Quality Assurance and Inspection of Concrete Masonry Construction

NCMA AIA/LA CES COURSE – C304a

MASONRY INSTITUTE OF IOWA

NATIONAL CONCRETE MASONRY ASSOCIATION

Sustainable Concrete Products for Structures and Hardscapes

CONCRETE PRODUCTS UNIVERSITY

Disclaimer

The National Concrete Masonry Association is a Registered Provider with The American Institute of Architects (AIA/CES) Continuing Education System. Credit(s) earned on completion of this program will be reported to AIA/CES for AIA members. Certificates of Completion will be provided to all attendees upon request.

This program is registered with AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

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

Course Description

This presentation provides an overview of the inspection and quality assurance provisions associated with concrete masonry construction as required by the 2015 *International Building and Residential Codes* (IBC and IRC) and TMS 602-13, *Specification for Masonry Structures*.

Learning Objectives

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

1. Distinguish between quality assurance and quality control.
2. Understand the code requirements for concrete masonry construction.
3. Identify the code requirements for concrete masonry inspection.
4. Evaluate construction tolerances.

Project Specification Items

Compressive strength, f'_m, & verification method

Submittal reporting & review process

Required quality assurance level

Sample panel requirements

Masonry unit and mortar types, colors, etc.

Reinforcement & accessory types, grades, corrosion protection

Details of pipes, conduits, accessories, movement joints, joint fillers, anchors

The Need for QA

The Need for QA and QC

- Higher quality and better masonry performance
- Increased confidence that the project will be constructed correctly and as designed
- Confidence in design reduces over-design
  - ➢ More cost efficient

QA vs. QC

What is the difference?

Quality Assurance (QA): the owner's or designer's efforts to determine project acceptability, accomplished through testing, field inspection, and QC

Quality Control (QC): contractor's or manufacturer's efforts to ensure the final properties of the product in effort to achieve a specified goal

Inspection

Inspection: the action(s) taken to ensure that the established quality assurance program will be met

Primary Inspectors

Building Department Inspectors

- Periodic visits
- Issue permits based on inspections
- Degree of inspection varies

Special Inspectors

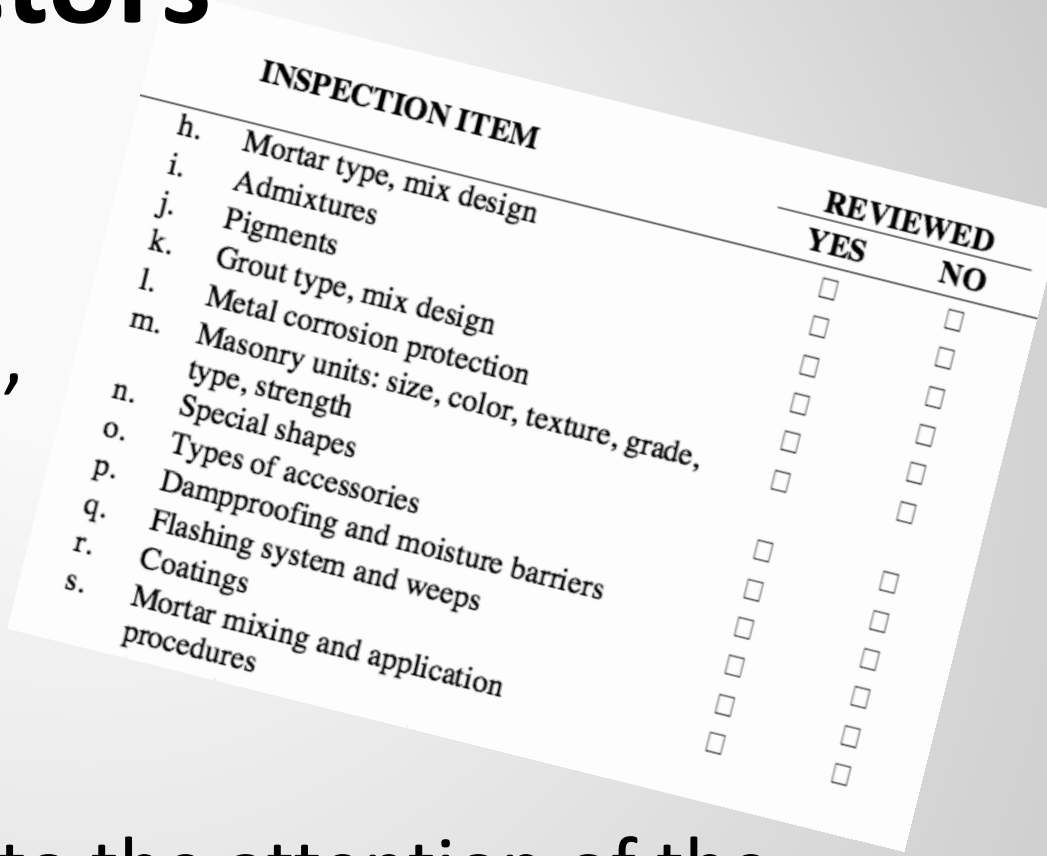
- Qualified individual(s) to examine defined aspects
- Typically hired by owner/designer

Designers – Architect/Engineer

- Observe construction

Duty of Inspectors

- To monitor, observe, verify, document, and report results



INSPECTION ITEM	REVIEWED YES	REVIEWED NO
h. Mortar type, mix design	☐	☐
i. Admixtures	☐	☐
j. Pigments	☐	☐
k. Grout type, mix design	☐	☐
l. Metal corrosion protection	☐	☐
m. Masonry units: size, color, texture, grade, type, strength	☐	☐
n. Special shapes	☐	☐
o. Types of accessories	☐	☐
p. Dampproofing and moisture barriers	☐	☐
q. Flashing system and weeps	☐	☐
r. Coatings	☐	☐
s. Mortar mixing and application procedures	☐	☐

- Bring problems or potential problems to the attention of the architect/engineer and contractor

***It is up to the architect/engineer to take action to resolve issues.

TMS 602 Specification

Synopsis and Keywords

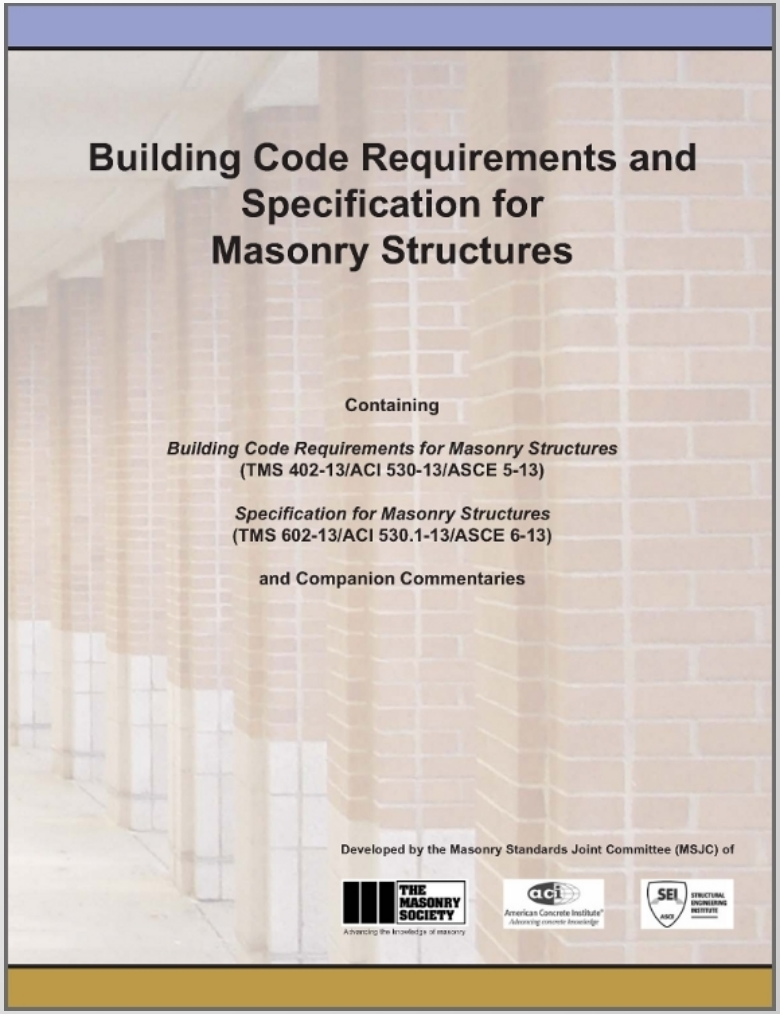
Preface

Part 1 – General

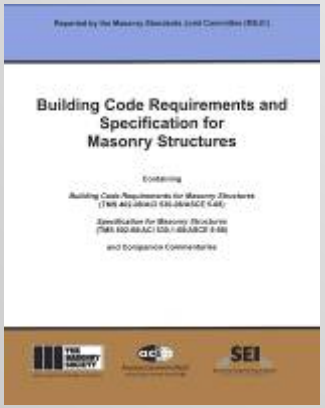
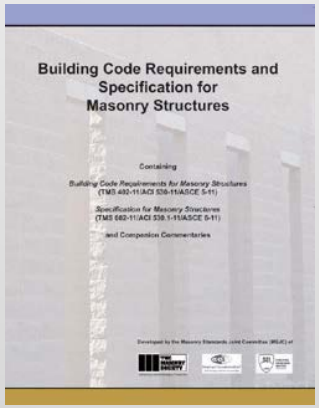
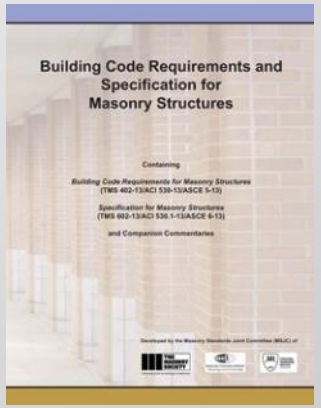
Part 2 – Products

Part 3 – Execution

Specification Checklist



IBC Reference Documents

2009 IBC	2012 IBC	2015 IBC
		
2008 TMS	2011 TMS	2013 TMS
		

TMS 602 Part 1: General

- Submittals
- Levels of inspection
- Masonry compressive strength
- Delivery, storage, and handling
- Project conditions

Article 1.5 – Submittals

Mix designs and test results

- Mortar and grout

Material certificates

- Reinforcement, anchors, ties, and fasteners
- Units, mortar and grout materials
- Self-consolidating grout

Construction procedures

- Hot and cold weather procedures

Submittals – Mortar and Grout

- Mortar
  - Type and proportions of ingredients for proportion spec
  - Mortar test results for property spec
- Grout
  - Type and proportions for proportion spec
  - Strength tests for property spec
  - Strength tests, slump flow, and VSI for self-consolidating grout

Submittals – Material Certificates

- Reinforcement
- Anchors, ties, fasteners, metal accessories
- Masonry units
- Mortar and grout materials
- Self-consolidating grout

Article 1.6 – Quality Assurance

Quality Assurance Levels – Level A (Basic Level), Level B (Intermediate), Level C (Rigorous)

Which to use?

- Building code typically prescribes based on type of structure/construction and design method:
  - essential vs. nonessential
  - prescriptive/empirical vs. engineered

Types of Inspection

Inspection, continuous – The Inspection Agency's full-time observation of work by being present in the area where the work is being performed.

Inspection, periodic – The Inspection Agency's part-time or intermittent observation of work during construction by being present in the area where the work has been or is being performed, and observation upon completion of the work.

Quality Assurance

QA Level	Facility Type	Construction
A	Non-essential	Empirically designed Glass unit masonry Masonry veneer
B	Non-essential	Engineered masonry
B	Essential	Empirically designed Glass unit masonry Masonry veneer
C	Essential	Engineered masonry

TMS 602 QA - Level A (basic)

Minimum Verification
Prior to construction, verify certificates of compliance used in masonry construction.

TMS 602 QA – Level B (intermediate)

Applies to essential facilities when inspecting:

- Empirically designed masonry
- Masonry veneers
- Glass unit masonry

Applies to non-essential facilities when inspecting:

- Engineered masonry

TMS 602 QA - Level B (intermediate)

MINIMUM SPECIAL INSPECTION				
Inspection Task	**Frequency [a]**		**Reference for Criteria**	
	Continuous	Periodic	TMS 402/ ACI 530/ ASCE 5	TMS 602/ ACI 530.1/ ASCE 6
1. Verify compliance with the approved submittals		X		Art. 1.5
2. As masonry construction begins, verify that the following are in compliance:				
a. Proportions of site-prepared mortar		X		Art. 2.1, 2.6 A
b. Construction of mortar joints		X		Art. 3.3 B
c. Grade and size of prestressing tendons and anchorages		X		Art. 2.4 B, 2.4 H

TMS 602 QA - Level B (intermediate)

Minimum Tests
Verify f'_m prior to construction*
For self-consolidating grout (SCG), verify slump flow and Visual Stability Index (VSI), as delivered to site

* except where specifically exempted by the Code (TMS 402)

TMS 602 QA - Level B (intermediate)

Minimum Special Inspection	
1. Verify compliance with approved submittals	P
2. Verify the following are in compliance:	
Proportions of site-prepared mortar	P
Construction of mortar joints	P
PS tendon & anchorage grade and size	P
Location of reinforcement, connectors, etc.	P
Prestressing technique	P

TMS 602 QA - Level B (intermediate)

Minimum Special Inspection	
3. Prior to grouting verify the following comply:	
Grout space	P
Grade, type, size of reinforcement, etc.	P
Placement of reinforcement, etc.	P
Proportions of site-prepared grout & PS grout	P
Construction of mortar joints	P

TMS 602 QA - Level B (intermediate)

Minimum Special Inspection	
4. Verify during construction:	
Size & location of structural elements	P
Type, size, & location of anchors	P
Welding of reinforcement	C
Prep, construction, & protection during hot and cold weather	P
Application & measurement of PS force	C
Grout placement is in compliance	C

TMS 602 QA - Level B (intermediate)

Minimum Special Inspection	
5. Observe preparation of grout specimens, mortar specimens, and/or prisms	P

TMS 602 QA - Level C (rigorous)

- Can be used for both essential and non-essential facilities
- Must be used with essential facilities requiring engineered design

TMS 602 QA – Level C (rigorous)

Minimum Tests
Verification of f'_m prior to construction *& for every 5,000 ft^2 during construction*
Verification of material proportions in premixed or preblended mortar, PS grout, & grout other than SCG as delivered to the project site
For self-consolidating grout, verify slump flow and Visual Stability Index (VSI), as delivered to site

TMS 602 QA – Level C (rigorous)

Minimum Special Inspection	
1. Verify compliance with approved submittals	P
2. Verify the following are in compliance:	
Proportions of site-mixed mortar & grout	P
Grade, type, size of reinforcement, etc.	P
Placement of units & mortar joint construction	P
Placement of reinforcement, etc.	*C*
Grout space prior to grouting	*C*

TMS 602 QA – Level C (rigorous)

Minimum Special Inspection	
2. Verify the following are in compliance (cont'd):	
Grout placement is in compliance	C
Size & location of structural elements	P
Type, size, & location of anchors	*C*
Welding of reinforcement	C
Prep, construction, & protection during hot and cold weather	P
Application & measurement of PS force	C

TMS 602 QA – Level C (rigorous)

Minimum Special Inspection	
3. Observe preparation of grout specimens, mortar specimens, and/or prisms	*C*

Article 1.6D Sample Panels

- Required for QA Levels B & C
- Workmanship criteria for contractor
- Min. 4 ft x 4 ft
- Display range of materials
- Used to accept/reject masonry work

Article 1.7 – Delivery, Storage, and Handling

Stipulates protection of materials on site:

- Don’t use damaged products.
- Keep mortar and grout materials dry.
- Don’t use contaminated materials.
- Store aggregates separately.
- Protect metal materials from permanent distortion and store off the ground.

