.076)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
7.5 (0.073)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
7.5 (0.070)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
7.5 (0.075)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
7.5 (0.072)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	N
7.5 (0.070)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
7.5 (0.067)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
7.5 (0.065)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
7.5 (0.069)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
7.5 (0.067)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
7.5 (0.065)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
7.5 (0.063)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y
7.5 (0.061)	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	Y	Y

Exterior Face: Exposed — Interior Face: 2-inch Insulation[3]

Calculated Rci (U-factor)	Climate Zones: Rmin 1	Rmin 2	Rmin 3	Rmin 4	Rmin 5	Rmin 6	Rmin 7	Umax 1	Umax 2	Umax 3	Umax 4	Umax 5	Umax 6	Umax 7
10 (0.068)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.066)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.064)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.062)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.060)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.063)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.061)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.059)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.058)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.056)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.059)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.057)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.056)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.054)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y
10 (0.053)	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	Y	Y

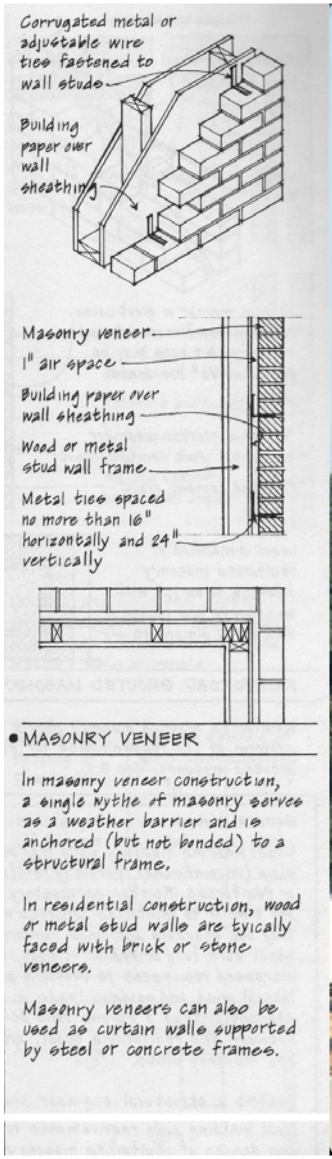
Source: *Dynamics of Masonry magazine*; Vol. 2, No. 4; 2014

Veneer

Typically over metal or wood stud substrate, perhaps within primary steel or concrete structural frame.

Masonry is **anchored** to the backup at frequent intervals.

generally @ 16” oc vert. and 32” oc horiz.



Governor's Residence
Raleigh, NC
Designed by Samuel Sloan and Gustavus Adolphus Bauer of Philadelphia
Built by 'the best workers' from the state penitentiary; brick made in prison
1891

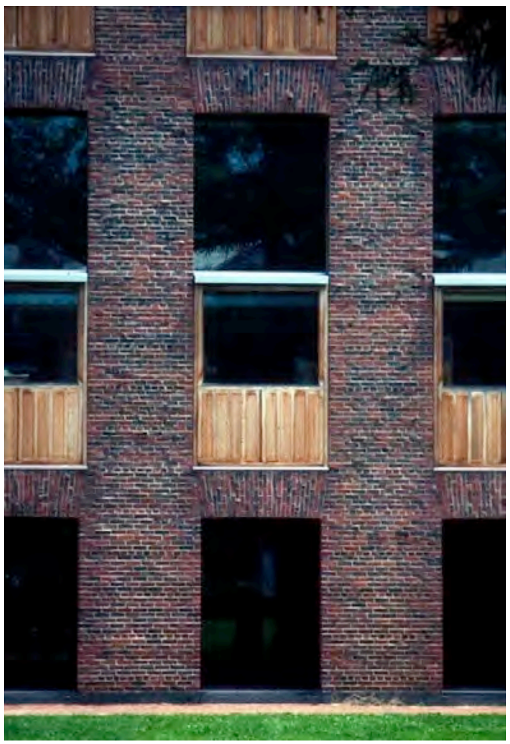
Modular: conforming to a multiple of a standard dimension

Nominal dimension (includes 1 mortar joint)
Actual dimension (unit dimensions only)

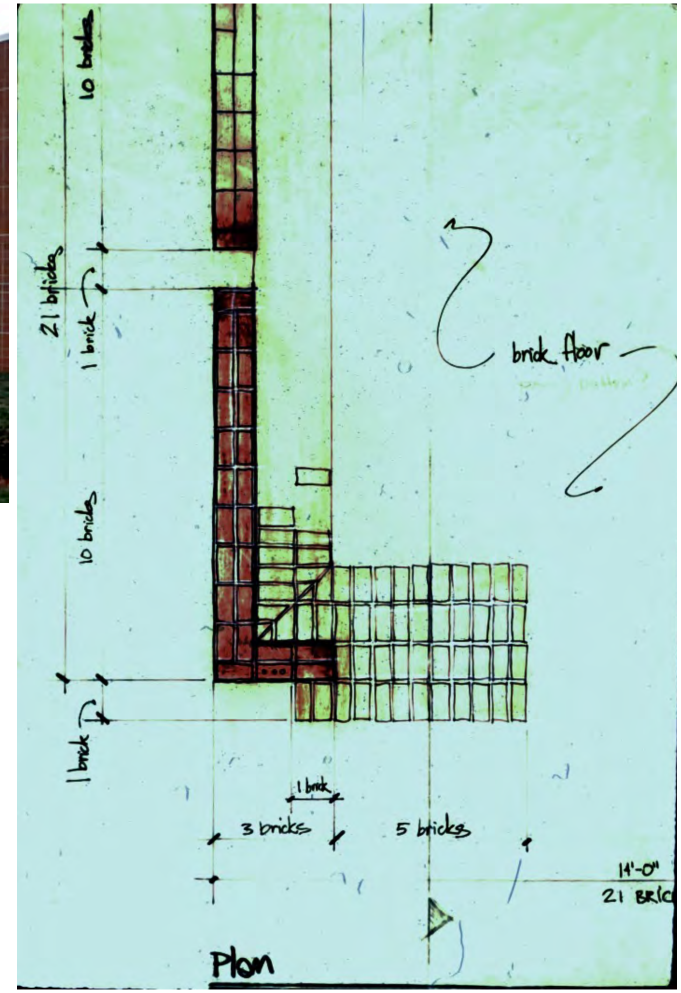
Nominal dimensions of a **modular brick**: **4 x 8 x 2 2/3 (2 5/8)**

Nominal dimensions of **normal concrete block**: **8 x 8 x 16**

NC Hospital Association Offices
Roger Cannon / O'Brien Atkins
Cary, NC



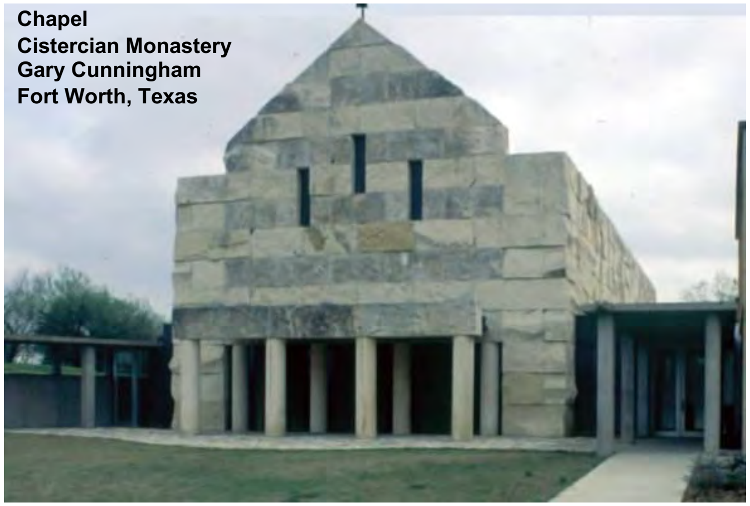
Exeter Academy Library
Louis Kahn
Exeter, NH
1971







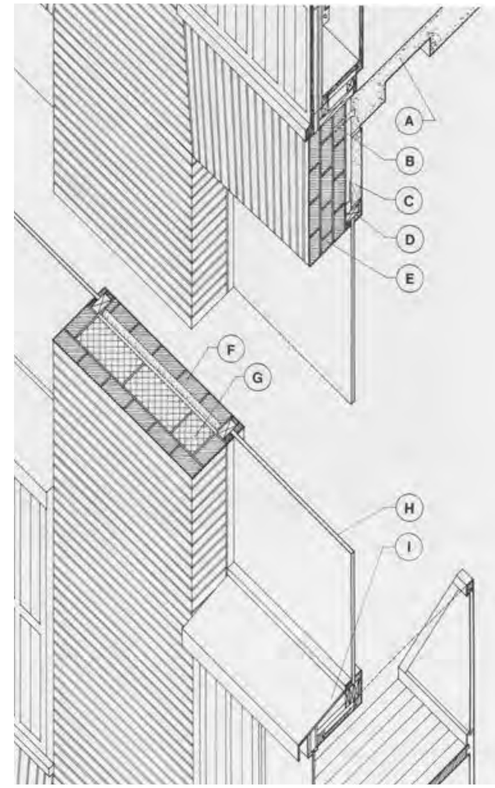




Chapel
Cistercian Monastery
Gary Cunningham
Fort Worth, Texas

openings in solid masonry walls
- lintel
- arch
- jack arch

Monticello
Thomas Jefferson
Virginia
1768-1809



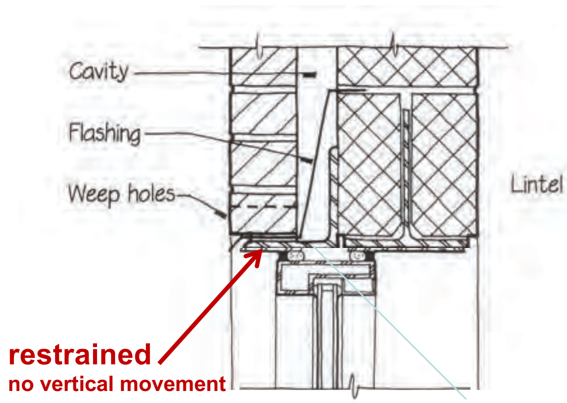
Exeter Library
Louis Kahn
Exeter, New Hampshire
1972

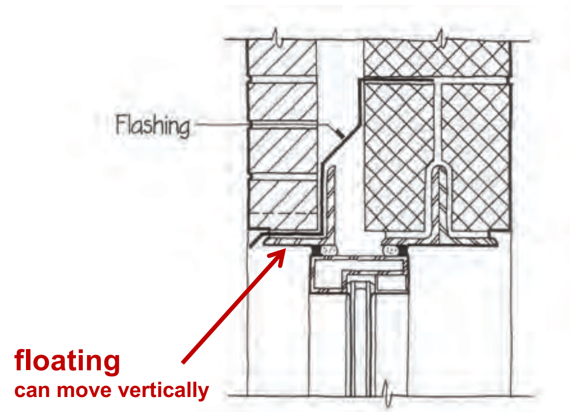
None of these rely on steel reinforcement

spanning openings in masonry walls:

- reinforced masonry
- precast concrete lintel
- cast in place concrete lintel

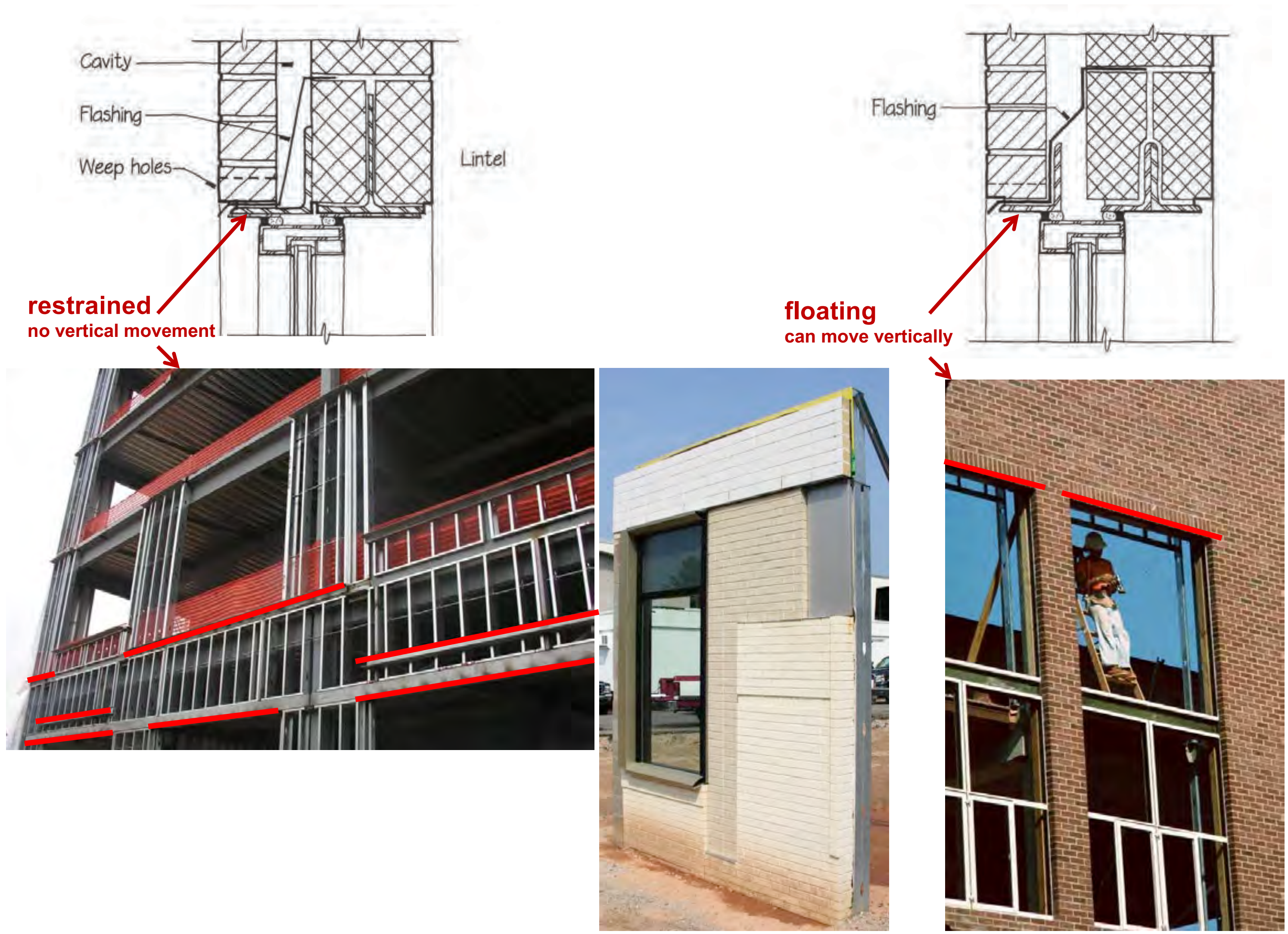
All rely on steel reinforcement



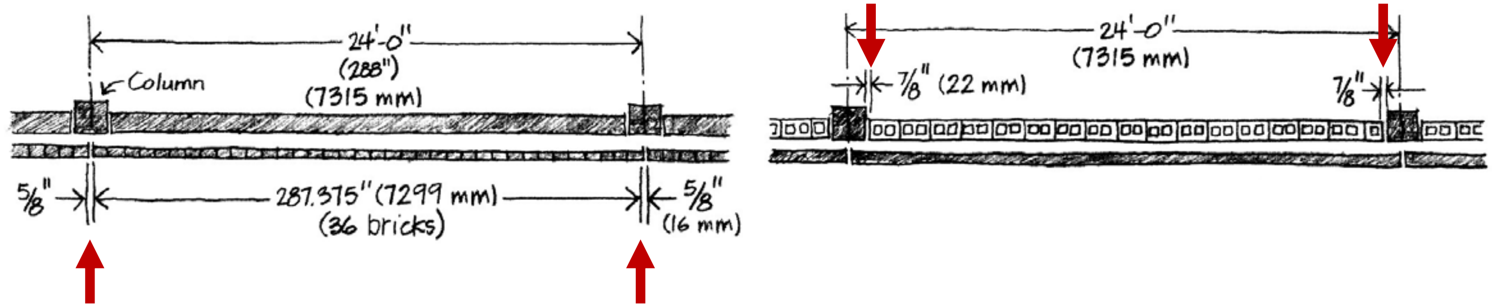


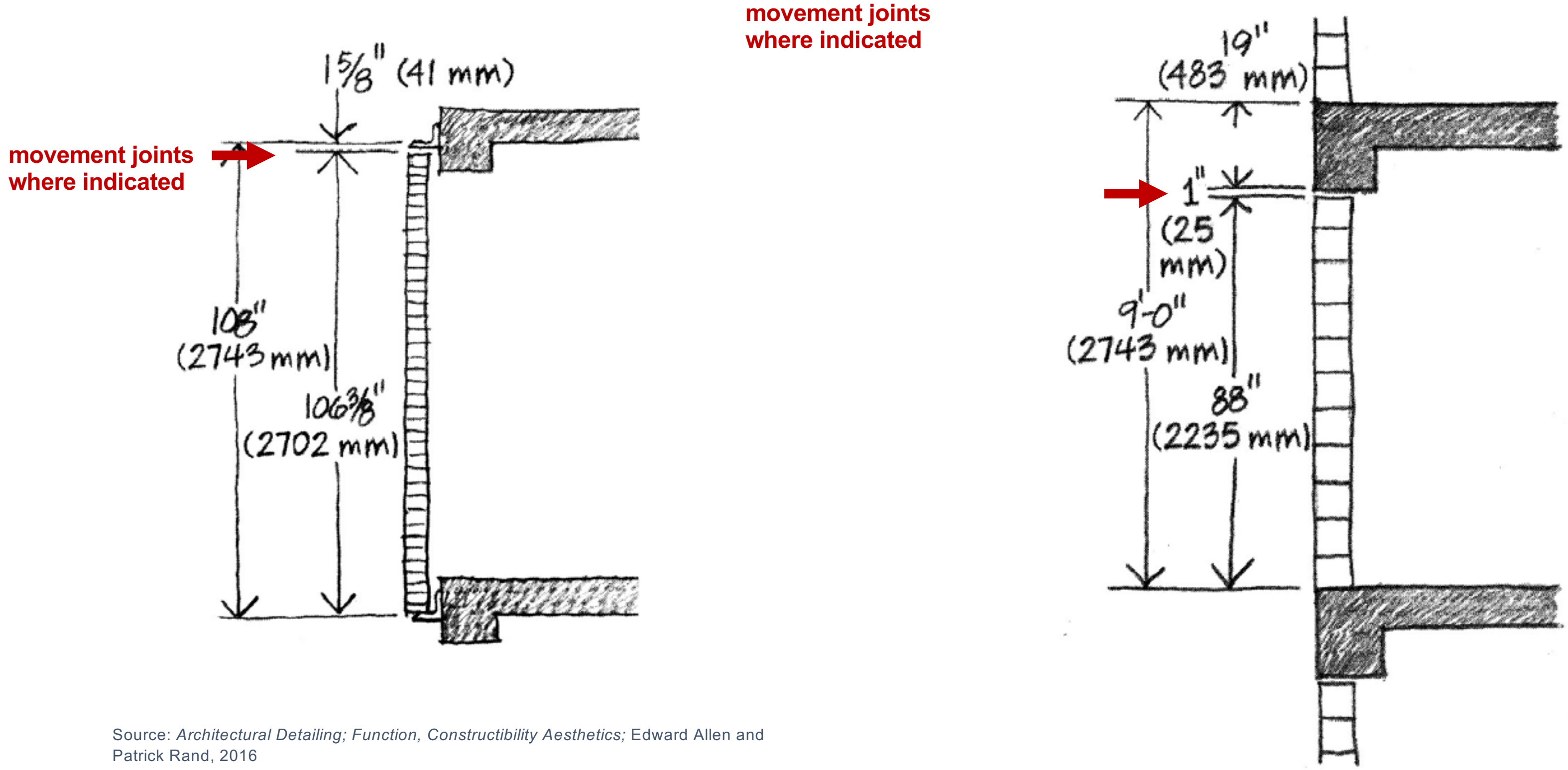
openings in masonry loadbearing and non-loadbearing wythes

