


BUILDING ENVELOPE TOLERANCES

Thank You Chapter Partners




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CSI Roundtable
Course # S003-040720TR
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Building Envelope Tolerance



COREY S ZUSSMAN, AIA, NCARB, ALA, RBEC, RRC, REWC, RWC, RRO,
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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 21st ed.

AAMA MCWM 1-89, Metal Curtainwall Manual

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

GANAL 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

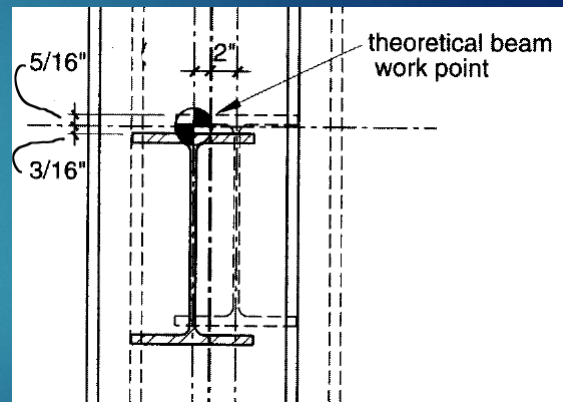
Steel Tolerance =	1/2"
Steel Deck Tolerance =	1/16"
Concrete Tolerance =	3/4"

	1 1/4"

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

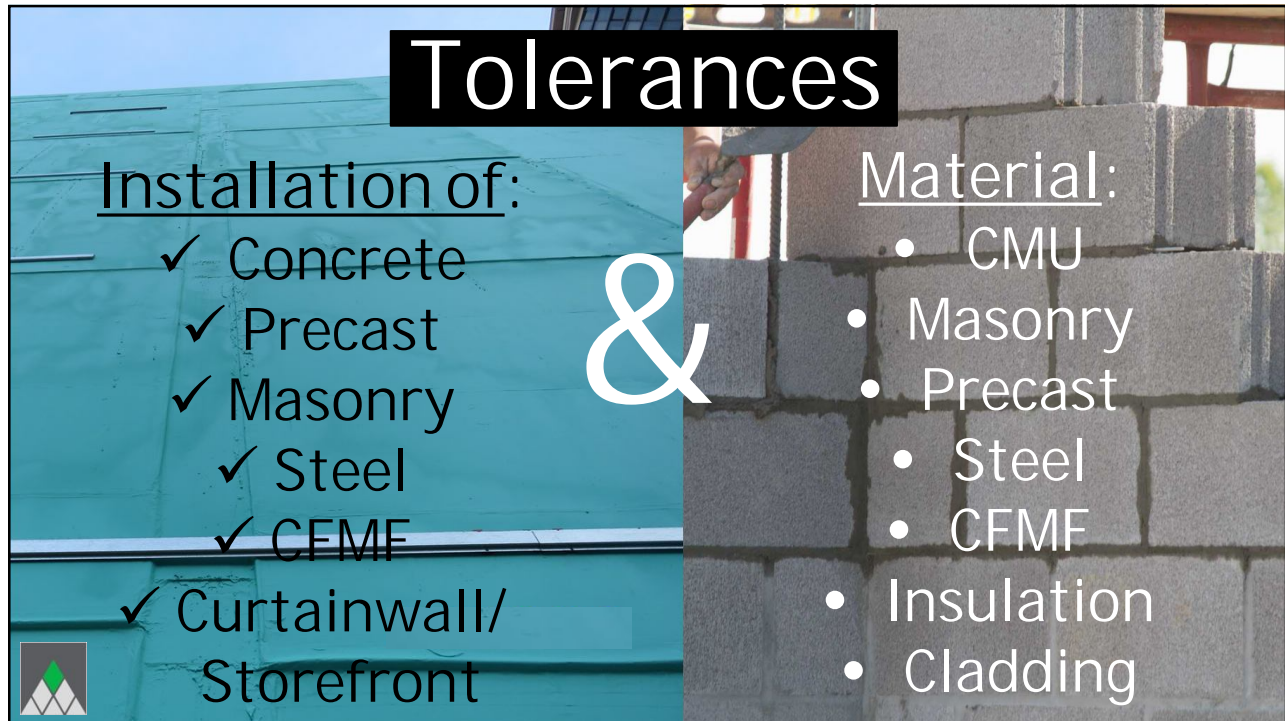
Installation of:

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

&

Material:

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

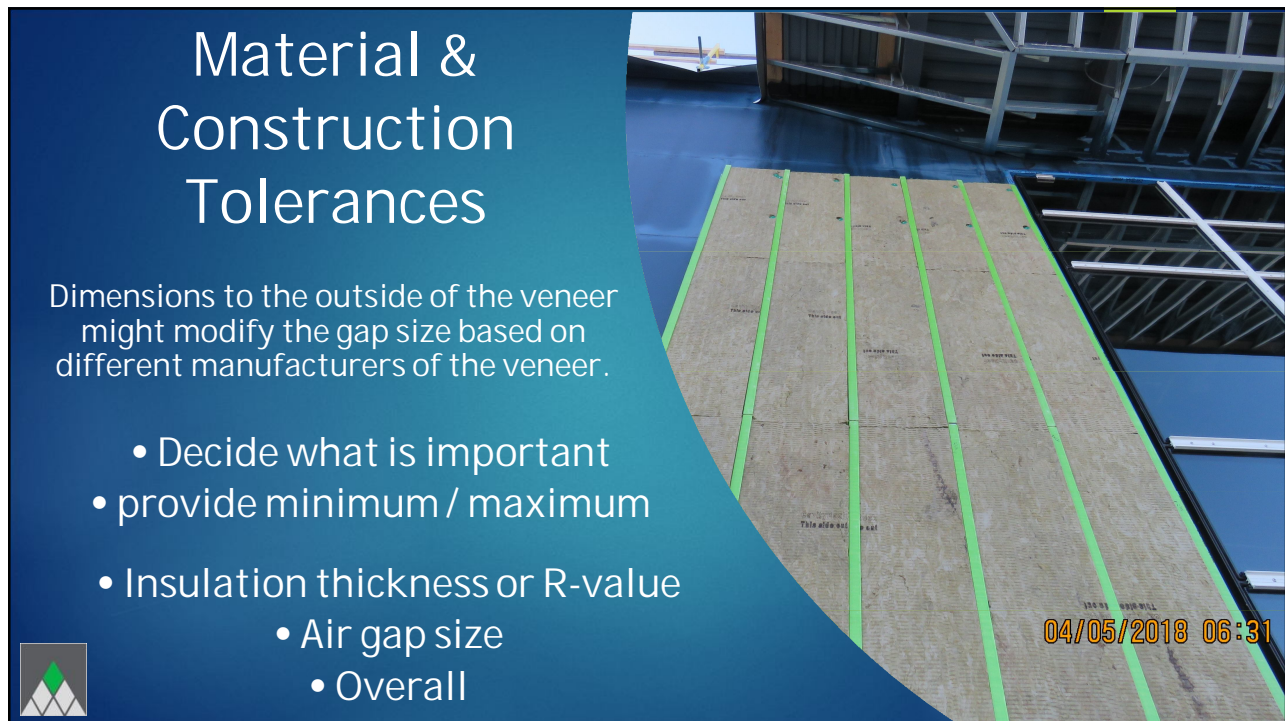


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Material & Construction Tolerances

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

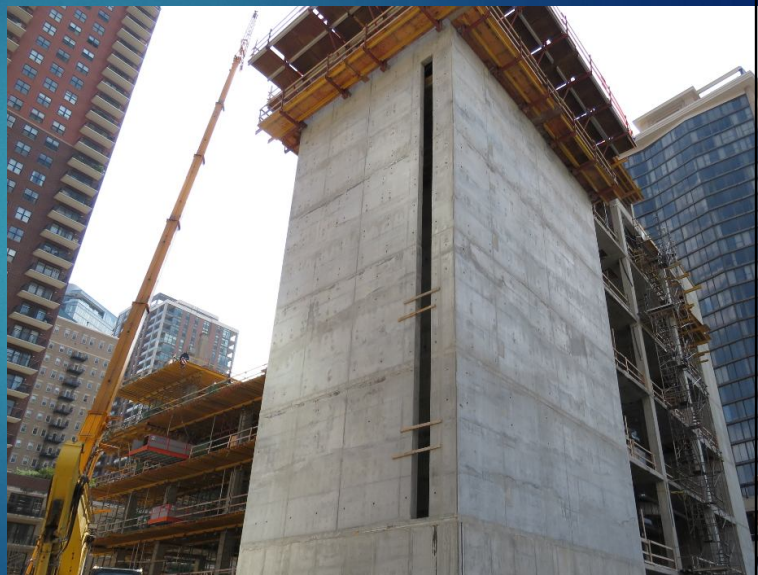
**Specification for Tolerances for
Concrete Construction and Materials
(ACI 117-10) and Commentary**

