Masonry 101, Part 2: Masonry Assemblages & Performance Attributes
Masonry Educators Workshop

TMSMEW2208

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W. Mark McGinley, Ph. D. , PE , FASTM, FTMS

The Masonry Society

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

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Learning Objectives

Masonry Assemblies

Learning Objectives include:

- Understand basic masonry Assemblies, construction techniques and the effects these have on Masonry Assembly Attributes
- Identify critical structural properties for masonry assemblies.
- Understand other material properties for masonry
- List other resources and topics for advanced studies
- Talk about other related performance issues in a panel discussion

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Masonry Assemblies

- Masonry is usually formed into walls
- Depending on its configuration and location, a wall may be load bearing, non load bearing, it may be a shear wall
- A wall may also be part of the exterior envelope, or control security, or fire, etc.

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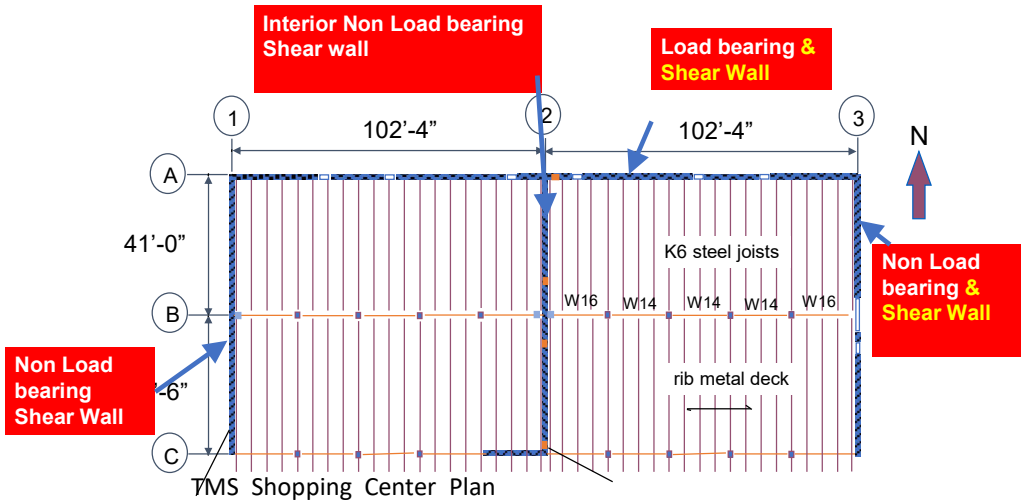

Vertical and Lateral Load resisting systems Example

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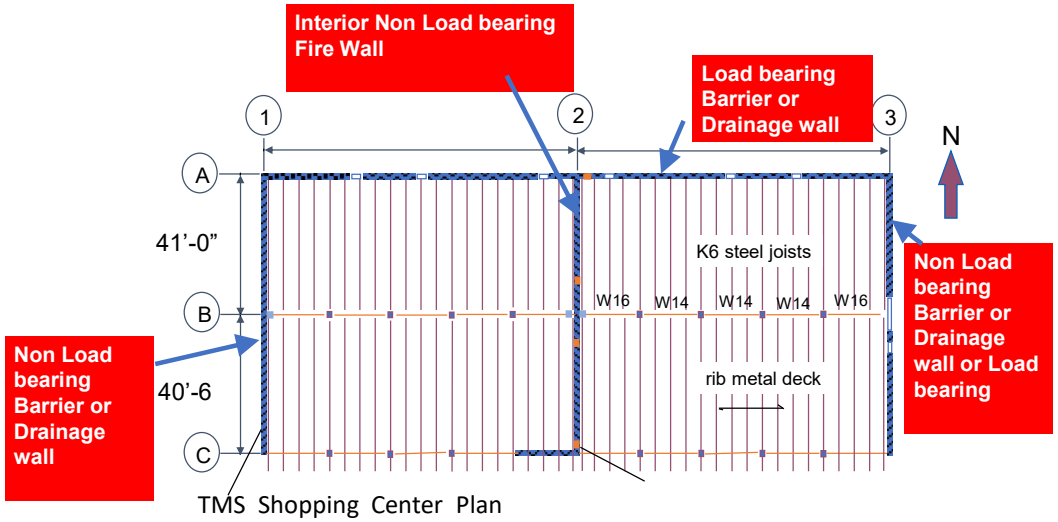

Example of Walls in a Building (MDG)

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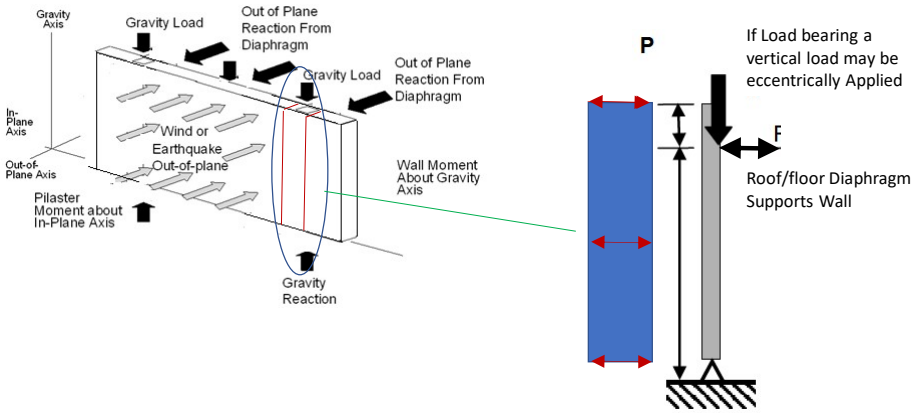
Masonry walls -Vertical and Out of Plane (OOP or Lateral) Loads



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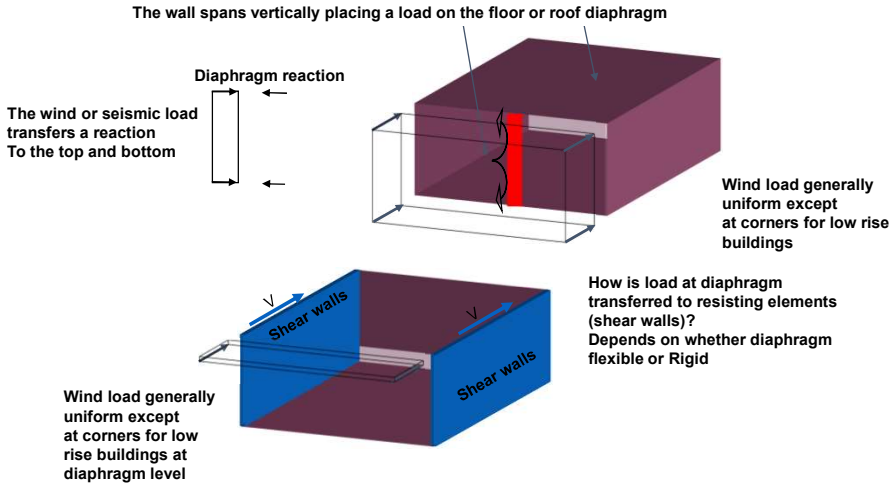
Masonry Walls –OOP (Lateral) Loads