Article 1.8 – Project Conditions

Defines conditions for:

- Protection of masonry during construction
- Cold weather construction
- Hot weather construction

Article 1.8 – Project Conditions

Cold weather construction procedures: 40 °F

Modify:

construction procedures → based on → ambient temperature

masonry protection →
- min. daily temp for grouted masonry
- mean daily temp for ungrouted

Article 1.8 – Project Conditions

Hot weather construction procedures

100 °F or 90 °F and wind speed > 8 mph

Modify:

preparation → based on → ambient temperature

construction → ambient temperature

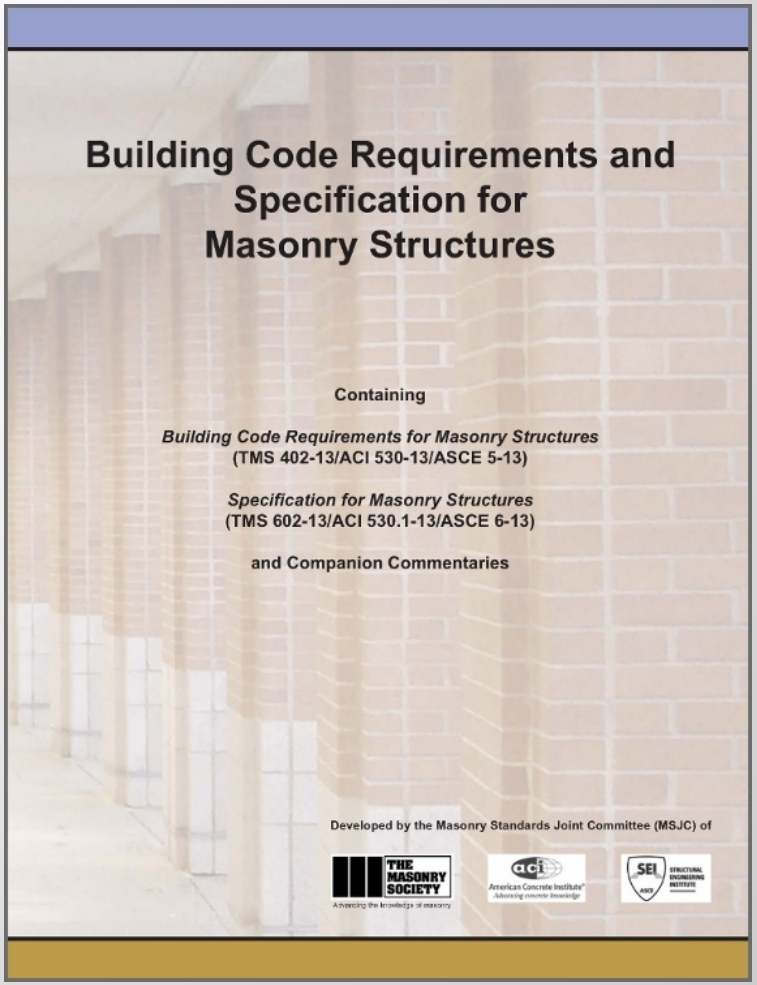
protection → mean daily temperature

TMS 602 Specification

Part 1 – General

Part 2 – Products

Part 3 – Execution



Verify Materials

Units

Mortar

Grout

Reinforcement

Prestressing tendons,
anchorages, and couplers

Joint reinforcement

Anchors, ties, accessories

Corrosion protection

Verification of f'_m

Article 1.4 defines the minimum compressive strength requirements for concrete masonry construction (f'_m). There are two ways to verify the assembly compressive strength:

1) prism testing; or
2) unit strength method

Verification of f'_m

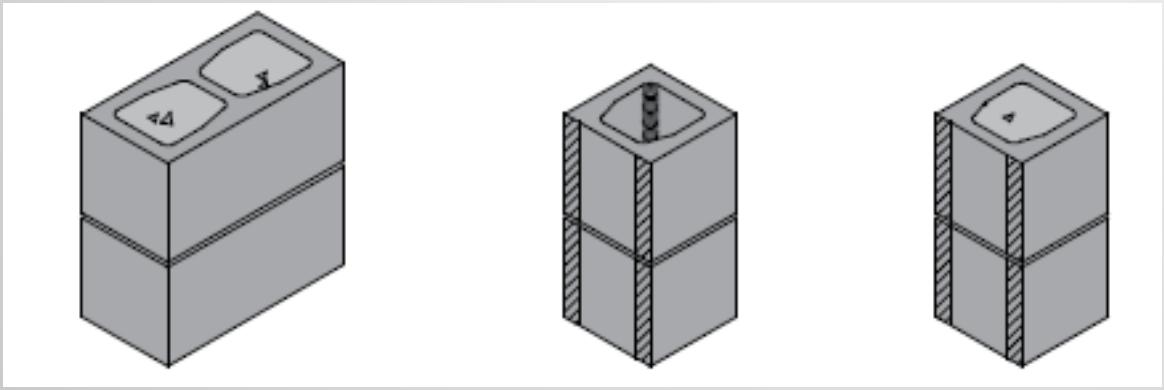
Unit Strength Method

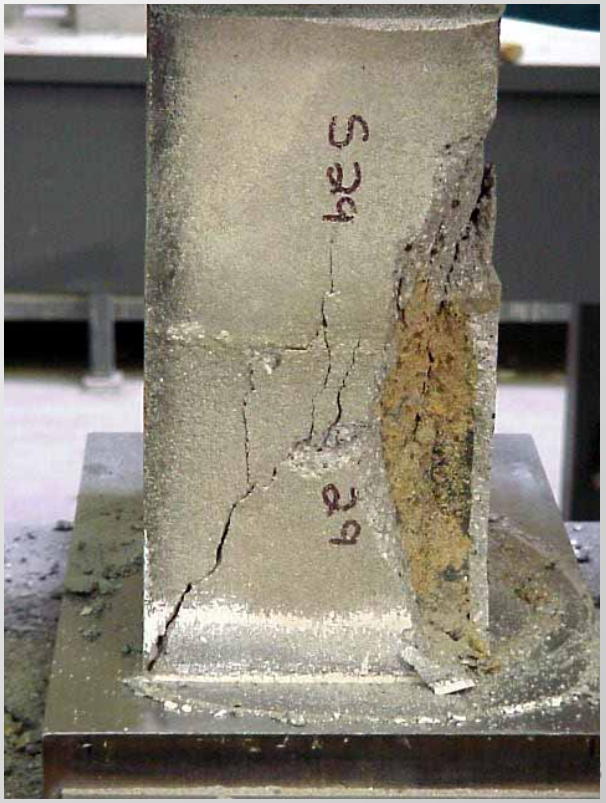
Net area compressive strength of masonry, psi	Net area compressive strength of concrete masonry units, psi	
	Type M or S	Type N
1,700	------	1,900
1,900	1,900	2,350
2,000	2,000	2,650
2,250	2,600	3,400
2,500	3,250	4,350
2,750	3,900	------
3,000	4,500	------

Verification of f'_m

Prism Test Method

Masonry prisms are constructed and tested in accordance with ASTM C1314.





Proportions of Site-Mixed Mortar

TABLE 1—ASTM C 270 Proportion Specification Requirements (ref. 4)

Proportions by volume (cementitious materials)

Mortar	Type	Portland cement or blended cement	Mortar Cement M	Mortar Cement S	Mortar Cement N	Masonry cement M	Masonry cement S	Masonry cement N	Hydrated lime or lime putty	Aggregate ratio (measured in damp, loose condition)
Cement-lime	M	1	...	...	...	...	...	...	1/4	
	S	1	...	...	...	...	...	...	over 1/4 to 1/2	
	N	1	...	...	...	...	...	...	over 1/2 to 1 1/4	
	O	1	...	...	...	...	...	...	over 1 1/4 to 2 1/2	
Mortar Cement	M	1	...	...	1	...	...	...	...	Not less than 2 1/4 and not more than 3 times the sum of the separate volumes of cementitious materials.
	M	...	1	...	...	...	...	...	...	
	S	1/2	...	...	1	...	...	...	...	
	S	...	...	1	...	...	...	...	...	
	N	...	...	...	1	...	...	...	...	
	O	...	...	...	1	...	...	...	...	
Masonry Cement	M	1	...	...	...	...	...	1	...	
	M	...	...	...	...	1	...	...	...	
	S	1/2	...	...	...	...	...	1	...	
	S	...	...	...	...	...	1	...	...	
	N	...	...	...	...	...	...	1	...	
	O	...	...	...	...	...	...	1	...	

Note—Two air-entraining materials should not be contained in mortar.

ASTM C270 Property Specification

Mortar Type	Compressive strength, min psi	Water retention, min %	Air Content , max %
M	2,500	75	12
S	1,800	75	12
N	750	75	14*
O	350	75	14*

* 20% for masonry cement, may also vary if mortar contains structural reinforcement

Mortar is Proportioned by Volume

Article 2.6 – Mixing

Mixing instructions for mortar and grout

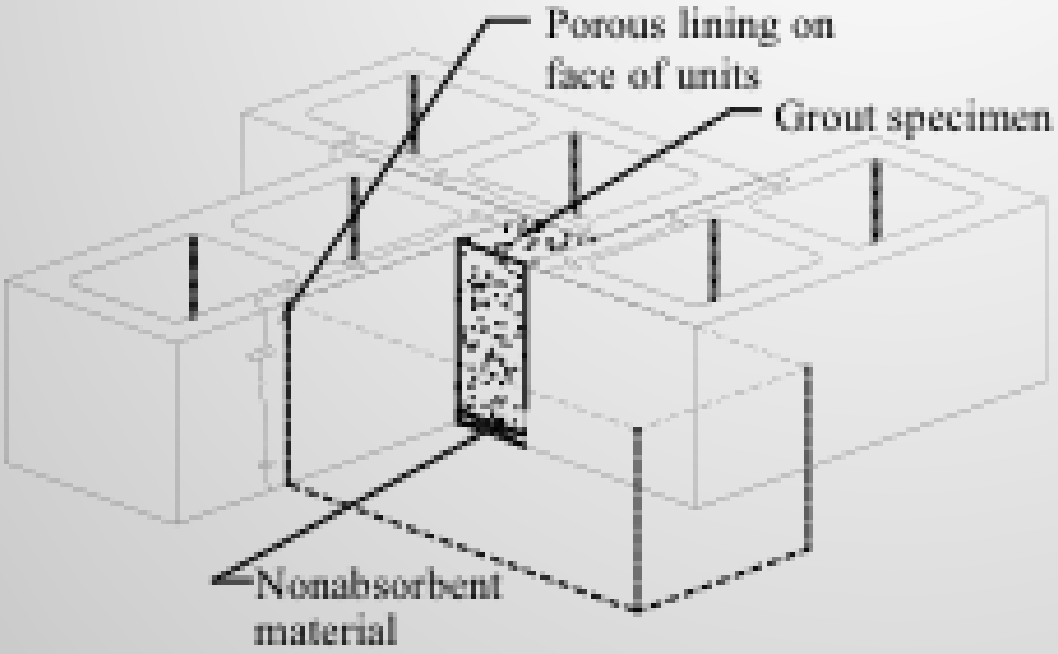
Proportions of Site-Prepared Grout

Type of grout	Portland or blended cement	Hydrated lime or lime putty	Aggregate*	
			Fine	Coarse
Fine	1	0 – 1/10	2 1/4 - 3	
Coarse	1	0 – 1/10	2 1/4 - 3	1 - 2

* Aggregate proportion is relative to the sum of the volumes of the cementitious materials; aggregate is measured in a damp loose condition.