- **steel lintel**
- **<u>restrained</u> shelf angle; fastened to backup, no vertical movement**
- **<u>floating</u> shelf angle; rests on veneer around opening, can move vertically**


Cavity
Flashing
Weep holes
Lintel
restrained
no vertical movement
Flashing
floating
can move vertically

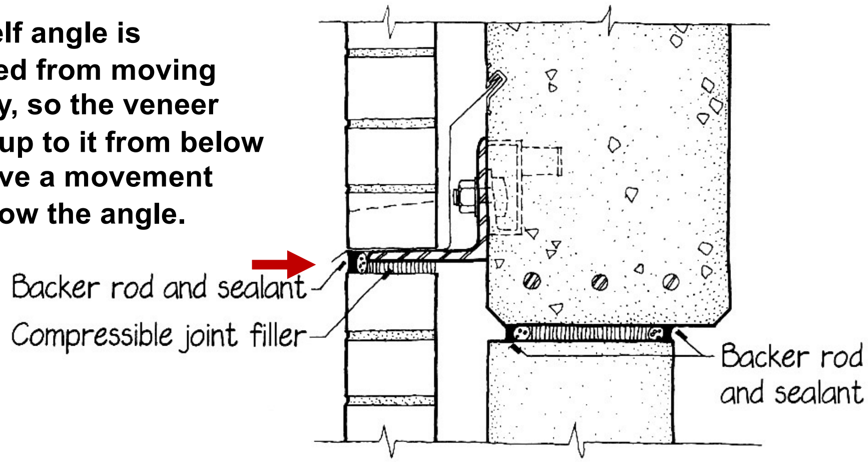
Non-loadbearing masonry wythes firmly bear at their bottom edges, but are **not** restrained on the sides or top.



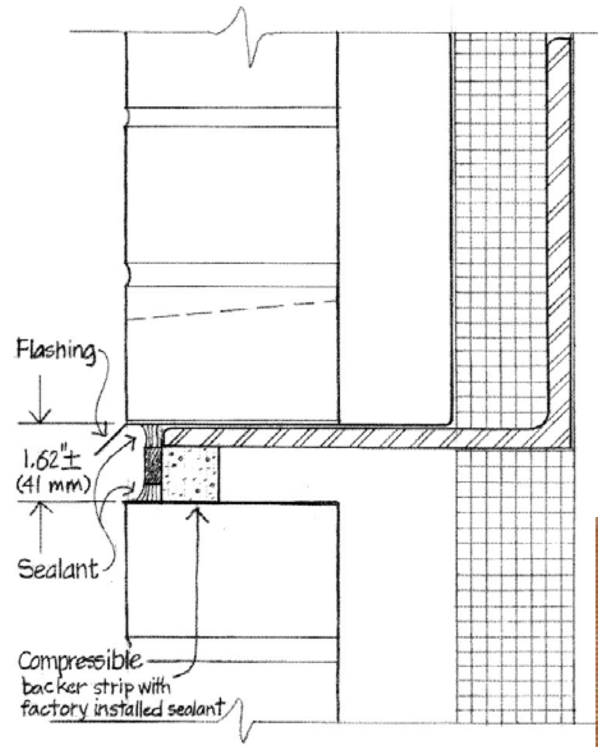


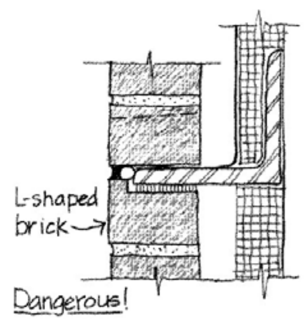
Source: *Architectural Detailing; Function, Constructibility Aesthetics;* Edward Allen and Patrick Rand, 2016

This shelf angle is restrained from moving vertically, so the veneer coming up to it from below must have a movement joint below the angle.

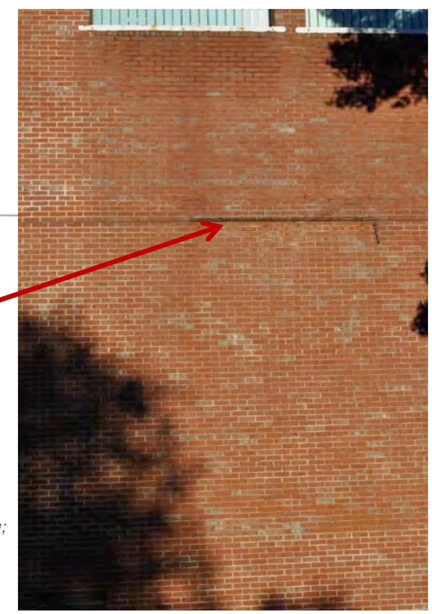


continuous shelf angles and movement joints





Source: *Architectural Detailing; Function, Constructibility Aesthetics;* Edward Allen and Patrick Rand, 2016



Causes of Movement in Building Materials and their Results

Cause	Result	Concrete	Concrete Masonry	Clay Masonry	Stone	Wood	Steel	Polymers
Temperature Change	Expansion / Contraction	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Moisture Content Change	Expansion / Contraction	Yes	Yes	Yes	Yes	Yes	No	Yes
Initial Moisture Absorption	Permanent Expansion	No	No	Yes	No	No	No	No
Water Freezing (phase change)	Expansion	Yes	Yes	Yes	Yes	No	No	Yes
Cement Hydration / Carbonation	Permanent Shrinkage	Yes	Yes	No	No	No	No	No
Load Application	Elastic Deformation	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sustained Load	Creep / Contraction	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: *Architectural Detailing; Function, Constructibility Aesthetics;* Edward Allen and Patrick Rand, 2016

(vertical joints accommodate horizontal movement)

Vertical Movement Joints				
Item	Size	Location		
		Corners	Typ. Spacing	Special
Exterior Stone Masonry	1/4"	at corner, or within 4' one side & 8' - 12' other side	20' - 25'	stress raisers
Exterior Clay Masonry	1/2"	"	20' – 25'	"
Exterior Concrete Masonry	3/8"	"	20' – 25' 1 ½ : 1 L to H ratio	"
CMU Back-up and Partitions	3/8"	"	20' - 25'	"

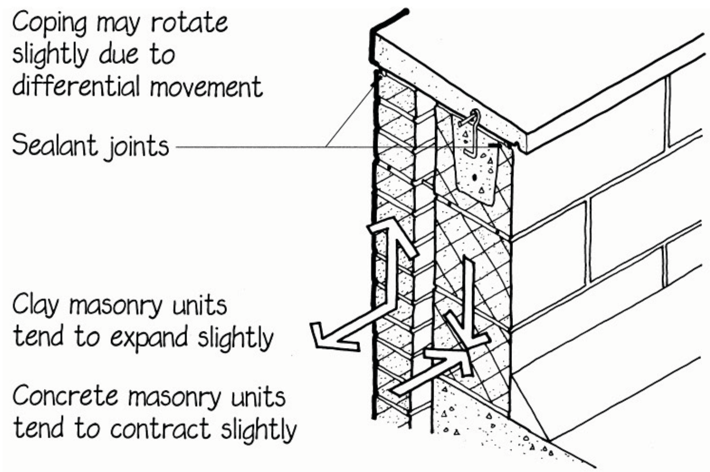
recommended:
$^3/_8$" – ½" joints @ < 25' oc

Notes:
1. Cut continuous horizontal joint reinforcement in movement joints.
2. Provide joints in shelf angles at movement joints in the exterior facing wythe.
3. Provide movement joints in concrete masonry back-up halfway between movement joints in clay masonry face.
4. Increase size or number of movement joints in parapets by 50 percent.

(horizontal joints accommodate vertical movement)

Horizontal Movement Joints **recommended @ each floor level**				
Item	Size	Location		
		Foundation	Intermediate Floor	Parapet
Clay Masonry	1/4" min. void	bond broken	void space & continuous structural support	bond broken & continuous support for all wythes
Stone & Concrete Masonry	1/8" min. void	bond broken	void space & continuous structural support	bond broken & continuous support for all wythes

Adapted from: "Minimum Requirements and Guidelines for the Exterior Building Envelope". Lynn Lauersdorf, Director, State of Wisconsin, Division of Facilities Development
ftp://doaftp1380.wi.gov/master_spec/Masonry/DOA4325P-Msnry%20Gdln.pdf



Joint width and spacing for brick cavity walls[1]

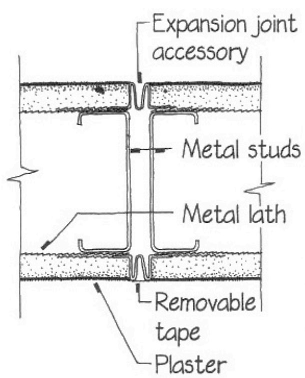
Anticipated expansion (△ L), inch	Joint width (2 △ L), inch	Joint spacing(L), feet
1/16	1/8	7
1/8	1/4	14
3/16	3/8	21
1/4	1/2	28

[1] Based on the amount of brick expansion caused by a 140° F temperature swing. Brick expansion is calculated by the formula:

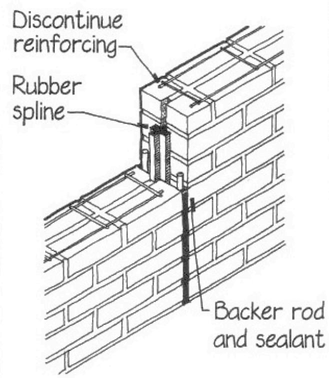
$$\triangle L = (0.0002 - 0.000004 \triangle T)\, L$$

recommended: 25' or less

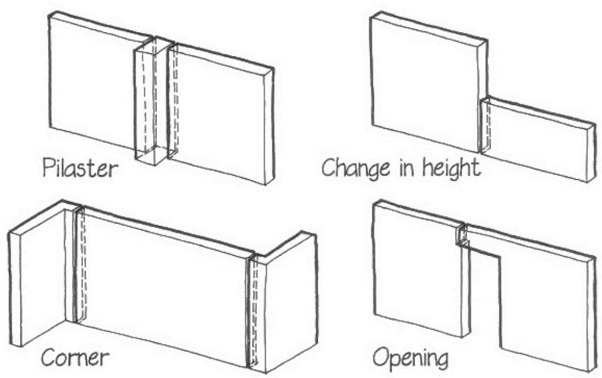
Expansion Joint



1. Expansion Joint in Plaster Wall



2. Expansion Joint in Brick Wall

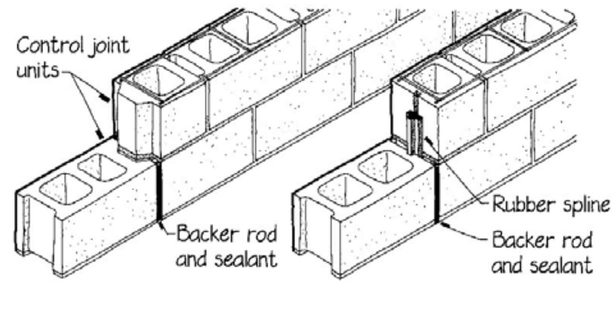


3. Locations for Expansion Joints in Masonry Walls

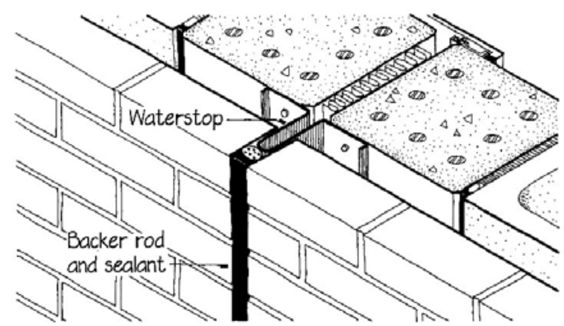
near but not at corner

TABLE 6-3: Recommended Control Joint Spacings for Various Materials

Material	Maximum Control Joint Spacing
Concrete slabs on grade	24 times slab thickness
Concrete exterior walls	20 ft (6.1 m)
Concrete masonry walls, joint reinforcing every second course	25 ft (7.6 m) or 1.5 times the height of the wall, whichever is less
Stucco walls	18 ft (5.5 m), 144 ft² in area (13.4 m²), or 2.5 times the height of the wall, whichever is less

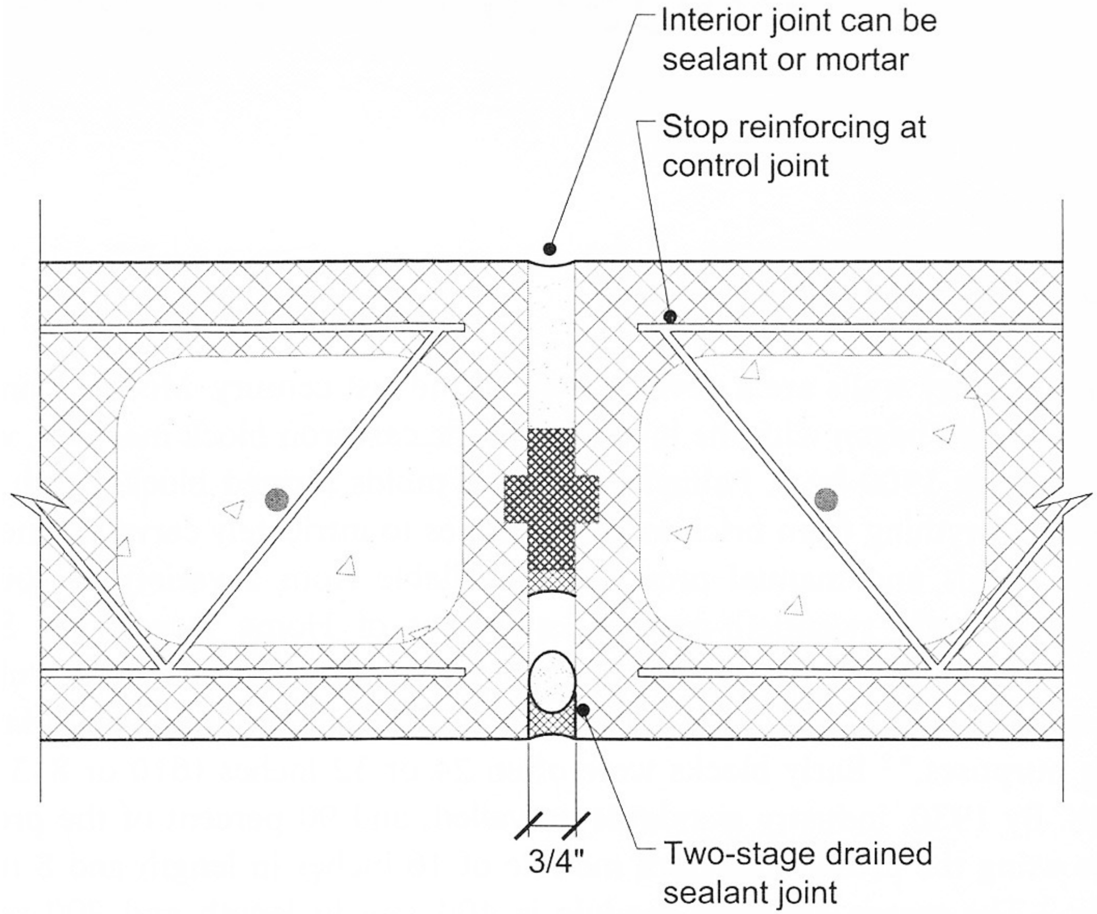


5. Control Joints in Concrete Masonry Walls



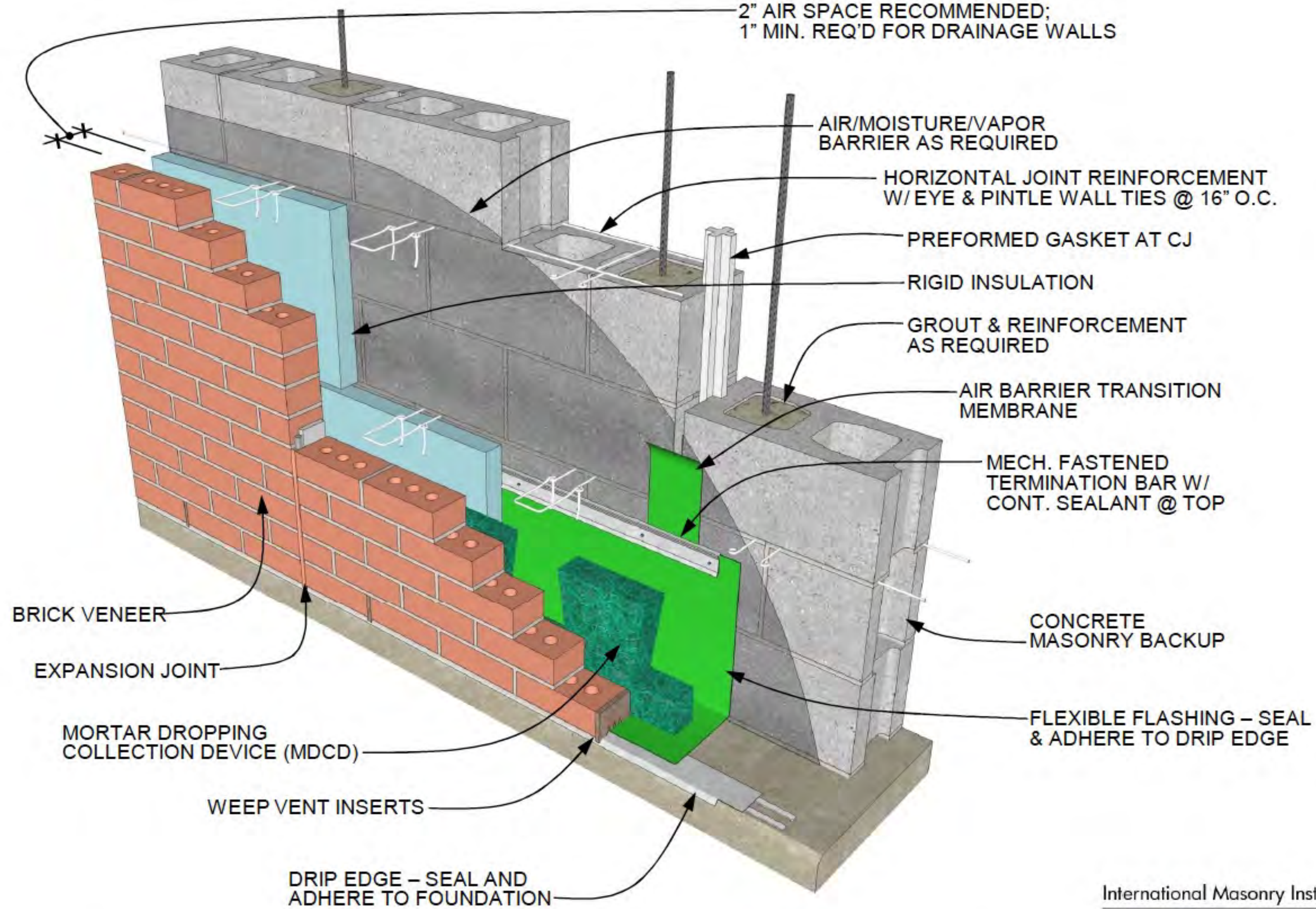
3. Building Separation Joint in Exterior Masonry Wall

Source: *Architectural Detailing; Function, Constructibility Aesthetics;* Edward Allen and Patrick Rand, 2016



Space joints to minimize uncontrolled cracking

Locate weep holes at the base of the joint.