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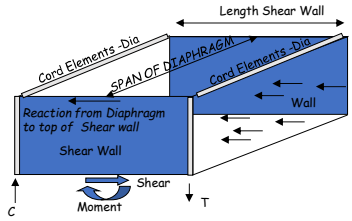
Masonry Walls -Lateral Loads

Lateral loads are resisted by diaphragms and Shear walls



Wind loads and inertial forces applied to walls out of plane are transferred to the floor and roof levels. These systems act as horizontal beams (diaphragms) and transfer the loads to supporting walls (shear walls) The shear walls take the loads to the ground.

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Masonry Assemblies - Strength

- Compression strength of the masonry assembly important in unreinforced masonry (URM) and reinforced masonry.
- Compression strength of the assembly is impacted by:
  - Unit strength
  - Mortar type M,S,N (strength)
  - Grout (presence and strength)

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CMU Unit Strength Table
TMS 602 Table 2

Net area compressive strength of concrete masonry, psi	Net area compressive strength of ASTM C90 concrete masonry units, psi (MPa)	
	Type M or S Mortar	Type N Mortar
1,700	---	1,900
1,900	1,900	2,350
2,000	2,000	2,650
2,250	2,600	3,400
2,500	3,250	4,350
2,750	3,900	----

- Table 1 gives similar values for clay brick . Min. Grout strength = 2000 psi or f'm

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Masonry Assemblies - Strength

- Flexural tensile strength of the Masonry assembly important in unreinforced masonry (URM) and reinforced masonry (for deflections)
- Tensile flexural strength of the assembly is impacted by:
  - Unit (hollow, solid)
  - Mortar type (M,S,N – System)
  - Direction of stress – parallel to bed joint or normal to bed joint
  - Grout (presence)
- Presence of reinforcing
- Workmanship

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Masonry Assemblies

Table 8.2.4.2 — Allowable flexural tensile stresses for clay and concrete masonry, psi (kPa)

Direction of flexural tensile stress and masonry type	Mortar types			
	Portland cement/lime or mortar cement		Masonry cement or air entrained portland cement/lime	
	M or S	N	M or S	N
Normal to bed joints				
Solid units	53 (366)	40 (276)	32 (221)	20 (138)
Hollow units[1]				
Ungrouted	33 (228)	25 (172)	20 (138)	12 (83)
Fully grouted	65 (448)	63 (434)	61 (420)	58 (400)
Parallel to bed joints in running bond				
Solid units	106 (731)	80 (552)	64 (441)	40 (276)
Hollow units				
Ungrouted and partially grouted	66 (455)	50 (345)	40 (276)	25 (172)
Fully grouted	106 (731)	80 (552)	64 (441)	40 (276)
Parallel to bed joints in masonry not laid in running bond				
Continuous grout section parallel to bed joints	133 (917)	133 (917)	133 (917)	133 (917)
Other	0 (0)	0 (0)	0 (0)	0 (0)

[1] For partially grouted masonry, allowable stresses shall be determined on the basis of linear interpolation between fully grouted hollow units and ungrouted hollow units based on amount (percentage) of grouting.

(From TMS 402)

Similar Table for Fr

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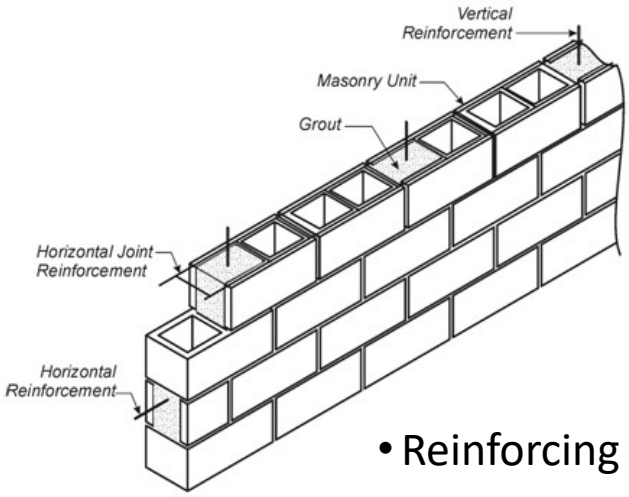
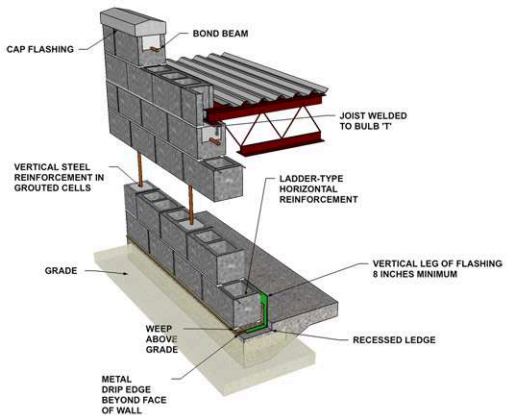
Masonry Assemblies – Strength - RM





- Reinforcing resists tension

http://www.masonrysystems.org/wall-systems/cavity-wall-concrete-block-veneer-reinforced-concrete-block/

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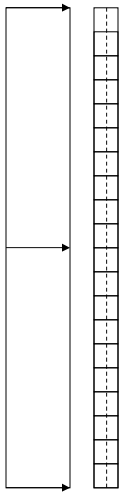
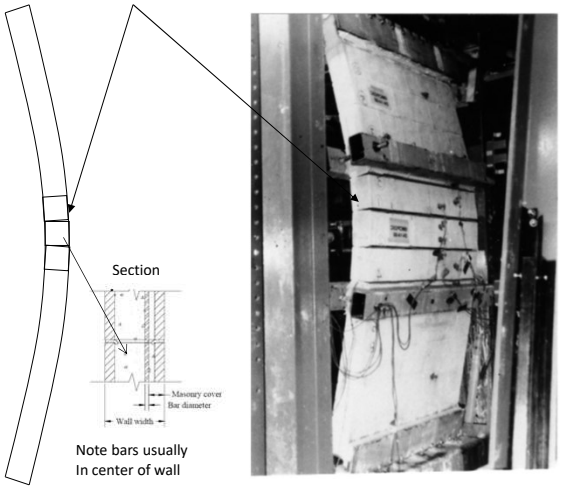
Masonry Assemblies – Strength - RM