An ACI Standard

Reported by ACI Committee 117



American Concrete Institute®



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CONCRETE TOLERANCES: FOUNDATIONS

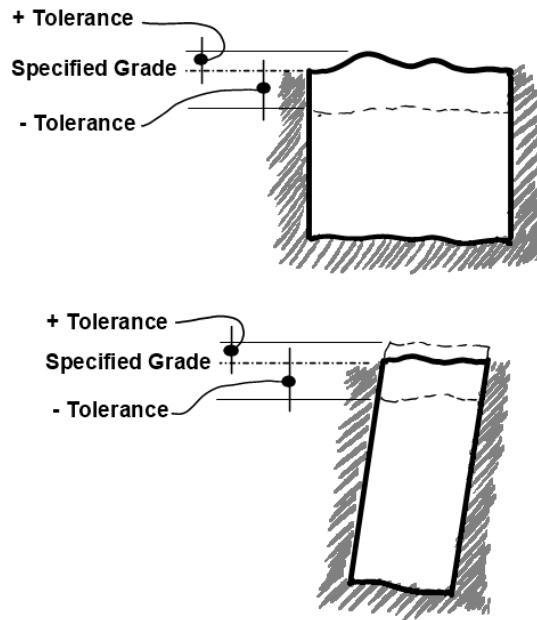
Deviation from elevation

Top surface of foundation vertical
deviation = $+ \frac{1}{2}"$ to $-2"$

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

Elevation Concerns/Results

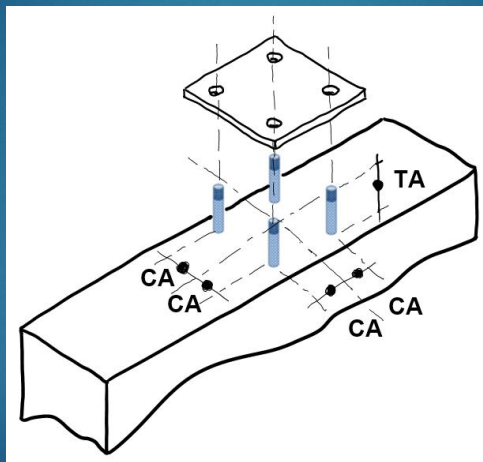
Precast.....Masonry.....CFMF



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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

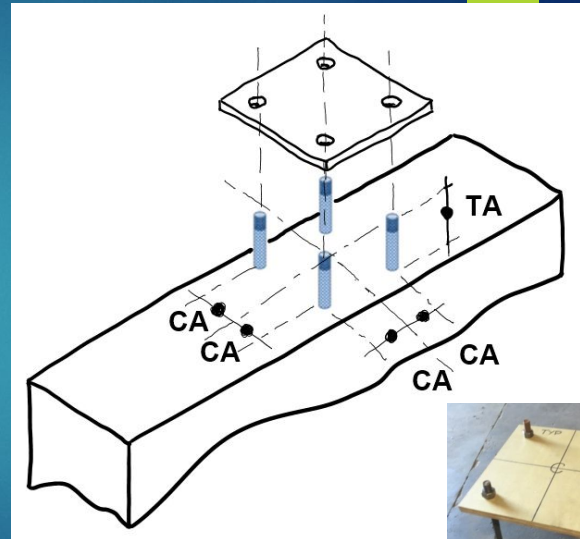
Top of anchor bolt from specified elevation Vertical deviation = $\pm \frac{1}{2}$ "

Centerline of individual anchor bolts from specified horizontal location:

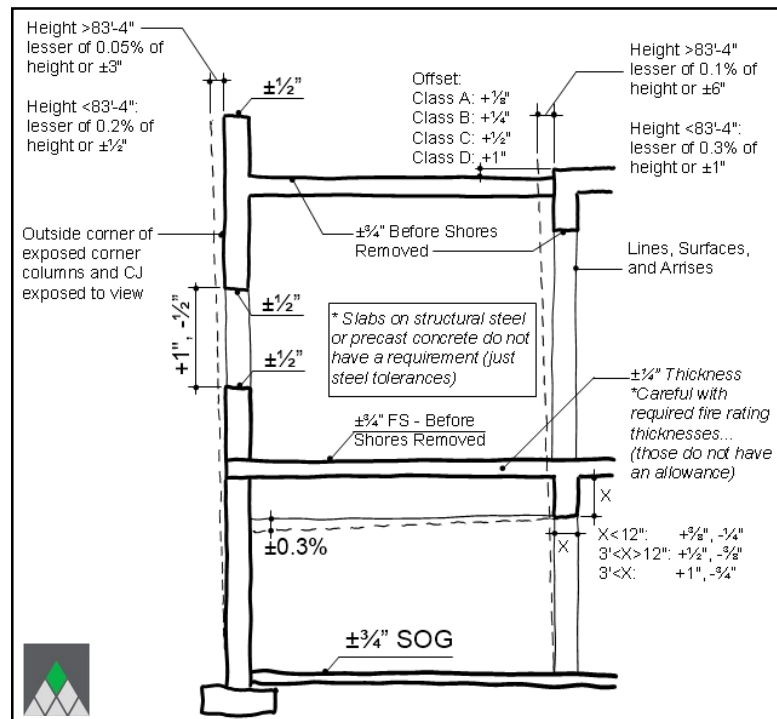
$\frac{3}{4}$ " and $\frac{7}{8}$ " bolts: $\pm \frac{1}{4}$ "

1", 1 $\frac{1}{4}$ ", and 1 $\frac{1}{2}$ " bolts: $\pm \frac{3}{8}$ "

1 $\frac{3}{4}$ ", 2", and 2 $\frac{1}{2}$ " bolts: $\pm \frac{1}{2}$ "



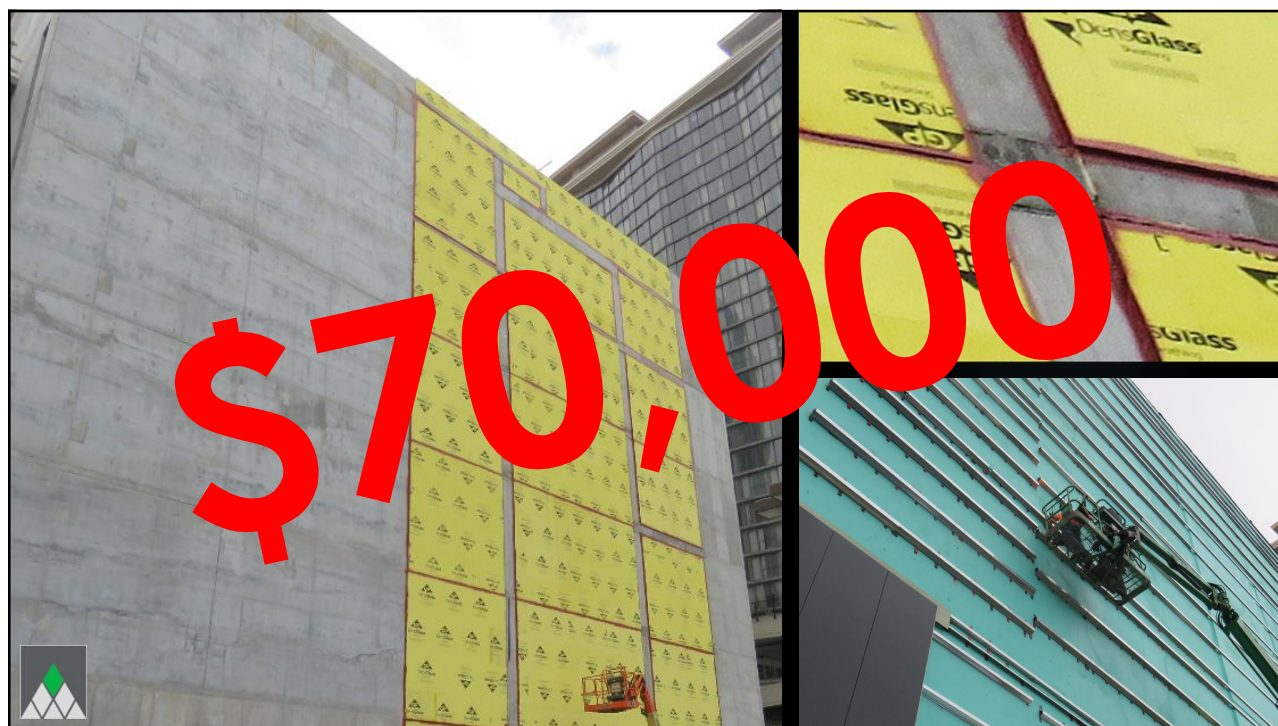
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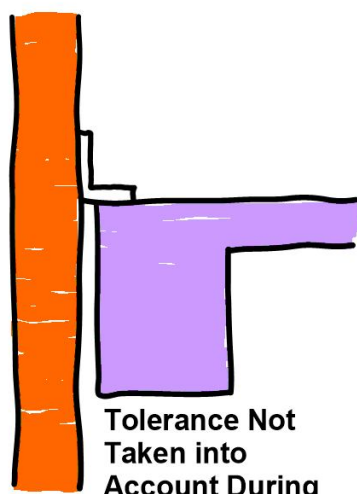
Cast in Place Concrete



