

# BUILDING ENVELOPE TOLERANCES

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# Building Envelope Tolerance

CSI Roundtable  
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 AIA/CES Provider #: S001



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# Building Envelope Tolerance

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# Building Envelope Tolerance

## Description:

**When designing the building envelope, we need to take into account constructability and tolerance of the materials, components, and systems.** Each material has a tolerance from material fabrication, component installation, as well as system installation tolerance. There are many acceptable locations which identify the tolerances of the material, component, or system. We will explore the different locations where these tolerances can be found and how to use them to better understand the building and make better constructed buildings.



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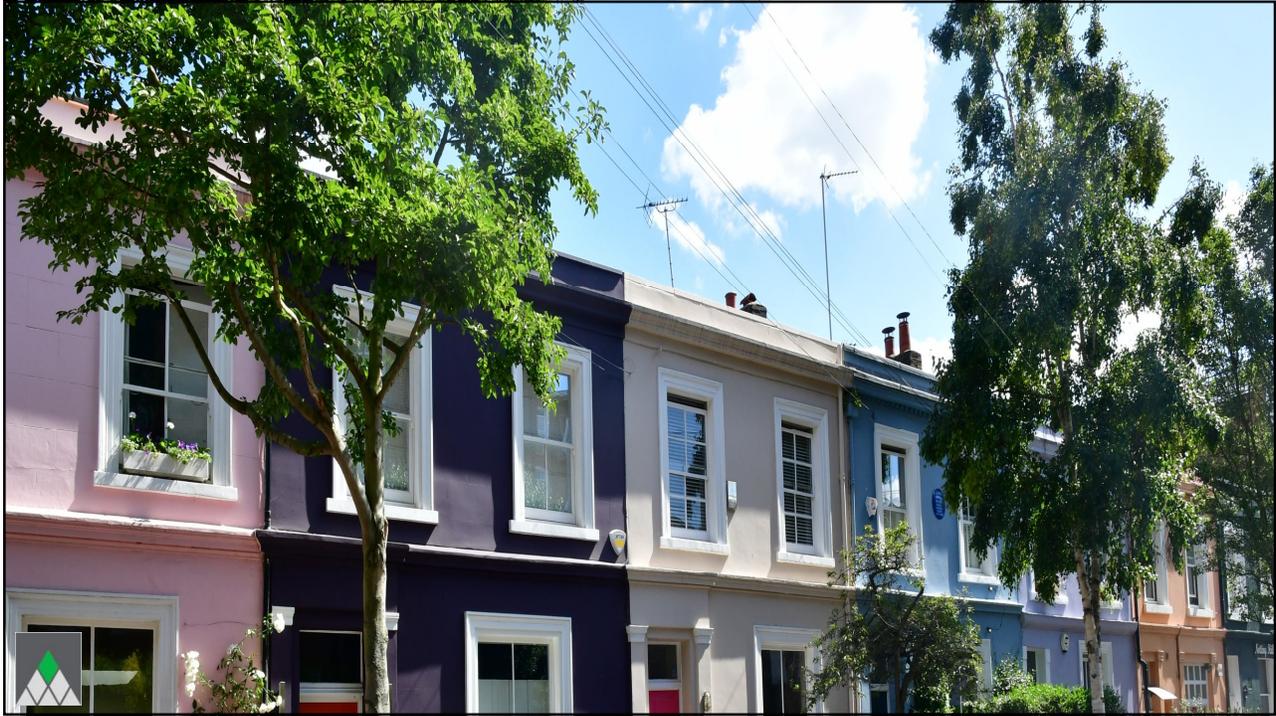
# Building Envelope Tolerance

## Learning Objectives:

1. Understand where to look to the accepted tolerances of materials, components, and building system with regard to the building envelope.
2. Evaluate the different tolerances for building envelope.
3. Learn to and calculate the overall tolerance.
4. Utilize the information on construction and material, component, and system installation tolerance and understand where to utilize this information in the Construction Documents.



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# Building Envelope Tolerance

## List of References:

Handbook of Construction Tolerances 2ed

by David Kent Ballast, AIA, CSI

ACI 117, Specifications for Tolerance for Concrete & Materials

MNL 116 / MNL 117, Quality Control for Structural Concrete / Architectural Concrete

MNL-135, Tolerance Manual for Precast & Prestressed Concrete

ASTM A6, Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, & Sheet Piling

AISC 303, Code of Standard Practice for Steel Buildings & Bridges

ASTM C55, ASTM C90, ASTM C129, ASTM 744 – CMU

ASTM C62, ASTM C216, ASTM 652, ASTM C1088 - Masonry

ACI 530.1/ASCE 6/TMS 602 – Specifications for Masonry Structures Dimension Stone Design Manual VI

Indiana Limestone Institute 21<sup>st</sup> ed.

AAMA MCWM 1-89, Metal Curtainwall Manual

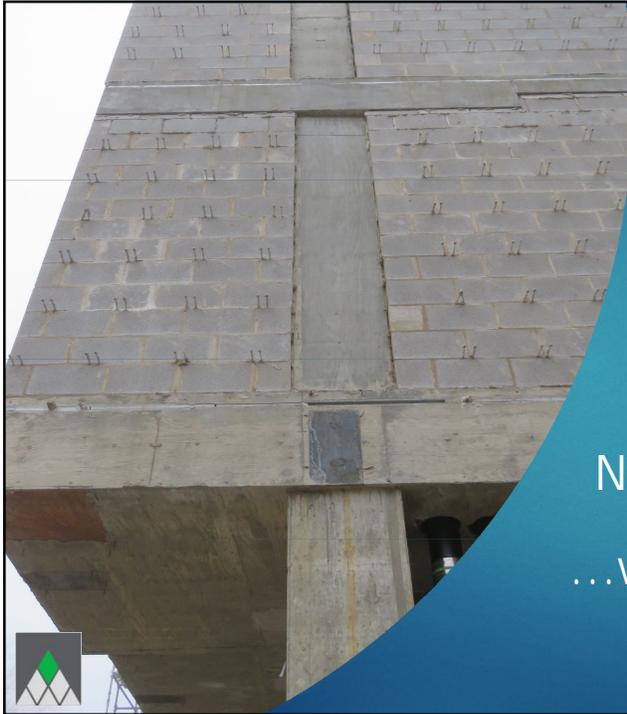
ANSI H35.2-2003, Dimensional Tolerances for Aluminum Mill Products

GANA Glazing Manual

SFM-1-87, Aluminum Storefront and Entrance Manual



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## Material & Construction Tolerances

NOT TYPICALLY ACCOUNTED FOR...  
...why we should **not** design to the minimums or code requirements

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## Tolerances for Roof

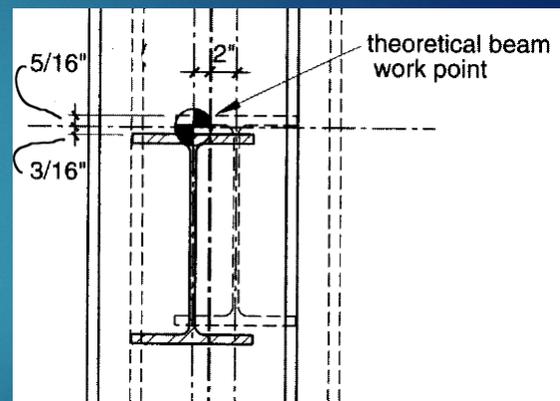
30'-0" Bay, 1/8" pitch & 1/4" pitch =  
**3 3/4" & 7 1/2" elevation change**

Steel Tolerance =	1/2"
Steel Deck Tolerance =	1/16"
Concrete Tolerance =	3/4"
	-----
	<b>1 1/4"</b>

OR

**35% off with 1/8" or 17.5% off with 1/4"**  
and still be within tolerance...

In a 1/4" pitch...If the dimension changes (from 30' to 10'...  
the roof pitch could be flat!)