Wall under out-of-plane Load



Walls Bending out of plane [Drysdale et-al Masonry Design]



Note bars usually In center of wall

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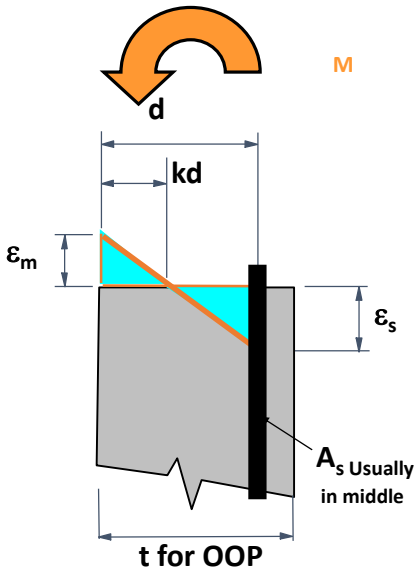
Masonry Assemblies – Strength - RM

Flexural Tensile Reinforcement Only single layer of steel - Strain Distribution

Assumptions

- Masonry in (net) flexural tension is cracked
- Reinforcing steel is needed to resist tension



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Masonry Assemblies – Strength - RM

- May have masonry walls that are not loadbearing but are providing lateral force resistance
- These are called Hybrid systems
- Detailing of the walls are critical in performance

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Grout very important – Construction - TMS 602 Section 3.2

- Grout space requirements are intended to provide adequate room for placement of grout.

Table 6 — Grout space requirements

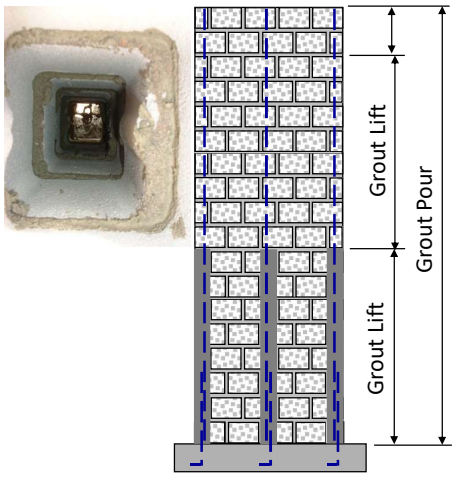
Grout type[1]	Maximum grout pour height, ft (m)	Minimum clear width of grout space,[2,3] in. (mm)	Minimum clear grout space dimensions for grouting cells of hollow units,[3,4] in. x in. (mm x mm)
Fine	1 (0.30)	3/4 (19.1)	1 1/2 x 2 (38.1 x 50.8)
Fine	5.33 (1.63)	2 (50.8)	2 x 3 (50.8 x 76.2)
Fine	12.67 (3.86)	2 1/2 (63.5)	2 1/2 x 3 (63.5 x 76.2)
Fine	24 (7.32)	3 (76.2)	3 x 3 (76.2 x 76.2)
Coarse	1 (0.30)	1 1/2 (38.1)	1 1/2 x 3 (38.1 x 76.2)
Coarse	5.33 (1.63)	2 (50.8)	2 1/2 x 3 (63.5 x 76.2)
Coarse	12.67 (3.86)	2 1/2 (63.5)	3 x 3 (76.2 x 76.2)
Coarse	24 (7.32)	3 (76.2)	3 x 4 (76.2 x 102)

[1] Fine and coarse grouts are defined in ASTM C476.

[2] For grouting between masonry wythes.

[3] Minimum clear width of grout space and minimum clear grout space dimension are the net dimension of the space determined by subtracting masonry protrusions and the diameters of horizontal bars from the as-built cross section of the grout space. Select the grout type and maximum grout pour height based on the minimum clear space.

[4] Minimum grout space dimension for AAC masonry units shall be 3 in. (76.2 mm) x 3 in. (76.2 mm) or a 3 in. (76.2 mm) diameter cell.



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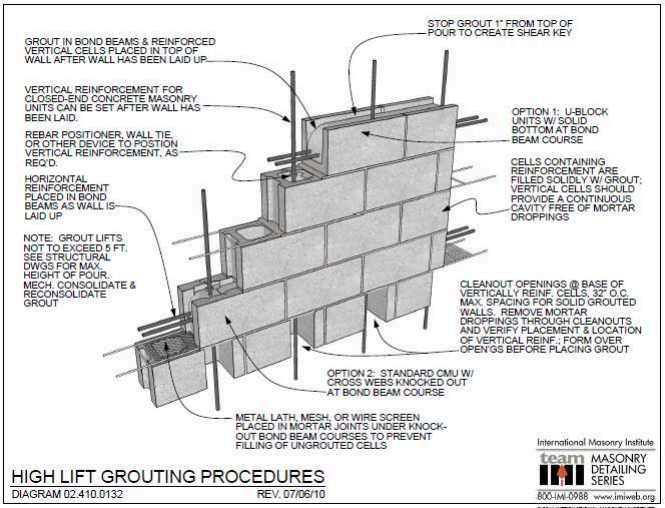
Construction: TMS 602 Section 3.2 High lift procedures

- Cleanouts and other procedures designed to ensures complete grouting and good contact between grout, rebar and units.