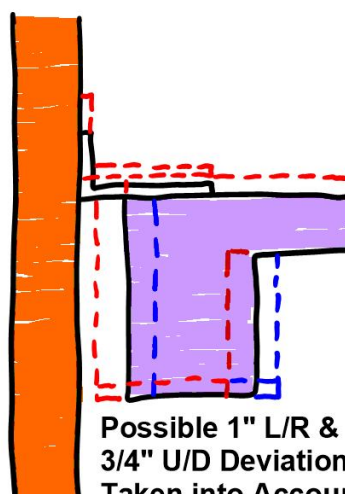


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Tolerance in Design Development

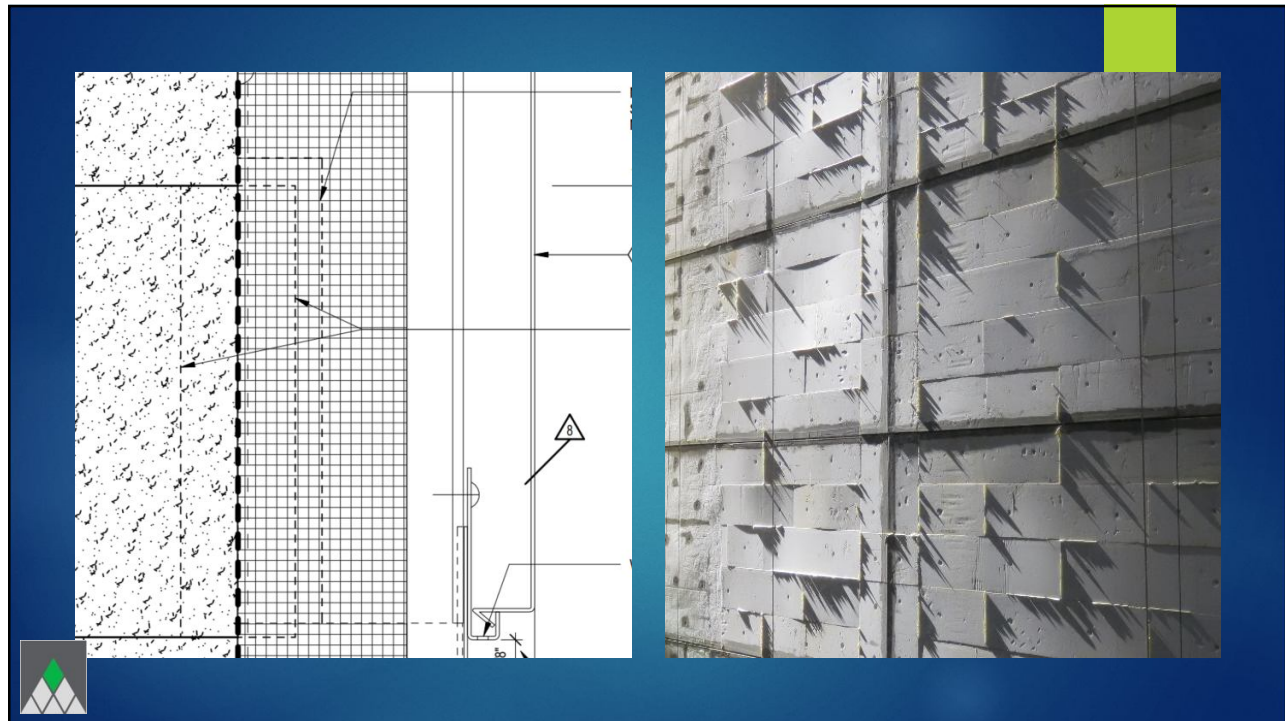


Tolerance Not
Taken into
Account During
Design



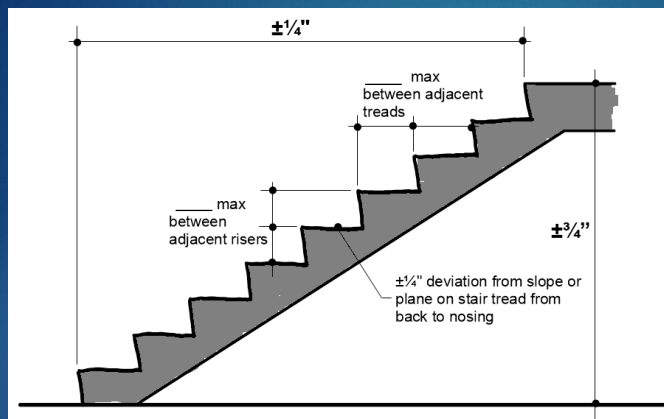
Possible 1" L/R &
3/4" U/D Deviation
Taken into Account
During Design

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Cast in Place Concrete Stairs