BASE OF WALL DETAIL FLASHING, DRIP EDGE, TERM. BAR, MOVEMENT JOINTS

DETAIL 01.030.0302A

REV. 12/2/14

International Masonry Institute

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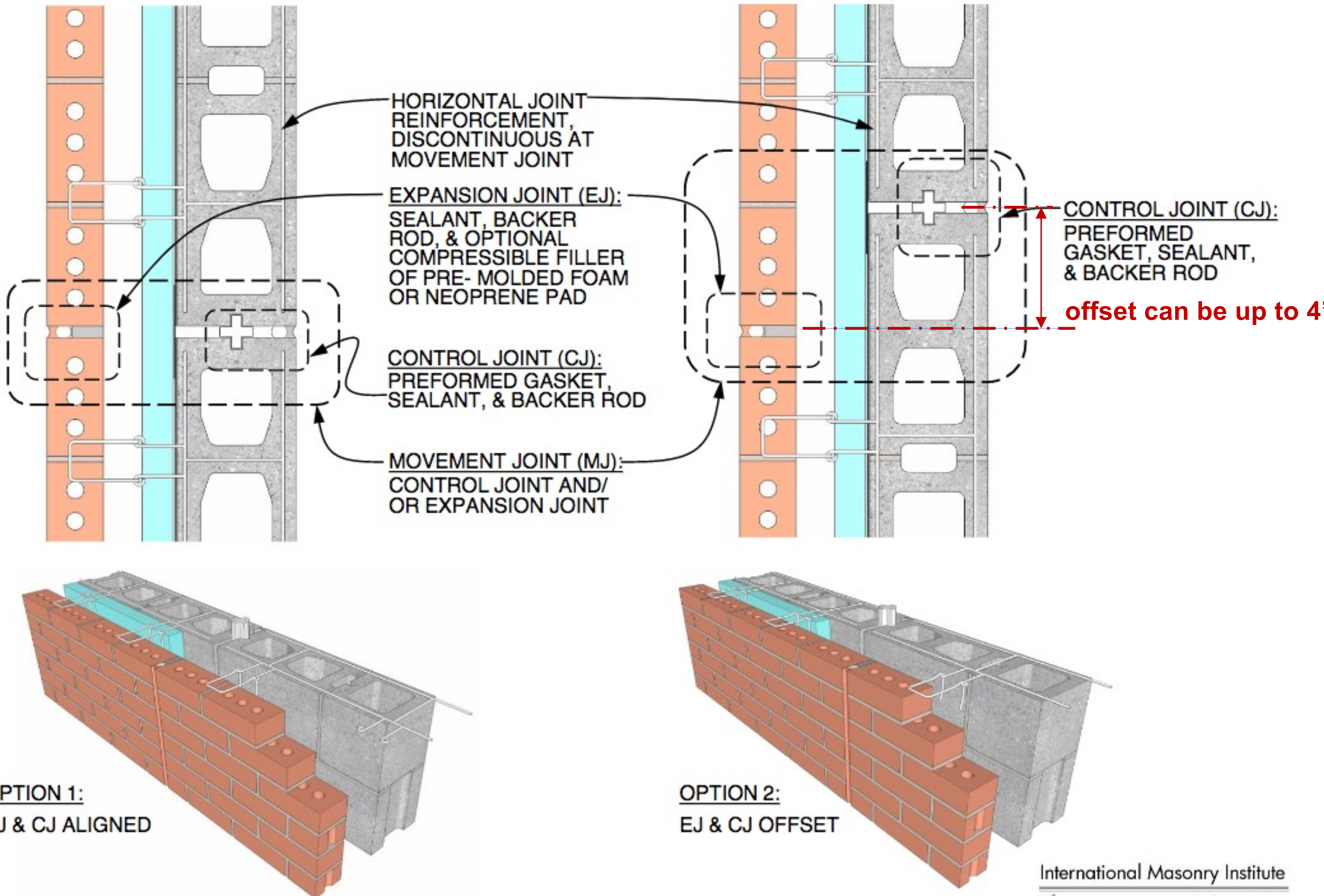
800-IMI-0988 www.imiweb.org



MOVEMENT JOINT

DETAIL 01.030.1301 REV. 03/14/11

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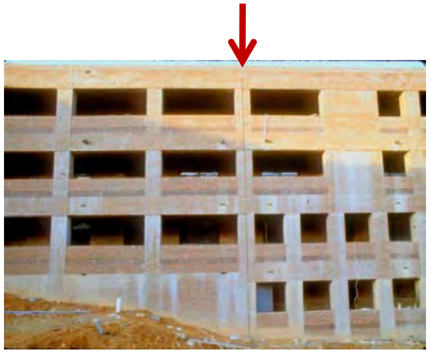
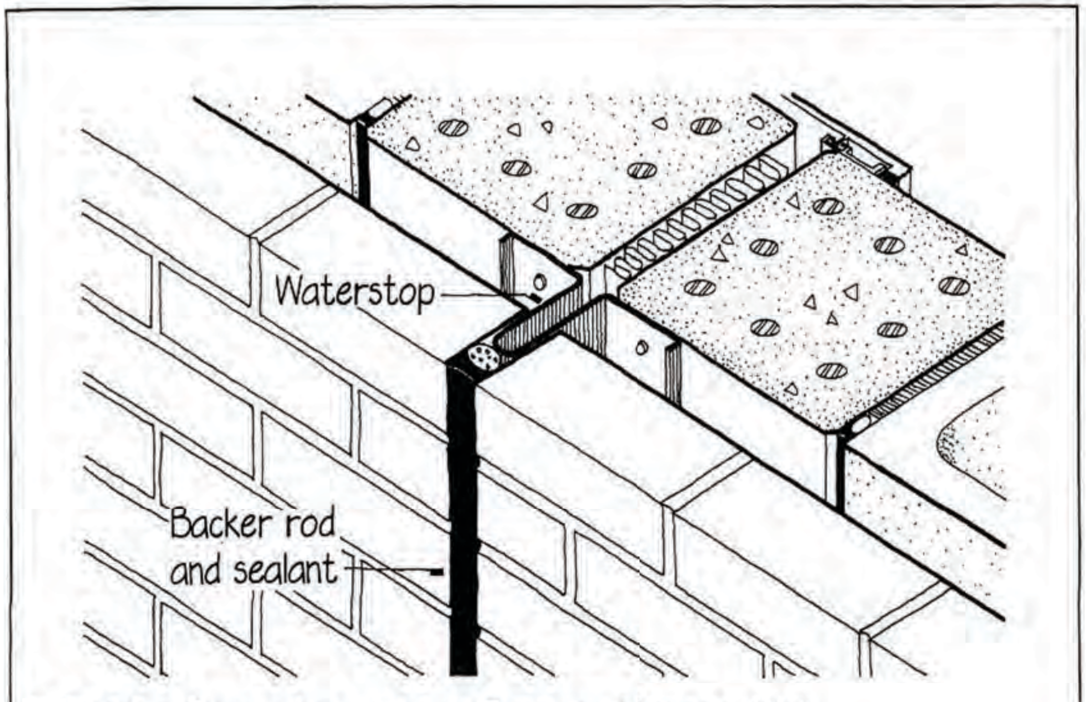




Building Separation Joint in Exterior Masonry Wall

In building separation joints, movement joints must align

discontinuous movement joints

Approximately 37’ 4” apart

Ransilla II Office Building
Mario Botta
Lugano, Switzerland

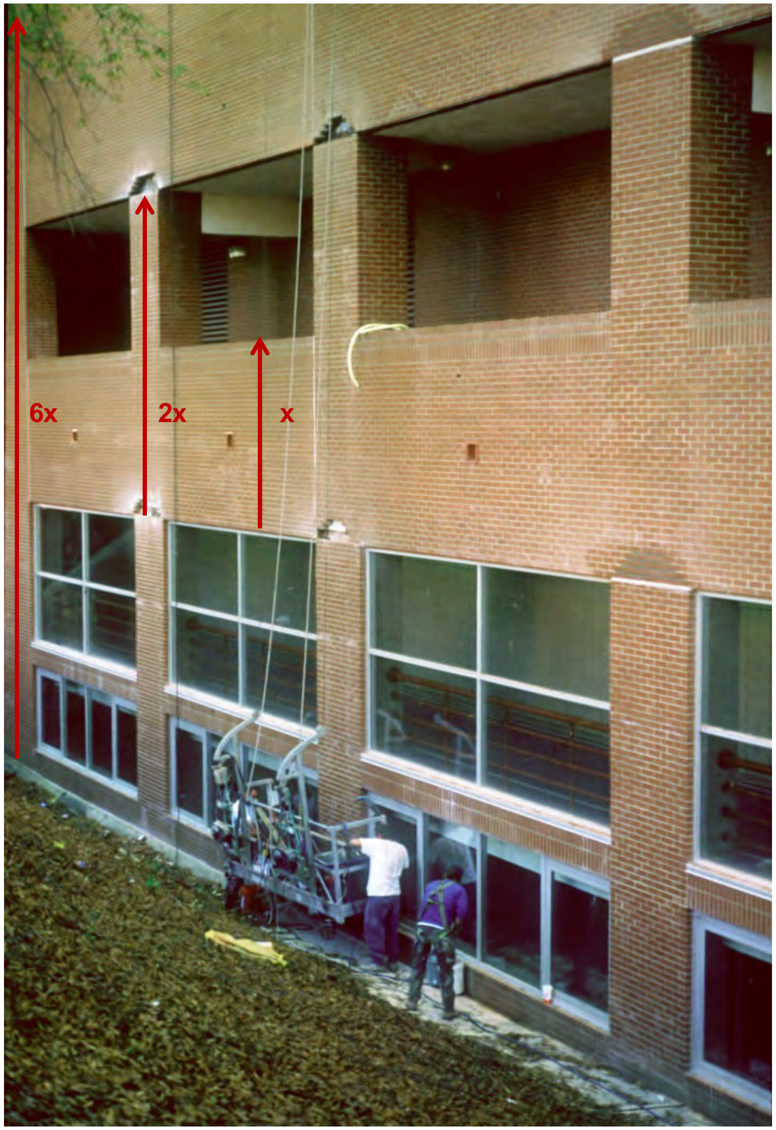
dark brick pavers, set in mortar,
undersized expansion joint

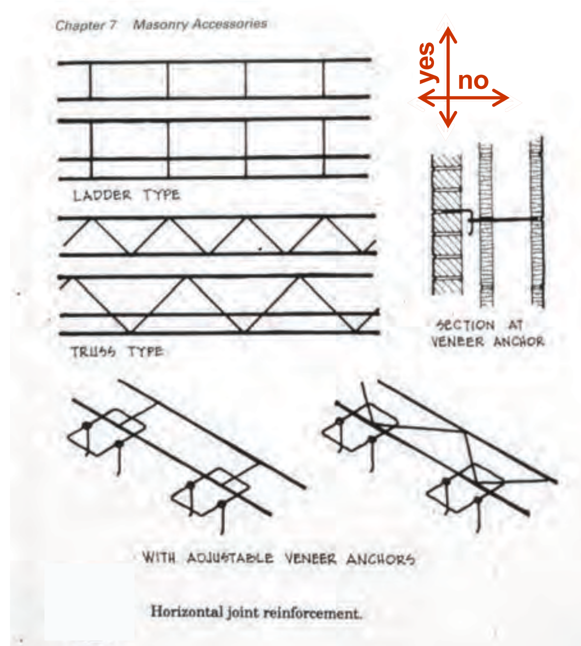
dark brick pavers, set in mortar,
no expansion joint

Horizontal movement joints in veneers should generally be at story height intervals vertically.

They should also be continuous across the elevation.

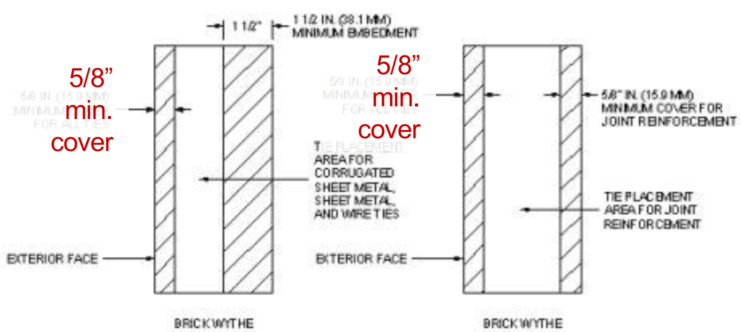
These shelf angles above the windows are **restrained**, not loose or floating. More movement joints are needed when angles are restrained.





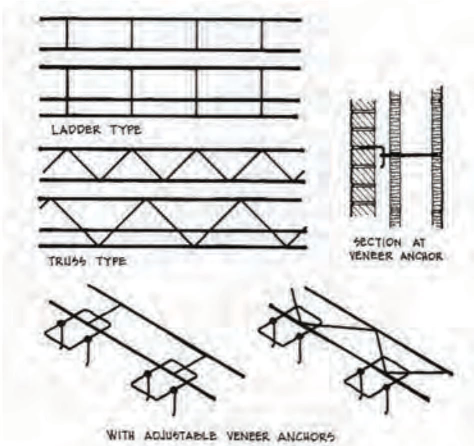
Horizontal joint reinforcement.

joint reinforcement
adjustable veneer anchors



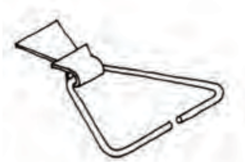
Veneers need a tie or anchor every 3.5 sf of veneer area.

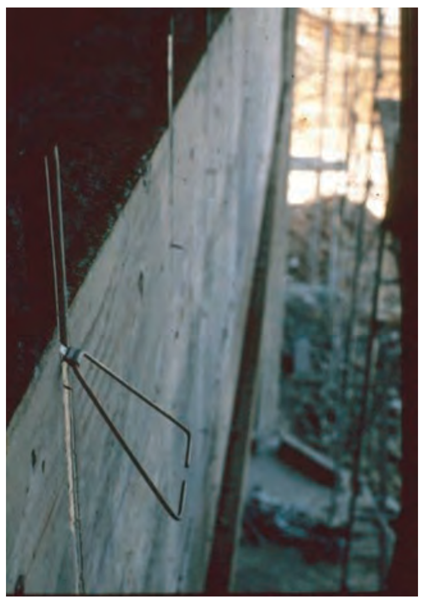
Recommended every 16" vertically and 32" horizontally.