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EXTERIOR Masonry Assemblages Can also be Classified by Envelope Function

- single wythe – Barrier System
  - » least expensive, least resistant to water penetration
- multiwythe noncomposite – Drainage Wall
  - » high expense and workmanship demands; high resistance to water penetration
- multiwythe composite- Barrier System
  - » moderate expense and workmanship demands, good resistance to water penetration

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EXTERIOR Masonry Assemblages Can also be Classified by Envelope Function

- Barrier wall
  - » single – wythe or multi – wythe with filled collar joint and wythes connected with metal ties

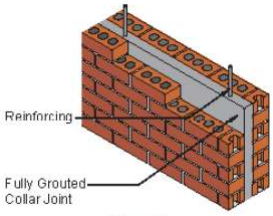

Figure 6
Reinforced Barrier Wall

Moisture Barriers

•Drainage wall – Masonry Veneer, Cavity wall

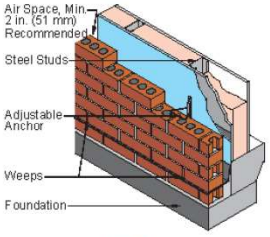

Figure 1
Brick Veneer/Steel Stud Wall

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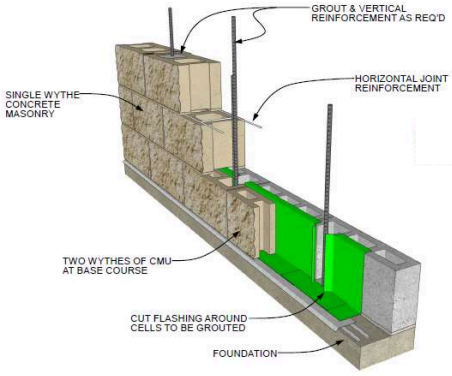
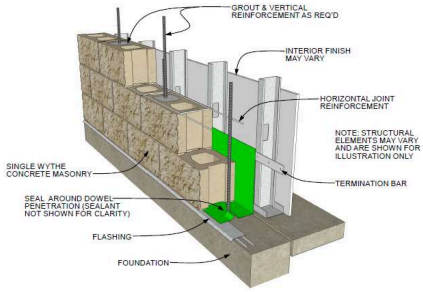
Barrier Walls

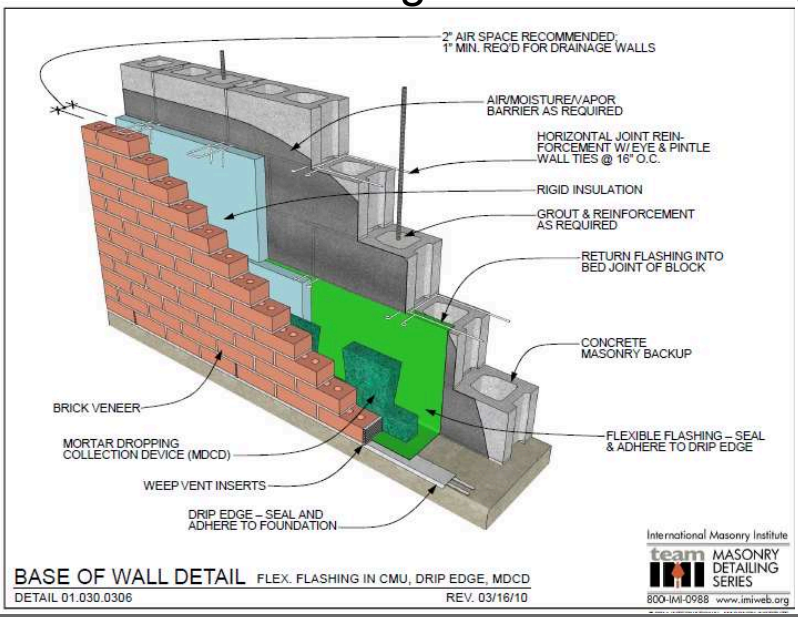
- Moisture Penetrates into wall but not through –
- Water hopefully dries to exterior –
- Note flashing and air space behind wall in case water gets too far and collect the water at base

(Figures from imi.org)





Moisture Barriers - Drainage Walls – Detailing critical



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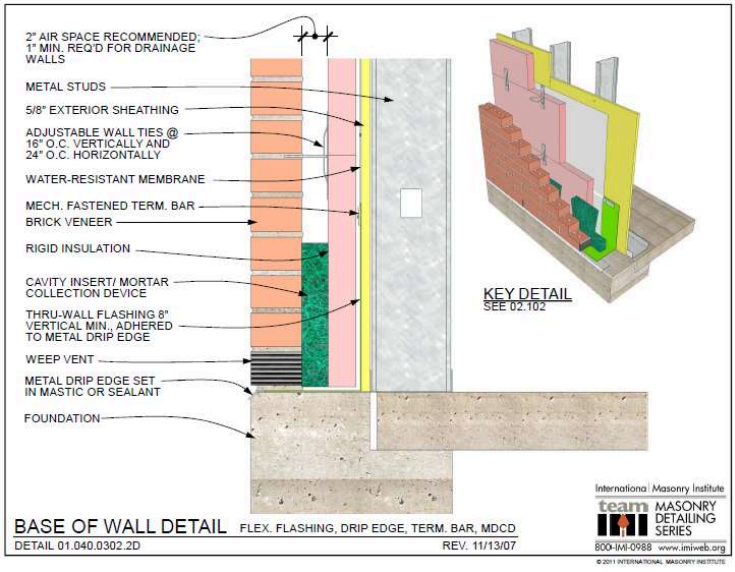
Moisture Barriers - Drainage Walls – Detailing critical



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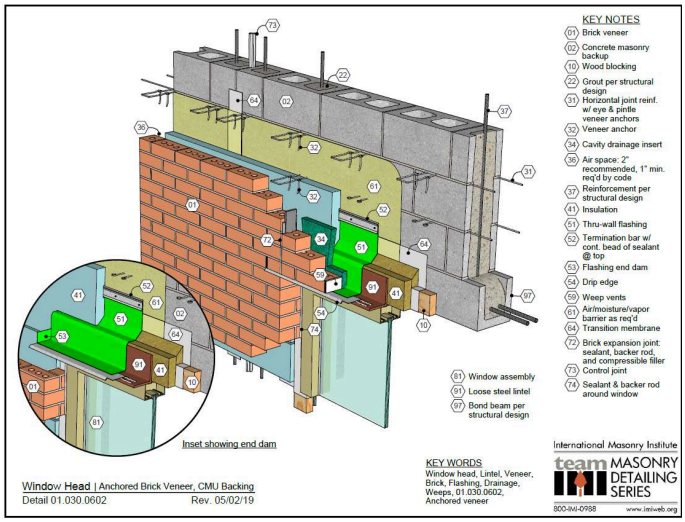
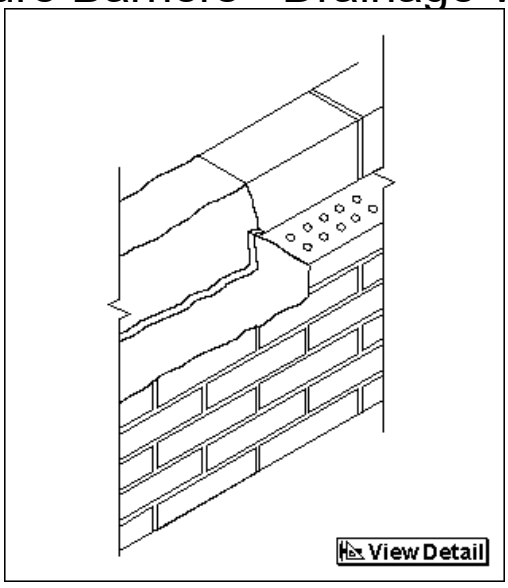
Moisture Barriers - Drainage Walls – Detailing critical