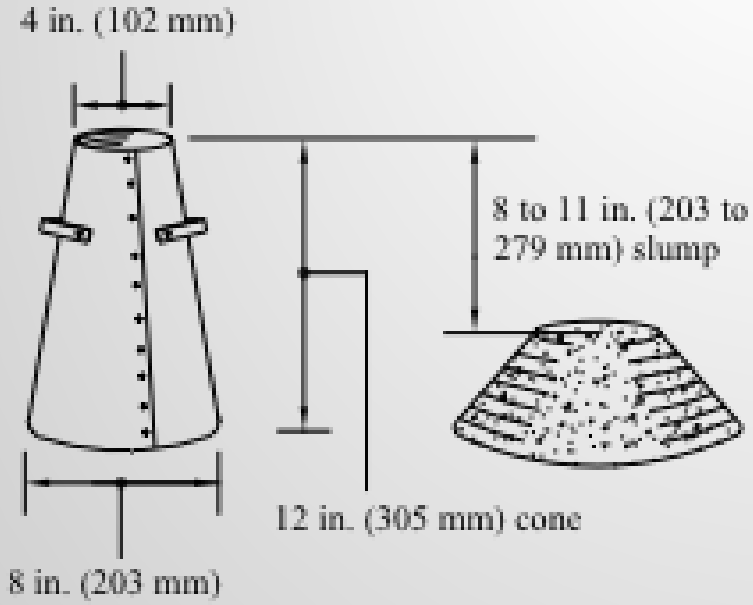
Verification of Grout Properties

Compression testing



Verification of Grout Properties

Slump



Self-Consolidating Grout

What is self-consolidating grout?

SCG is a stable, highly fluid grout that does not segregate when placed and requires no consolidation or reconsolidation.

SCG is not a watered-down grout.

Verification of SCG Properties

ASTM C1019:

– Compressive strength

ASTM C1611:

- Slump flow, required, 24 – 30 inches
- Visual stability index (VSI), required, < 1
- Relative viscosity, $T_{20}(T_{50})$, voluntary

Verification of SCG Properties

Slump flow

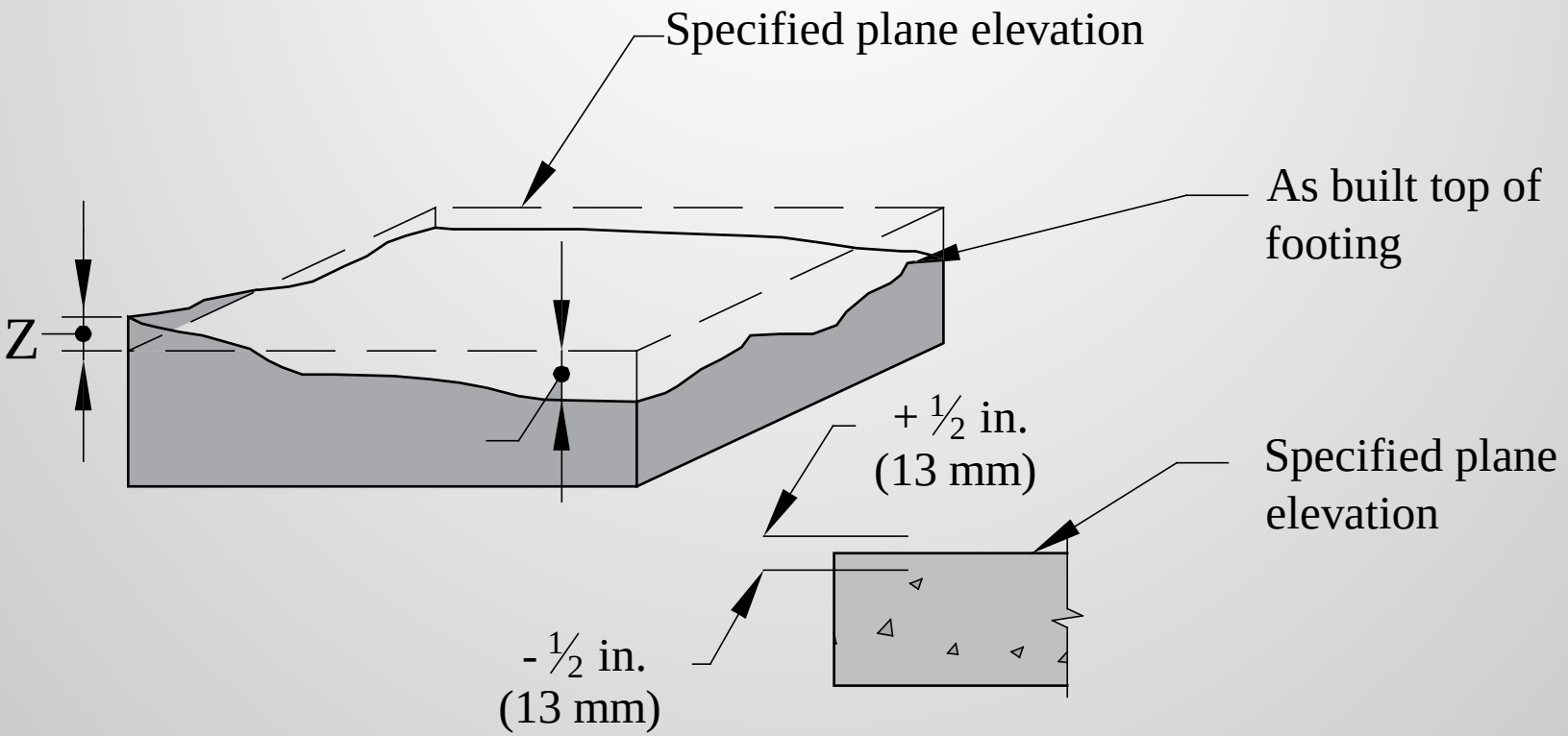
Verification of SCG Properties

Visual Stability Index (VSI)

Article 3.1 – Inspection

Foundation tolerance of +/- ½”

- More stringent than ACI 117



3.2 – Preparation

- Clean reinforcement, anchor bolts and units
- No wetting units – wet cutting permitted
- Remove debris before grouting via cleanouts for lifts over 5’-4” – reasonably clean
- No wet sticking of reinforcement

3.3 – Masonry Erection

Running bond is default bond pattern

Head and bed joints – size and tolerances

Hollow units – see next slide

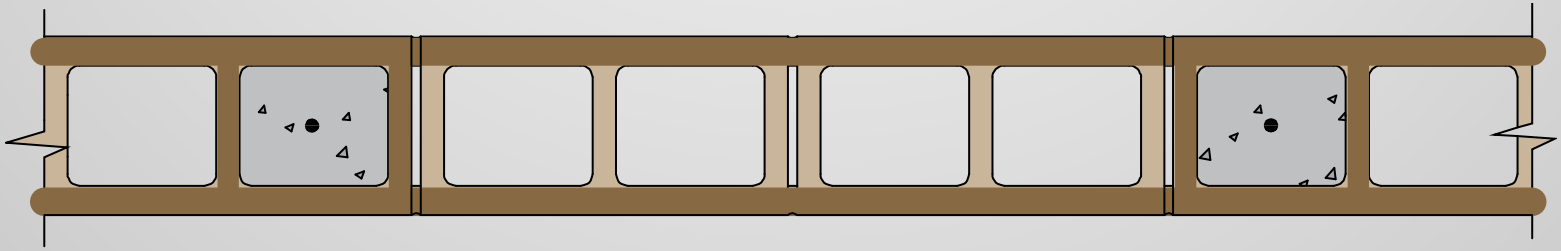
Solid units – fully mortared head and bed joints

- No slushing of head joints.
- Shove unit against adjoining unit.

3.3 – Masonry Erection

Hollow unit masonry

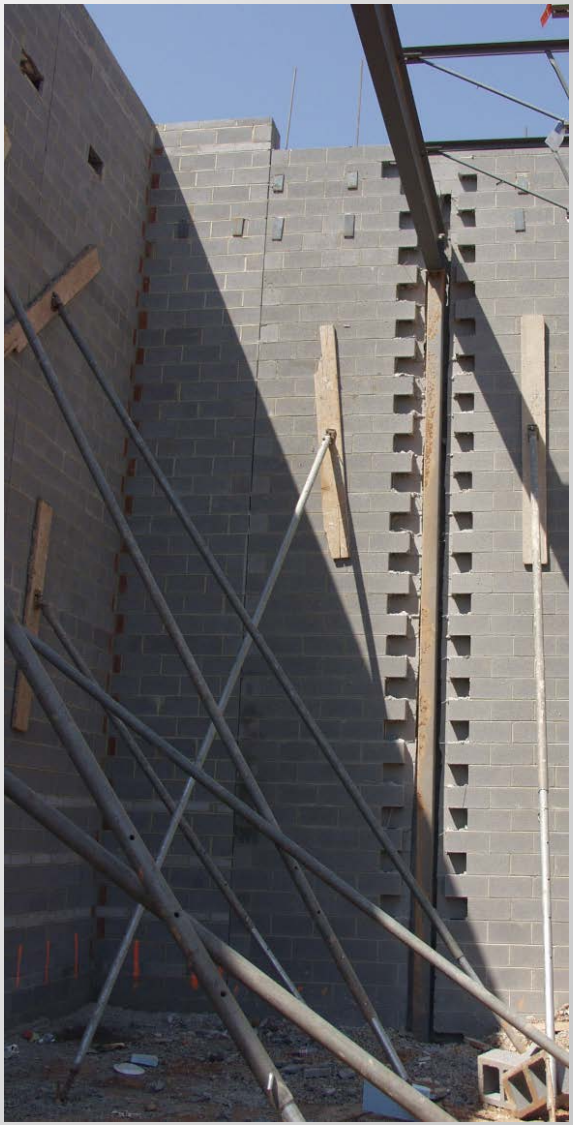
- Face shell mortar bedding
- Webs mortared in all courses of piers, columns, and pilasters or for confinement
- Head joints mortared equal to face shell thickness
- Align vertical cells to be grouted



3.3 – Masonry Erection

Brace to ensure stability

- Internal bracing accepted by OSHA and ASCE 37 *Design Loads on Structures During Construction*
- See TEK 3-4C *Bracing Concrete Masonry Walls Under Construction*



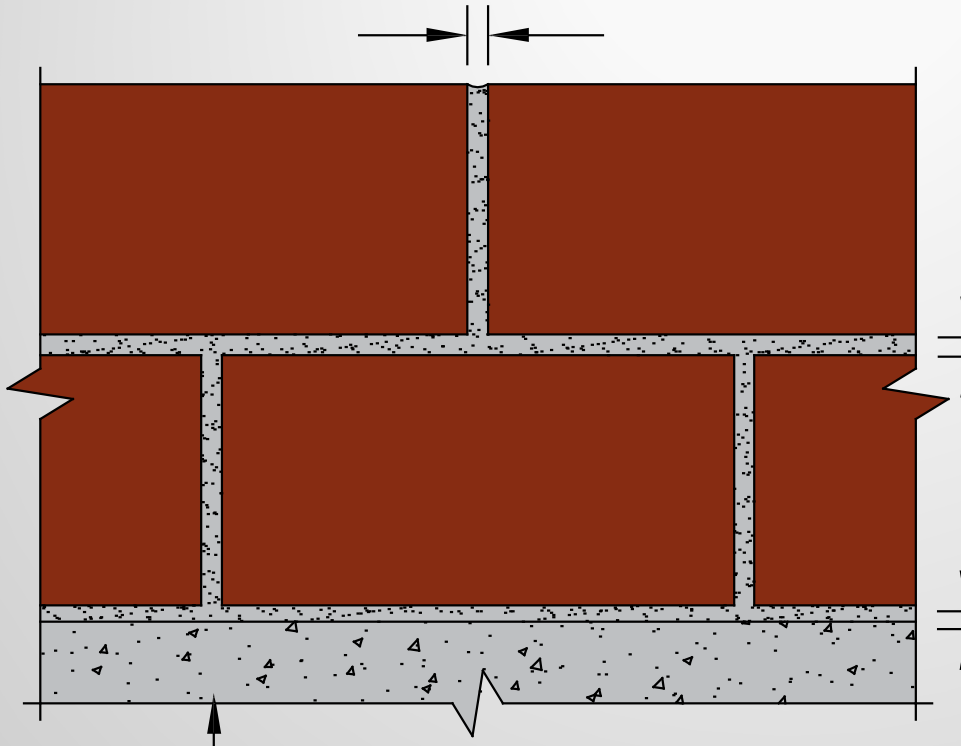
3.3 – Masonry Erection

Placing adhered veneer

- Neat cement paste to backing and unit
- Type S mortar – 3/8” to 1¼” thickness
- Tool mortar joints
- No embedding of aluminum unless isolated

Construction Tolerances

Head joint thickness
= ⅜ in. - ¼ in., + ⅜ in.



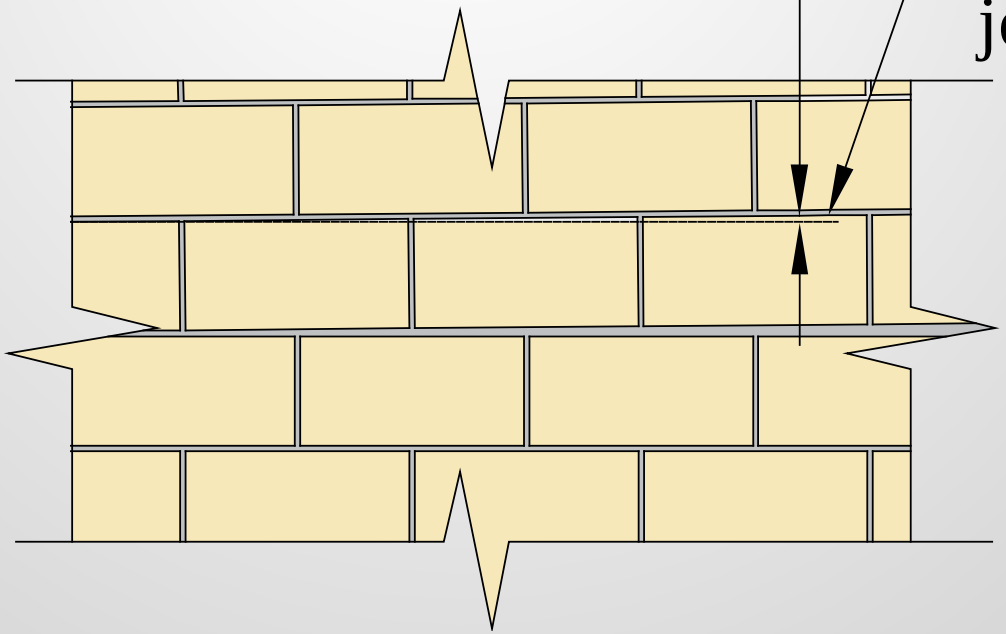
Bed joint thickness =
⅜ in. ± ⅛ in.