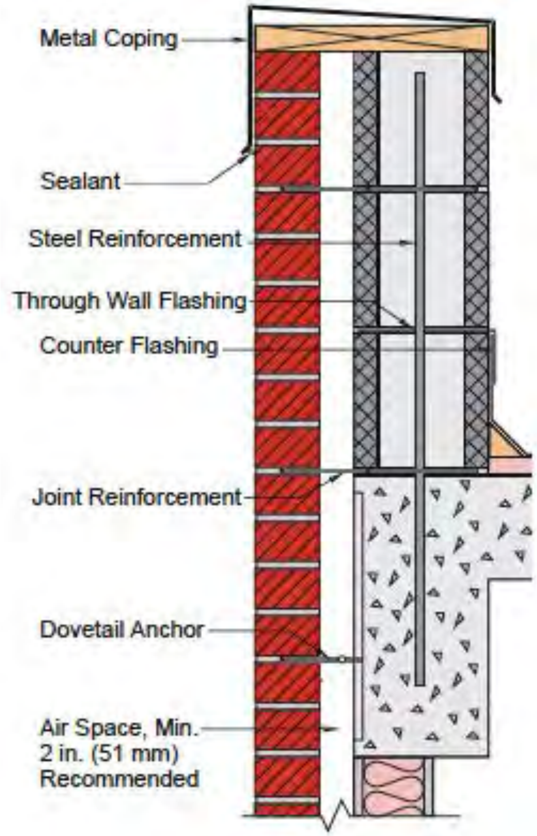
Wall configuration	*2-Wire ladder*	*2-Wire truss*	*3-wire ladder*	*3-wire truss*	*2-wire ladder or truss with adjustable ties*	*2-wire ladder or truss with fixed tab ties*	*2-wire ladder or truss with seismic ties*
Single-wythe CMU ▪ With vertical reinforcing steel	●						
Single-wythe CMU ▪ Without vertical reinforcing steel		●					
Multi-wythe ▪ Insulated Cavity ▪ Both wythes laid at same time ▪ Backing and facing wythes both CMU			●				
Multi-wythe ▪ Uninsulated cavity ▪ Both wythes laid at same time ▪ Backing and facing wythes both CMU			●	●			
Multi-wythe ▪ Wythes laid at different times ▪ Backing wythe CMU facing wythe clay masonry				●			
Multi-wythe ▪ Uninsulated cavity ▪ Both wythes laid at same time ▪ Backing wythe CMU facing wythe clay masonry		● **No!**				●	
Multi-wythe ▪ Both wythes laid at same time ▪ Backing and facing wythes both CMU ▪ Seismic performance Category C			●	●			
Multi-wythe ▪ Wythes laid at different times ▪ Backing wythe CMU facing wythe clay masonry ▪ Seismic performance Category C							●

Joint reinforcement selection guide. (*Adapted from Mario Catani, "Selecting the Right Joint Reinforcement for the Job,"* The Magazine of Masonry Construction, *January 1995.*)





dovetail anchor

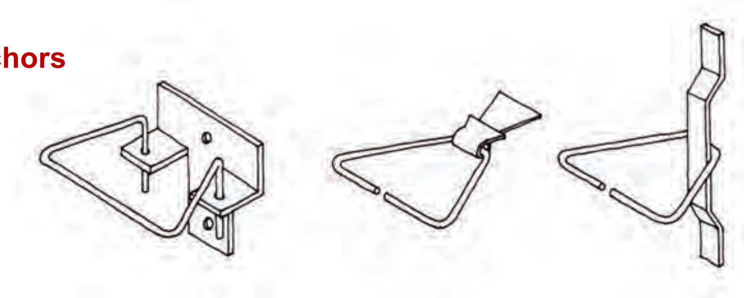


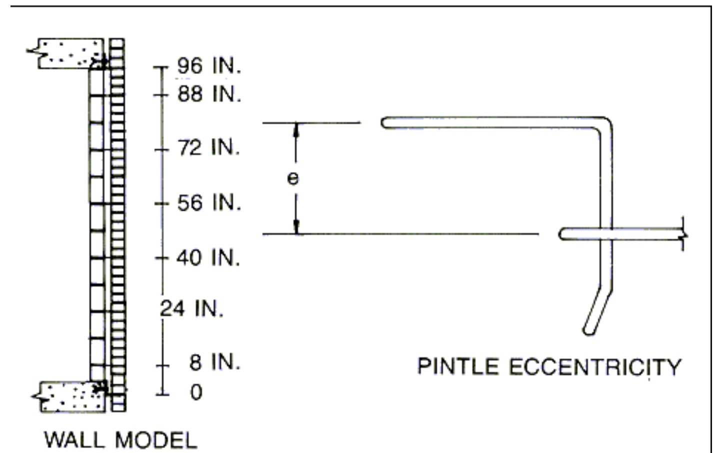
Masonry Parapet Wall

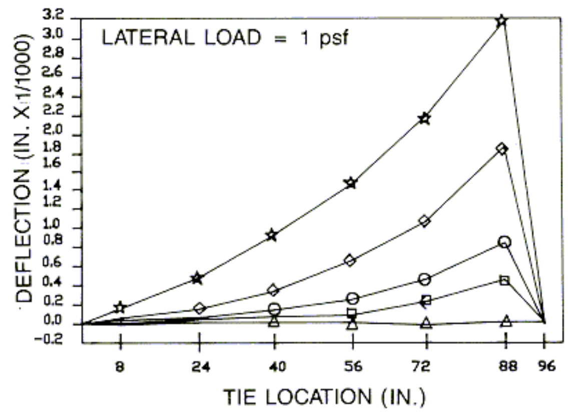
Veneers need a tie or anchor every 3.5 sf of veneer area.

Generally every 16" vertically and 32" horizontally.

adjustable anchors







△ = STANDARD

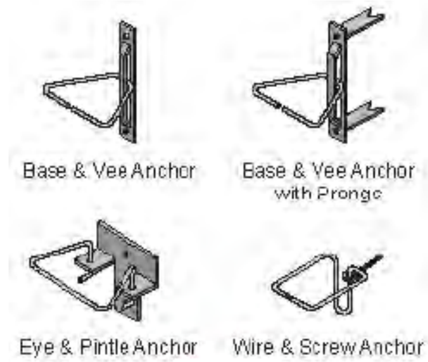
◇ = DOUBLE EYE AND PINTLE, e = 1 IN.

○ = SINGLE EYE AND PINTLE, e = 1/2 IN.

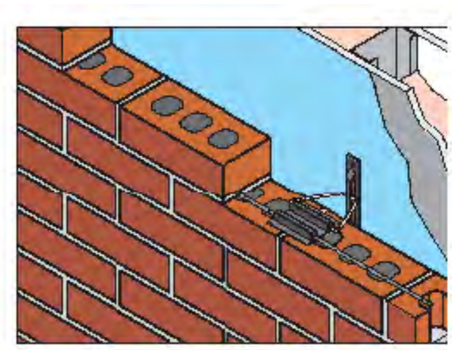
□ = DOUBLE EYE AND PINTLE, e = 1/2 IN.

☆ = SINGLE EYE AND PINTLE, e = 1 IN.

Tech Notes 44B - Wall Ties for Brick Masonry [Revised May 2003]

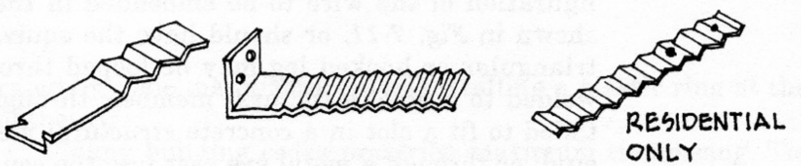


Adjustable Anchor Assemblies



anchors or ties

Seismic Anchor Assemblies



Corrugated anchors.

TABLE A LIFE EXPECTANCY OF GALVANIZED COATINGS (ADAPTED FROM AMERICAN GALVANIZERS ASSOC.)

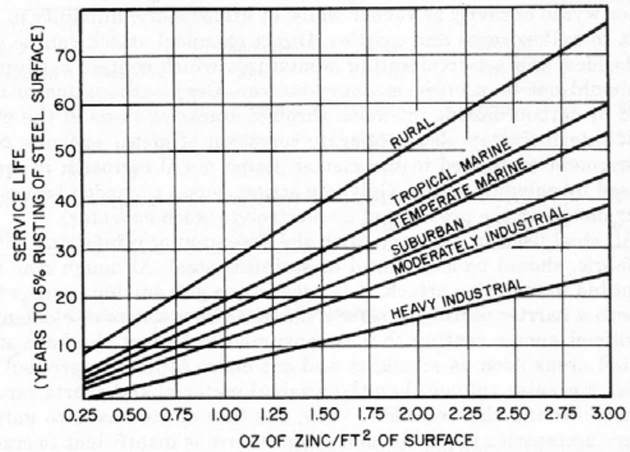


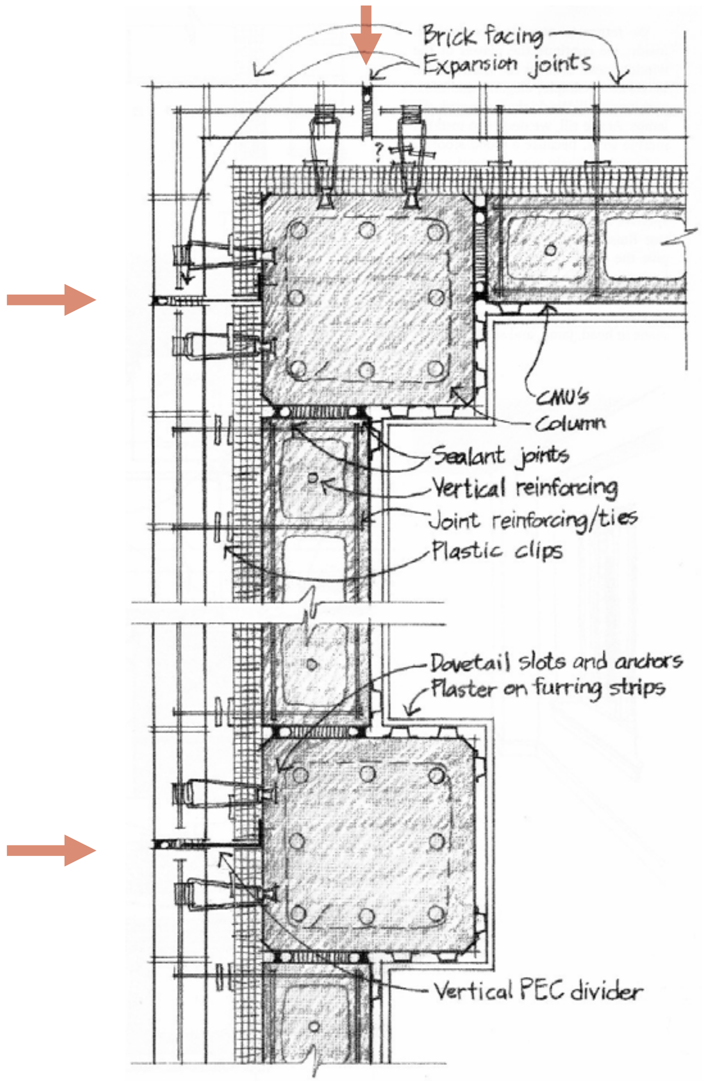
TABLE B LIFE EXPECTANCY OF GALVANIZED CAVITY WALL TIES* (ADAPTED FROM CLAYFORD T. GRIMM)

Probability of occurrence (%)	Corrosion rate (10^{-4} oz. zinc/sq ft/yr)	Life expectancy (yr)			
		ASTM A153, class B2		ASTM A153, class B1	
		Minimum	Average	Minimum	Average
5	2415	5.2	6.2	7.5	8.3
10	1791	7.0	8.4	10.1	11.2
20	1075	11.6	14.0	16.7	18.6
25	875	14.3	17.1	20.6	22.9
33	656	19.1	22.9	27.4	30.5
50	393	31.8	38.2	45.8	50.9

*Data taken in climatic areas with a driving rain index of 2.5 to 5.0 (see Chap. 9).

Life expectancy of galvanized coatings.

Masonry Design and Detailing for Architects, Engineers and Contractors; Christine Beall, 2003



Source: *Architectural Detailing; Function, Constructibility Aesthetics;* Edward Allen and Patrick Rand, 2007

Anchors or ties are installed at edges of veneer panels, and at greater frequency in stackbonded panels

Controlling Water Leakage / 3 Strategies

For water to penetrate through a building assembly three conditions must all occur *at the same time*.

There must be:

1. an **opening** through the assembly.
2. **water present** at the opening.
3. a **force** to move the water through the opening.

If any one of these three conditions is not met, water will not penetrate the assembly.

In designing any exterior detail, therefore, we can pursue one or more of three strategies.

We can try to:

1. **eliminate openings** in building assemblies.
2. **keep water away from openings** in building assemblies.
3. **neutralize forces that move water through openings** in bldg. assemblies.

Complete success in any one of these three strategies will result in the complete elimination of water leaks. But sometimes in detailing we pursue two of these strategies or even all three of them at the same time, because this gives added security in case one of them fails due to poor workmanship or building deterioration.

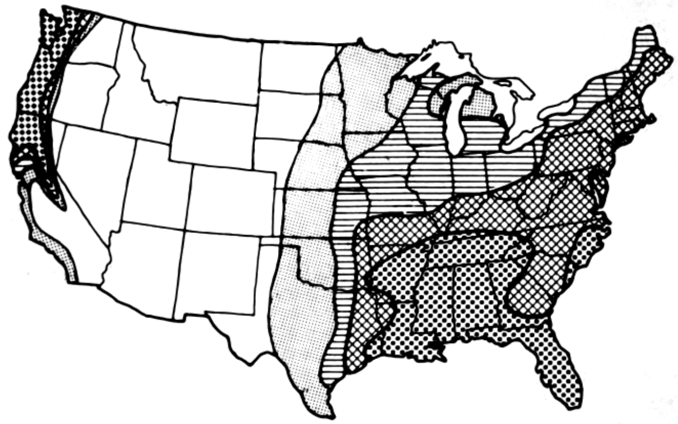
These strategies can be applied in any sequence, and in any combination.

Source: *Architectural Detailing; Function, Constructibility Aesthetics;* Edward Allen and Patrick Rand, 2016

Weep detail. College of Engineering, Portland State University, Portland, OR, ZGF Architects

Glass vestibule enclosure meets slate masonry wall. Alston Public Library, Alston, MA; Machado and Silvetti

Various materials come together at a window sill. Johnson Residence, Raleigh, NC; Jessica Johnson Arch.

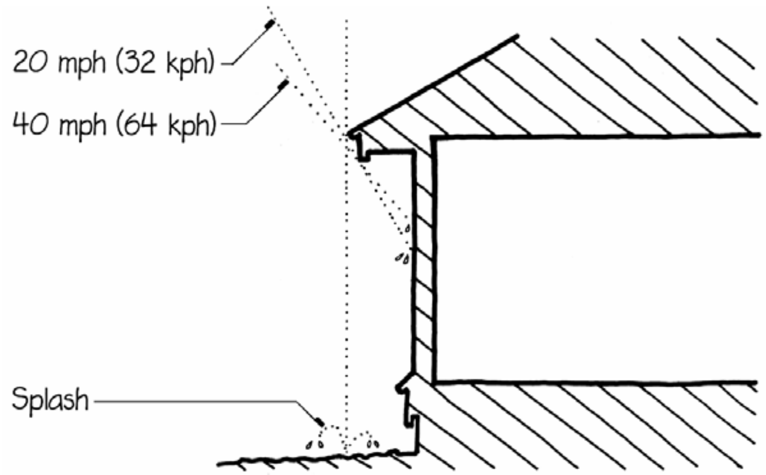


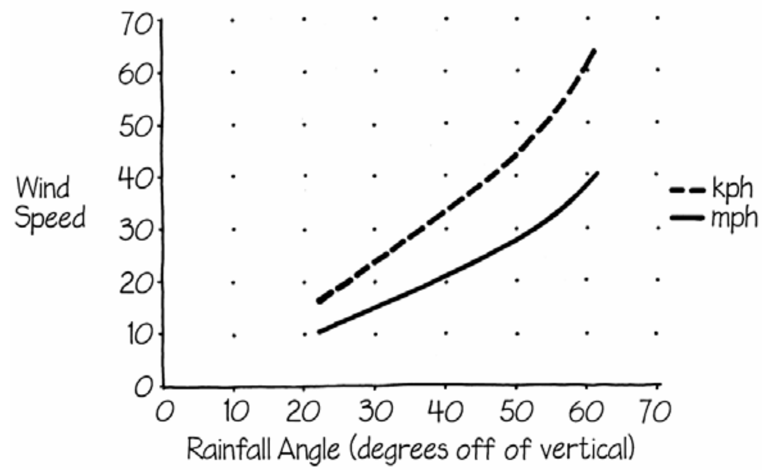
ANNUAL PRECIPITATION
(inches)
20 30 40 50 60+

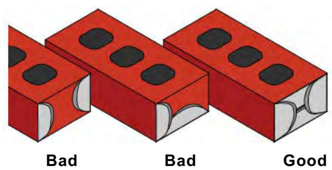
Driving Rain Index

WALL EXPOSURE TO WIND-DRIVEN RAIN*					
Driving rain index†		*Wall standing above surroundings*			
		Yes (unprotected)‡		*No (protected)‡*	
		Wall near facade edge§		*Wall near facade edge§*	
Greater than	*Less than*	*Yes*	*No*	*Yes*	*No*
0	1.5	Severe	Moderate	Sheltered	Sheltered
1.5	3.0	Severe	Moderate	Moderate	Sheltered
3.0	5.0	Severe	Severe	Severe	Moderate
5.0	—	Severe	Severe	Severe	Severe

TABLE A GRADE REQUIREMENTS FOR FACE EXPOSURES			
	Weathering index		
Exposure	*Less than 50*	*50 to 500*	*500 and greater*
In vertical surfaces			
In contact with earth	MW	SW	SW
Not in contact with earth	MW	SW	SW
In other than vertical surfaces			
In contact with earth	SW	SW	SW
Not in contact with earth	MW	SW	SW



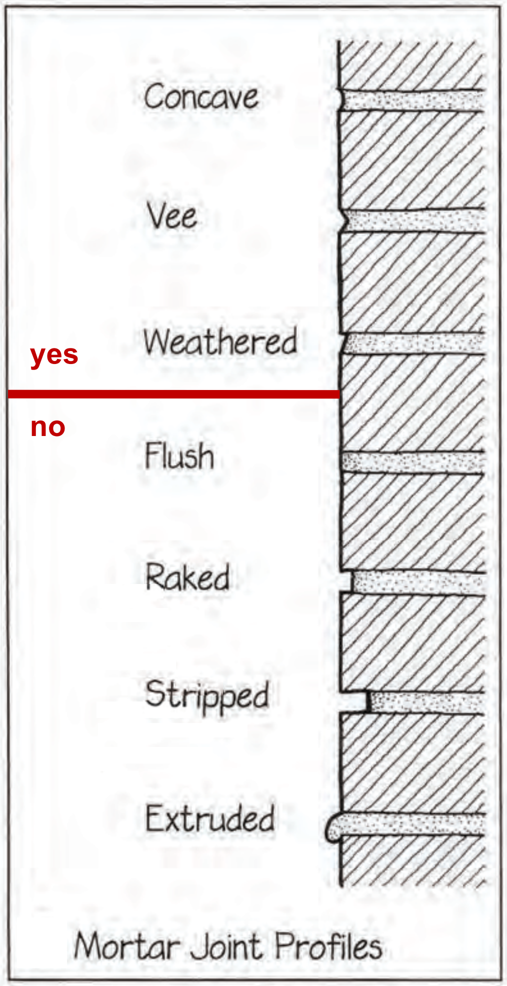


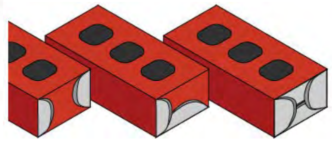


Head Joints
(BIA Technote 7b)

Source: *Architectural Detailing; Function, Constructibility Aesthetics;* Edward Allen and Patrick Rand, 2016