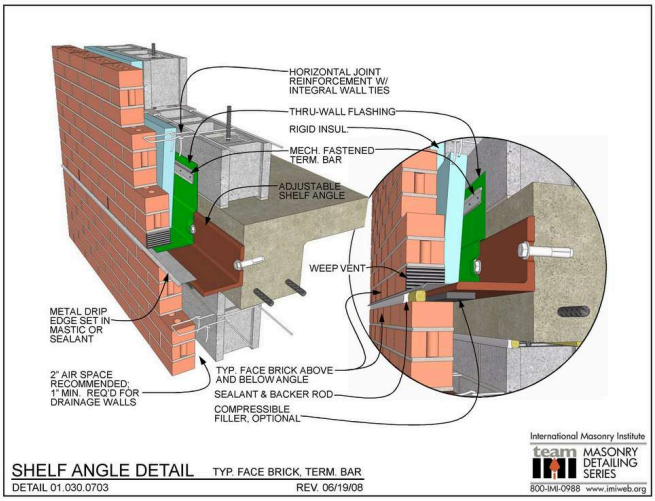


Moisture Barriers - Drainage Walls – Detailing critical



- End Dams needed at window heads and ends, etc.

Moisture Barriers - Drainage Walls – Detailing critical



- Masonry Moves and Moisture barrier must control this as well

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Masonry Assemblies MOVE!!!!

Movements are produced by:

- Thermal differences
- Shrinkage
- Moisture Expansion
- Elastic- deformation both of the masonry and any supporting structural systems
- Creep
- Foundation Settlements
- Clay and Concrete masonry different

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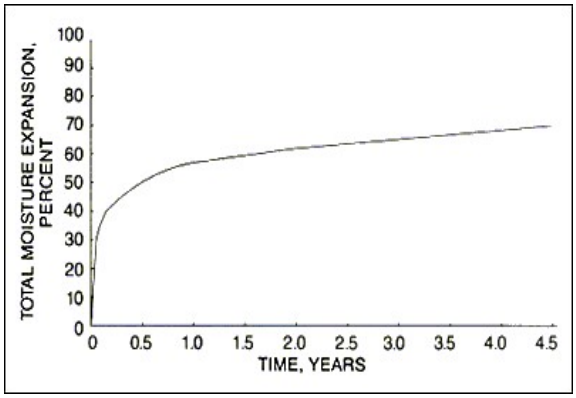
Movements of Clay Masonry Materials/Assemblies (in-plane)



Brick are the smallest when cooled from the kiln. **CLAY UNITS GROW**
Expansion ranges from 0.0002 to 0.0009 in/in the MSJC code gives 0.0003 in/in. = k_e
Research indicates that unit expansion may not always be greater that panel expansion (interaction of mortar and brick in cryptoflorescence) and horizontal movements are greater than vertical.

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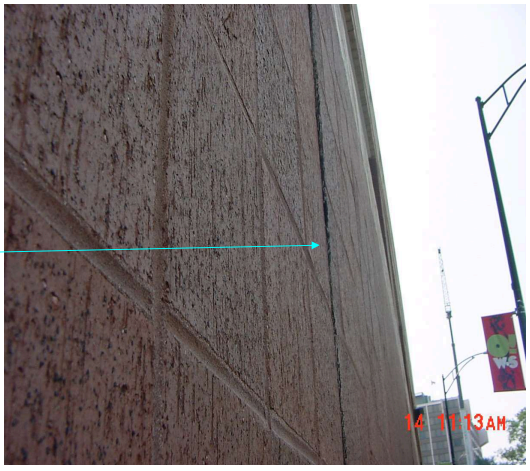
Control of Movements of Clay Masonry Assemblies

Clay masonry can expand significantly

Benson Convention Center

Sealant forced out



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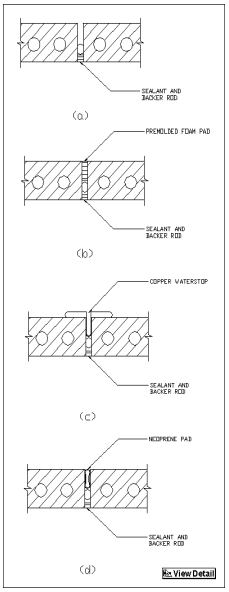
Expansion Joints in Clay Masonry

The primary function of this joint is allow free expansion of the masonry but must also resist water penetration and air movement

Note that expansion joints and control joints are not the same

Expansion joints must be free to move and but must be sealed to weather



BIA Tech note 18A Vertical Expansion Joints

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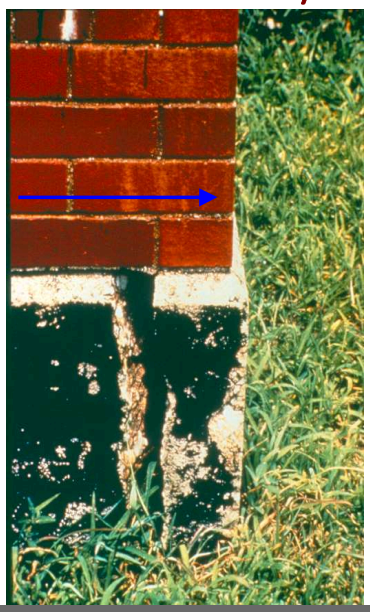
Placement of Vertical Expansion Joints in Clay Masonry

Walls do move

Foundation was bonded to wall and went with movement

Flashing can stop this



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Placement of Vertical Expansion Joints in Clay Masonry