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# Tolerances

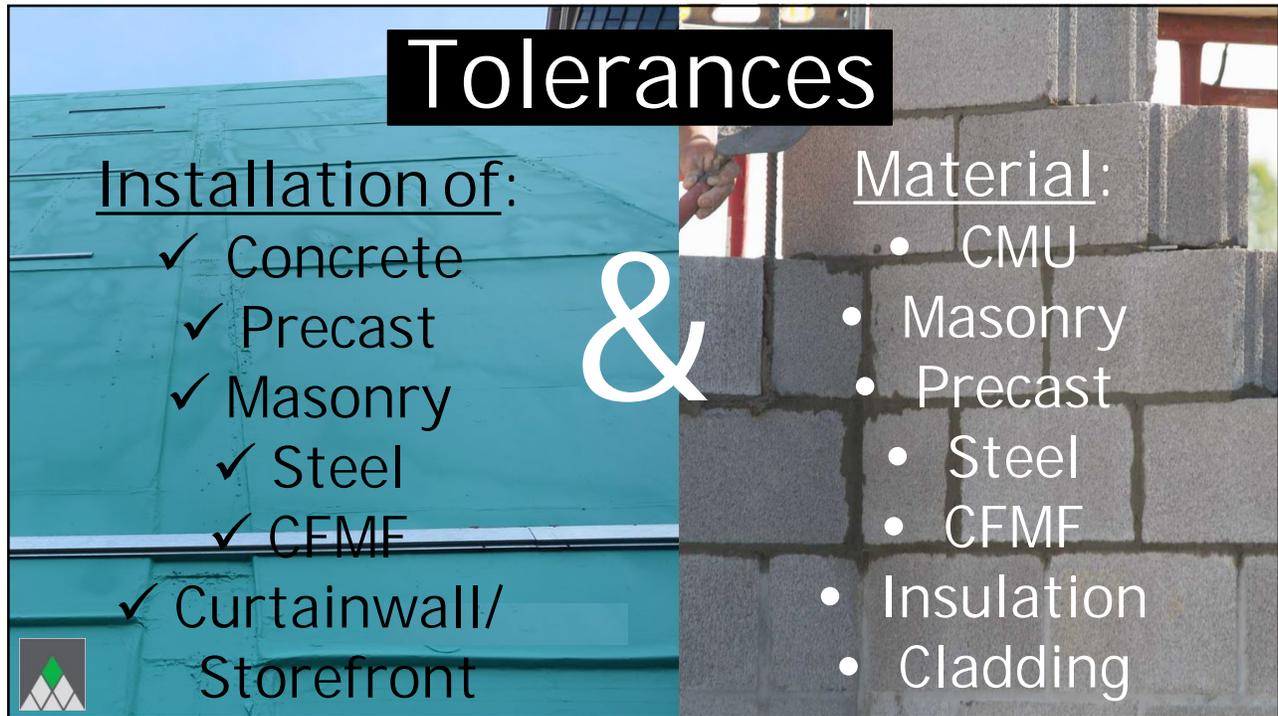
Installation of:

- ✓ Concrete
- ✓ Precast
- ✓ Masonry
- ✓ Steel
- ✓ CFMF
- ✓ Curtainwall/  
Storefront

&

Material:

- CMU
- Masonry
- Precast
- Steel
- CFMF
- Insulation
- Cladding

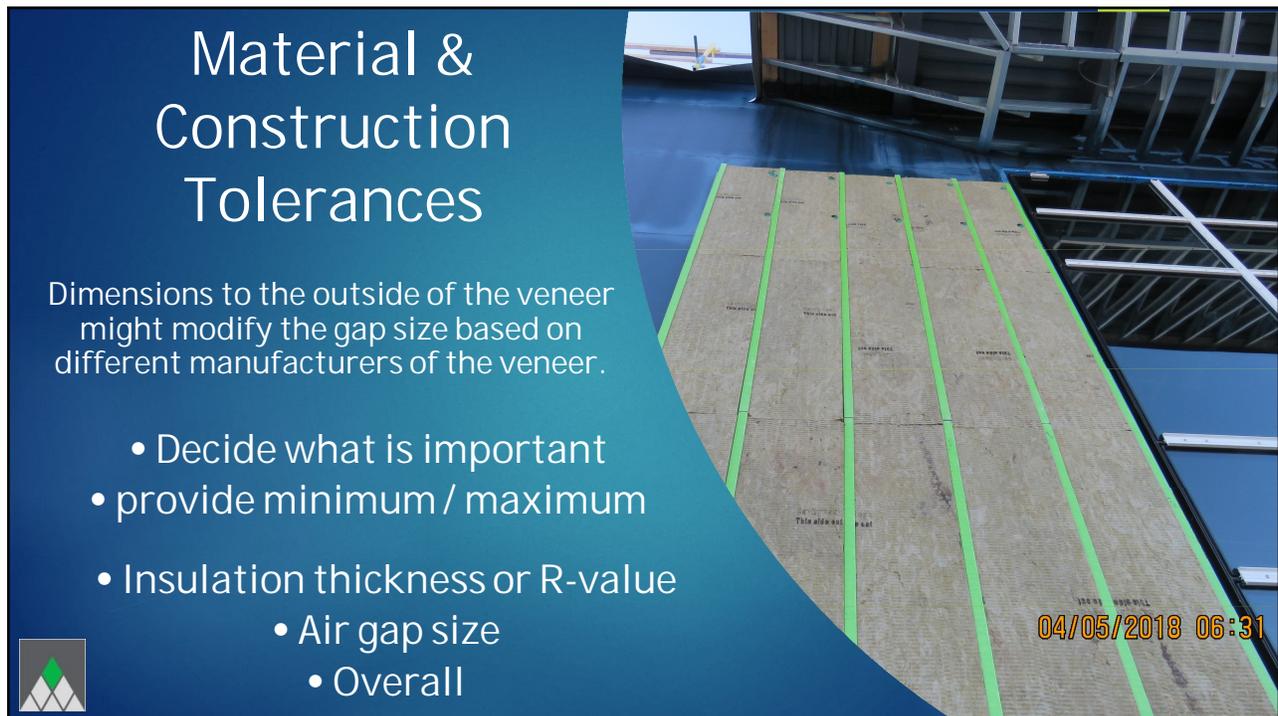


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## Material & Construction Tolerances

Dimensions to the outside of the veneer might modify the gap size based on different manufacturers of the veneer.

- Decide what is important
- provide minimum / maximum
- Insulation thickness or R-value
  - Air gap size
  - Overall



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# Material & Construction Tolerances

Tolerances need to be based on many items, including:

- Deflection
- System(s) tolerances
- Material Installation Tolerance



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# CONCRETE

ACI 117-10

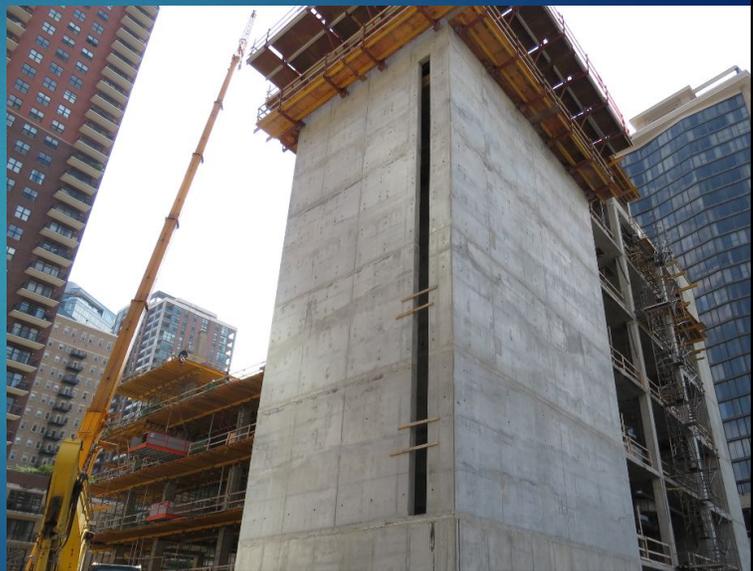
**Specification for Tolerances for  
Concrete Construction and Materials  
(ACI 117-10) and Commentary**

An ACI Standard

Reported by ACI Committee 117



American Concrete Institute®



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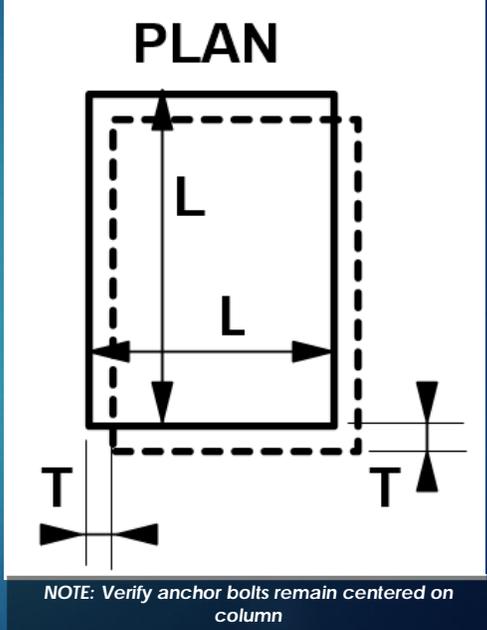
# CONCRETE TOLERANCES: FOUNDATIONS

## Deviation from plan location

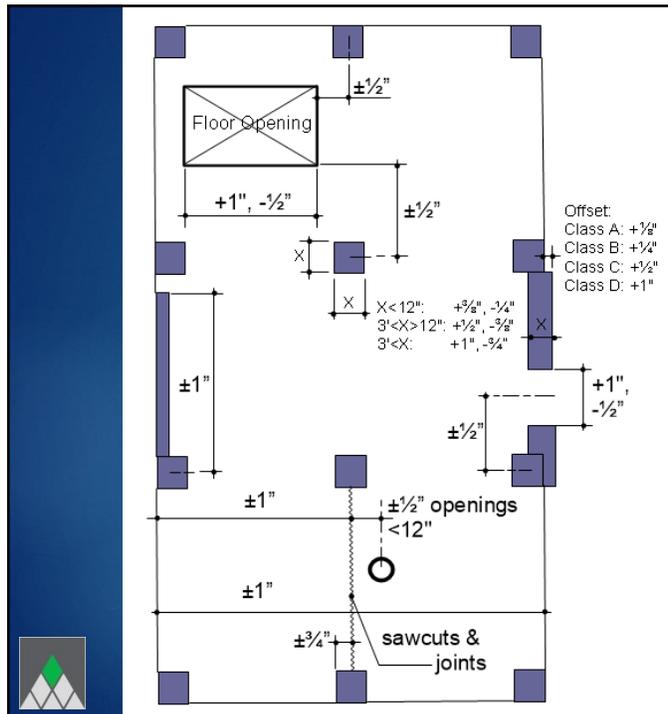
Foundations Horizontal deviation of the as-cast edge:

Dimensions is 8' <= ±1/2"

Dimension is < 8' = the greater of ± 2% of specified dimension or ±1/2"



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# CONCRETE TOLERANCES: FLOOR PLAN



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## CONCRETE TOLERANCES: FOUNDATIONS

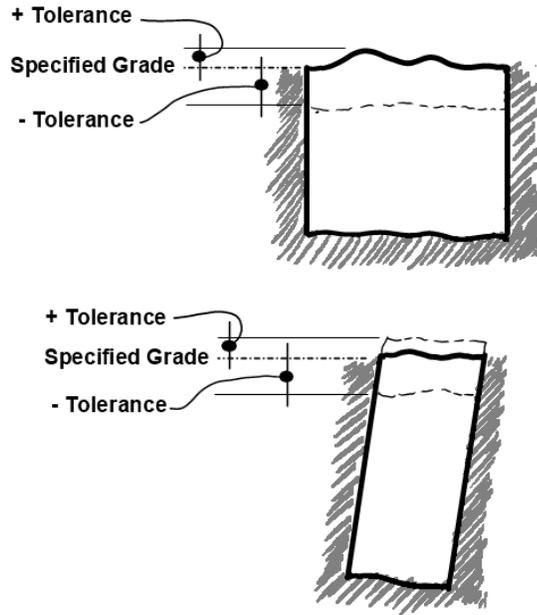
### Deviation from elevation

Top surface of foundation vertical deviation =  $+1/2"$  to  $-2"$

Top surface of drilled piers vertical deviation =  $+1"$  to  $-3"$

### Elevation Concerns/Results

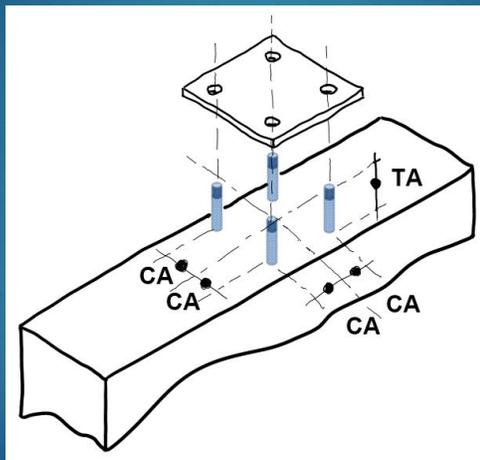
Precast.....Masonry.....CFMF



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## ANCHOR BOLT TOLERANCE

- 1)  $\pm 1/16"$
- 2)  $\pm 1/4"$
- 3)  $\pm 1/2"$



**What is Centerline  
of individual  
anchor bolts  
(3/4" dia)  
from specified  
horiz location?**



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# ANCHOR BOLT TOLERANCE

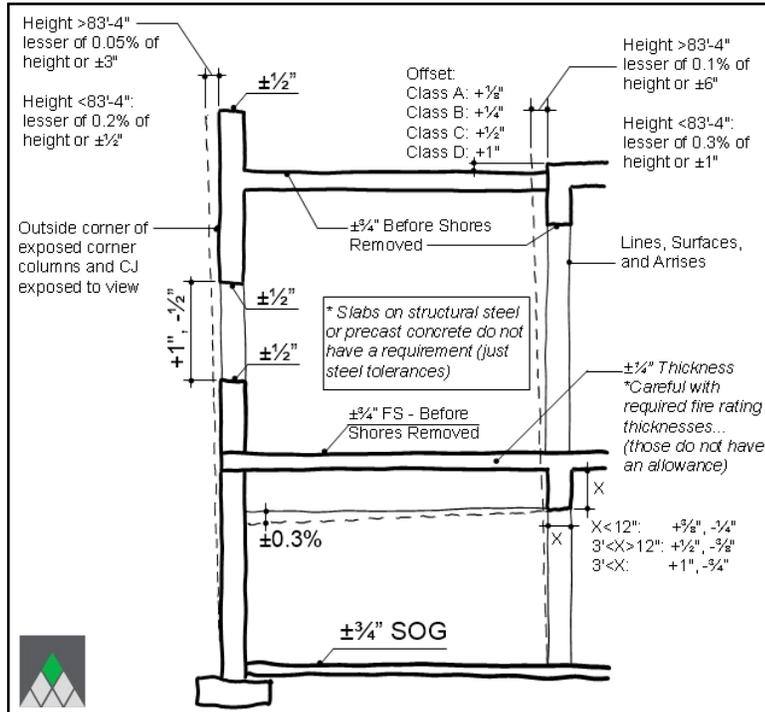
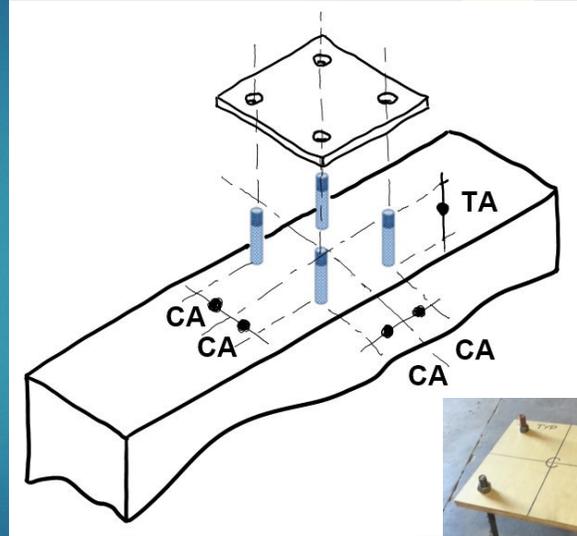
Top of anchor bolt from specified elevation Vertical deviation =  $\pm 1/2"$

Centerline of individual anchor bolts from specified horizontal location:

3/4" and 7/8" bolts:  $\pm 1/4"$

1", 1 1/4", and 1 1/2" bolts:  $\pm 3/8"$

1 3/4", 2", and 2 1/2" bolts:  $\pm 1/2"$



# Cast in Place Concrete





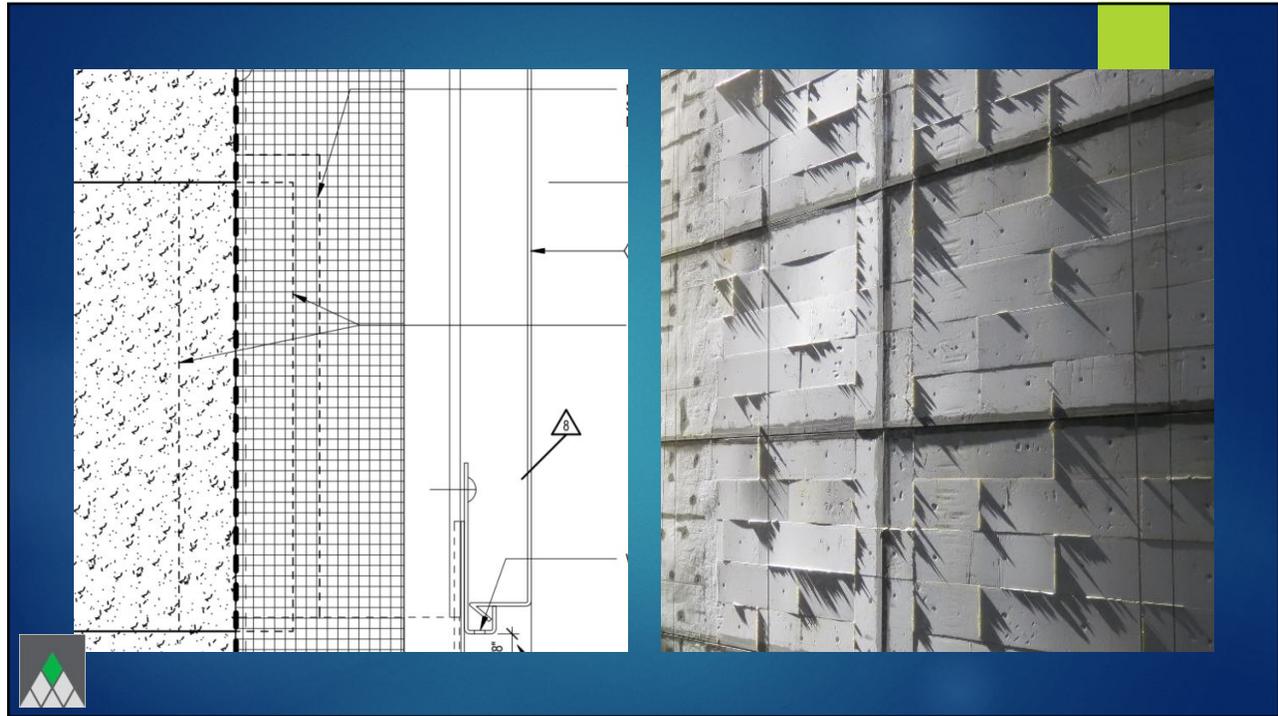
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### Tolerance in Design Development

**Tolerance Not Taken into Account During Design**

**Possible 1" L/R & 3/4" U/D Deviation Taken into Account During Design**

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## Cast in Place Concrete Stairs

The diagram shows a cross-section of a staircase. It includes the following labels and dimensions:

- $\pm 1/4''$  (horizontal dimension at the top)
- max between adjacent treads
- max between adjacent risers
- $\pm 3/4''$  (vertical dimension on the right)
- $\pm 1/4''$  deviation from slope or plane on stair tread from back to nosing

POP  
QUIZ

What is maximum differential dimension between treads & risers?