Initial bed joint thickness=
¼ in. min.
¾ in. max.

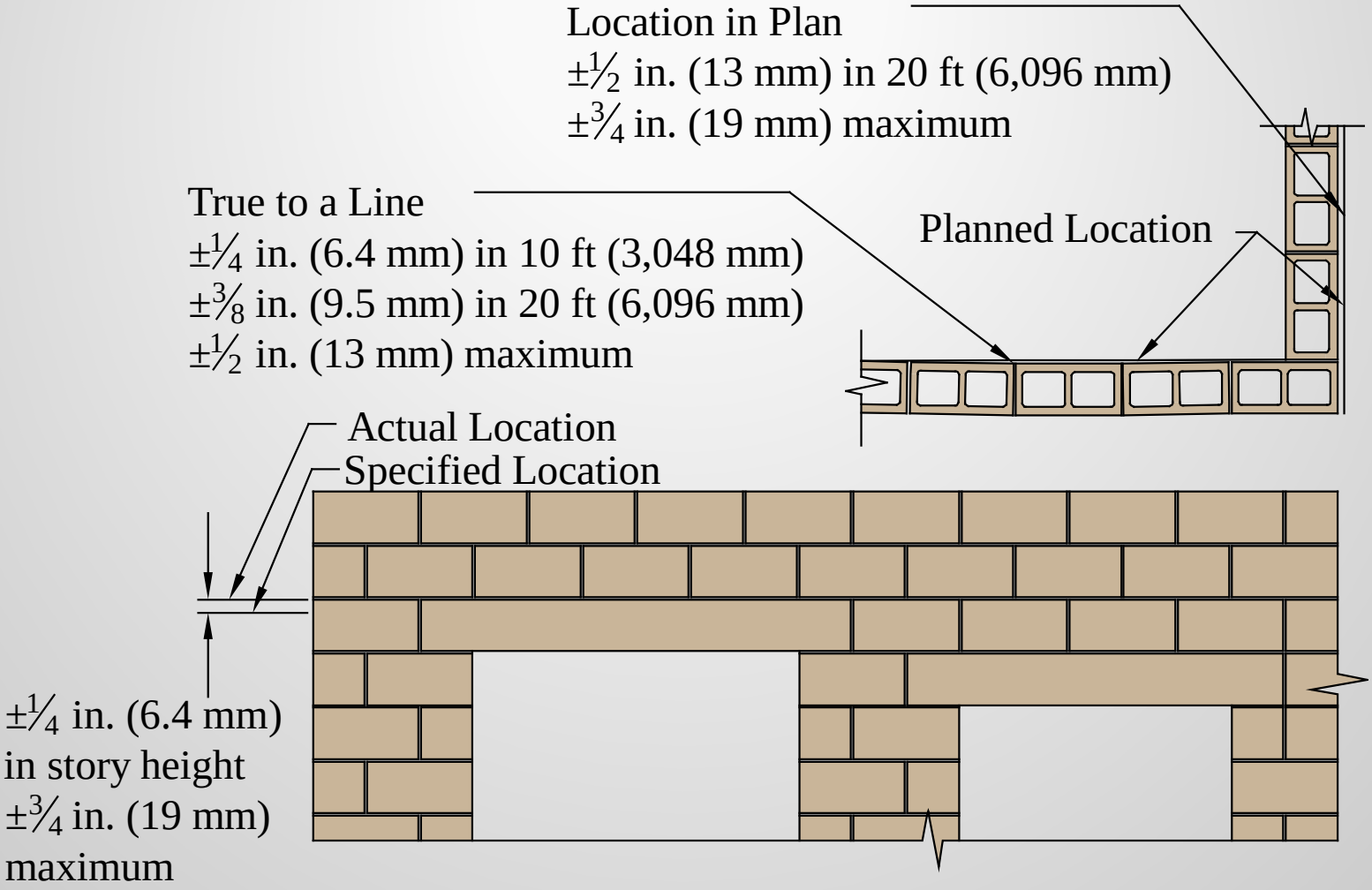
Footing

Level

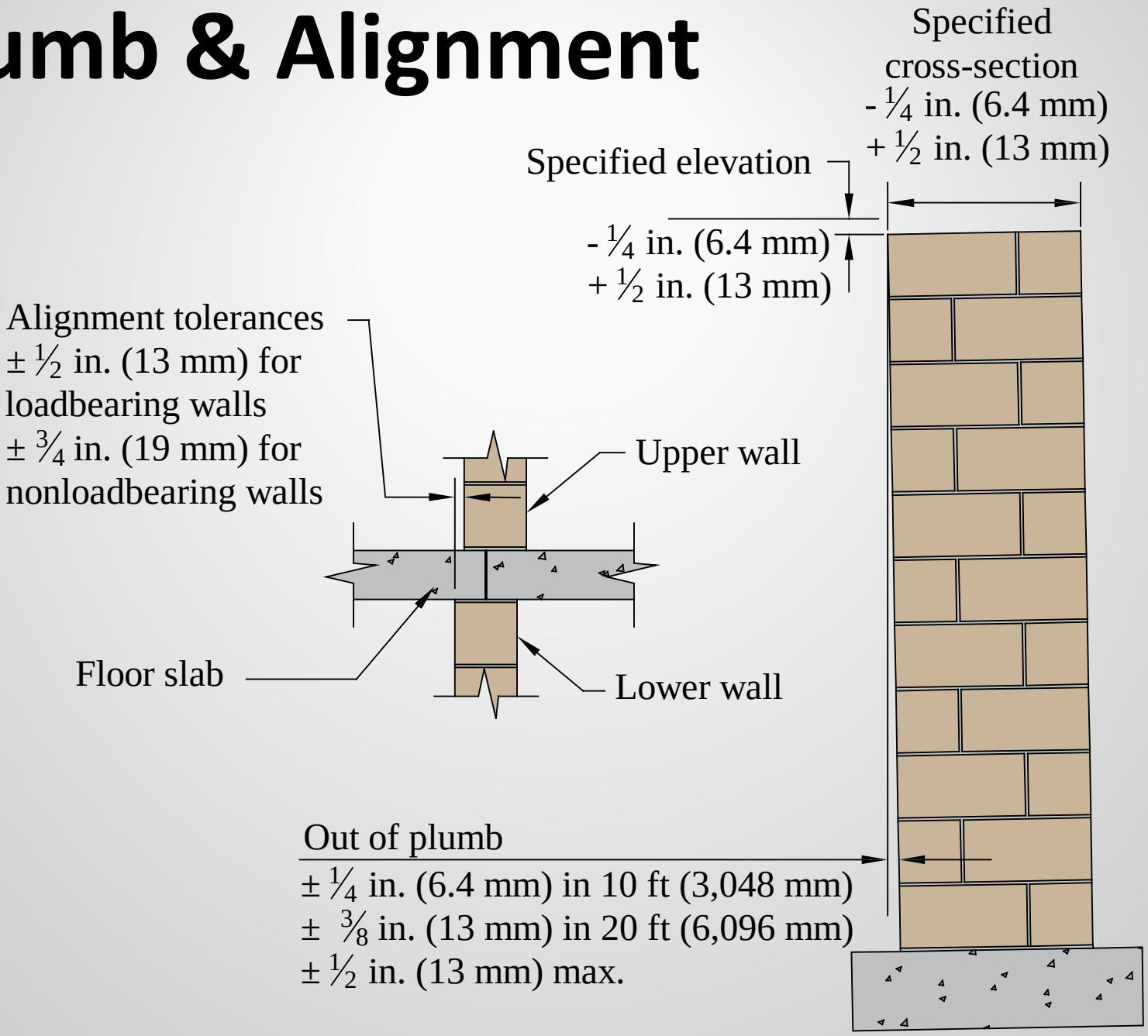
± ¼ in. (6.2 mm) in 10 feet (3,048 mm)
± ½ in. (13 mm) maximum



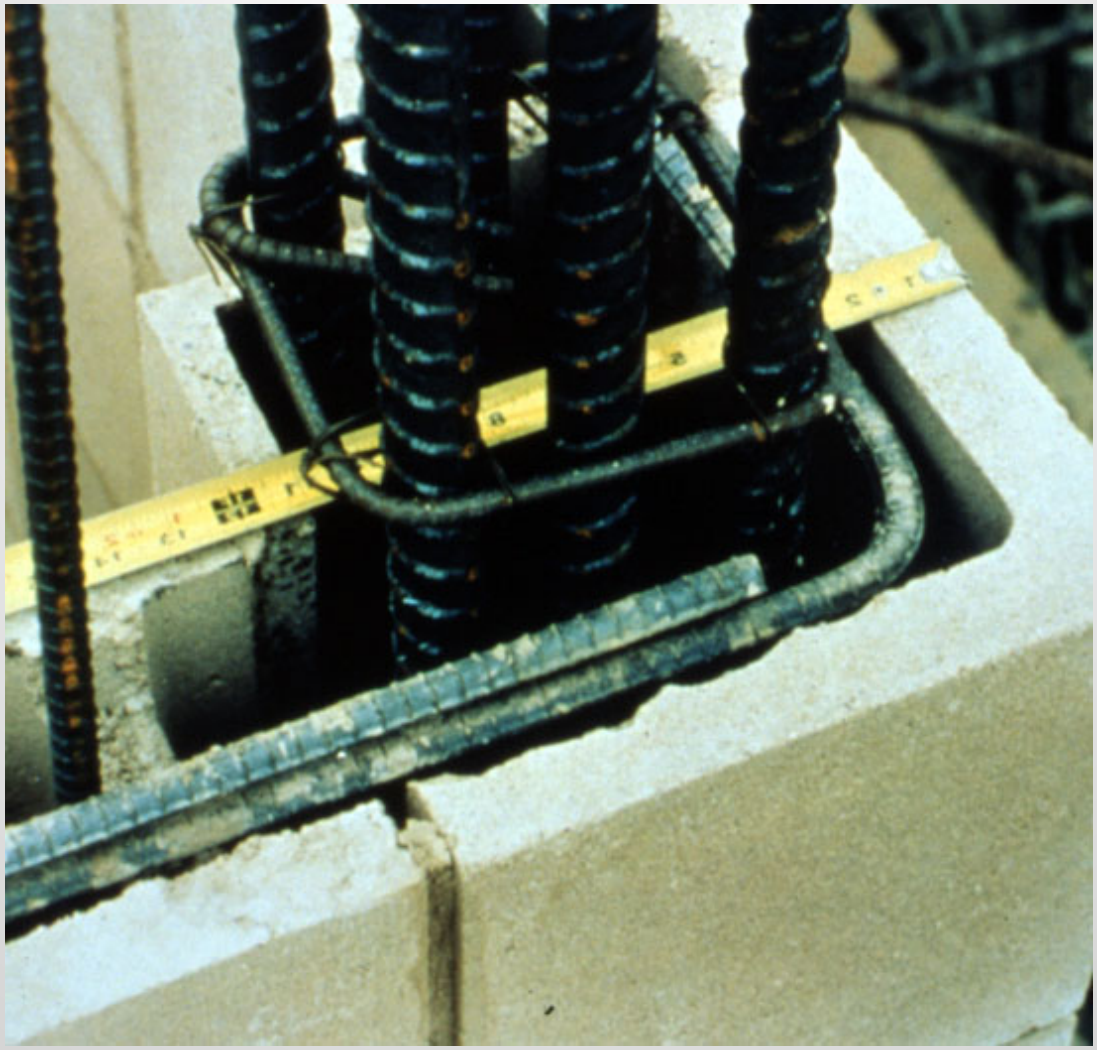
Size & Location of Structural Elements



Plumb & Alignment



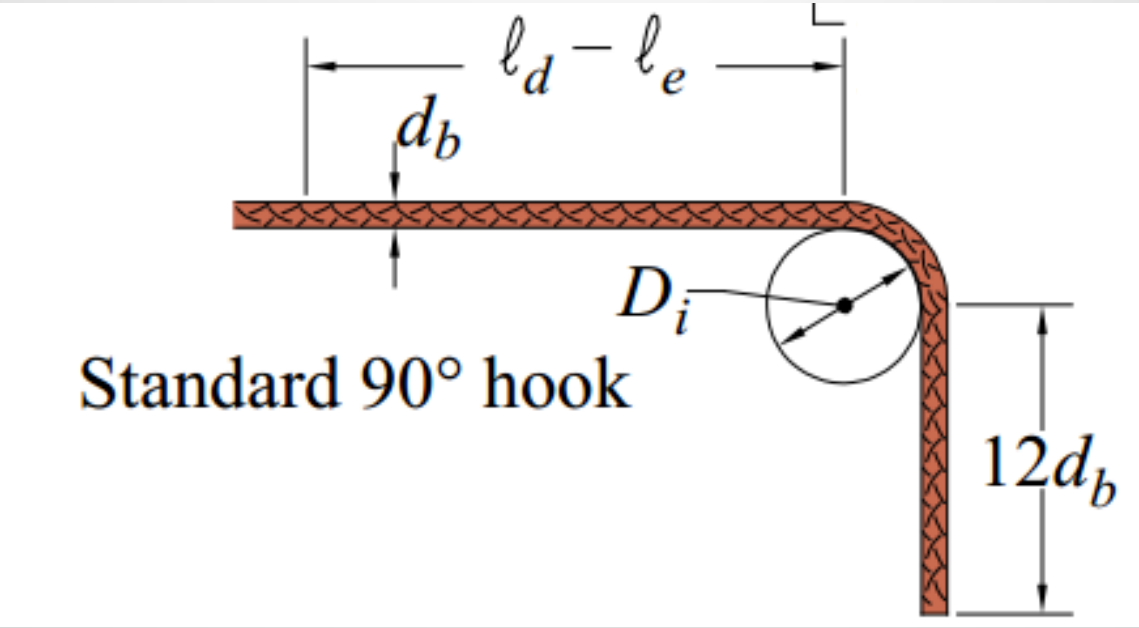
Reinforcement Requirements



Article 2.7 – Fabrication

Bend diameters for reinforcing steel

Standard hooks



Reinforcement Preparation

Remove mud, oil, heavy rust, large amounts of mill scale, or other materials that will adversely affect or reduce the bond.