Corner opening cracks

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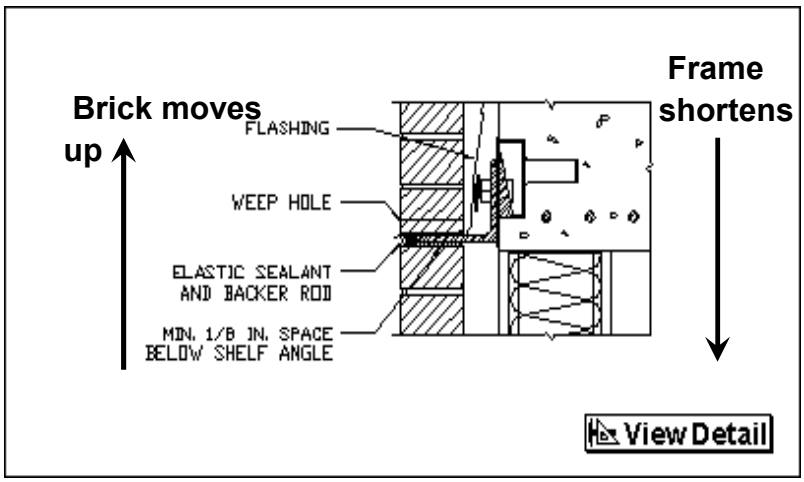
Horizontal Expansion Joints in Clay Masonry



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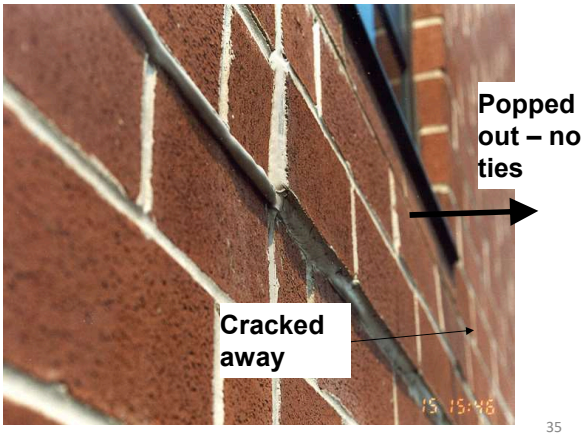
Horizontal Expansion Joints in Clay Masonry

Problems – Closed mortar joints



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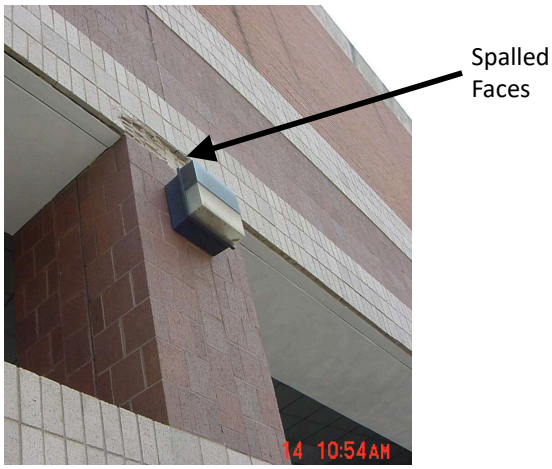
Horizontal Expansion Joints in Clay Masonry

Problems – Closed mortar joints –



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Control Joints in Concrete Masonry - Configuration (NCMA.org)

Control joints are a joint that creates a weakness in the masonry wall and allows the cracks to form in the joint NCMA Tek Note 10-2A

Concrete Shrinks!!

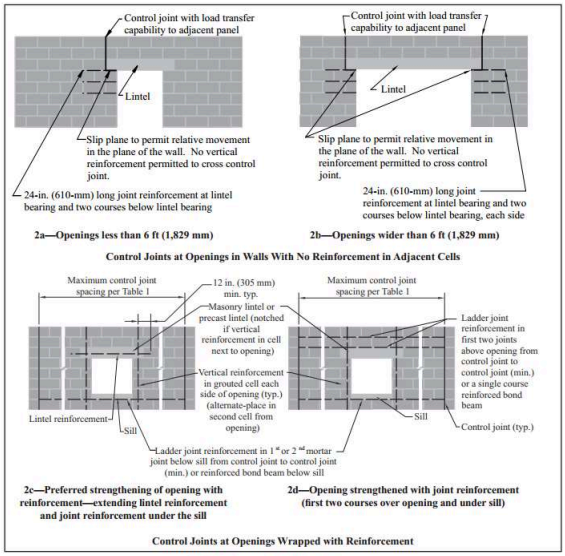
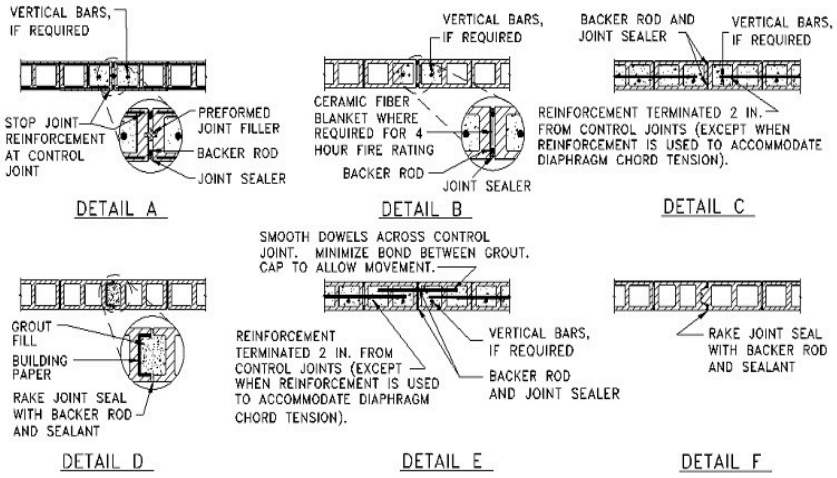


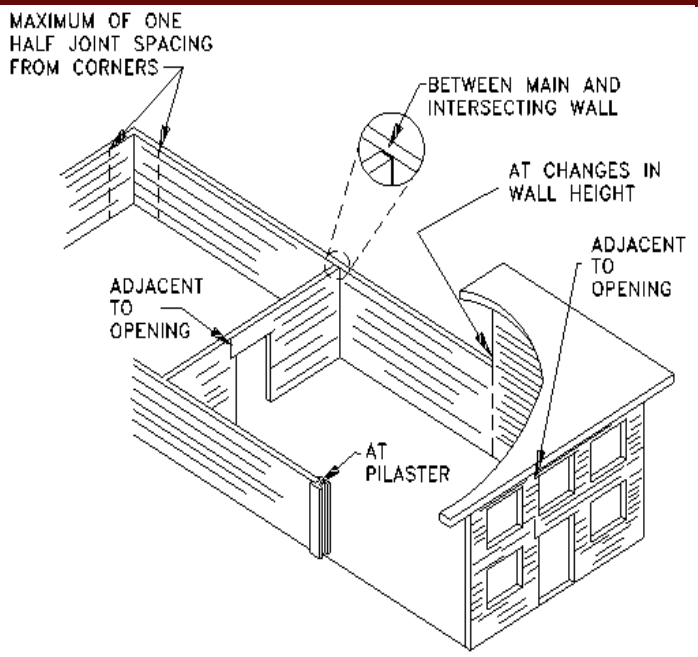
Figure 2—Control Joints at Openings

Control Joints in Concrete Masonry - Configuration (NCMA.org)