- 1)  $\pm 1/16''$ ,  $\pm 1/8''$
- 2)  $\pm 3/16''$ ,  $\pm 3/16''$
- 3)  $\pm 1/4''$ ,  $\pm 1/4''$

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**Cast in Place Concrete Stairs**

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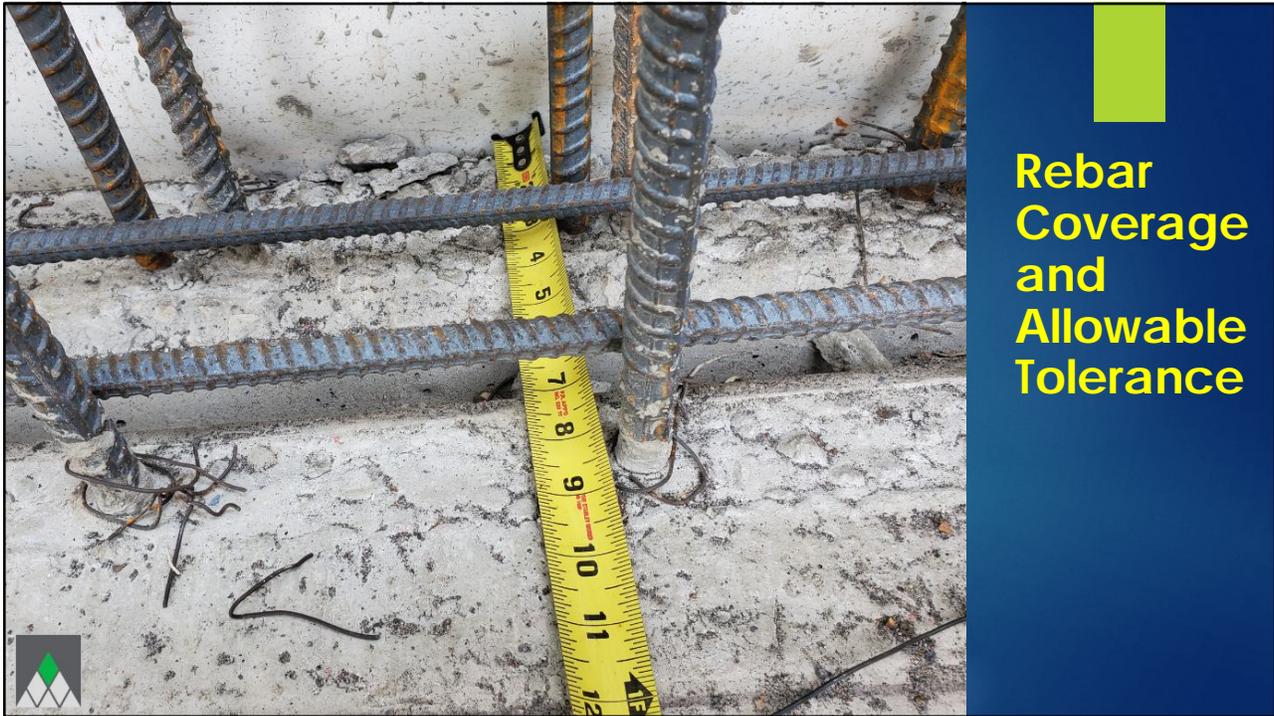
<u>Concrete / Rebar Condition</u>	<u>Coverage</u>
<b>Concrete:</b>	
Concrete against Earth:.....	3 Inches
#6 thru #18 bar exposed to weather.....	2 Inches
#5 or less bar exposed to weather.....	1 ½ Inches
#14 thru #18 bar NOT exposed to weather.....	1 ½ Inches
#11 or less bar NOT exposed to weather.....	¾ Inches
<b>Concrete Beams or Columns:</b>	
Primary Reinforcement, Ties, Stirrups, Spirals, etc.....	1 ½ Inches
<b>Shells or Folded Plate Members:</b>	
#6 or larger bar .....	¾ Inches
#5 or less bar .....	½ Inch

Bar Size	Tolerance
≤12"	- 3/8"
≥12"	- 1/2"

**Rebar Coverage and Allowable Tolerance**

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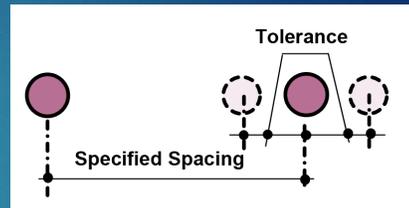
## CONCRETE TOLERANCES: Reinforcing

### Non-prestressed Reinforcement

Member Depth (or Thickness) is  $<4"$  =  $\pm 1/4"$

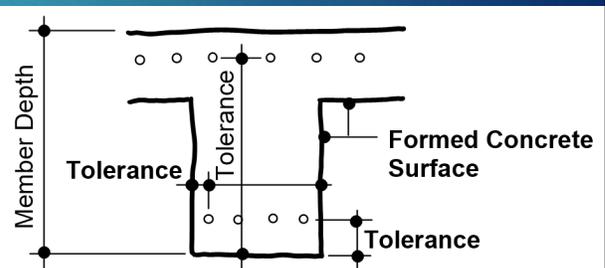
Member Depth (or Thickness) is  $4"<12"$  =  $\pm 3/8"$

Member Depth (or Thickness) is  $>12"$  =  $\pm 1/2"$



Per ACI 117, Rebar Installation Tolerances:

Bar Size	Tolerance
$\leq\#4$	$\pm 1/4"$
$\#5-\#12$	$\pm 3/8"$
$\geq\#12$	$\pm 1/2"$

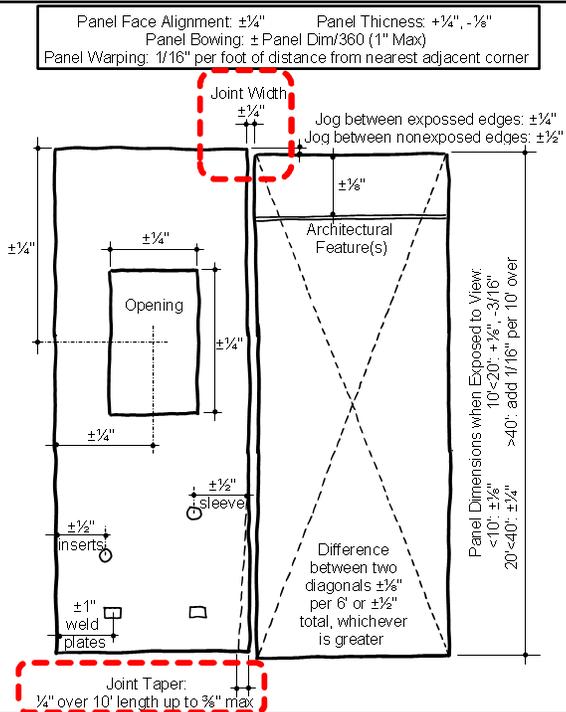


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# PRECAST CONCRETE



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## Architectural Precast Concrete Panel Fabrication Tolerances MNL 117