Light rust, mill scale, or a combination of both will be accepted without cleaning or brushing if the dimensions and weights of a cleaned sample are not less than those required by the applicable ASTM specification.

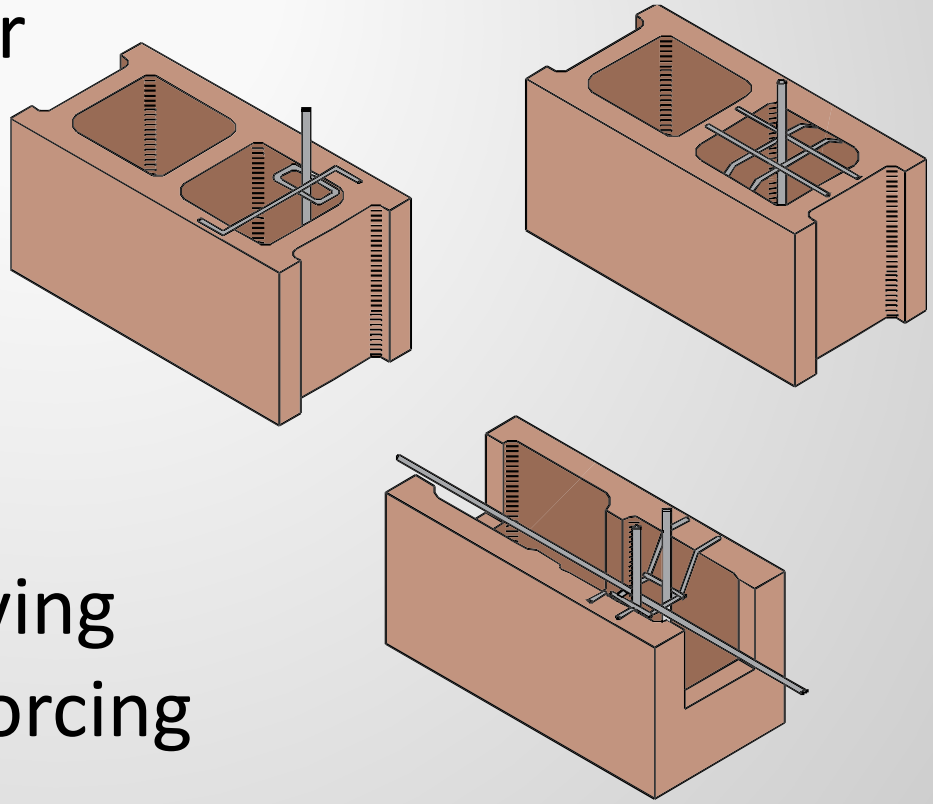
3.4 – Reinforcement Installation

No contact of dissimilar metals.

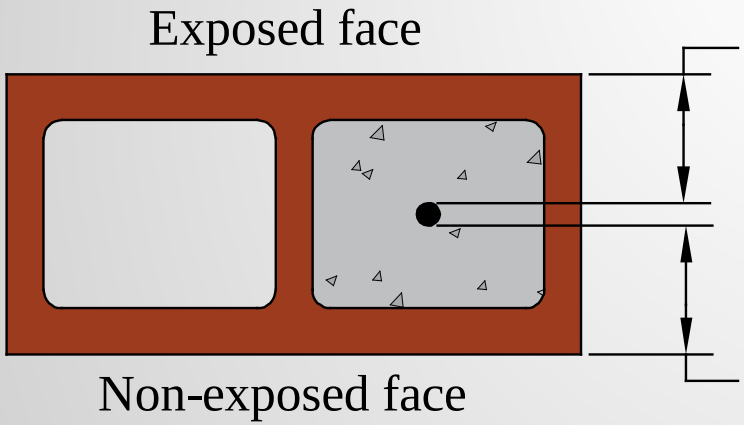
Clearances:

- ¼” for fine grout
- ½” for coarse grout

Maintain position by tying reinforcement or reinforcing bar positioners.



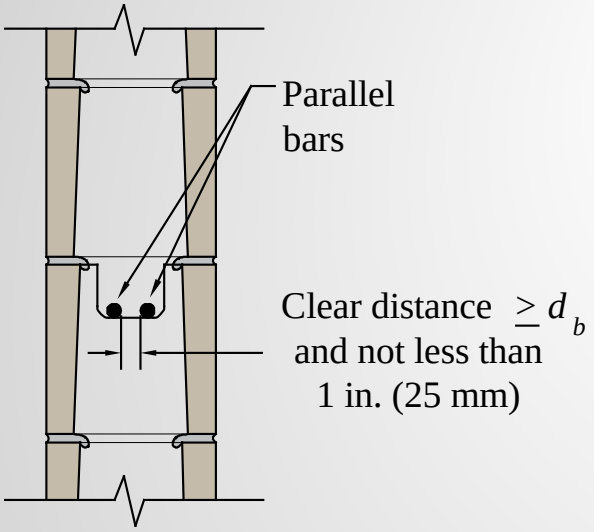
Reinforcement Cover

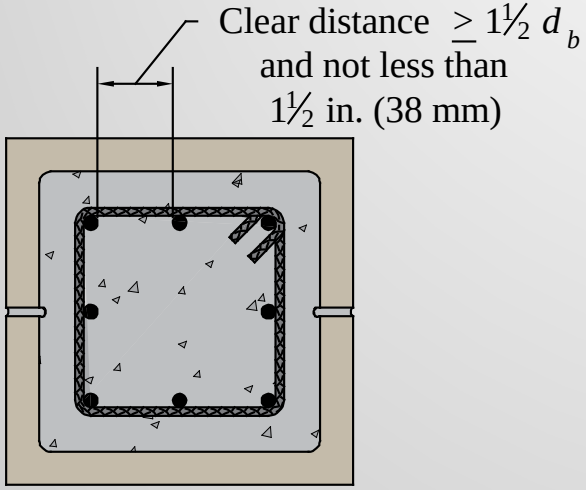


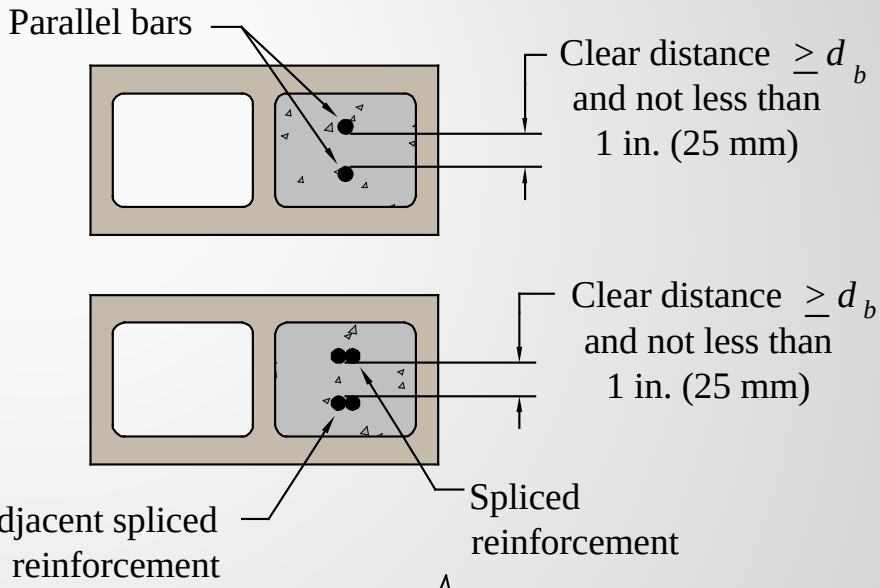
Minimum cover requirements:
2 in. (51 mm) for bars la rger than No. 5 (M#16)
1 ½ in. (38 mm) for No. 5 (M#16) bars and smaller

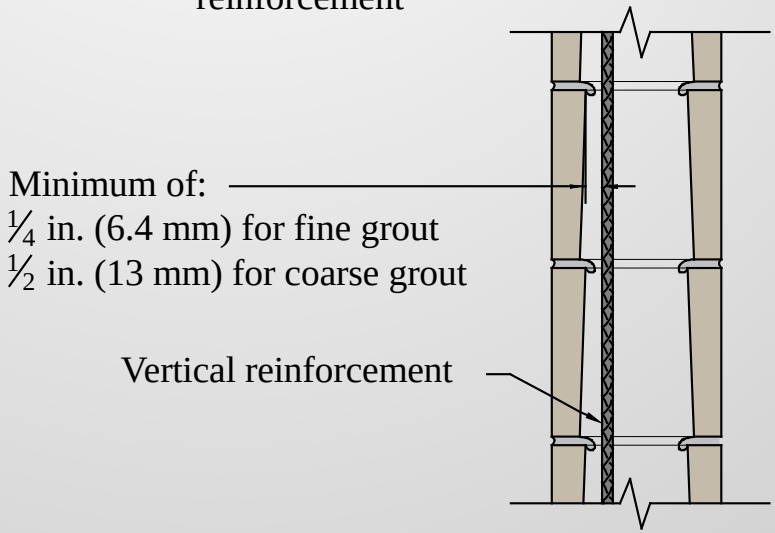
Minimum cover requirements:
1 ½ in. (38 mm)