Control joints are a joint that creates a weakness in the masonry wall and allows the cracks to form in the joint NCMA Tek Note 10-2A



Control Joint Placement in Concrete Masonry per NCMA Tek Note 10-2A



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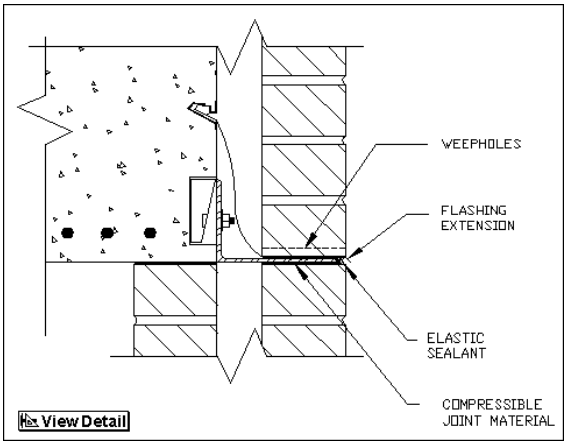
Moisture Barriers - Drainage Walls – Detailing critical. What's Wrong with this detail?



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Energy – Thermal envelope performance
Air/thermal barrier Compliance Options - IECC

Prescriptive → R-value table / U-factor table

Trade-off - Envelope → COMcheck

Total building performance → EnergyPlus/Design Builder, Sefaira, TREAT, BSim, etc.

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Prescriptive requirements – Envelope – Varies

TABLE 5.5-4 Building Envelope Requirements for Climate Zone 4 (A, B, C)*

Climate Zone 4 B

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.173	R-5.0 c.i.
Metal Building[a]	U-0.055	R-13.0 + R-13.0	U-0.055	R-13.0 + R-13.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal Building	U-0.084	R-19.0	U-0.084	R-19.0	U-0.113	R-13.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.064	R-13.0 + R-3.8 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass						
Steel-Joist						
Wood-Framed and Other						
Slab-On-Grade Floors						
Unheated						
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-0.500		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[c]	U-0.40		U-0.40		U-1.20	
Metal framing (curtainwall/storefront)[d]	U-0.50	SHGC-0.40 all	U-0.50	SHGC-0.40 all	U-1.20	SHGC-NR all
Metal framing (entrance door)[d]	U-0.85		U-0.85		U-1.20	
Metal framing (all other)[d]	U-0.55		U-0.55		U-1.20	

Walls, Above-Grade Mass U-0.104 R-9.5 c.i.

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Terminology

R-value: describes how well a material insulates under steady state temperature conditions; R = 1/U

U-factor: describes how well a material conducts heat under steady state temperature conditions; U = 1/R

Heat capacity (HC): describes how well a material stores and releases heat under transient temperature conditions (thermal mass)

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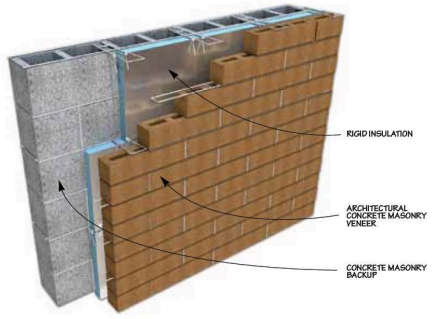
Prescriptive R-Value Compliance

Masonry cavity wall:
- Cavity width can be varied to accommodate insulation
- R-values largely independent of grout schedule
- Exposed masonry provides maximum durability



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Prescriptive R-Value Compliance

Continuous interior insulation:
- R-values independent of grout schedule
- Allows exterior exposed masonry
- Furring space can be used for wiring and utilities

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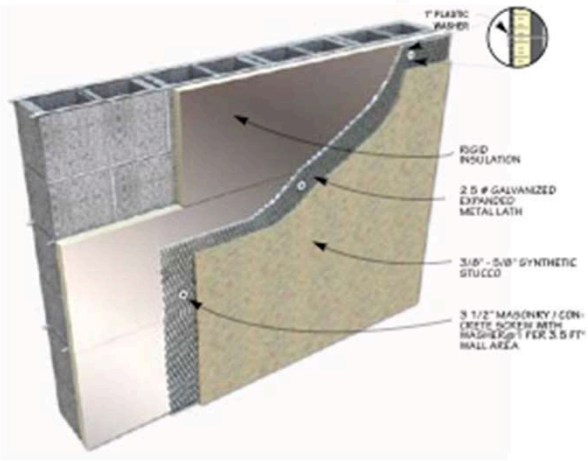
Prescriptive R-Value Compliance

Continuous exterior insulation:
- R-values independent of grout schedule
- Allows interior exposed masonry, maximizing thermal mass benefits



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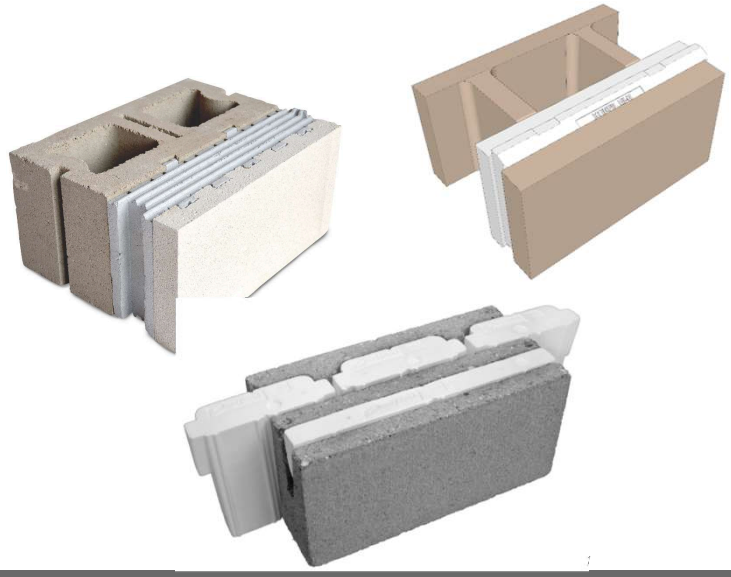
CMU Products for Energy Efficiency