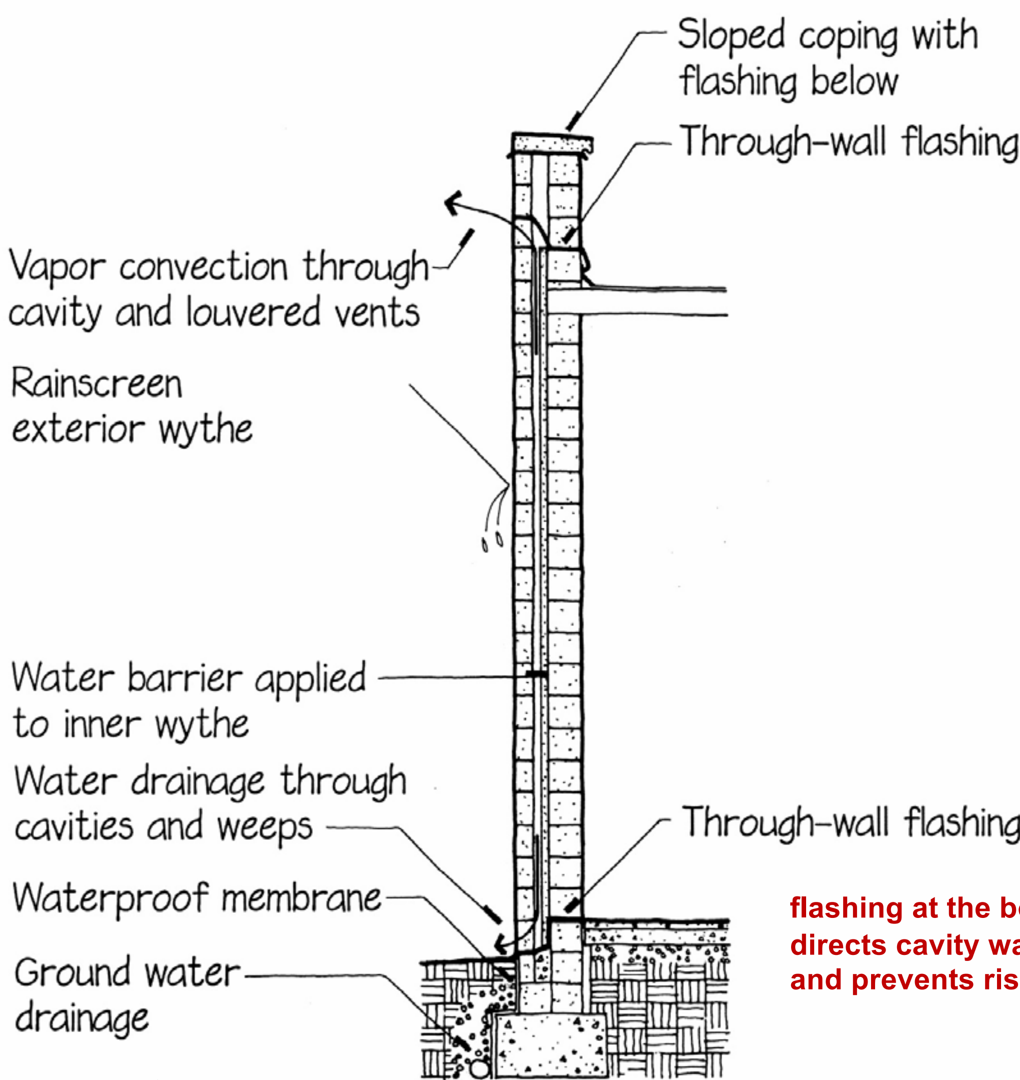
Less Absorbent Materials





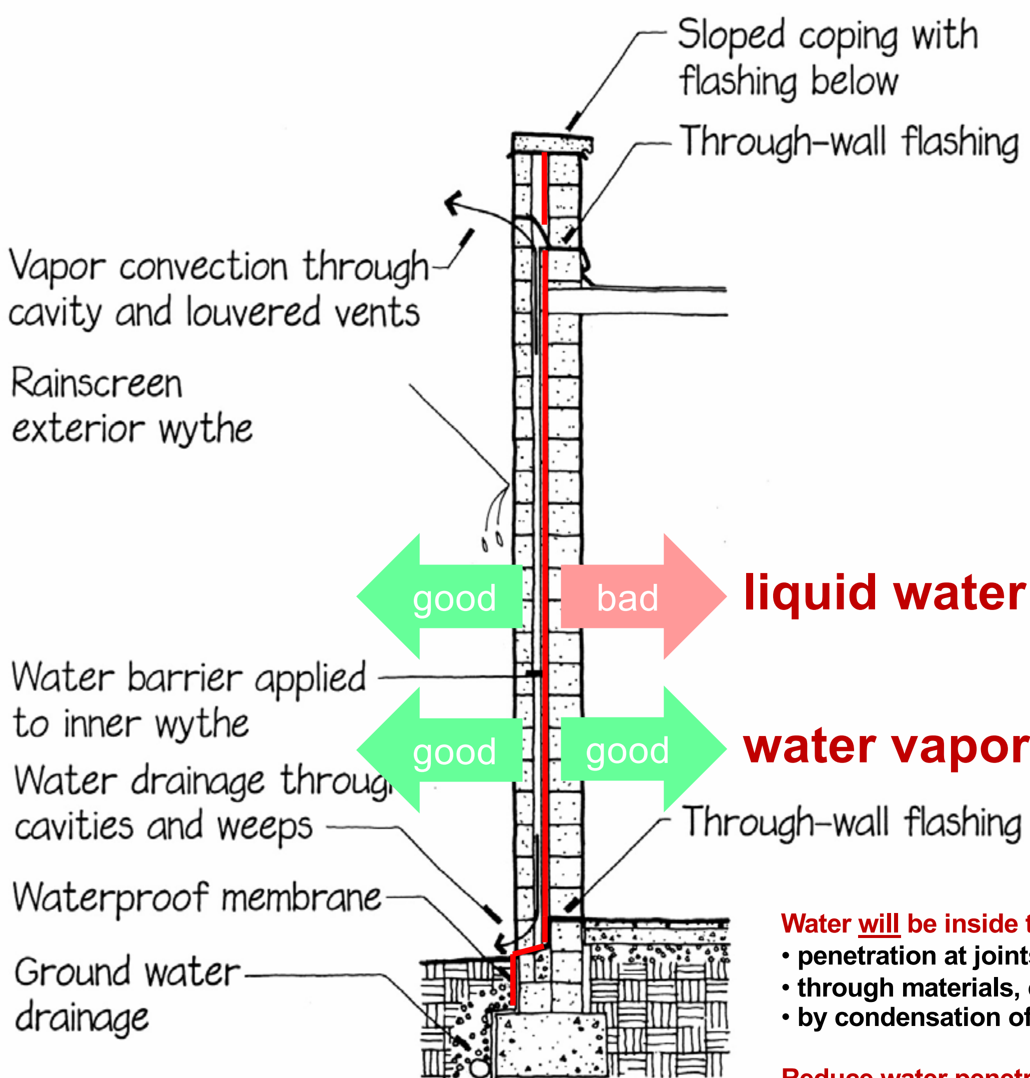
Head Joints
(BIA Technote 7b)

weeps @ 33” oc or less (per IBC)



flashing at the bottom directs cavity water out and prevents rising damp

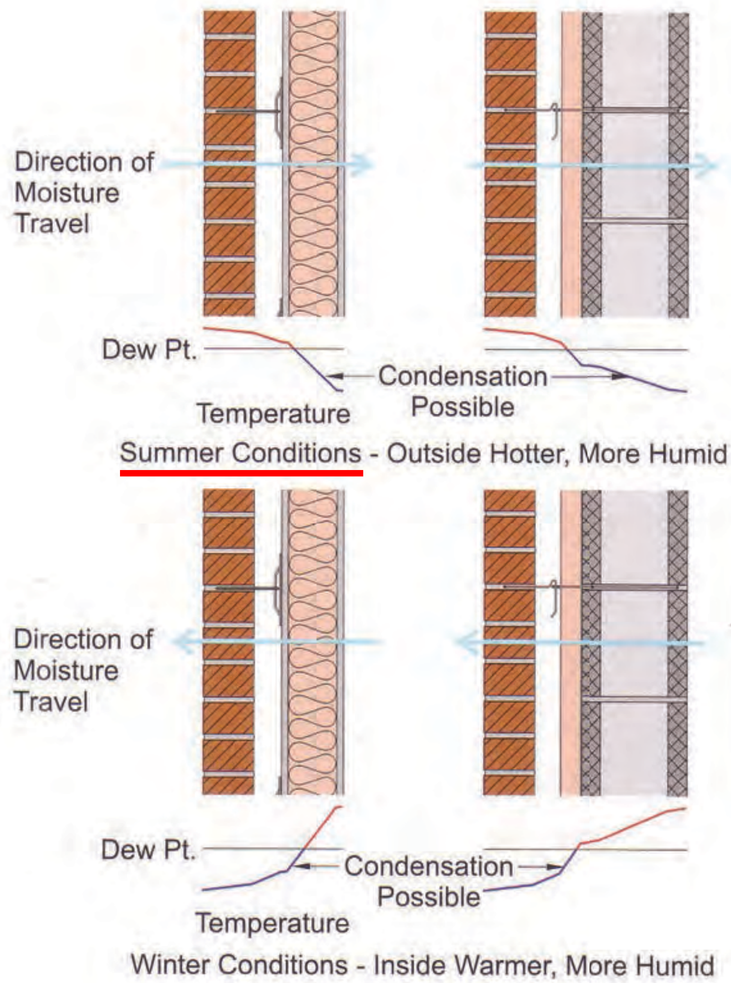
Source: *Architectural Detailing; Function, Constructibility Aesthetics;* Edward Allen and Patrick Rand, 2016



Source: *Architectural Detailing; Function, Constructibility Aesthetics;* Edward Allen and Patrick Rand, 2016

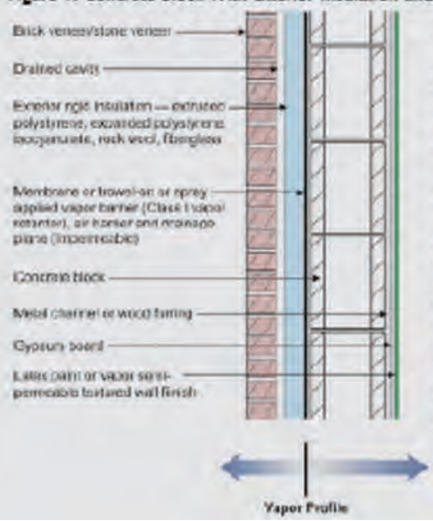
Water will be inside the wall assembly:
- **penetration at joints,**
- **through materials, especially mortar**
- **by condensation of vapor**

Reduce water penetration
Prevent water from reaching interior



Possible Locations of Condensation

Figure 1: Concrete Block With Exterior Insulation and Brick or Stone Veneer



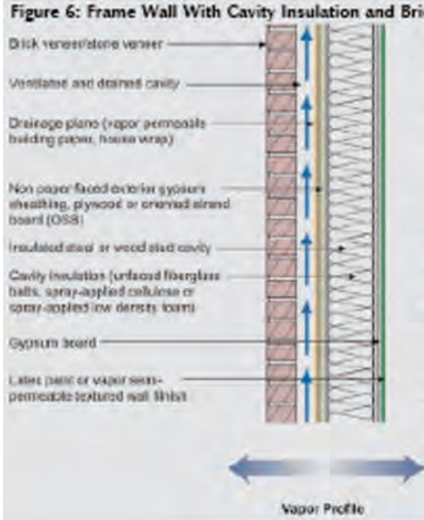
Applicability – all hygro-thermal regions

This is arguably the most durable wall assembly available to architects and engineers. It is constructed from non-water sensitive materials and due to the block construction has a large moisture storage (or hygric buffer) capacity.

It can be constructed virtually anywhere. In cold climates condensation is limited on the interior side of the vapor barrier as a result of installing all of the thermal insulation on the exterior side of the vapor barrier (which is also the drainage plane and air barrier in this assembly).

In hot climates any moisture that condenses on the exterior side of the vapor barrier will be drained to the exterior since the vapor barrier is also a drainage plane. This wall assembly will dry from the vapor barrier inwards and will dry from the vapor barrier outwards.

Figure 6: Frame Wall With Cavity Insulation and Brick or Stone Veneer



Applicability – Limited to mixed-humid, hot-humid, mixed-dry, hot-dry and marine regions – can be used with hygro-thermal analysis in some areas in cold regions; should not be used in very cold and subarctic/arctic regions

This wall is a flow through assembly – it can dry to both the exterior and the interior. It has a Class III vapor retarder on the interior of the assembly (the latex paint on the gypsum board). It is critical in this wall assembly that the exterior brick veneer (a “reservoir” cladding) be uncoupled from the wall assembly with a ventilated and drained cavity.

The cavity behind the brick veneer should be at least 2 inches wide (source: Brick Institute of America) and free from mortar droppings. It must also have air inlets (“weep holes”) at its base **and** air outlets (“weep holes”) at its top in order to provide back ventilation of the brick veneer.

The drainage plane in this assembly is the building paper or building wrap. The air barrier can be any of the following: the interior gypsum board, the exterior gypsum wallboard or the exterior building wrap.

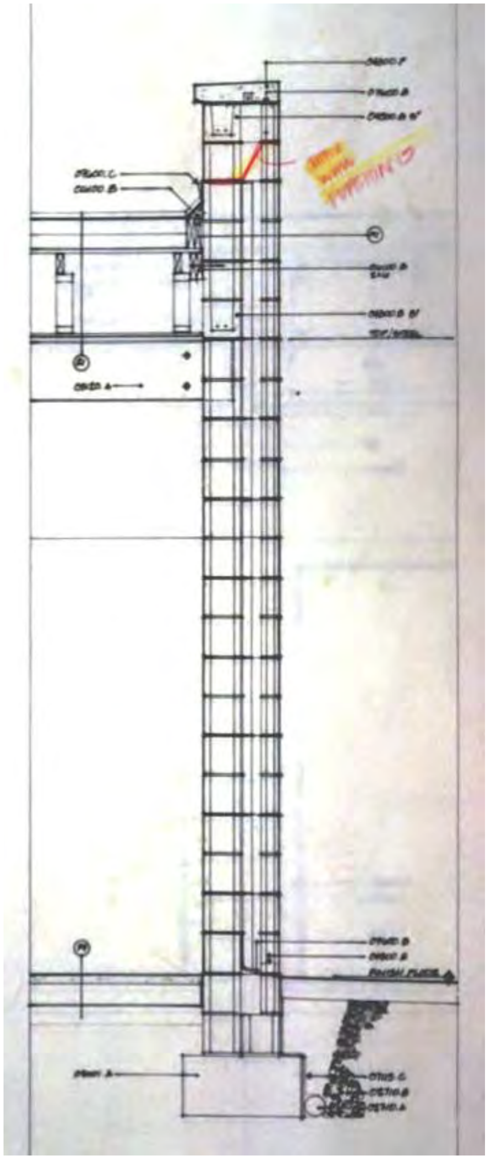
Joseph Lstiburek, Ph.D., P.Eng.
Building Science Corporation 2005

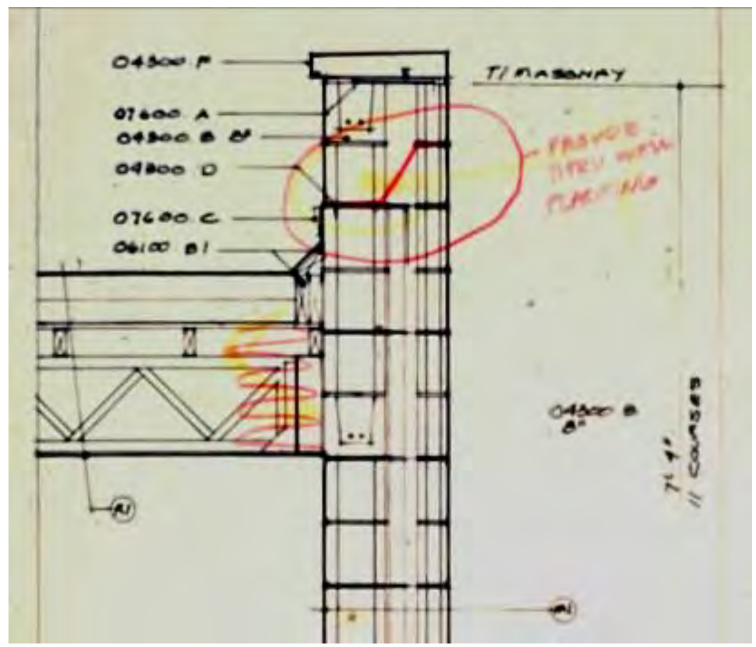
Properties of Flashing

	Material	Advantages	Disadvantages and Limitations
	Stainless steel. dead soft, annealed. Minimum thickness 0.015"; installed cost 100%	Hard, impervious, strong, very durable	Difficult to form and join; stiff, poor bond to mortar, labor intensive.
	Cold-rolled copper. Minimum thickness 16 oz.; installed cost 90%	Impervious, flexible, durable, easily formed and joined	Damaged by excessive flexing; runoff can stain other surfaces.
	Lead-coated copper. Minimum thickness 16 oz.; installed cost 95%	Similar to copper; runoff does not stain other surfaces	Similar to copper, requires care in soldering.
Never in masonry	Aluminum. Minimum thickness 0.032"; installed cost 60%	Fairly durable; can be formed, corrosion resistant except in presence of lime	High thermal coefficient; cracks easily when bent; cannot be field sealed; corroded by lime
Never in masonry	Galvanized steel. Minimum thickness 0.0217"; installed cost 80%	Hard, impervious, easily formed and joined, low thermal coefficient	Subject to early corrosion.
	Lead. Minimum thickness32 oz.; installed cost 75%	Easily formed and joined.	Easily torn; affected by lime in mortar; creeps.
Never in masonry	Zinc. Installed cost 80%	Easily formed and joined.	Creeps; destroyed by corrosion; cracks easily in thermal cycling.

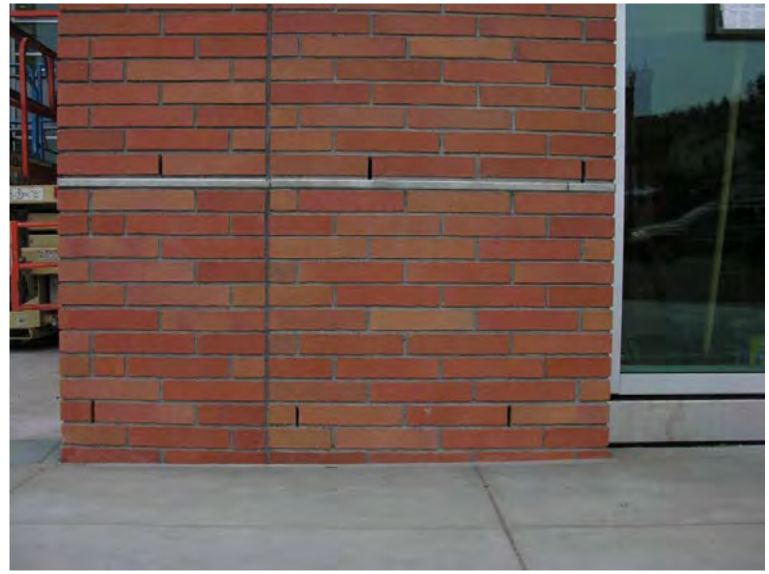
The flashing materials below this line can only be used internally because they are vulnerable to sunlight.