Reinforcement Clearance



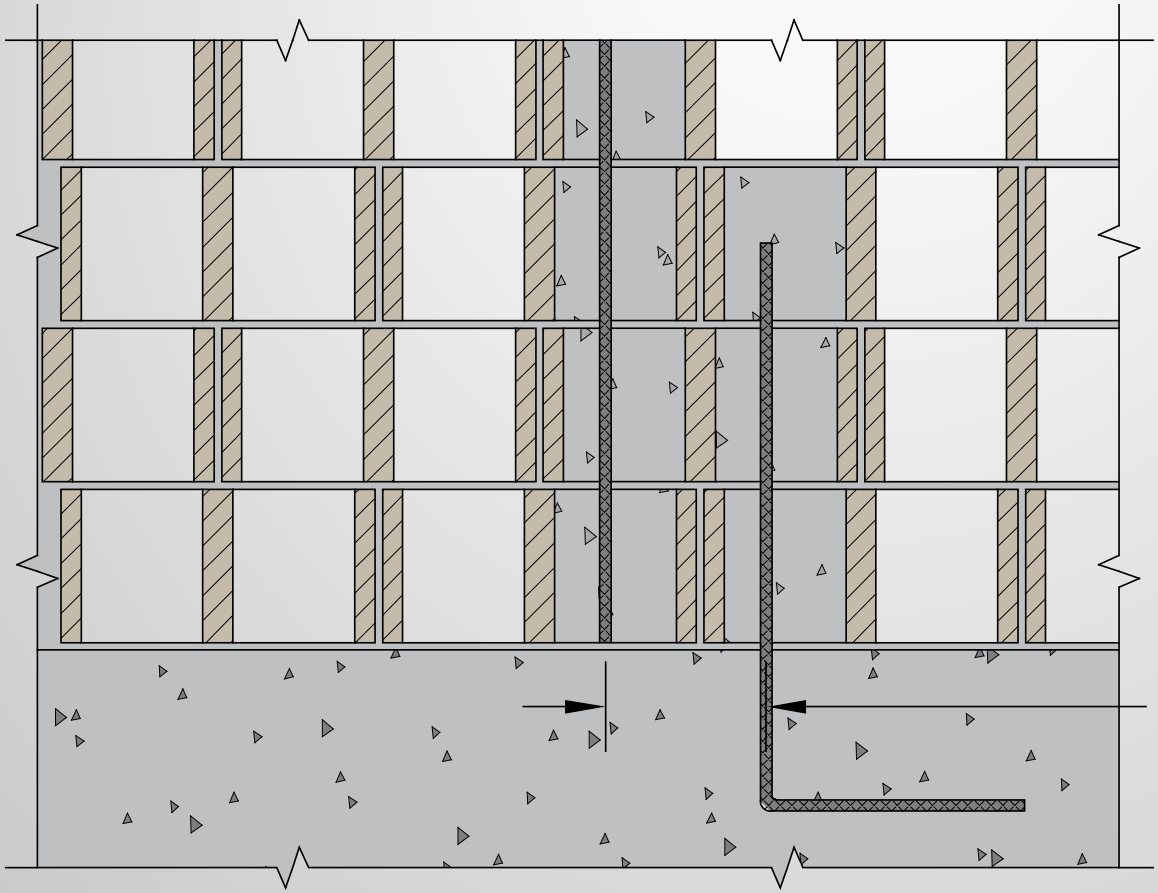




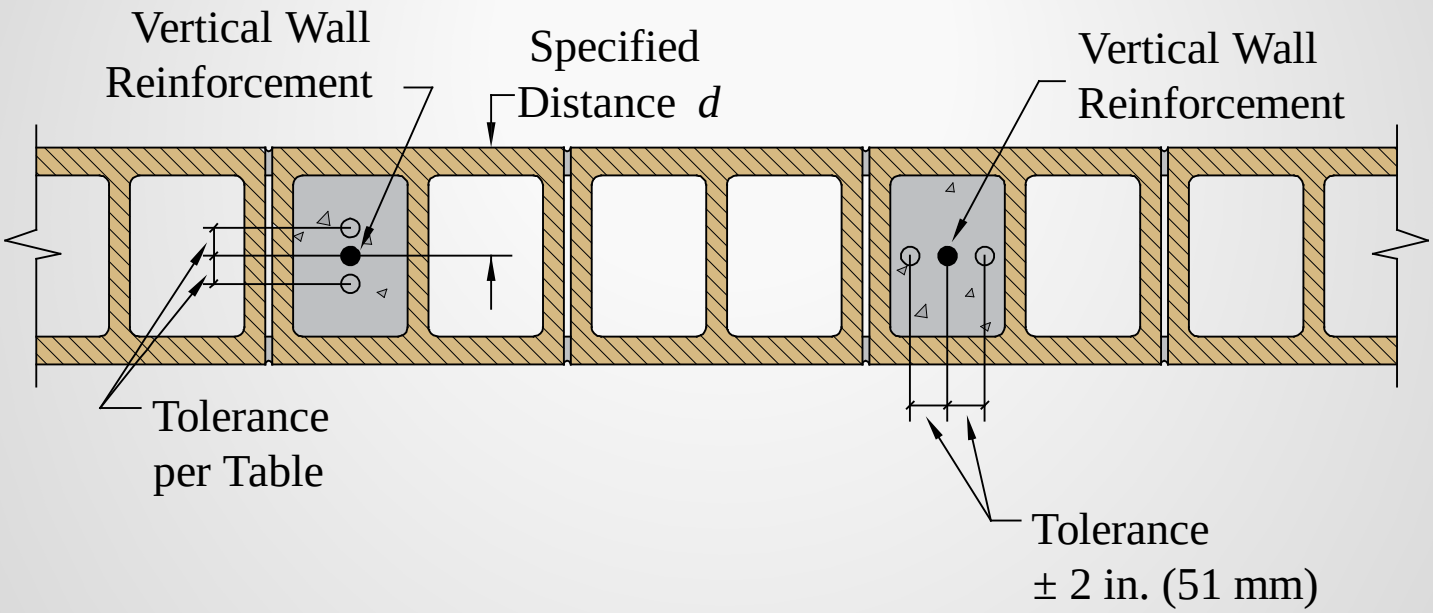


Reinforcement Splices

Noncontact lap splice



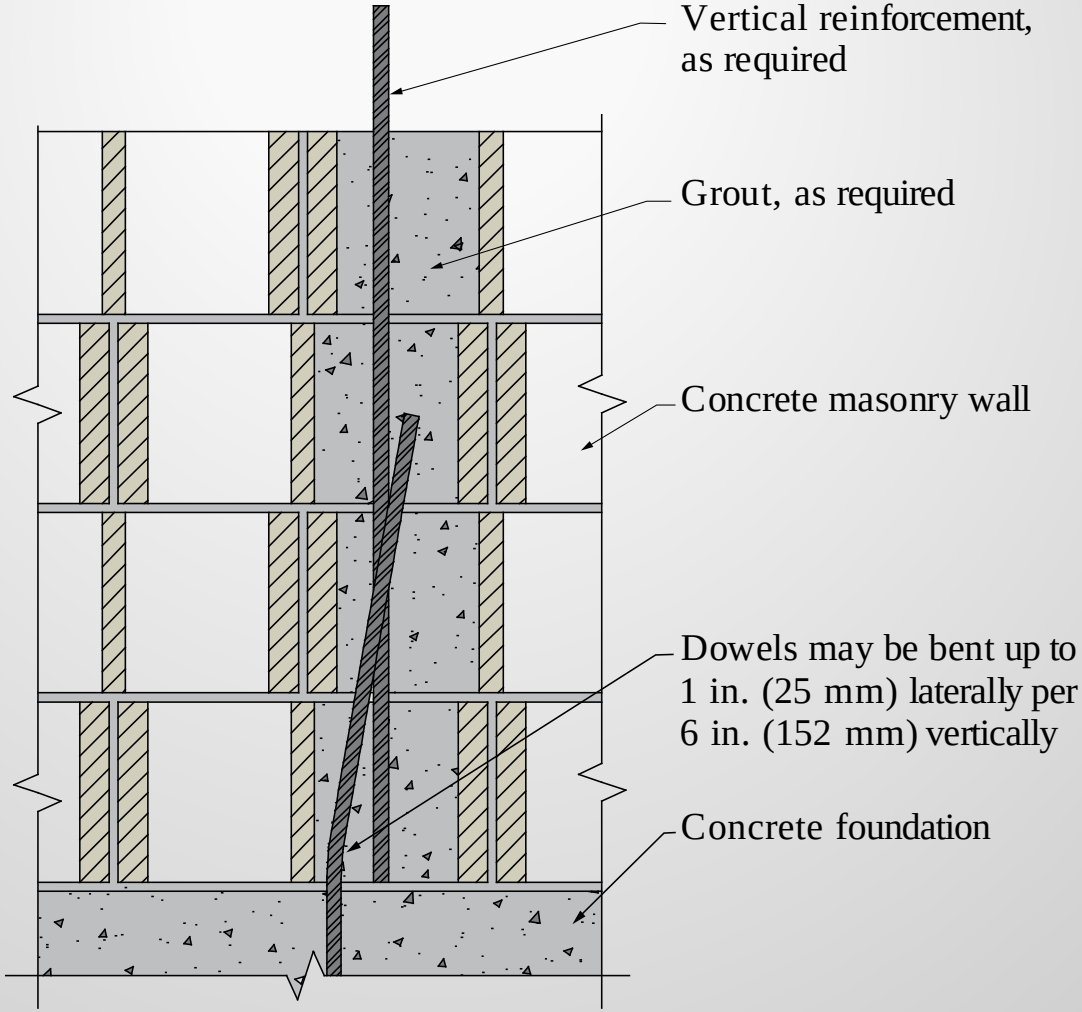
Reinforcement Tolerances



Specified Distance d From Face of Wall to Center of Reinforcement	Allowable Tolerance
$d \leq$ 8 in. (203 mm)	± ½ in. (13 mm)
8 in. (203 mm) < $d \leq$ 24 in. (607 mm)	± 1 in. (25 mm)
$d >$ 24 in. (607 mm)	± 1¼ in. (32 mm)