Additional Resources, Websites

- ICC – International Code Council, www.iccsafe.org
- TMS – The Masonry Society, www.masonrysociety.org
- MIA – Masonry Institute of America www.masonryinsitute.org
- BIA – Brick Industry Association, www.gobrick.com
- IMI - International Masonry Institute, www.imiweb.org
- NCMA – National Concrete Masonry Association, www.ncma.org
- PCA – Portland Cement Association, www.cement.org
- ASTM – ASTM International – www.astm.org

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Panel Discussion

Me , You and Courtney Fried (BIA), Brian Trimble (IMI), Jerry Painter, maybe Nick Lang (NCMA).

What do you want Guidance in?

- Such as BIM?
  - BIM- M (for masonry) – initiative – videos - details – TMS – masonrycontractors.org
  - Masonry IQ – Plug in for Revit addresses masonry modules , units, much more
- Such as Resilience?

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Resiliency = Above Code

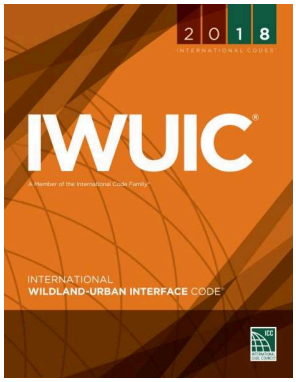
- The term **'above code'** is often used to describe resiliency programs and standards.

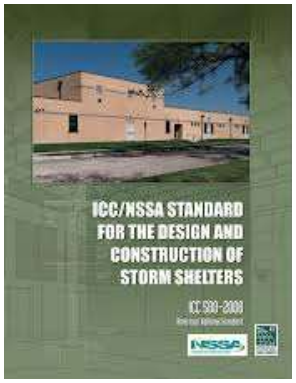
Fire | High Winds | Environment (Green)

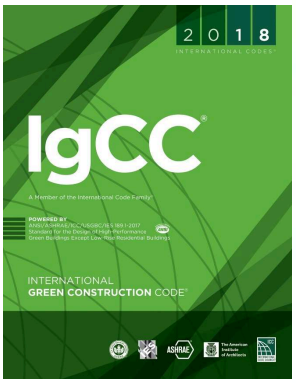
Building Code

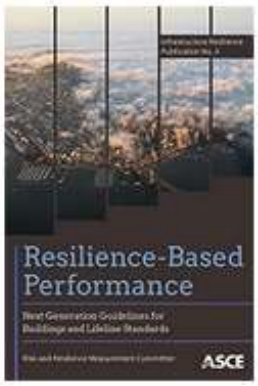
Resiliency Standards

'Above code' standards for construction:





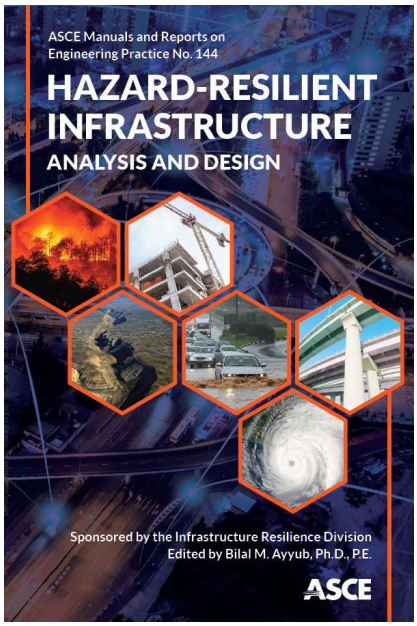




Resiliency Design ASCE Manual Of practice

The manual set goals and objectives, describes a methodological framework for achieving hazard resilient infrastructure.

- Describes available and mature methods for assessing the resilience of systems and facilities individually and collectively as systems
- Focuses on economics of resilience and risk management.
- Summarizes methods used by microeconomists for examining resilience enhancing alternatives.
- Provides an overall design approach of resilient-infrastructure systems – with examples and case studies.
- Covers community socioeconomics and offers guidance on ways to account for such
- Provides a review of emerging resilience-enabling technologies for new and existing infrastructure systems.



What's Masonry's Role?

- Strength, durability, non-combustibility, impact resistance, flood and mold resistance, and thermal performance…all inherent properties of masonry construction.

- While masonry doesn't define a resilient building or community, it is a key cornerstone to achieving these goals.

Resources

- AIA - https://www.aia.org/topics/56-resilience
- FLASH - https://flash.org/
- FEMA - https://www.fema.gov/about/offices/resilience
- NIBS - https://www.nibs.org/page/mmc
- Resilient Design Institute – resilientdesign.org/
- RELi - http://c3livingdesign.org/?page_id=5110
- ASCE -https://sp360.asce.org/PersonifyEbusiness/Merchandise/Product-Details/productId/273766313
- Many cities and states have information on resilience

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What do you want Guidance in?

- ?

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This concludes The American Institute of Architects Continuing Education Systems Course

THE MASONRY SOCIETY

The Masonry Society

Contact information:
Email: m.mcginley@Louisville.edu

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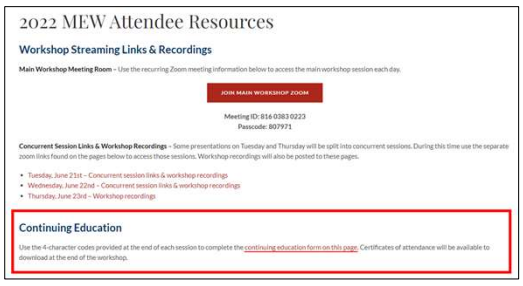
Certificates of Attendance

Session: Masonry Assemblages & Discussion of Performance Attributes

Code: NZB9

- Submit this code through the continuing education link on the workshop resources page
- Select this session from the menu and enter the code shown above (not case-sensitive)



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Certificate of Attendance Instructions

- After submitting the form, please allow TMS staff up to 2-3 business days to process your request
- Certificates of attendance will be available to download from the My Events tab on your Account Page, as shown below, at the end of the workshop

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