	Material	Advantages	Disadvantages and Limitations
	Copper-bituminous fabric. Minimum thickness 5 oz.(copper); installed cost 50%	Easily formed and joined; good bond to mortar	Easier torn than metal.
	Neoprene or rubberized asphalt. Minimum thickness 0.030"; installed cost 55%	Easily formed and joined; reliable, flexible.	Can be punctured; strength limited; requires protection against sun.
Never in masonry	PVC. Minimum thickness 0.030"; installed cost 25%	Easily formed and joined; impervious when new	Aging deterioration and hardening; easily punctured and cut; weak; brittle under load.
Never in masonry	Fiber-reinforced bituminous fabric. Installed cost 35%	Effective when intact; easy to form.	Easily damaged; weak; needs multiple plies; cracks in thermal cycling.




04300 F
T/ MASONRY
07600 A
04300 B 8"
04300 D
07600 C
06100 B1
PROVIDE THRU WALL FLASHING
04300 B 8"
7'-4" 11 COURSES

College of Engineering
Portland State University
Zimmer Gunsel Frasca
Portland, OR



active drainage flashing
wicking material is continuous on top of metal flashing

no weeps required

THROUGH-WALL FLASHING COMPARISON CHART

Properties	Rubberized Asphalt (Peel & Stick)	Flash-Vent Copper	Flash-Vent Stainless Steel
Base Material	Petroleum	Copper	Stainless Steel
Recycled Content	1% - 3%	90%-93%	60%-70%
Recylable	No	Yes	Yes
Warranty	5 year (maximum)	Lifetime	Lifetime
Lap Joints in 100'	17	2	2
Gap Span	less than 1/4"	width of cavity	width of cavity
Fire Resistant (ASTM E84)	No	Yes	Yes
Mold Resistant (ASTM D3273)	Unknown	Yes	Yes
Tensile Strength (ASTM D412)	1,200	32,000	100,000+
Puncture Resistance (ASTM E154)	80 psi	450 psi	2,500+ psi
Chemically Compatible with All Wall Components	No	Yes	Yes
Primer Required	Yes	No	No
Mortar Netting Required	Yes	No	No
Drip Edge Required **	Yes	No	No
Installed Flashing System Cost per Lineal Foot ***	$3.57	$2.74	$2.45

Holy Name of Jesus Cathedral
O'Brien & Keane
Raleigh, NC
2016

https://www.youtube.com/watch?v=dM5Yb7PS08w

Keeping Air Spaces Clean

Mortar droppings should be prevented from falling into the cavity. Bevel the bed joint away from the cavity, as shown in Figure 6. When brick are laid on a beveled bed joint, a minimum of mortar is squeezed out of the joint, as shown in Photo 7.

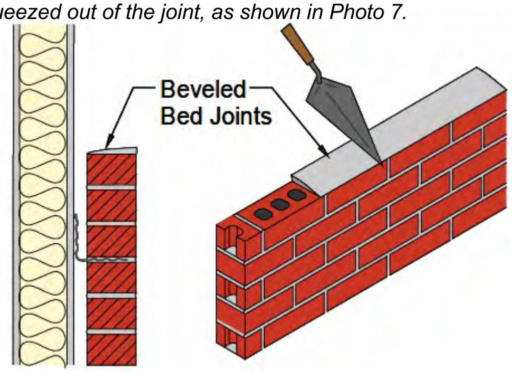
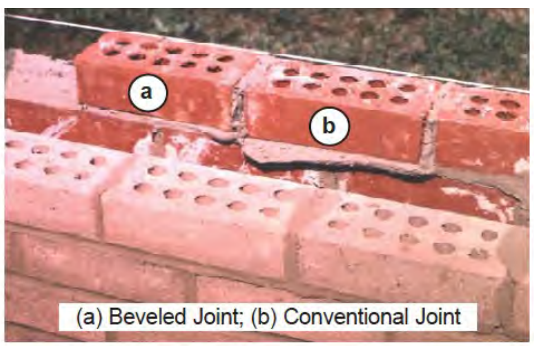


Figure 6

bevel bed joint away from cavity
roll the brick into place
squeeze excess mortar toward the exterior



(a) Beveled Joint; (b) Conventional Joint

Photo 7

Beveled and Conventional Mortar Joints

good workmanship

cavity batten collects mortar droppings

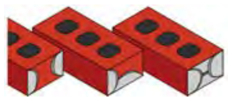
Don't expect what you don't inspect.
Doug Burton, Whitman Masonry
At the time he said this he was President of the NC Mason Contractor's Assoc.

Source: BIA Technote 7b; “Water Penetration Resistance - Construction and Workmanship”

Head joints are normally 3/8"

tolerances:
- ¼", +3/8"

Are 1/8" and 3/4" wide joints OK?



Bad Bad Good

Head Joints
(BIA Technote 7b)

3.3.2 Placing Mortar:

3.3.2.1 Mix mortar in accordance with the requirements of [ASTM C 270] [UBC 21-15]. Control batching procedure to ensure proper proportions by measuring materials by volume or weight as specified. Control amount of mixing water and mortar consistency. Discard mortar or grout that has partially set. Discard mortar not used within 2-1/2 hours of initial mixing. Re-temper within 2-1/2 hours of mixing to replace moisture lost by evaporation. Do not retemper colored mortars.

Mortar bond is a function of the water cement matrix being absorbed into the surface pores of the units. Compatibility of unit surface texture, absorption, mortar workability and water content are critical factors. Retempering colored mortar can result in color inconsistencies.

3.3.2.2 Lay solid masonry units with full head and bed joints. Do not deeply furrow bed joints. Butter ends of units with sufficient mortar to fill head joints. Back bevel bed joints to minimize mortar droppings in cavity.

Full head and bed joints are critical to attain proper strength and to reduce water penetration in masonry walls. Deep furrowing of the bed joint reduces the contact area and creates voids. Slushed mortar does not fill head joints and does not result in good bond.

3.3.2.3 Supply face shell bedding for hollow masonry units except at base course, grouted cells, and at piers, columns and pilasters where mortar bedding is also required at cross webs.

Mortar bedding specified in 3.3.2.3 is standard. Full mortar beds (mortared cross webs) may be required by engineering analysis.

3.3.2.4 Supply nominal joint thickness of [3/8 in.] [1/2 in.] [____.]

Mortar joint widths are adjusted to accommodate unit size variations and to maintain consistent coursing. Testing has shown that bed joints thicker than 3/8 in. have lower bond strength. Joints less than 1/4 in. thick can experience too much water loss that inhibits proper bond and compressive strengths.

In brick, the head joints must be **full**.

In block, the head joints need to be **full in the planes of the face shells**, but not in between.

3.3 CONSTRUCTION

3.3.1 Site Tolerances: Maintain the following construction tolerances:

3.3.1.1 Dimension of Elements:

A. in cross section or elevation, -1/4 in., +1/2 in.

B. mortar joint thickness:
bed joints, ±1/8 in.;
head joints, -1/4 in., +3/8 in.;
collar joints, -1/4 in., +3/8 in.

C. grout space or cavity width, -1/4 in., +3/8 in.

3.3.1.2 Elements:

A. variation from level:
bedjoints ±1/4 in. in 10 ft., ±1/2 in. maximum; [top surface of bearing walls, ±1/4 in. in 10 ft., ±1/2 in. maximum;]

B. variation from plumb, ±1/4 in. in 10 ft., ±3/8 in. in 20 ft., ±1/2 in. maximum;

C. true to a line, ±1/4 in. in 10 ft., ±3/8 in. in 20 ft., ±1/2 in. maximum;

D. alignment of columns and walls (bottom versus top), ±1/2 in. for bearing walls, ±3/4 in. for non-bearing walls.

3.3.1.3 Location of Elements:

A. indicated in plan, ±1/2 in. in 20 ft., ±3/4 in. maximum;

B. indicated in elevation, ±1/4 in story height, ±3/4 in. maximum;

3.3.1.4 In Placement of Reinforcement: refer to Code.

These are the tolerances used in the MSJC Specification (ACI 530.1/ASCE 6/TMS 602). They are intended to assure proper structural performance only and will not necessarily produce the desired appearance. ASTM tolerances on size of units will affect tolerances in joint width. Clay brick unit type (FBS, FBA or FBX) will also affect joint width and placement tolerances. Specified tolerances should be selected based on desired appearance and specified units. For example, stack bond masonry with FBX brick can and should be built to tight tolerances, but tolerances for FBA brick should be less restrictive to allow for greater variation in unit sizes and to achieve the characteristic look of "historic" masonry or of hand-made units. Use mock-up panel to demonstrate specified tolerances. Masonry tolerances must be maintained despite greater allowable tolerances for structural frames. Shelf angles may need to be shimmed or multiple angle sizes may be required to maintain proper support of the masonry. Also, provisions for a variety of anchor lengths may be required.

True to a line as used in C. at the left and in the MSJC Specification refers to the straightness of the wall in plan.

Source: TMS "Annotated Guide to Masonry Specifications"

TABLE B TOLERANCES ON DIMENSIONS					
Specified dimension or average brick size in job lot sample (in.)	*Maximum permissible variation (in.) plus/minus*				
	Column A (for specified dimension)		*Column B (for average brick size in job lot sample)**		
	Type FBX	*Type FBS*	*Type FBX*	*Type FBS, Smooth†*	*Type FBS, Rough‡*
3 and under	1/16	3/32	1/16	1/16	3/32
Over 3 to 4 incl.	3/32	1/8	1/16	3/32	1/8
Over 4 to 6 incl.	1/8	3/16	3/32	3/32	3/16
Over 6 to 8 incl.	5/32	1/4	3/32	1/8	1/4
Over 8 to 12 incl.	7/32	5/16	1/8	3/16	5/16
Over 12 to 16 incl.	9/32	3/8	3/16	1/4	3/8

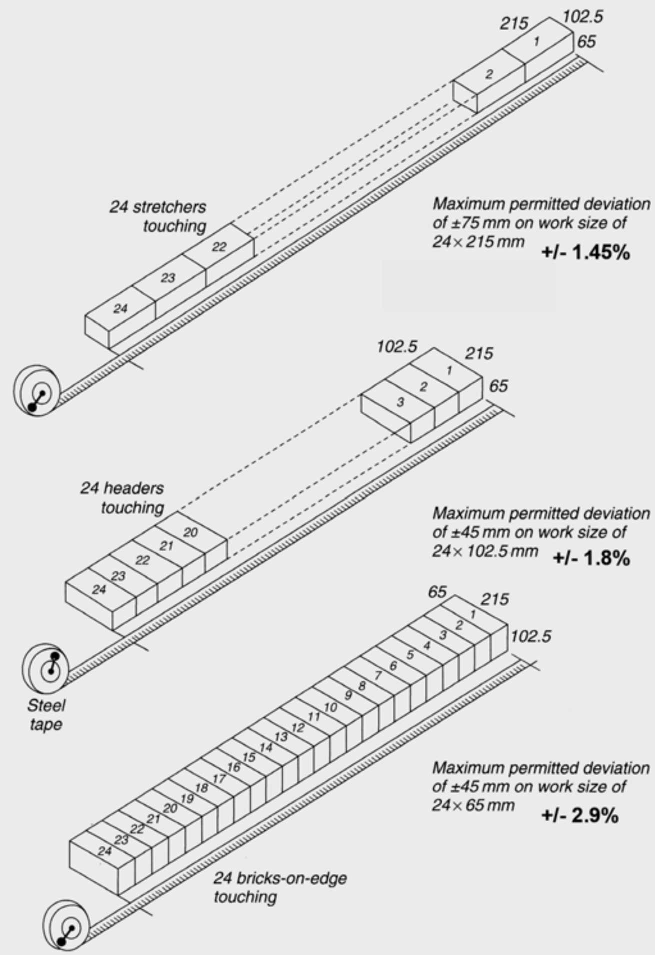
*Lot size shall be determined by agreement between purchaser and seller. If not specified, lot size shall be understood to include all brick of one size and color in the job order.

†Type FBS Smooth units have relatively fine texture and smooth edges, including wire cut surfaces. This definition relates to dimensional tolerances only.

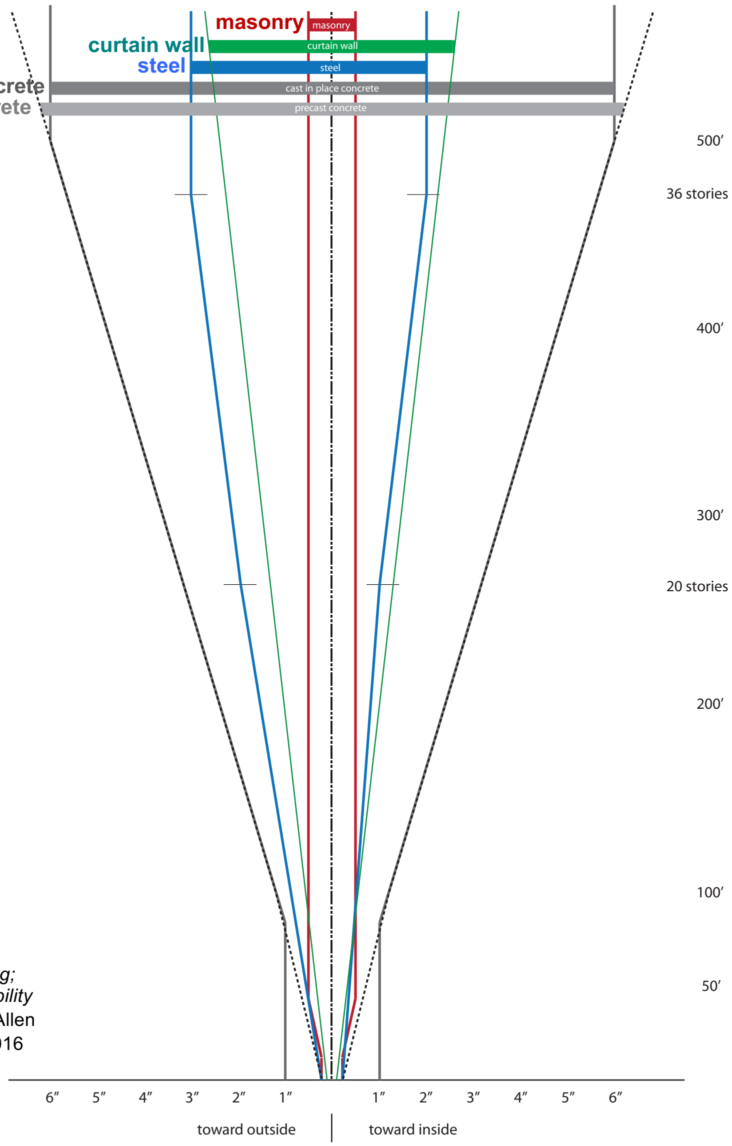
‡Type FBS Rough units have textured, rounded, or tumbled edges or faces. This definition relates to dimensional tolerances only.

TABLE C TOLERANCES ON DISTORTION		
Maximum dimension, (in.)	*Maximum permissible distortion (in.)*	
	Type FBX	*Type FBS*
8 and under	1/16	3/32
Over 8 to 12 incl.	3/32	1/8
Over 12 to 16 incl.	1/8	5/32

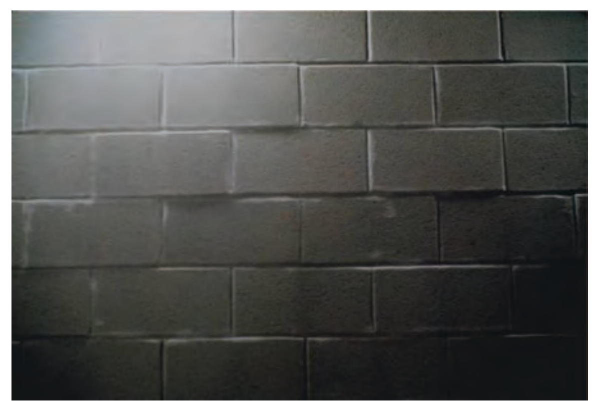
ASTM C216 brick chippage, dimension, and distortion tolerances. (*Copyright, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pa. 19103. Reprinted with permission.*)

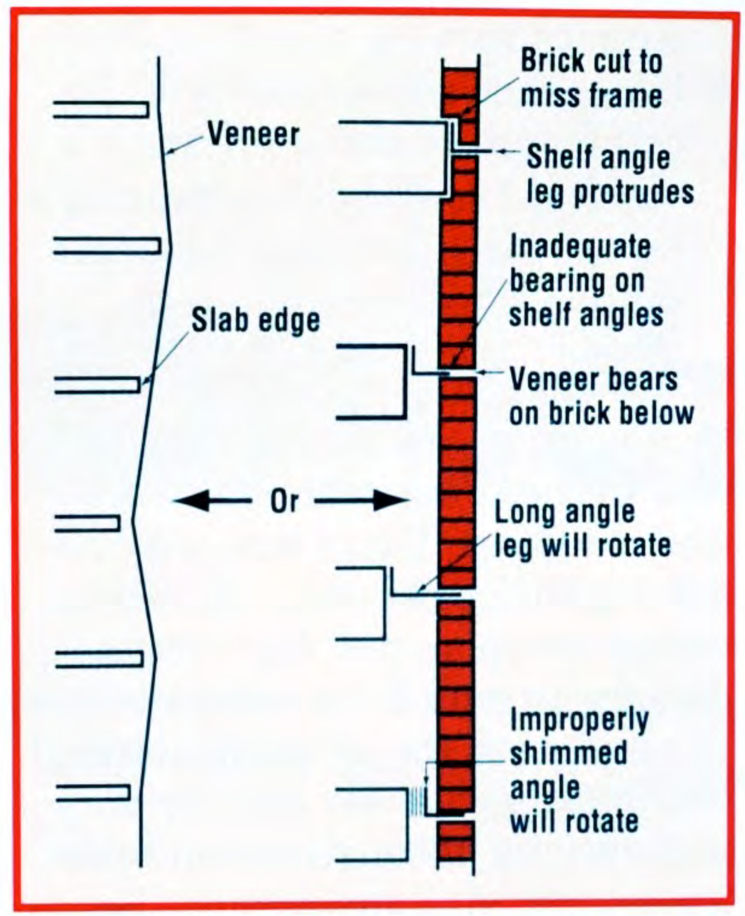


Brickwork for Apprentices
Figure 2.5 Carrying out a BS 3921 test for dimensional deviations