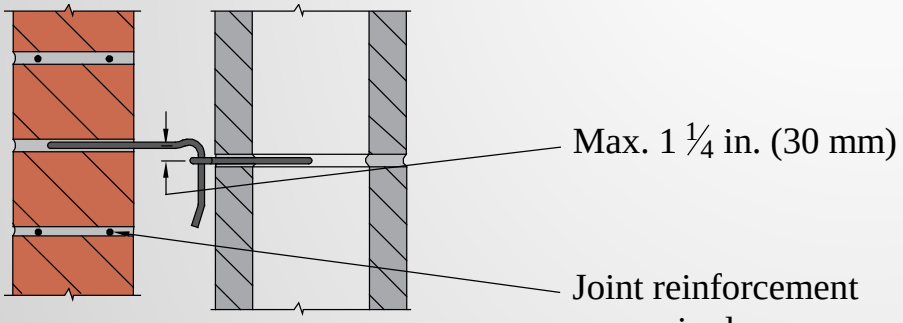
Reinforcement Installation

Permitted bending of reinforcement dowels

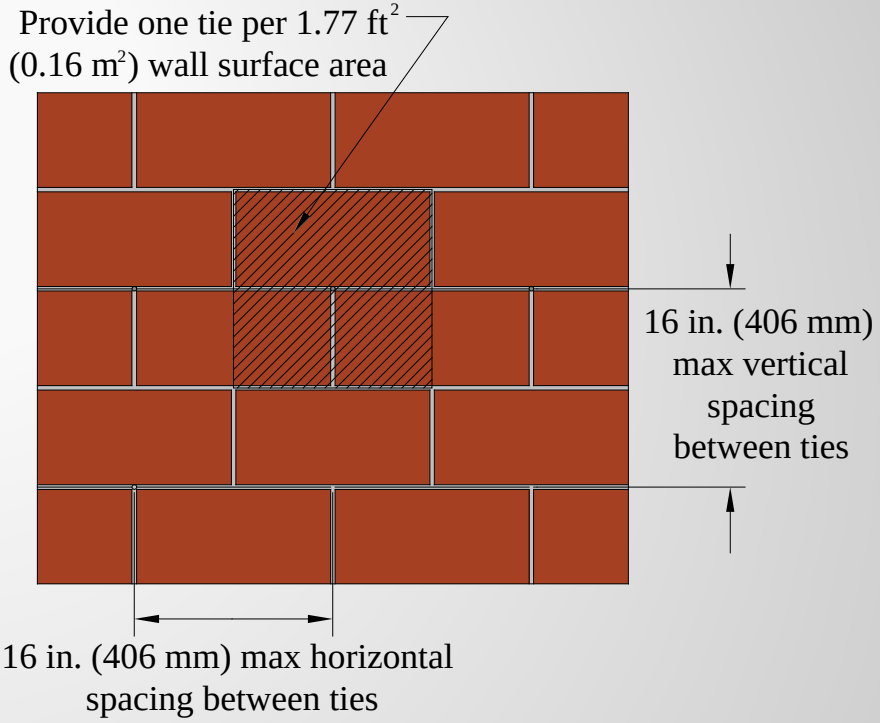


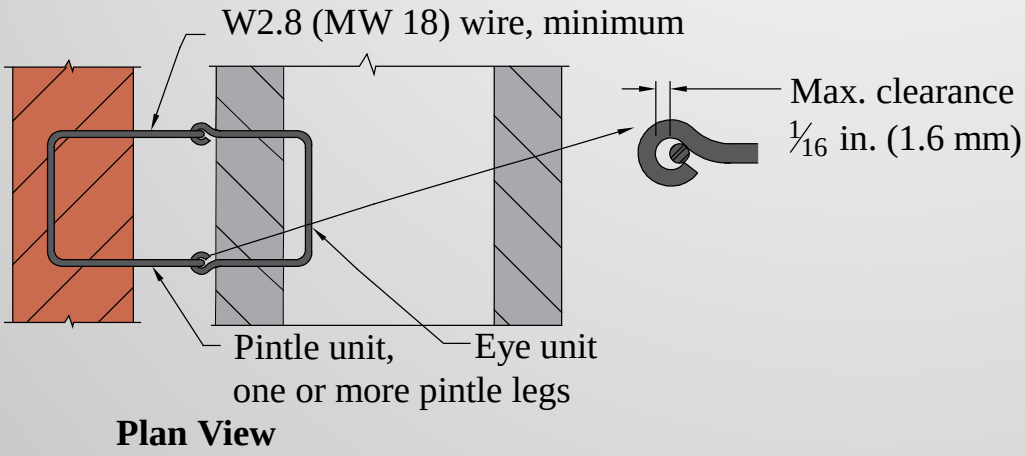
Wall Tie Installation

Adjustable ties



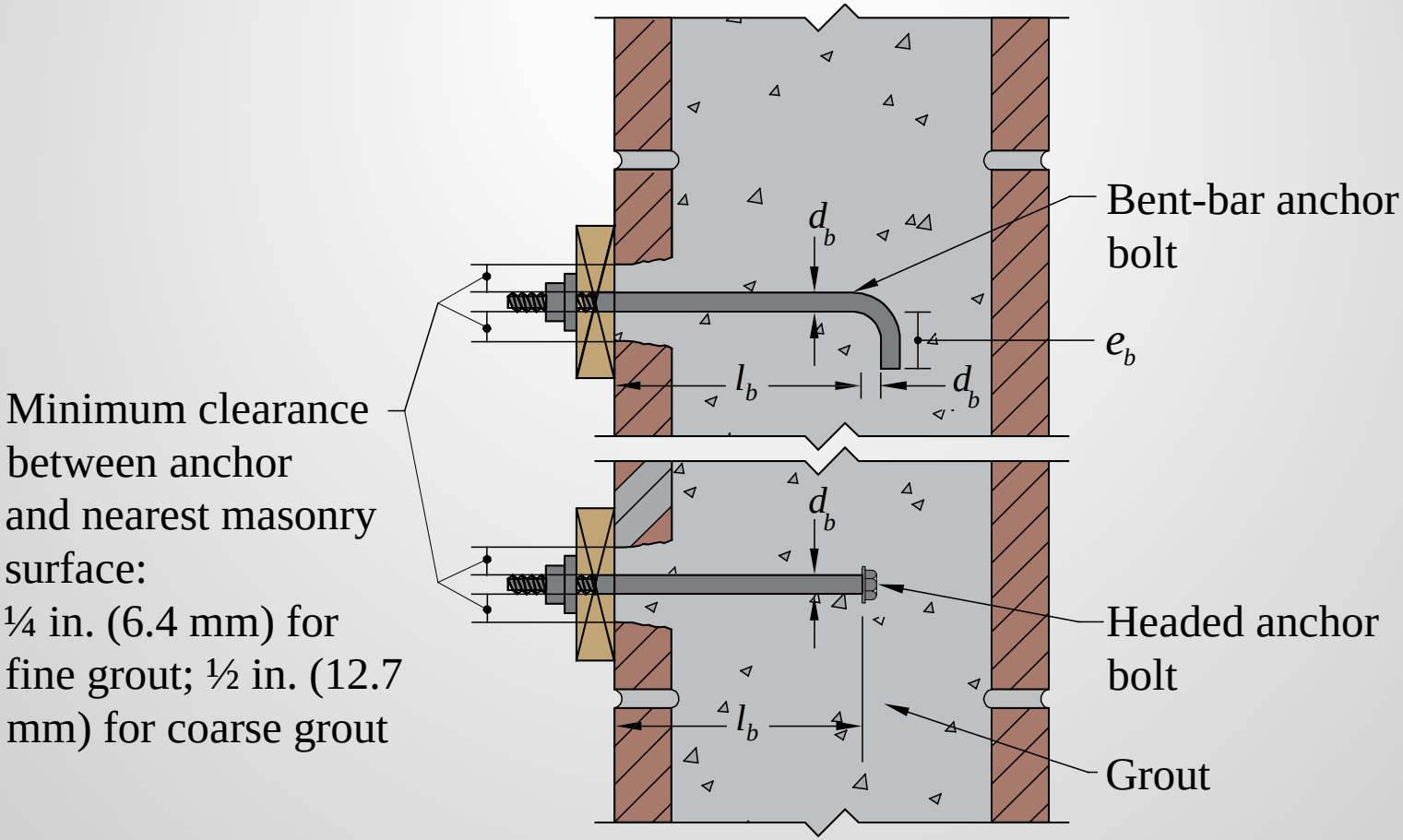
Vertical Section





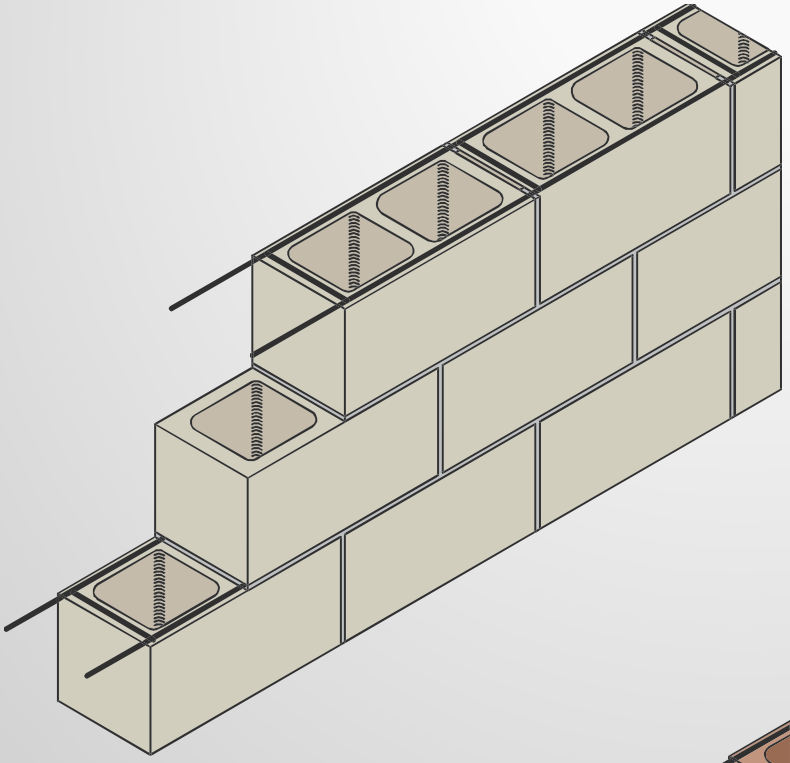
Plan View

Anchor Bolt Installation

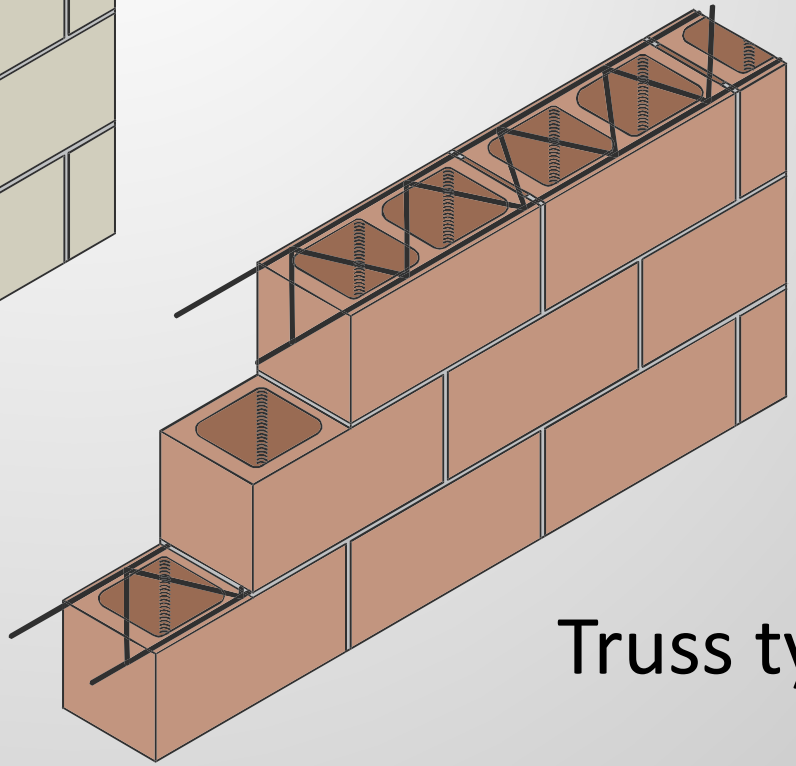


Joint Reinforcement

Two or more longitudinal wires connected with cross wires forming a truss or ladder configuration

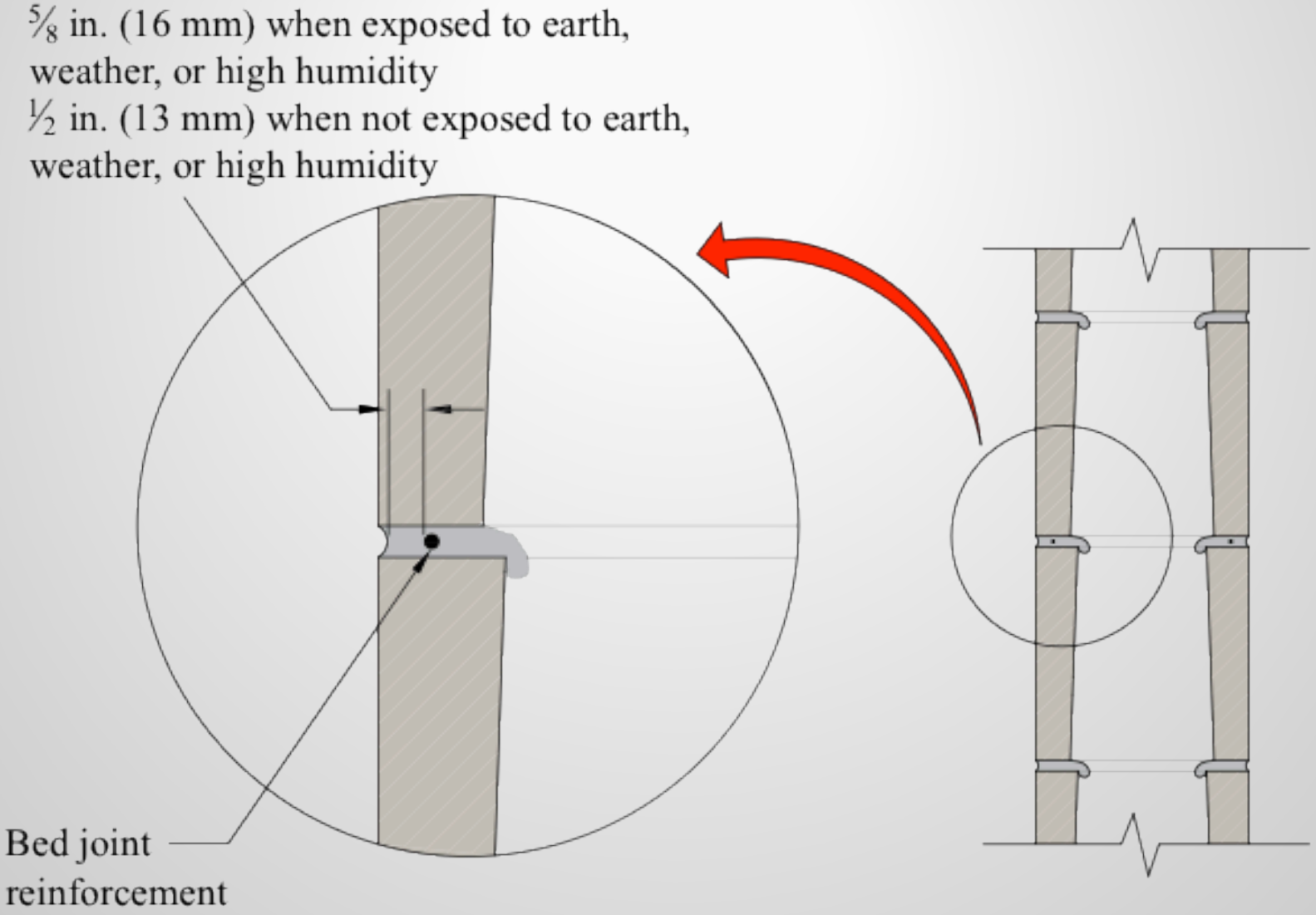


Ladder type



Truss type

Joint Reinforcement Cover

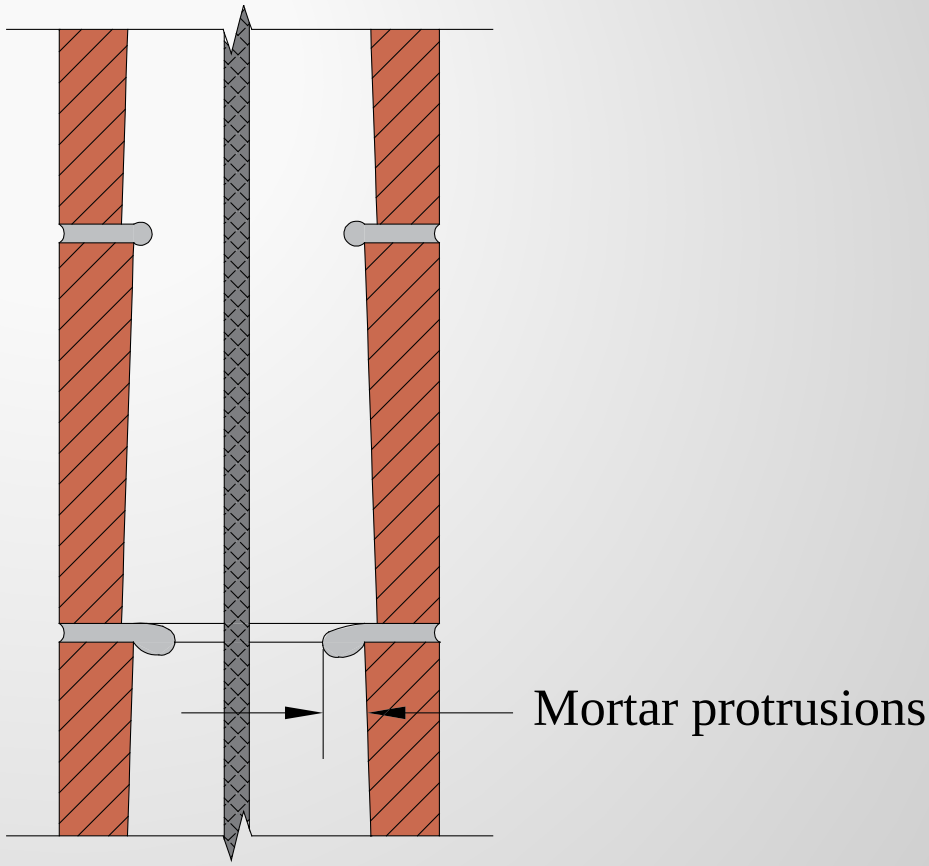


Cleanouts

- Required for pours over 5 ft-4 in.
- 32 in. on center max. horizontal spacing
- 3-inch minimum opening

Removal of Mortar Fins

- Protruding more than ½ inch
- To permit the passage of grout

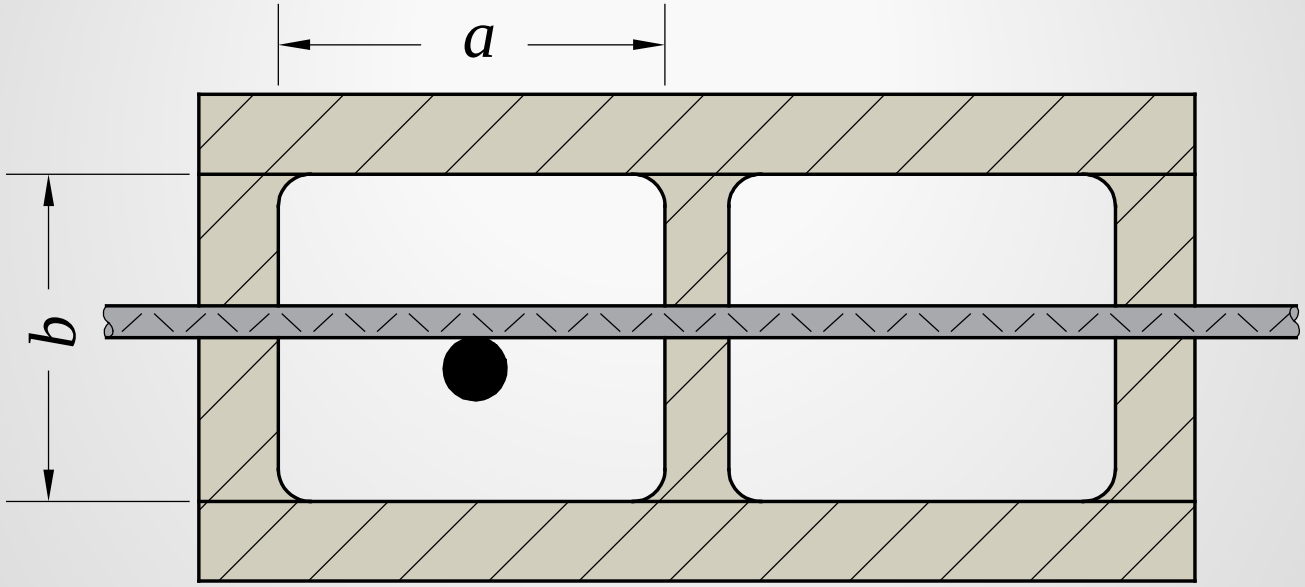


Prior to grouting, remove mortar protruding more than ½ in. (13 mm) into grouted cells

Grout Placement

Grout type	Max grout pour height, ft	Min clear width of grout space, in.	Min clear grout space dimensions, in.
Fine	1 5.33 12.67 24	3/4 2 2 1/2 3	1 1/2 x 2 2 x 3 2 1/2 x 3 3 x 3
Coarse	1 5.33 12.67 24	1 1/2 2 2 1/2 3	1 1/2 x 3 2 1/2 x 3 3 x 3 3 x 4