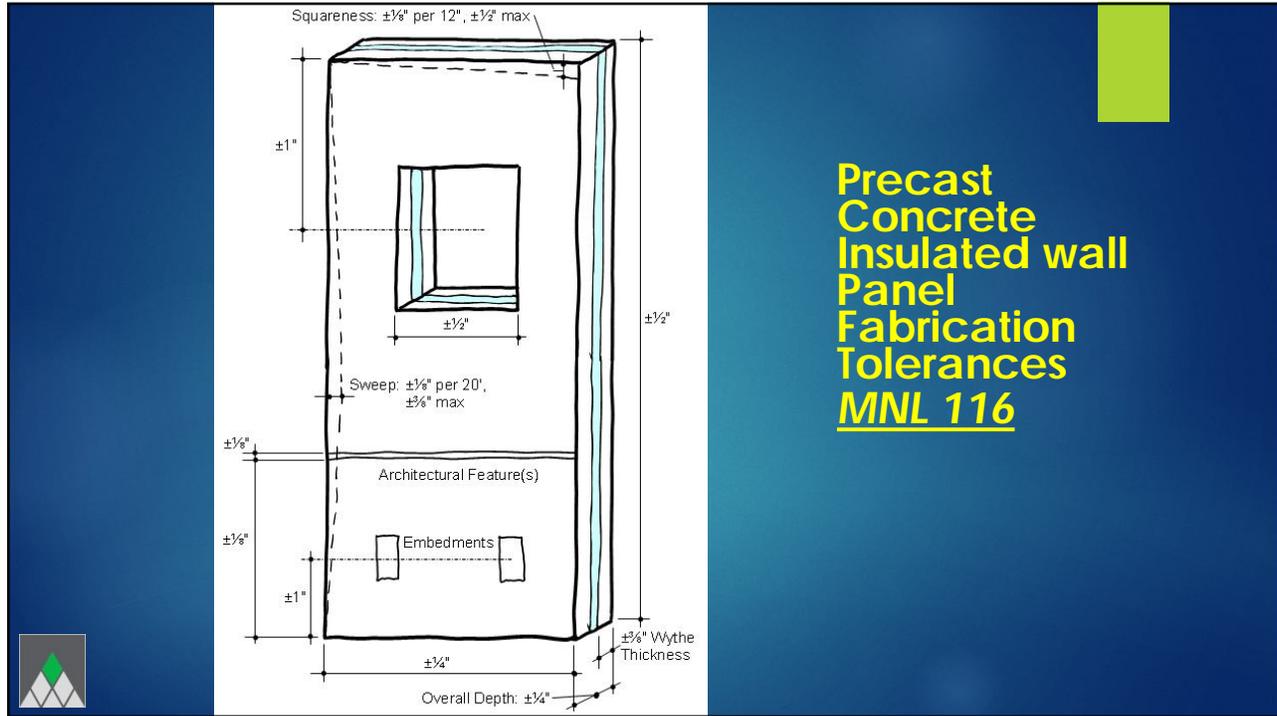
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## MNL 116 TOLERANCES

- 1)  $\pm 1/4''$
- 2)  $\pm 1/2''$
- 3)  $\pm 1''$

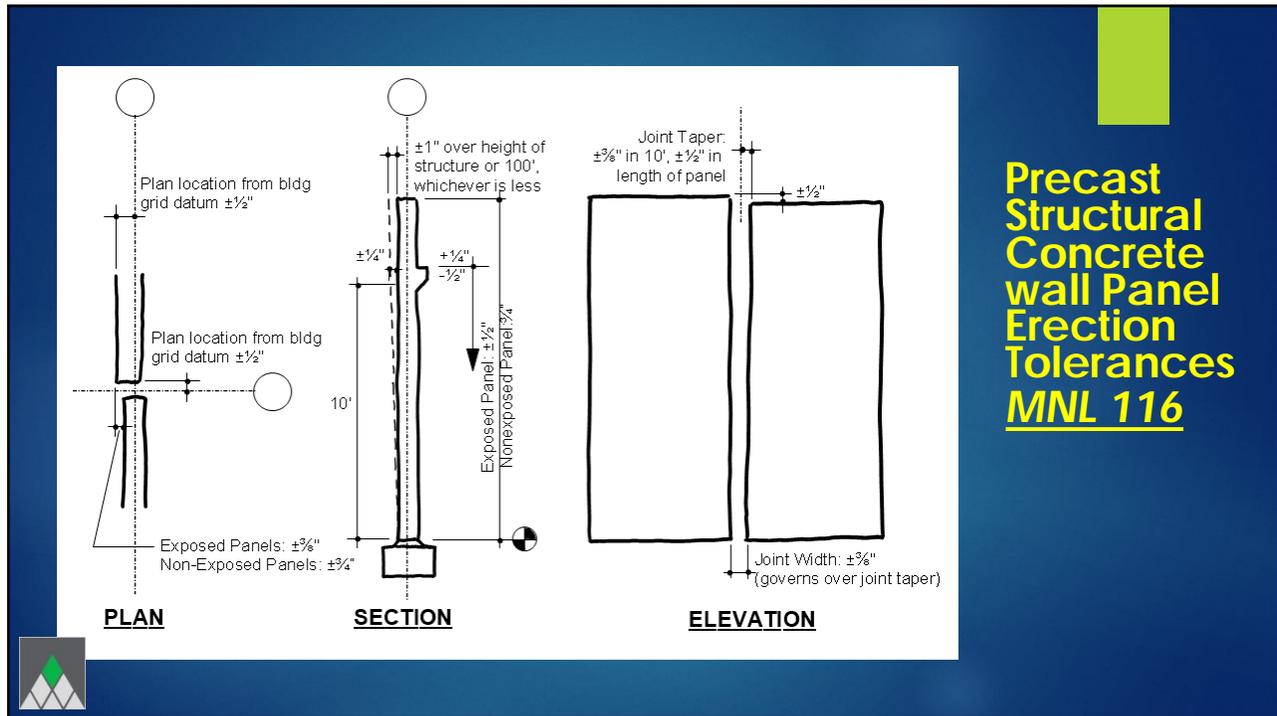
What is the tolerance for opening vertical location?

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**Precast  
Concrete  
Insulated wall  
Panel  
Fabrication  
Tolerances  
MNL 116**

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**Precast  
Structural  
Concrete  
wall Panel  
Erection  
Tolerances  
MNL 116**

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**PLAN**

Plan location from bldg grid datum  $\pm\frac{1}{2}$ "

$\pm\frac{1}{4}$ "

**SECTION**

$\pm 1"$  over height of structure or 100', whichever is less

10'

$\pm\frac{1}{4}$ "

$+\frac{1}{4}"$   
 $-\frac{1}{2}"$

Exposed Panel:  $\pm\frac{1}{2}"$   
Nonexposed Panel:  $\pm\frac{1}{2}"$

**ELEVATION**

Joint Width:  $\pm\frac{1}{4}"$  (governs over joint taper)

Joint Taper:  $\pm\frac{3}{8}"$  maximum;  $\pm\frac{1}{4}"$  in 10'

$\pm\frac{1}{4}"$  Exposed

**Precast Architectural Concrete wall Panel Erection Tolerances MNL 117**

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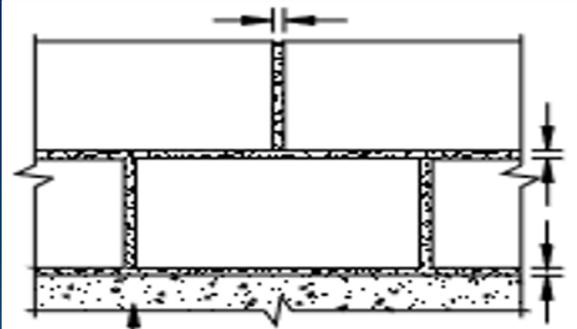
# MASONRY

**TMS 402/602-16**  
**Building Code Requirements and Specification for Masonry Structures**

Containing:  
TMS 402-16 Building Code Requirements for Masonry Structures (formerly also designated as AC 308 and AC 308.5)  
TMS 602-16 Specification for Masonry Structures (formerly also designated as AC 508.1 and AC 508.4)  
and Companion Commentaries

**INTERNATIONAL MASONRY SOCIETY**  
The Masonry Society  
www.masonry.org

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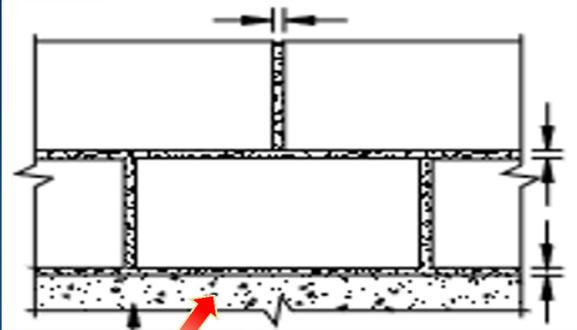



**WHAT IS THE ALLOWABLE TOLERANCE OF THE THICKNESS OF A TYPICAL CMU BED JOINT?**

- 1)  $(3/8'') \pm 1/4''$
- 2)  $(3/8'') \pm 1/8''$
- 3)  $(3/8'') + 1/4''$  to  $-1/8''$

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**HEAD JOINT THICKNESS =  $(3/8'') - 1/4''$  to  $+3/8''$**



**BED JOINT THICKNESS =  $(3/8'') \pm 1/8''$**

**INITIAL BED THICKNESS =  $1/4''$  min to  $1\ 1/4''$  max**

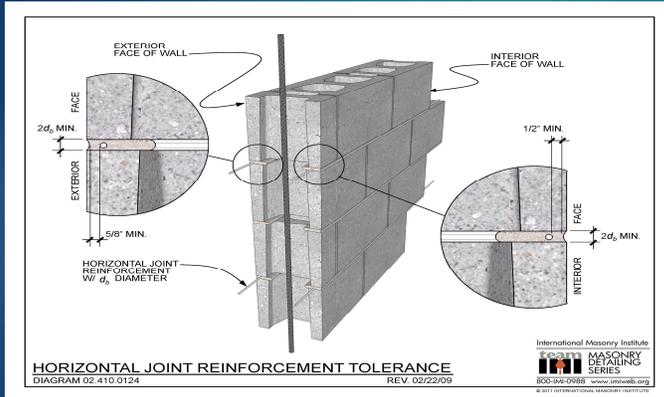
**Footing Allowable Tolerance  $\pm 1/2''$  (ACI 117)**

*Note: TMS 402-6.1.2.3...Max wire size =  $1/2$  joint thickness*

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# HORIZONTAL JOINT REINFORCEMENT

Note: TMS 402-6.1.2.3...Max wire size = 1/2 joint thickness



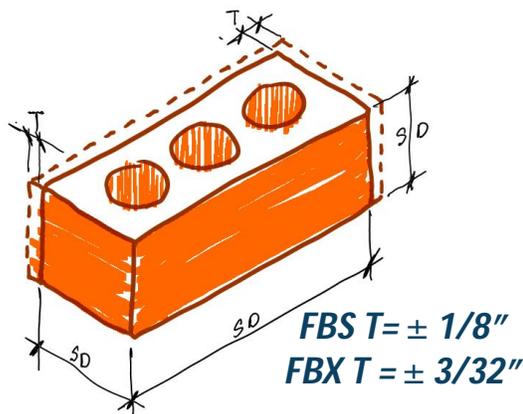
So, based on the Code and allowable tolerances...