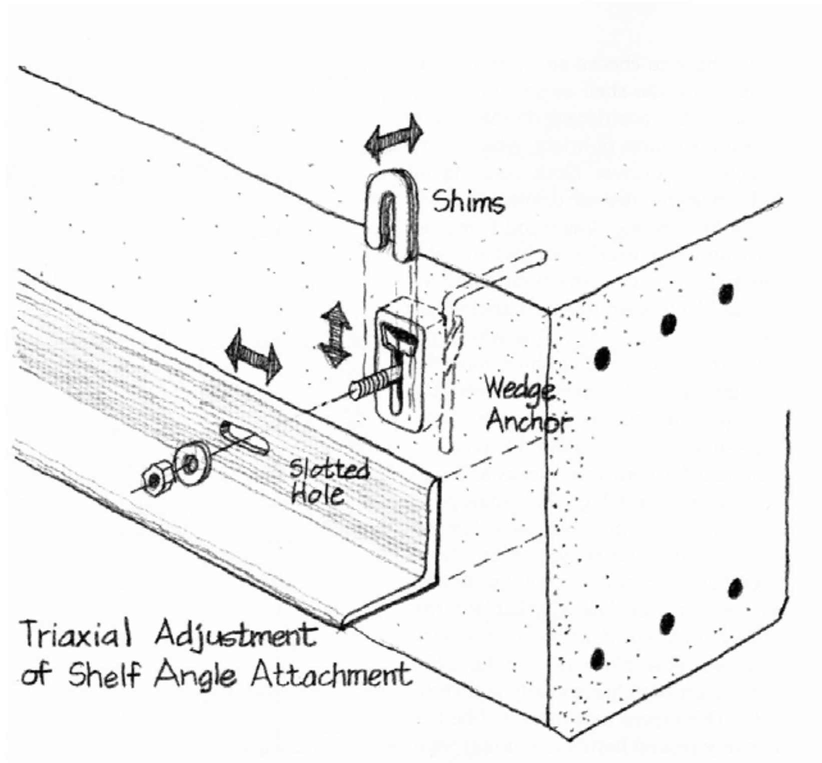


Source:
Architectural Detailing; Function, Constructibility Aesthetics; Edward Allen and Patrick Rand, 2016





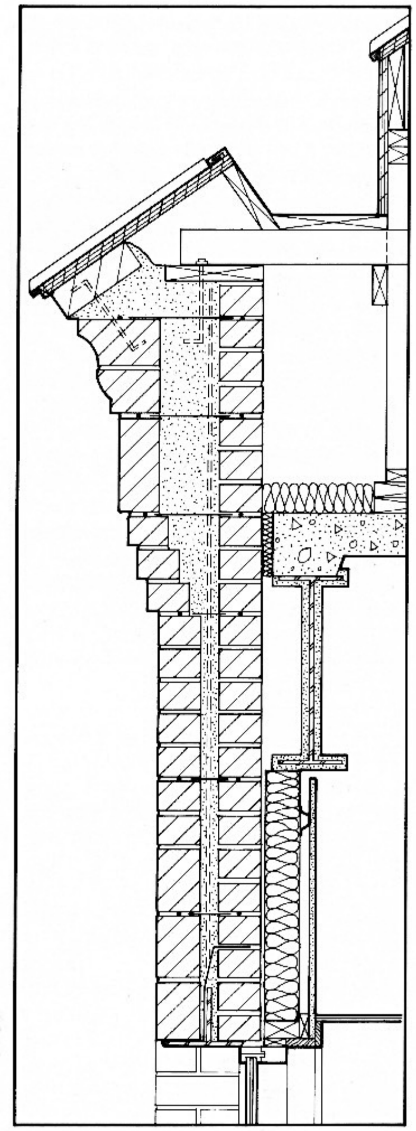
Attempting to maintain plumb cladding on an out-of-plumb frame can lead to a range of problems.



Source: *Architectural Detailing; Function, Constructibility Aesthetics;*
Edward Allen and Patrick Rand, 2016


Tyvek


ARCHITECTURAL
TECHNOLOGY
FALL 1985
THE AMERICAN INSTITUTE OF ARCHITECTS



Two specimens were built representing each of the following five cavity/weep mechanisms.

One specimen was oriented east, the other oriented west, thereby providing all specimens with equal exposure to sunlight over the course of one day:

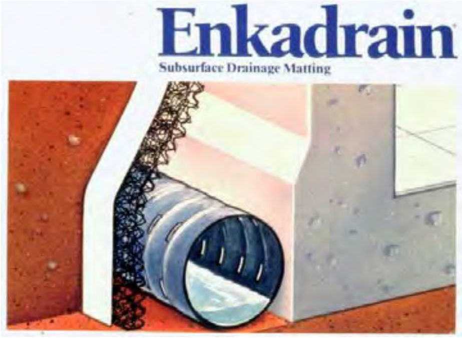
1. **Sash cord left in place**, 24" (61cm) on center

2. **Sash cord removed**, 24" (61cm) on center

3. **Open head joints**, 24" (61cm) on center

4. **Pea gravel installed in the bottom 12"** (30cm) of the cavity, open head joints 24" (61cm) on center

5. **Mortar collection net** (similar to AKZO-Nobel's Enkadrain) installed in the bottom 16" (41cm) of the cavity, open head joints 24" (61cm) on center


Enkadrain
Subsurface Drainage Matting

Two wall specimens were built representing each of the following five cavity weep mechanisms. One specimen of each was oriented east, the other oriented west, thereby providing all specimens with equal exposure to sunlight over the course of each day.

1. **Sash cord left in place**, 24" (61cm) on center

2. **Sash cord removed**, 24" (61cm) on center

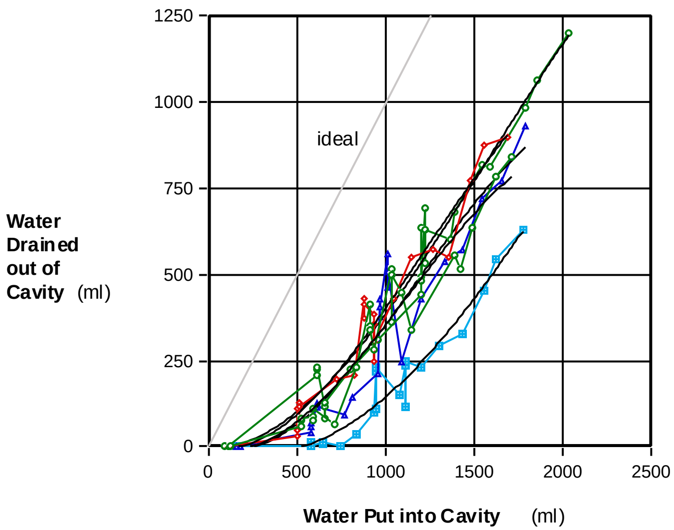
3. **Open head joints**, 24" (61cm) on center

4. **Pea gravel** installed in the bottom 12" (30cm) of the cavity, open head joints 24" (61cm) on center

5. **Mortar collection net** (similar to AKZO-Nobel's Enkadrain) installed in the bottom 16" (41cm) of the cavity, open head joints 24" (61cm) on center

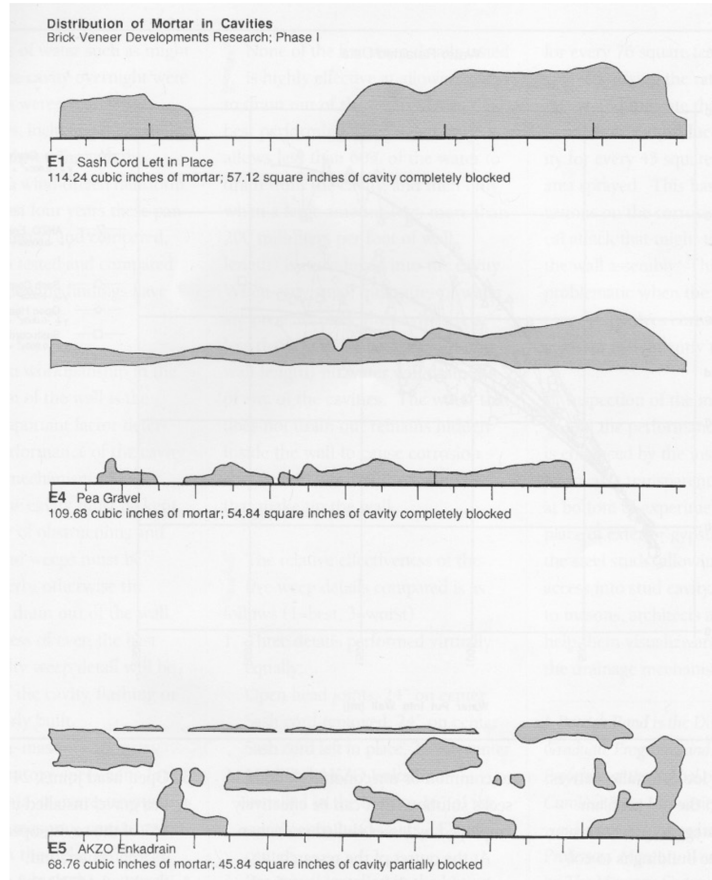

pea gravel
W4
mortar collection net

Water Drainage through Cavities and Weeps



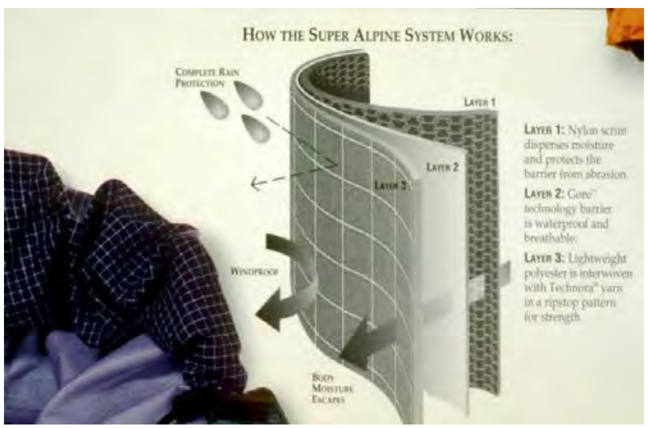
Effectiveness of various cavity and weep mechanisms in draining water out of wall. All weeps are at 24” (61cm) on center.

- Open Head Joints
  $y = -0.000x^3 + 0.001x^2 - 0.195x + 6.501$
- Sash Cord Removed
  $y = -0.000x^3 + 0.001x^2 - 0.146x + 4.074$
- Sash Cord Left in Place
  $y = -0.000x^3 + 0.001x^2 - 0.035x - 1.583$
- Mortar Collection Net with Open Head Joints
  $y = -0.000x^3 + 0.001x^2 - 0.244x + 12.680$
- Pea Gravel with Open Head Joints
  $y = -0.000x^3 + 0.000x^2 - 0.289x + 33.355$



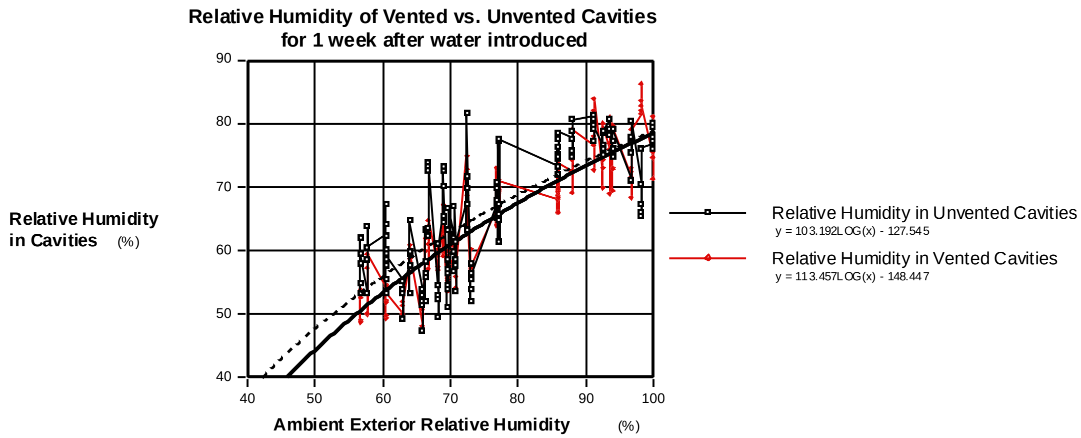
Distribution of **mortar droppings** observed in selected cavities. All weeps are at 24” (61cm) on center.

	Strategies to Make a Building Wall Moisture Resistant							
Examples	multiwythe brick wall	"dryblock" additive in cmu	painted cmu wall	foundation wall water-proofing & drainage matting	cavity wall or veneer const. with drainage mechanism	ventilate the cavity of the wall to the outside	rainscreen with pressure - equalization chamber	
Material is Barrier	⟵						⟶	**Assembly is Barrier**
One or two multifunctional materials in a simple additive assembly	Use materials that are intrinsically resistant to moisture	Alter the basic material with modifiers to increase moisture resistance	Apply a sealant to the surface of an intrinsically vulnerable material	Apply layers of sealant and drainage media onto exterior surface	Interupt the path of porous materials within the wall	Convect water vapor from within the wall	Repel moisture with air pressure in compart-mented cavities	**Layers of specialized, sometimes redundant materials in a complex, integrated assembly**



Drainage through cavities and weeps is not a complete means to get water out of the wall assembly.

Convection and drying through evaporation is an economical added strategy.



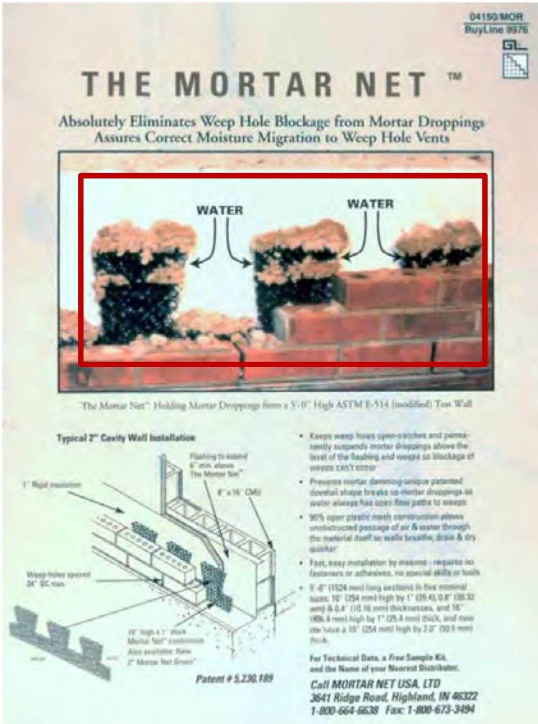
cavity ventilation

Relative humidity in vented cavities is +/- 20% lower than in an unvented version of the same type of weep.

The solid line in the chart represents the vented cavities.

in CMU: open head joints @ 16” oc

in brick: open head joints @ 8” oc



04150/MOR
BuyLine 9976

THE MORTAR NET ™

Absolutely Eliminates Weep Hole Blockage from Mortar Droppings
Assures Correct Moisture Migration to Weep Hole Vents

The Mortar Net™ Holding Mortar Droppings from a 5'-0" High ASTM E-514 (modified) Test Wall

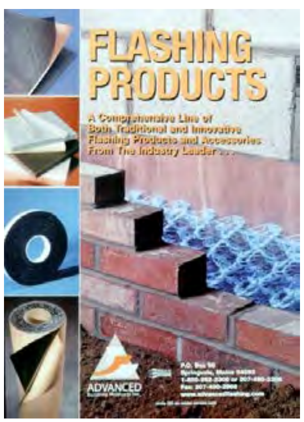
Typical 2" Cavity Wall Installation

- Keeps weep holes open-catches and permanently suspends mortar droppings above the level of the flashing and weeps so blockage of weeps can't occur
- Prevents mortar damming-unique patented dovetail shape breaks up mortar droppings so water always has open flow paths to weeps
- 90% open plastic mesh construction allows unobstructed passage of air & water through the material itself so walls breathe, drain & dry quicker
- Fast, easy installation by masons - requires no fasteners or adhesives, no special skills or tools
- 5'-0" (1524 mm) long sections in five nominal sizes: 10" (254 mm) high by 1" (25.4), 0.8" (20.32 mm) & 0.4" (10.16 mm) thicknesses, and 16" (406.4 mm) high by 1" (25.4 mm) thick, and now we have a 10" (254 mm) high by 2.0" (50.8 mm) thick.

Patent # 5,230,189

For Technical Data, a *Free Sample Kit*, and the Name of your Nearest Distributor,

Call MORTAR NET USA, LTD
3641 Ridge Road, Highland, IN 46322
1-800-664-6638 Fax: 1-800-673-3494



CavClear® Masonry Mat

Description: A fluid-conducting, non-absorbent polymer mesh made from 100% recycled plastic that is installed full-height in the airspace.

Purpose: Prevents mortar from bridging the airspace and results in a continuous area for drainage and ventilation.

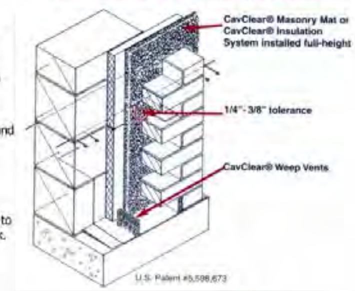
Applications: Specify and detail full-height in insulated cavity walls and stone construction where ties are located 16" O.C.

Dimension: 16" x 96"

Masonry Mat Thickness: 1/2", 3/4", 1", 1-1/4", and 1-3/4". Select to allow 1/4" to 3/8" tolerance between CavClear® Masonry Mat and brick.

Installation: Install horizontally between ties.

Typical Drainage Wall Using CavClear®



Features and Benefits

Prevents Moisture-Related Failures

- Eliminates callbacks – Proper drainage and adequate ventilation reduce cracking and promote durability.
- Ensures long-term performance – Maintain proper ventilation and prevent moisture/thermal bridging.

Ensures Water Management

- Prevents mortar bridging – Mortar bridges obstruct a continuous moisture migration path, inhibiting proper drainage.
- Eliminates weep obstructions – Mortar is kept in proximity to the mortar joint so it does not fall to the flashing or weeps.