Grout Space



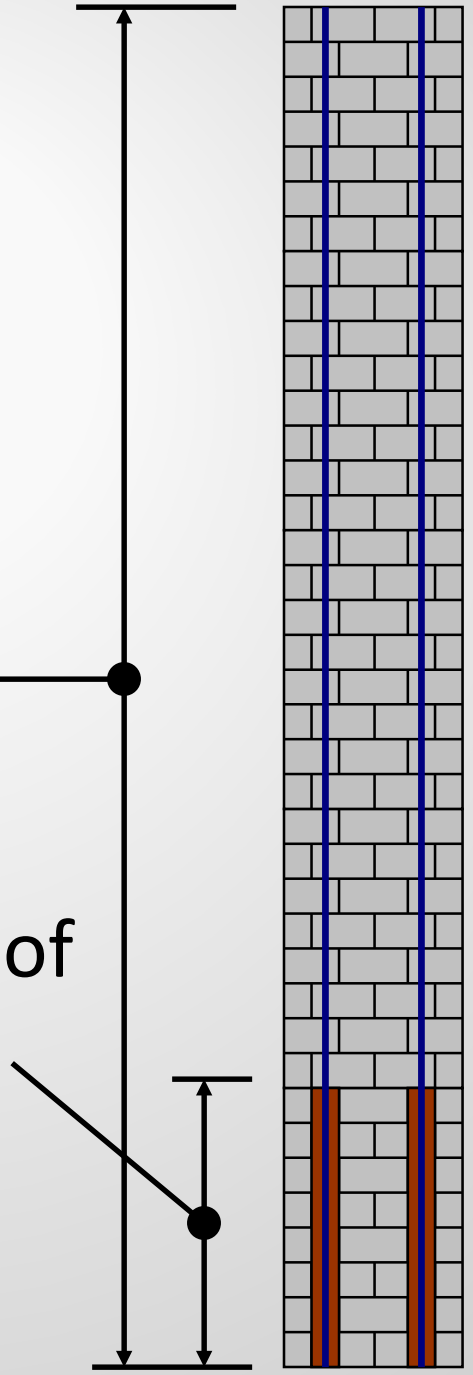
$a \geq$ Minimum grout space dimension

$b \geq$ Minimum grout space dimension + horizontal bar diameter + horizontal protrusions

Grout Placement

Grout pour = the total height of masonry to be grouted

Grout lift = the vertical height of grout placed at one time



Grout Lift Height –12.67 ft if:

- Masonry cured for at least 4 hours
- Grout slump between 10 & 11 inches
- No intermediate bond beams between top and bottom of pour height
- Cure masonry for at least 4 hours prior to grouting

Grout Consolidation

- Eliminates voids
- Pours 12 inches or less in height: mechanical consolidation or puddling
- Pours exceeding 12 inches: mechanical consolidation with reconsolidation after initial water loss and settlement

* Not required for self-consolidating grout

Grout Placement

Placing time – 1 ½ hrs

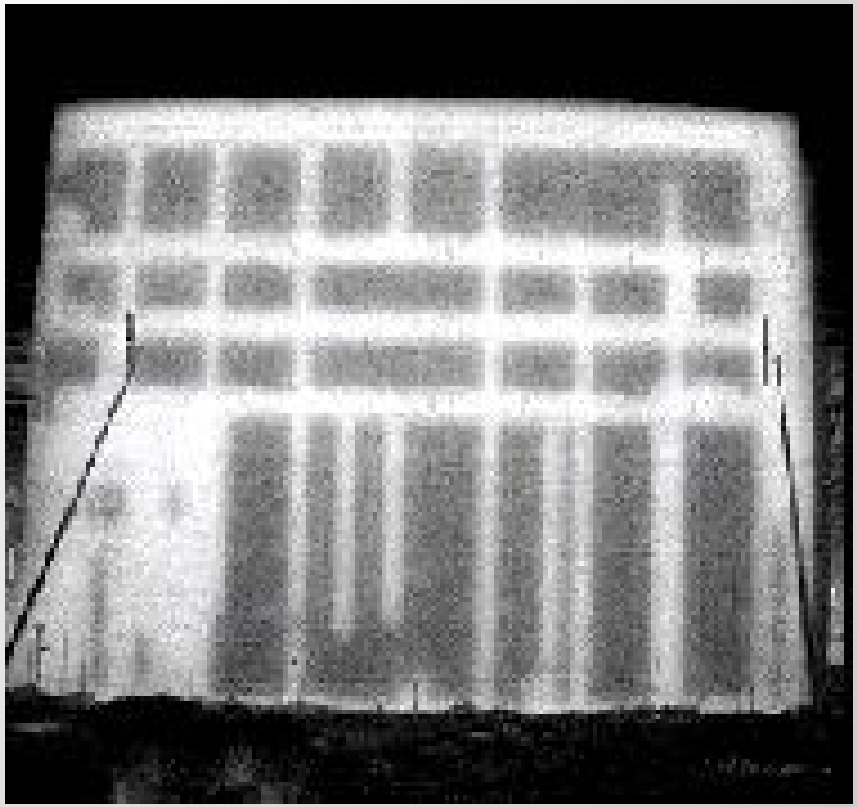
Confine using material that permits bond

Grout key – 1 ½” at a cold joint

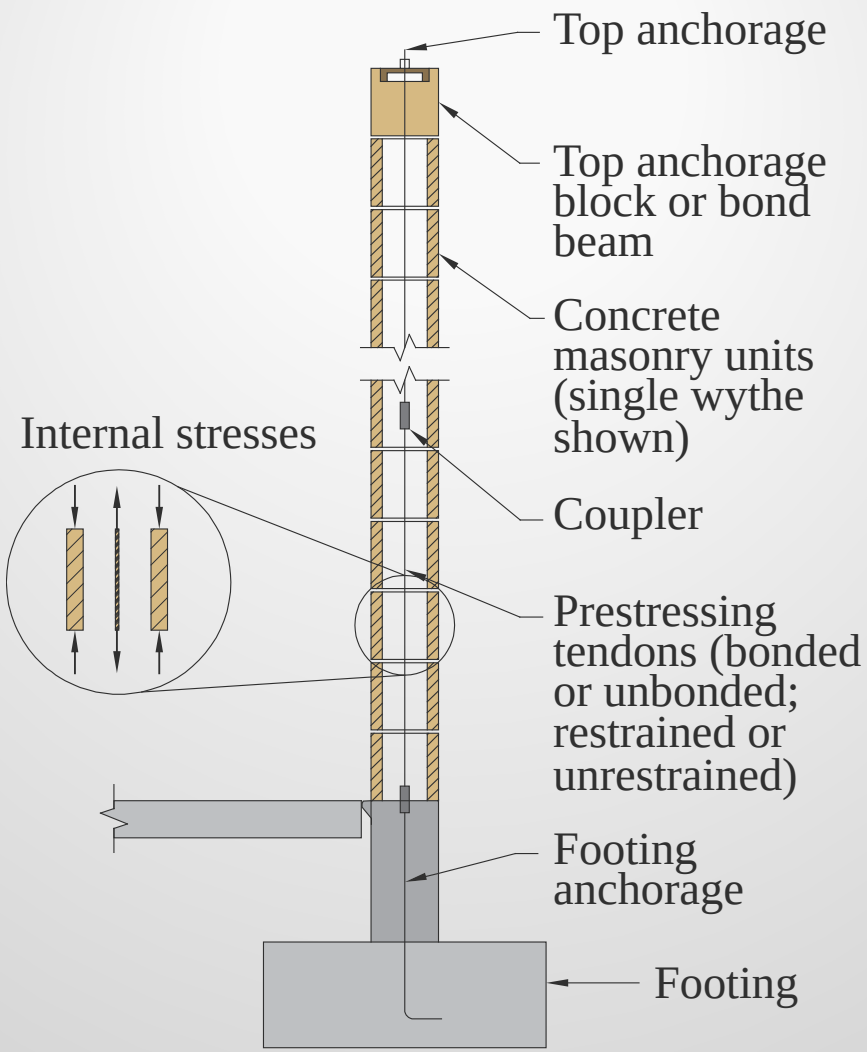
Grout Demonstration Panel

If the proposed grout space geometry, grouting procedures, or construction techniques do not comply, a grout demonstration panel must be constructed and approved before masonry construction begins.

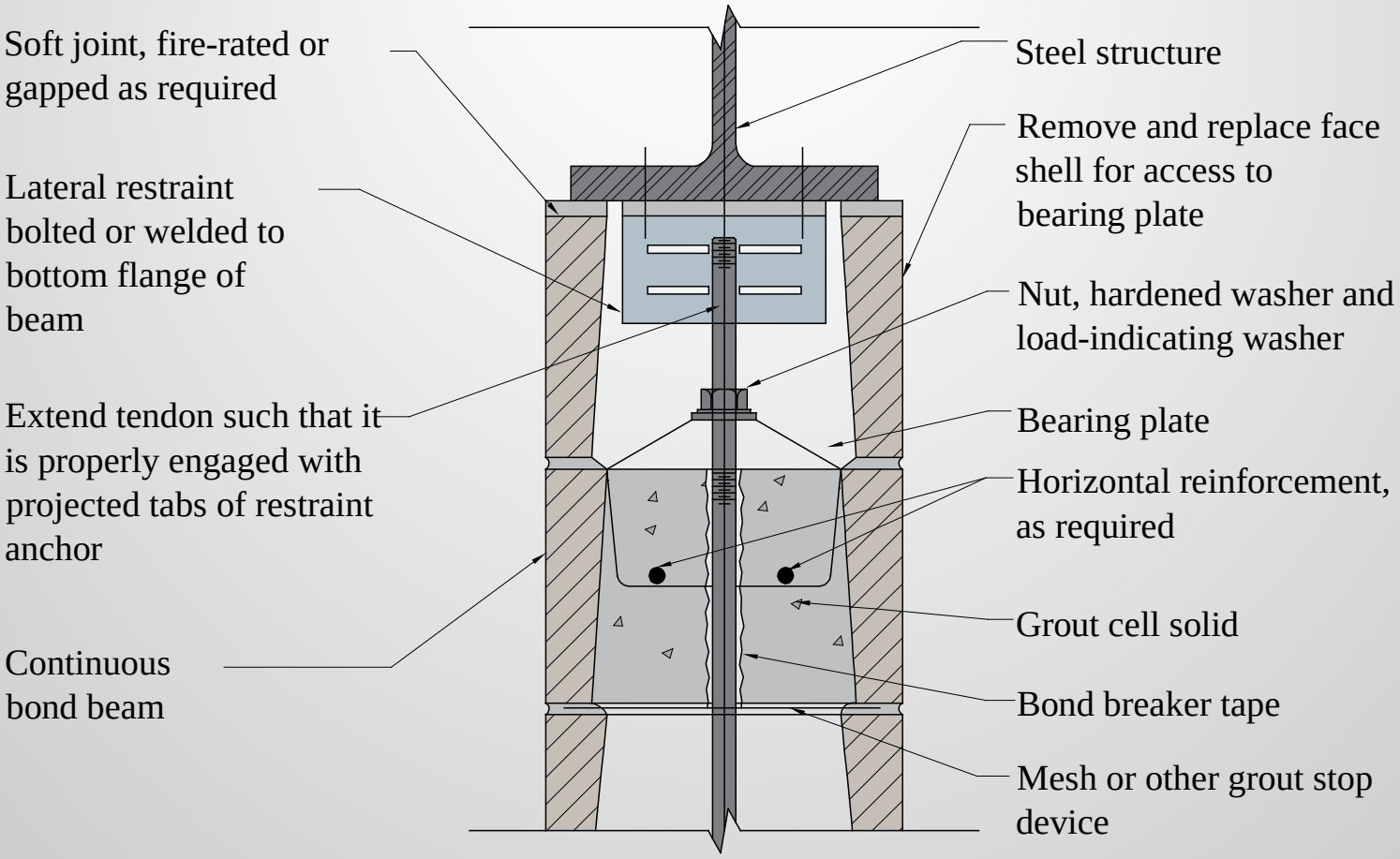
Infrared Photography



Prestressed Concrete Masonry



Prestressing Anchors, Couplers, and Positioners



Prestressing Site Tolerances

1. Out-of-plane direction for masonry beams, columns, walls and pilasters with cross-sectional dimensions:

   < 8 in. $\pm$ 1/4 in.

   ≥ 8 in. $\pm$ 3/8 in.

2. In-plane direction $\pm$ 1 in.

Application & Measurement of Prestressing Force

Two methods (use both):

1. Compare measured tendon elongation to required elongation

2. Measure the jacking force or tension.

The two values must be within 7% of each other for post-tensioned elements, within 5% for pretensioned.

Grouting Bonded Prestressing Tendons

Three requirements:

1. Properly mix
2. Maintain masonry above 35 ^{o}F
3. Maintain prestressing grout below 90 ^{o}F

Additional Resources

NCMA:
TEK 3-Series, Construction
E-Details, Section 1D Code Construction Tolerances & 1E Code Detailing
Presentation C204a, Grouting

The Masonry Society (TMS):
Masonry Construction Checklist

Course Evaluations

In order to maintain a high-quality learning experience, a required course evaluation will be distributed and collected at the end of this education session.

NCMA/AIA Continue Education System Course Evaluation

We want to ensure our training sessions are as meaningful as possible and appreciate your candid feedback of the course reference below. ***Please complete and drop off before you leave or mail to***

Session Title _____

Program Number _____ **Date** _____ **Location** _____

Please indicate your role:
☐ Architect ☐ Intern ☐ Specification Writer ☐ Legal/Accounting/Staff

Circle one number per question

		Poor			Excellent
1.	Overall satisfaction with this session:	1	2	3	4
2.	Course learning objectives clearly stated and met:	1	2	3	4
3.	Satisfaction with the format of this workshop:	1	2	3	4
4.	Met overall personal objectives for attending:	1	2	3	4
5.	Overall quality of training aids (handouts, audio/visual, etc.):	1	2	3	4
6.	Quality of session content:	1	2	3	4
7.	Applicability/value of new knowledge, ideas, or information:	1	2	3	4
8.	Overall knowledge and presentation of speakers:	1	2	3	4

9. This course was non-biased, non-promotional of product, material or service Yes ☐ No ☐

If no, please explain _____

How could this session be improved? _____

What other topics would be of interest? _____

Additional comments? _____

Please offer additional on the reverse of this evaluation. Thanks!

Questions?

NATIONAL CONCRETE MASONRY ASSOCIATION
Sustainable Concrete Products for Structures and Hardscapes

Thank you for your time!

This concludes the American Institute of Architects Continuing Education Systems Course.

13750 Sunrise Valley Drive
Herndon, VA 20171
703.713.1900
e-mail ncma@ncma.org
www.ncma.org