Does a 3/16" wire size truly work?



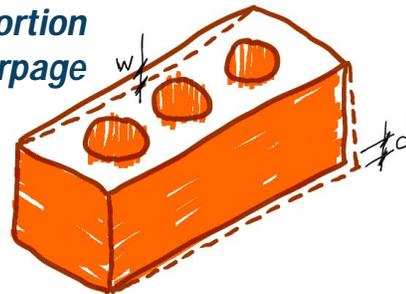
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# MASONRY TOLERANCE ASTM C216 – FBX & FBS



SD = Specified Dimension  
T = Tolerance

d = Distortion  
w = Warpage



$FBS w = \pm 3/32"$   
 $FBX w = \pm 1/16"$   
 $FBS d = \pm 3/32"$   
 $FBX d = \pm 1/16"$



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**The joint tolerance is to take the masonry tolerance into account**

**HEAD JOINT THICKNESS = (3/8") -1/4" to +3/8"**

**Footing Allowable Tolerance ± 1/2" (ACI 117)**

**MASONRY TOLERANCE** ASTM C216 - FBX & FBS

*d = Distortion*  
*w = Warpage*

FBS  $T = \pm 1/8"$   
FBX  $T = \pm 3/32"$

FBS  $w = \pm 3/32"$   
FBX  $w = \pm 1/16"$

FBS  $d = \pm 3/32"$   
FBX  $d = \pm 1/16"$

*SD = Specified Dimension*  
*T = Tolerance*

**BED JOINT THICKNESS = (3/8") ± 1/8"**

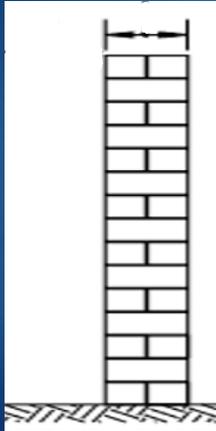
**INITIAL BED THICKNESS = 1/4" min to 1 1/4" max**

**So...we need to take the masonry unit tolerance into account**

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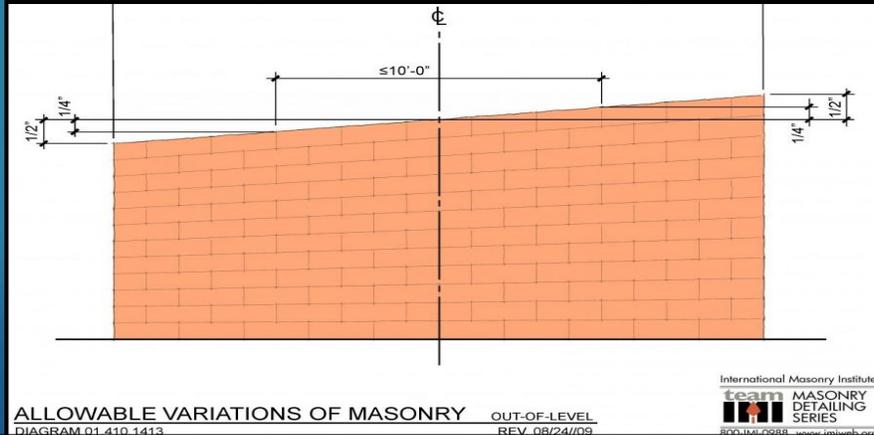
## MASONRY WALL TOLERANCE

**CROSS SECTIONAL**  
- 1/4" to + 1/2"



**ELEVATION**

Load Bearing :  $\pm 1/4"$  in 10' (Max  $1/2"$ )  
Non-Load Bearing :  $\pm 1/4"$  per story (Max  $\pm 3/4"$ )



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## VARIATION IN PLUMB

*H = Wall Height*  
*D = Allowable Variation*

When  $H < 10'-0"$

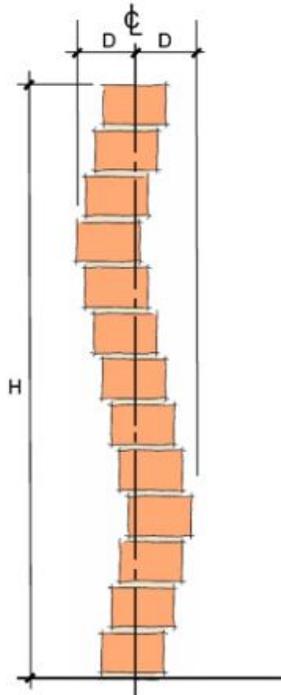
$D < 1/4"$

When  $H < 20'-0"$

$D < 3/8"$

When  $H > 20'-0"$

$D < 1/2"$



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## MASONRY REBAR TOLERANCE

POP  
QUIZ

- 1)  $\pm 1\frac{1}{2}"$
- 2)  $\pm 1"$
- 3)  $\pm \frac{1}{2}"$



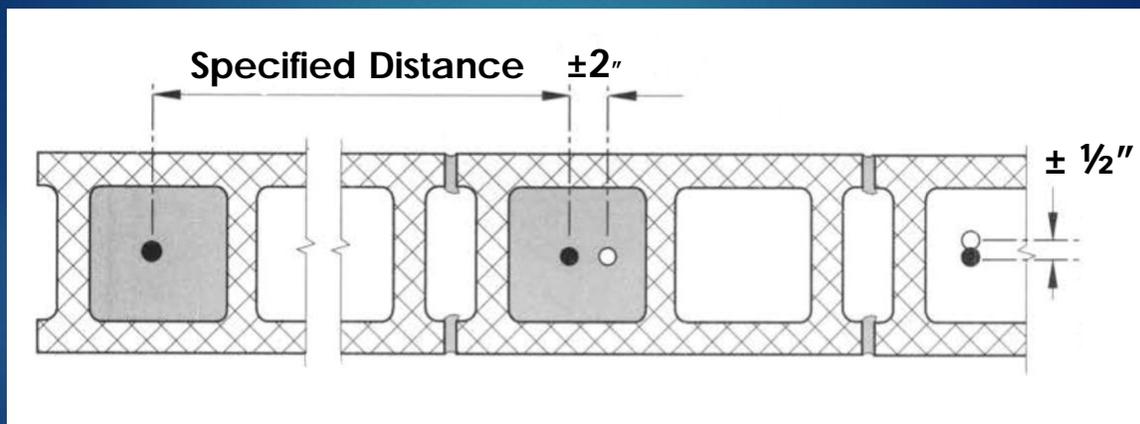
What is vertical rebar tolerance in depth location in an 8" CMU wall?



ACI 530

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## MASONRY REBAR TOLERANCE

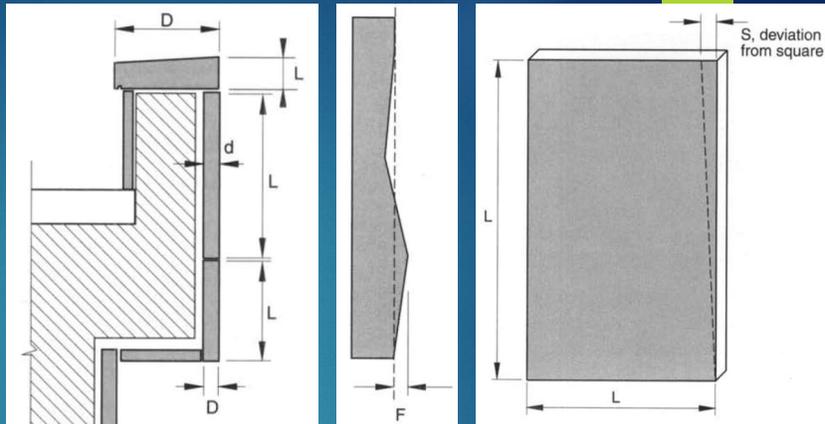


ACI 530

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# LIMESTONE FABRICATION TOLERANCES

Specifying how the limestone is cut is important for tolerances.