Reduce Life-Cycle Costs

- Reduce energy costs – Prevent mortar bridges that allow thermal and moisture transfer between the wythes.
- Designed for sustainability and performance – An obstructed airspace will cause drainage and ventilation problems that lead to costly repair.

Made from 100% Recycled Plastic

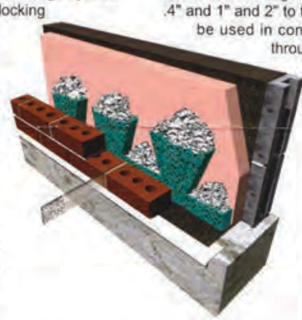
- Energy Star Product – CavClear is an Energy Star Partner.

BRICK VENEER

MORTAR NET

THE MORTAR NET® DRAINAGE SYSTEM

Mortar Net® is the industry's leading drainage system. It prevents mortar droppings from blocking weep vents and allows moisture to rapidly migrate to the building exterior. What's more, it allows proper air movement in and out of the cavity, which eliminates pressure differentials that force moisture into the wall, aids in rapid drying of the wall, and prevents conditions which may promote mold growth, efflorescence, spalling and decay.



HOW MORTAR NET® WORKS

Mortar Net® is fast and easy to use. It requires no fasteners or adhesives, no special skills or tools. After the first one or two courses of bricks are laid, place a continuous row of Mortar Net® in the cavity or collar joint on the flashing (dovetail side up) against the inside of the outer wythe at the base of the wall.

Mortar Net® is slightly compressible and is available in .4" and 1" and 2" to fit the size of the wall cavity. It must be used in conjunction with an impermeable through-wall flashing that extends to at least 6" above the Mortar Net®.

Mortar Net® .4" and 1" material is made of high-density polyethylene. Mortar Net® 2" is made of recycled polyester. This material will not oxidize, rot, promote mold or fungus, or react with other common building materials such as mortar cement, asphalt, modified bitumen, PVC, copper, or galvanized metal, thereby ensuring long-term performance for all materials.

MORTAR NET® SIZES

WIDTH	HEIGHT	LENGTH	PKG. QTY.
.4"	10"	5'	250 lf
1"	10"	5'	100 lf
2"	10"	5'	100 lf

COMPARATIVE STUDY RESULTS

Comparative Study of the Effectiveness of Two Wall Drainage Systems Used in Masonry Cavity Wall Construction.

Test Method: ASTM E-514 (modified)
Test Date: December 4, 1994
Test Performed by: Robert L. Nelson & Associates Construction Materials Laboratory (847) 882-1146
Complete test results are available upon request.

TEST RESULTS

Drainage System	Mortar Net®	Pea Gravel
First Visible Water on Cavity Side of Brick	10 minutes	7 minutes
Appearance of Flowing Water on Cavity Side of Brick	17 minutes	16 minutes
Water Volume Passing Through Weep Hole at the Brick Wythe Face:		
• After 3 Hours	2.6 gal/hr.	.51 gal/hr.
• After 72 Hours	2.9 gal/hr.	1.06 gal/hr.

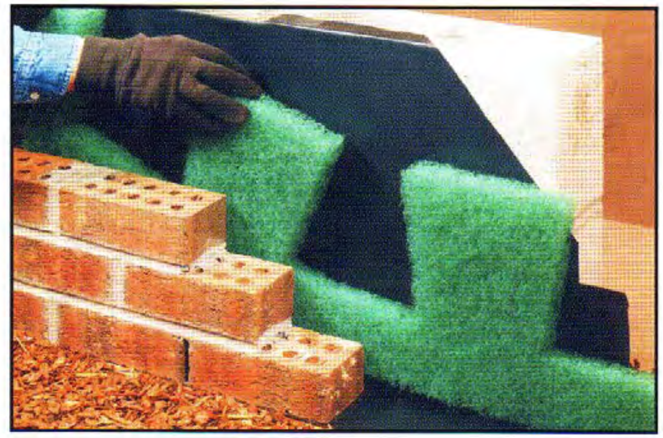
WEEP VENTS

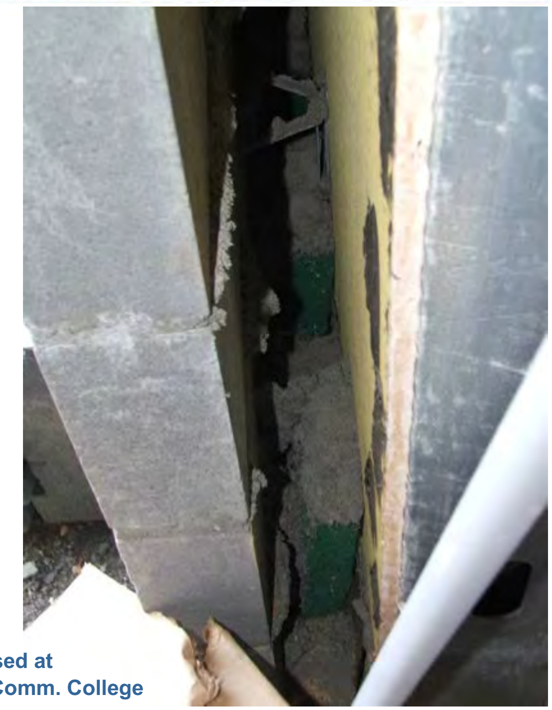
MORTAR NET® WEEP VENTS™

For Mortar Net® our Mortar Net® Weep Vents™ add extra assurance that masonry walls will drain correctly for life, while maintaining their finished appearance.

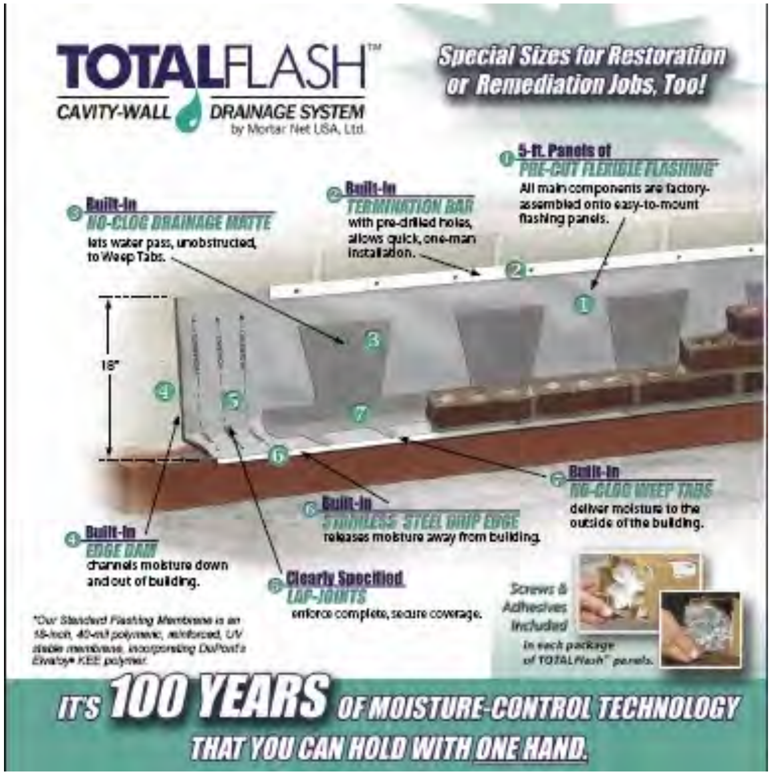
They could not be easier to install. Simply place a vent at the bottom of a head joint on 24" centers. No adhesives are required. Each vent measures 2.5" x 3.5" x .5", is made from 90% open mesh recycled polyester, and is bonded with a flame-retardant adhesive to provide resilience and strength. They are available in a choice of attractive colors to match the mortar being used, including brown, tan, red, almond, white or gray. Mortar Net® Weep Vents™ are packaged 125 per box. Special sizes are available upon request.

Thanks to recent innovations, our latest Mortar Net® Weep Vents™ deliver 36% more airflow than ever before.





MortarNet used at
Wake Tech Comm. College



1. 5-foot, Pre-Cut Panels of Flexible Flashing. No cutting needed.
2. *Built-In* Termination Bar. Just screw it in.
3. *Built-In* Drainage Matte defeats mortar-droppings.
4. *Built-In* Edge Dams.
5. *Built-In* No-Clog Weep Tabs.
6. *Built-In* Stainless Steel Drip Edge.
7. Clearly Defined Lap-Joints for precise coverage.
8. All Screws & Adhesives included in each package.
9. Stainless Steel Corners, Corner Boots, and End Dams avail.

Mortar Net USA reports that the builders who've used TOTAL*Flash* in their masonry cavity-walls have seen labor savings of 50% or more, compared to conventional moisture-control detailing.

State clearly what is expected.

Then ask the contractor and suppliers to **show you** what they understand.

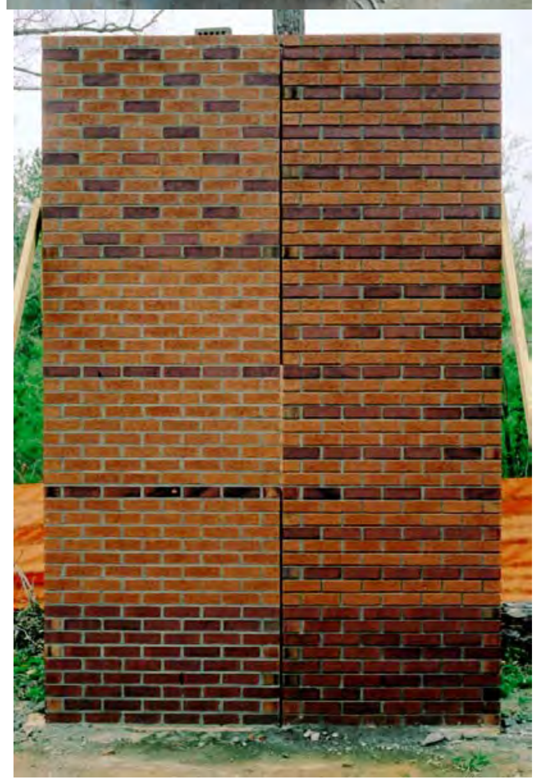
1.4 SUBMITTALS

1.4.1	**Product Data:**	List products for which manufacturer's technical data submittals are required such as anchors, ties, flashing, mortar pigments, etc.
1.4.2	**Shop Drawings: Submit shop drawings for [shop-fabricated sheet metal flashing details] [steel reinforcement].**	List items for which shop drawings are required.
1.4.3	**Samples:**	List products for which physical examples are required such as masonry units, flashing, etc.
1.4.4	**Test Reports:**	List items for which test reports are required, such as masonry units, prisms, mortar or grout, and load capacity data for anchors and ties. Test report of IRA for clay units is recommended.
1.4.5	**Certifications: Submit manufacturer's certification of compliance for [____________________________].**	List products (such as anchors or ties) for which manufacturer's certifications of compliance are acceptable in lieu of test reports.

1.5 QUALITY ASSURANCE

1.5.1	**Qualifications:**	Specify qualifications for the contractor, manufacturers or installer, such as requiring a minimum length of experience. Coordinate with Division 1 Section on Quality Assurance.
1.5.3	**Sample Panel: [First 100 sq. ft. of masonry installed shall] [Construct ____ x ____ ft. freestanding wall section to] serve as sample panel for Architect's approval of workmanship, including installation of units, unit color, color blending, mortar color, and tooling of mortar joints. The sample panel, when accepted, shall become the project standard for quality of work and appearance. Leave panel in place until masonry work is complete and has been accepted.**	Use sample panels to establish project appearance and workmanship standards. Specify freestanding or part of structure.

Source: TMS "Annotated Guide to Masonry Specifications"



sample panel

1.5.4 **Mock-Up: [First 100 sq. ft. of masonry installed shall] [Construct ___ x ___ ft. freestanding wall section to] serve as mock-up panel for Architect's approval of workmanship, including installation of units, unit color, color blending, mortar color, and tooling of mortar joints, [ties,] [anchors,] [flashing,] [weeps,] [shelf angles,] and [{expansion} {and control} joints]. The mock-up, when accepted, shall become the project standard for quality of work, methods of installation and appearance. Leave mock-up in place until masonry work is complete and has been accepted. Complete all submittals before scheduling mock-up construction. Notify Architect one week in advance of time when mock-up construction will begin.**

Use mock-up panels instead of sample panels on larger projects to set standards for appearance, workmanship and installation of critical components. Mock-ups can also be used to demonstrate cleaning methods and surface treatments. List requirements for number, size and components of mock-up panels. Specify freestanding or part of structure. Give criteria on which acceptance or rejection will be based.

1.5.5 **Pre-Construction Testing:**

mock-up panel

Source: TMS "Annotated Guide to Masonry Specifications"

above left: before powerwashing
above right: after powerwashing

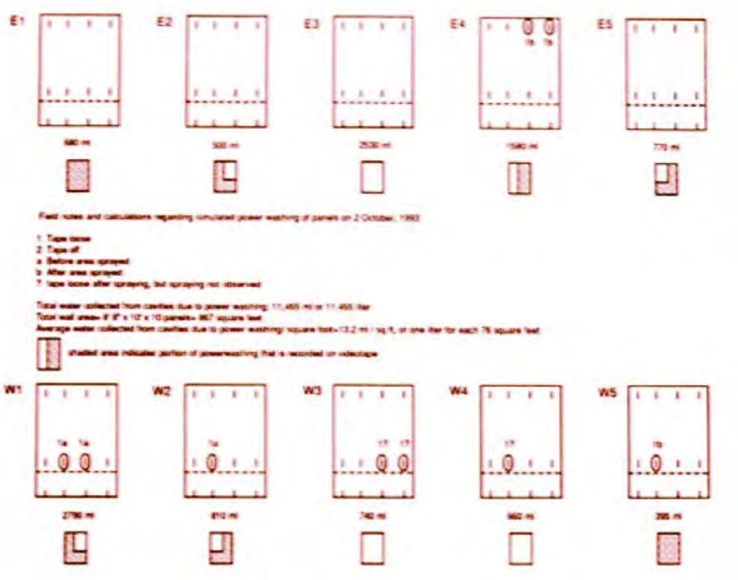
powerwashing

- Work clean to minimize need
- The earlier the better
- Use the least pressure and chemicals that will clean the masonry surfaces

no powerwashing required

NEVER powerwash sand-faced brick

Follow manufacturer's instructions regarding how to clean a particular masonry product



Following **powerwashing** procedures recommended by BIA,
we found that we **put in more than a half-gallon of water / 35 sf.**

Worse, powerwashing often involves the use of acids in the fluid.

THE BRICK INDUSTRY ASSOCIATION
TECHNICAL NOTES on Brick Construction
1850 Centennial Park Drive, Reston, Virginia 20191 | www.gobrick.com | 703-620-0010
1
June 2006

Cold and Hot Weather Construction

	Temperature[1]	Preparation Requirements (Prior to Work)	Construction Requirements (Work in Progress)	Protection Requirements (After Masonry Is Placed)
Hot Weather	Above 115 °F or 105 °F with a wind velocity over 8 mph (46.1 °C or 40.6 °C with a 12.9 km/hr wind)	Shade materials and mixing equipment from direct sunlight. Comply with hot weather requirements below.	Use cool mixing water for mortar and grout. Ice must be melted or removed before water is added to other mortar or grout materials. Comply with hot weather requirements below.	Comply with hot weather requirements below.
	Above 100 °F or 90 °F with 8 mph wind (above 37.8 °C or 32.2 °C with a 12.9 km/hr wind)	Provide necessary conditions and equipment to produce mortar having a temperature below 120 °F (48.9 °C). Maintain sand piles in a damp, loose condition.	Maintain mortar and grout at a temperature below 120 °F (48.9 °C). Flush mixer, mortar transport container, and mortar boards with cool water before they come into contact with mortar ingredients or mortar. Maintain mortar consistency by retempering with cool water. Use mortar within 2 hr of initial mixing.	Fog spray newly constructed masonry until damp, at least three times a day until the masonry is three days old.

Keep all materials **below 120 degrees** before and after placement.

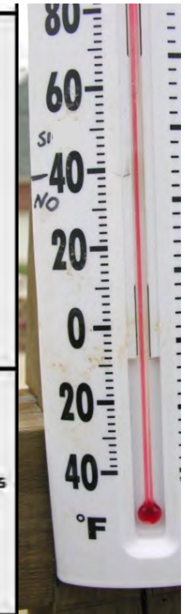
Mortar **at least 40 degrees**.

Grout **at least 70 degrees**.

Keep all masonry assemblies **above freezing for at least 24 hours**.

Cover, wrap, use heaters if necessary.

Cold Weather	40 °F to 32 °F (4.4 °C to 0 °C)	Do not lay masonry units having either a temperature below 20°F (-6.7°C) or containing frozen moisture, visible ice, or snow on their surface. Remove visible ice and snow from the top surface of existing foundations and masonry to receive new construction. Heat these surfaces above freezing, using methods that do not result in damage.	Heat mixing water or sand to produce mortar between 40 °F (4.4 °C) and 120 °F (48.9 °C). Do not heat water or aggregates used in mortar or grout above 140 °F (60 °C). Heat grout materials when their temperature is below 32 °F (0 °C).	Completely cover newly constructed masonry with a weather-resistive membrane for 24 hr after construction.
	32 °F to 25 °F (0 °C to -3.9 °C)	Comply with cold weather requirements above.	Comply with cold weather requirements above. Maintain mortar temperature above freezing until used in masonry. Heat grout materials so grout is at a temperature between 70 °F (21.1 °C) and 120 °F (48.9 °C) during mixing and placed at a temperature above 70 °F (21.1 °C).	Comply with cold weather requirements above.
	25 °F to 20 °F (-3.9 °C to -6.7 °C)	Comply with cold weather requirements above.	Comply with cold weather requirements above. Heat masonry surfaces under construction to 40°F (4.4°C) and use wind breaks or enclosures when the wind velocity exceeds 15 mph (24 km/h). Heat masonry to a minimum of 40°F (4.4°C) prior to grouting.	Completely cover newly constructed masonry with weather-resistive insulating blankets or equal protection for 24 hr after completion of work. Extend time period to 48 hr for grouted masonry, unless the only cement in the grout is Type III portland cement.
	20 °F and Below (-6.7 °C and Below)	Comply with cold weather requirements above.	Comply with cold weather requirements above. Provide enclosure and heat to maintain air temperatures above 32 °F (0 °C) within the enclosure.	Maintain newly constructed masonry temperature above 32°F (0°C) for at least 24 hr after being completed by using heated enclosures, electric heating blankets, infrared lamps, or other acceptable methods. Extend time period to 48 hr for grouted masonry, unless the only cement in the grout is Type III portland cement.



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