Finish type	Length, L, in (mm)	Deviation from flat surface, F, in (mm)	Critical depth, D, in (mm)	Non-critical depth, d, in (mm)	Deviation from square, S, in (mm)
Smooth machine finish	$\pm 1/16$ (2)	$\pm 1/16$ (2)	$\pm 1/16$ (2)	$\pm 1/2$ (13)	$\pm 1/16$ (2)
Diamond gang finish	$\pm 1/16$ (2)	$\pm 1/4$ (6)	$\pm 1/8$ (3)	$\pm 1/2$ (13)	$\pm 1/16$ (2)
Chat sawed finish	$\pm 1/16$ (2)	$\pm 1/4$ (6)	$\pm 1/8$ (3)	$\pm 1/2$ (13)	$\pm 1/16$ (2)
Shot sawed finish	$\pm 1/16$ (2)	$\pm 1/2$ (13)	$\pm 1/4$ (6)	$\pm 1/2$ (13)	$\pm 1/16$ (2)

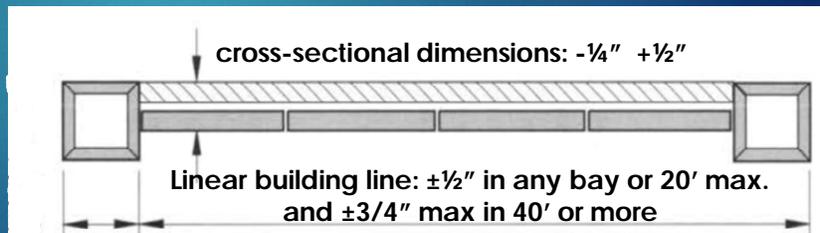
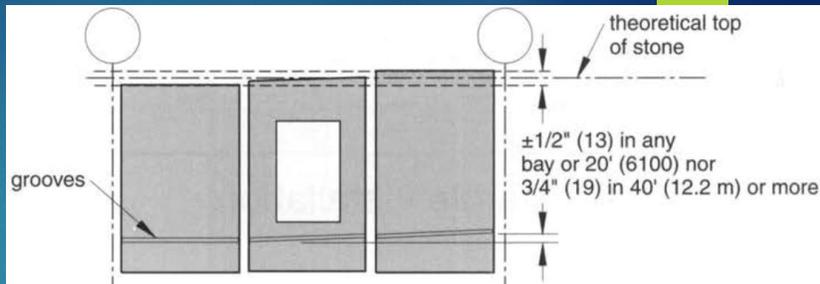
Source: Indiana Limestone Handbook, 21<sup>st</sup> ed. Indiana Limestone Institute of America, Inc.

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**Tolerance for Plumb**

- $\pm 1/2$ " max. in 40' or more for any element
- one story or 20'
- $\pm 1/4$ " in 10'
- $\pm 3/8$ " for one story or 20' max for lines & surfaces of col & walls
- $\pm 1/4$ " for one story or 20' max for external corners, expansion jts, and other conspicuous lines

## LIMESTONE INSTALLATION



Source: Indiana Limestone Handbook, 21<sup>st</sup> ed. Indiana Limestone Institute of America, Inc.

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# STEEL



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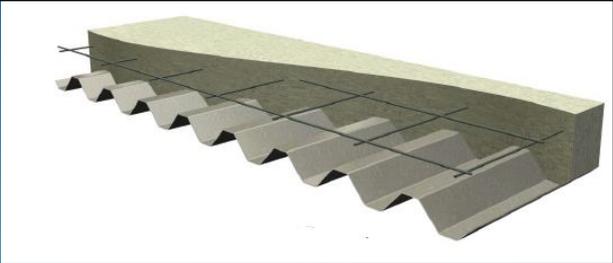
## Steel Deck Manufacture & Installation Tolerances

**Minimum Edge Distance for installation:**

Steel deck could be butted/end ° lapped at supports.

Steel deck overlap shall be 2" with a ±½" tolerance (minimum overlap is 1½" to 2½" ...However, overlaps greater than 2½" are acceptable.

Minimum edge distance of a fastener for the deck is ½".



ASC Steel Deck Fabrication Tolerances	
Length of Panel:	±½"
Coverage Width:	-¾", +¾"
Sweep of Panel:	¼" in 10'
Square of Panel:	⅛" per foot width
Height of Panel:	±1/16"

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# Steel Angle Manufacture Tolerances

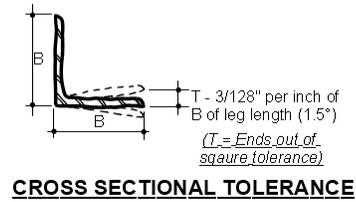
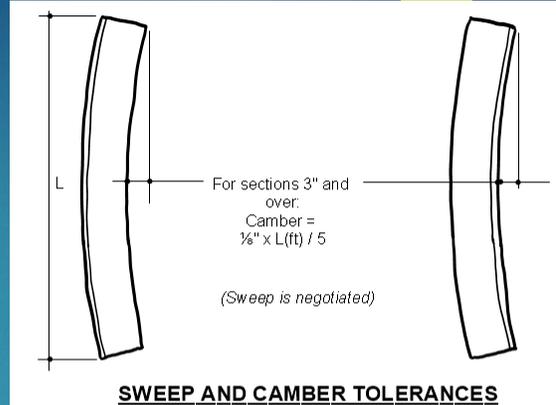
## Variation in sizes (length) for Angle

	Over, B	Under, B
2" < 3"	1/16"	1/16"
3" < 4"	1/8"	3/32"
4" < 6"	1/8"	1/8"
> 6"	3/16"	1/8"

Unequal Legs, longer leg determines classification

## Variation in Length of Angle

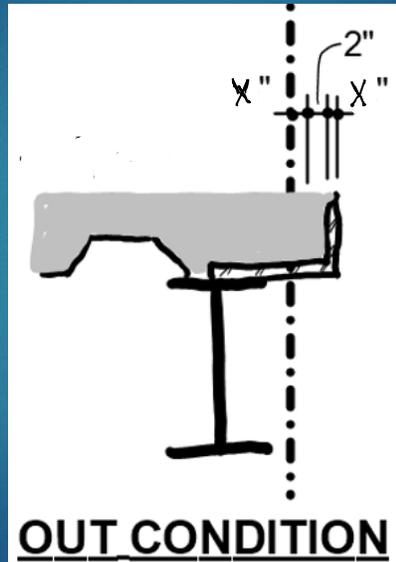
	5' to 10'		10' to 20'		20' to 30'		30' to 40'	
	Over	Under	Over	Under	Over	Under	Over	Under
Under 3"	5/8"	0	1"	0	1 1/2"	0	2"	0
3" & Over	1"	0	1 1/2"	0	1 3/4"	0	2 1/4"	0



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# SLAB EDGE TOLERANCE

- 1) -1/2", +1/2"
- 2) -1/2", +1/4"
- 3) -1/4", +1/2"

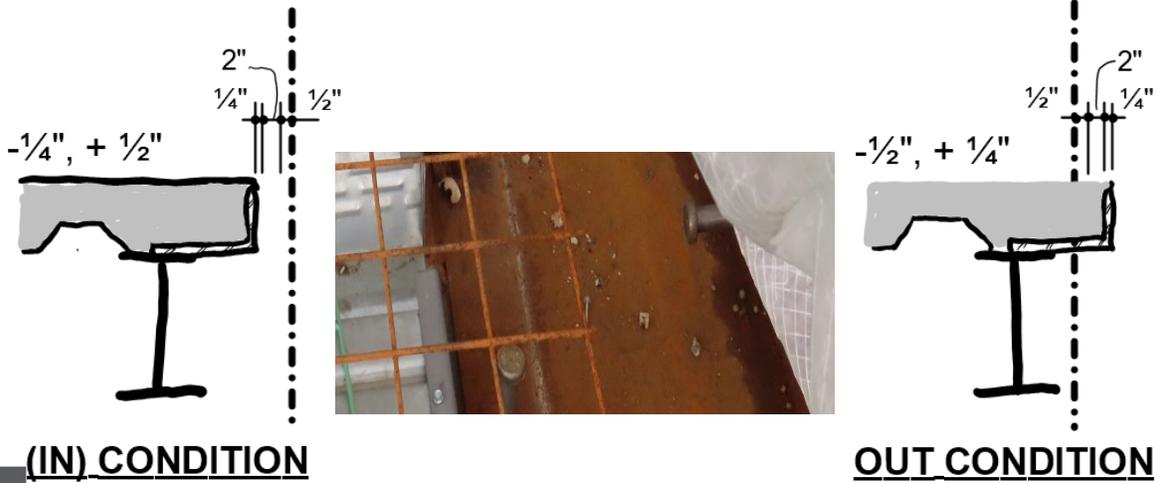


What is the tolerance for the slab edge out condition?

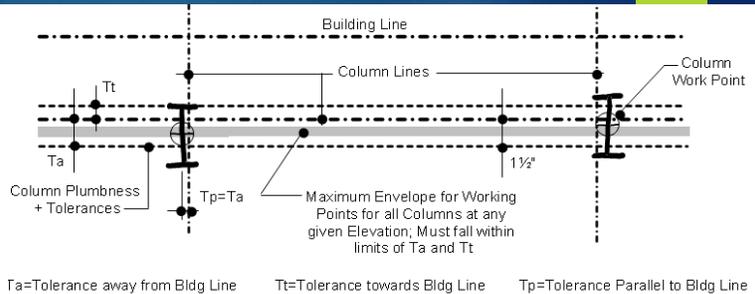
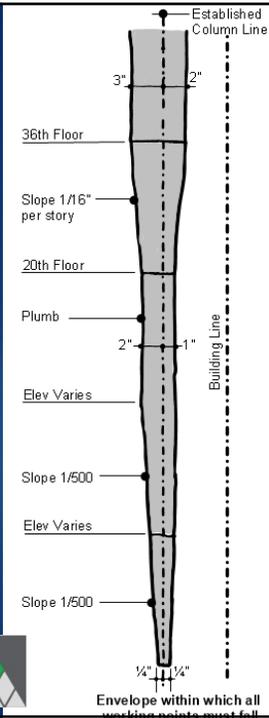


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## Steel Angle Installation @ Slab Edge Tolerance

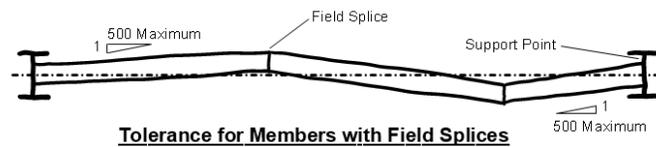


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**Tolerance for Columns with Continous Intermediate Beams**

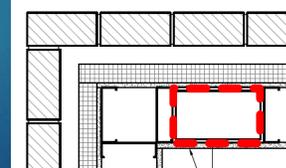
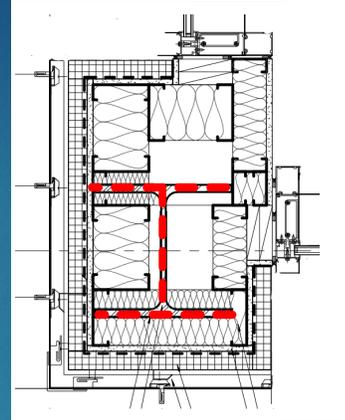
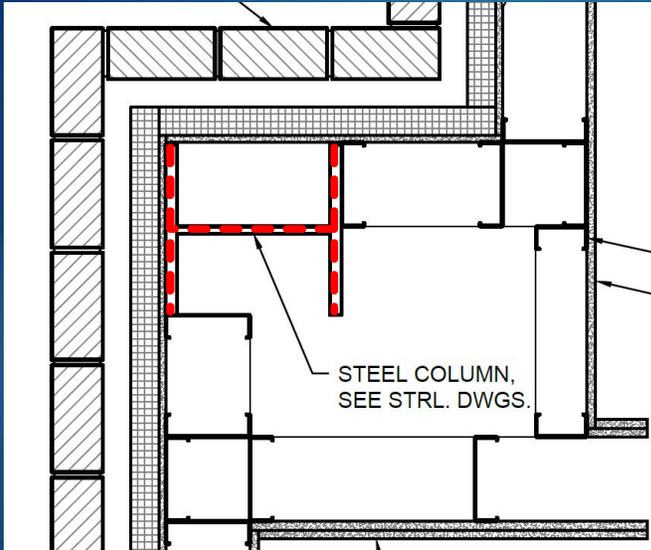
### Exterior Steel Column Installation Tolerances



**Tolerance for Members with Field Splices**

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# Tolerances



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# STOREFRONT & CURTAINWALL



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## Storefront Tolerances

**Storefront Fabrication Tolerance**

- Maximum 1/8" Between Diagonals in Glazing Framing
- Total Length: Verify w/Manufacturer
- Height: Verify w/Manufacturer

**Storefront Installation Tolerance**

- Maximum 1/8" Between Diagonals in Glazing Framing
- Offset Between Adjacent Members: ± 1/16"
- Clearance from Masonry: ± 1/2" Recommended, ± 1/4" Minimum
- Plumb: 1/8" per 12'
- Floor Level Under Door: ± 1/16"

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## Curtainwall Tolerance

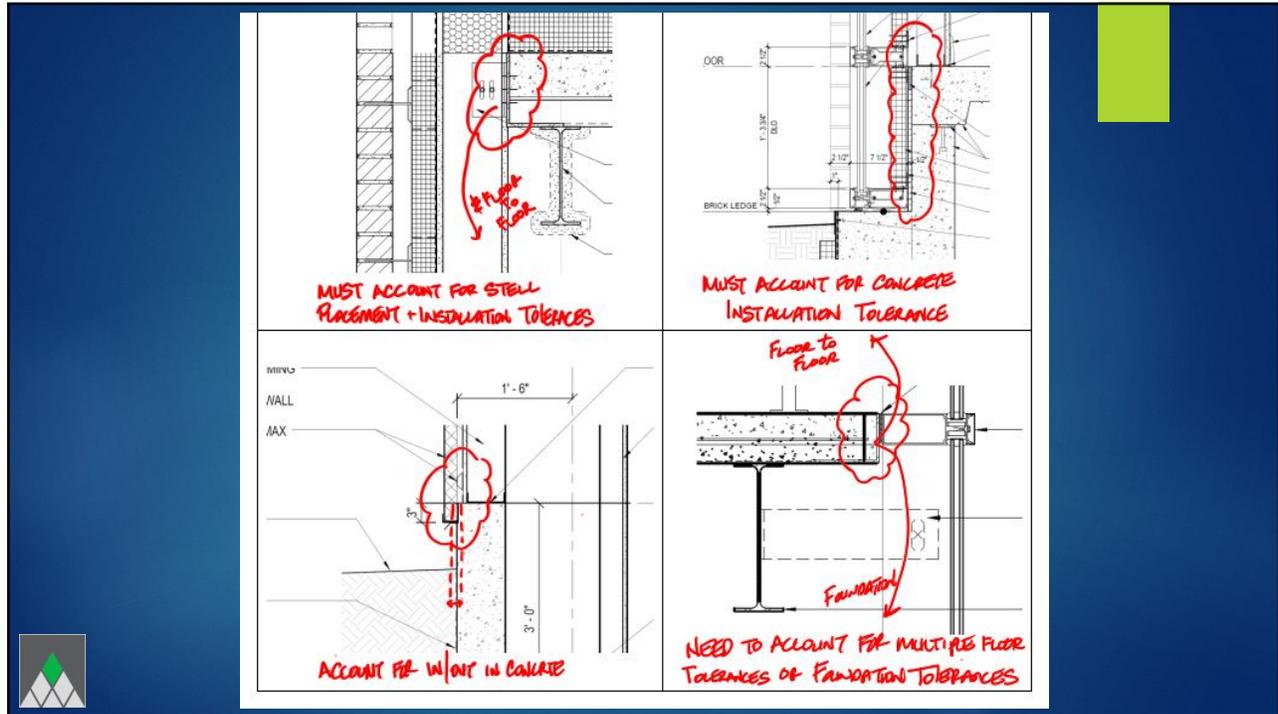
**Curtain Wall Fabrication Tolerance**

- ± 1/8" from Location Shown on the Drawings
- Maximum 1/8" between diagonals in Glazing Framing
- Individual Tubes, Shapes, and other Framing Members: Refer to Manufacturer's Instructions
- ± 1/8" From Location Shown on Drawings
- Height: ± 1/8" or Manufacturer's Standard
- Maximum Alignment Offset Between Two Identical members end to end: ± 1/16"
- Width: ± 1/8" or Manufacturer's Standard

**Curtain Wall Installation Tolerance**

- Building Frame Tolerance Specified Elsewhere Listed in the Curtain Wall Specifications
- Maximum Offset ± 1/16"
- Variation from Plane: 1/8" per 12' or 1/2" in any Total Length

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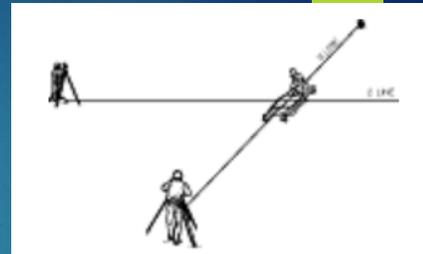


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# Construction

Control Lines  
Or  
Material

What are the  
consequences of  
either?



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## What is your tolerance for that system?

*Simple question, but do you know or understand what your tolerance is...for the concrete foundation wall top surface, window rough opening, window framing, glass feature, etc.?*

**Do your specifications call out a tolerance?**

**Do you have specifications on that featured system?**

**What is acceptable to the next trade?**



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*I am frequently asked what certain trade tolerances are after the installation is complete, which is too late for the next trade and the work has already been installed.*

These questions are even more important when we do not have specifications on our project or there are a few notes on the drawings.

**Don't wait until it is too late, every pre-install meeting should be reviewing the construction tolerances of that trade item as well as the following trade items. If you cannot answer these questions above...**

**Most trade associations have tolerance guidelines, however, they will likely favor the product...if there are no specifications, review these tolerances early.**



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## THANK YOU FOR ATTENDING

This Concludes The American Institute of Architects  
Continuing Education Systems Course

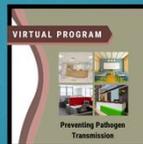
### Building Envelope Tolerances

Course # S003-040720TR

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### Preventing Pathogen Transmission Through Surface Material Specifications

Tuesday, August 25, 11:30am-1:00pm CT  
By: Linda Lybert, Healthcare Surfaces Institute



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