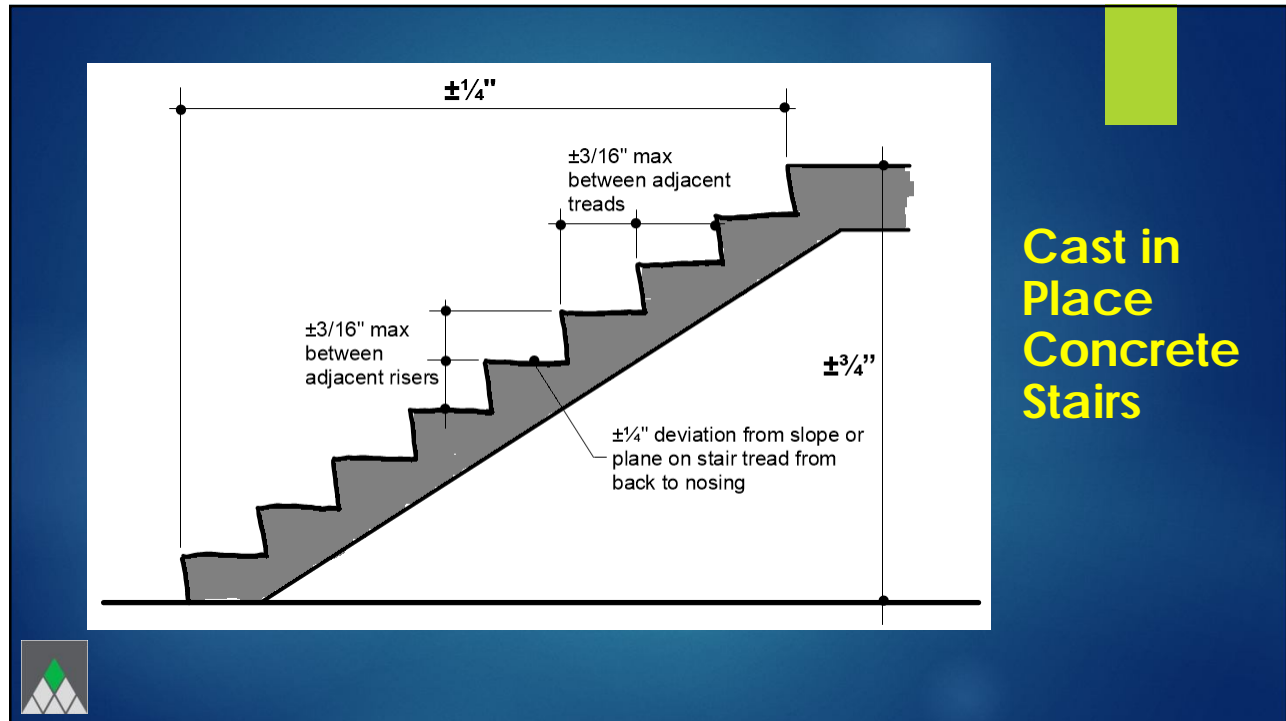


- 1) $\pm 1/16''$, $\pm 1/8''$
- 2) $\pm 3/16''$, $\pm 3/16''$
- 3) $\pm 1/4''$, $\pm 1/4''$




What is maximum differential dimension between treads & risers?

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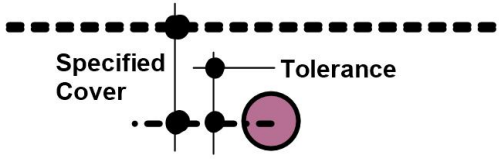
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<u>Concrete / Rebar Condition</u>		<u>Coverage</u>
Concrete:		
Concrete against Earth:.....		3 Inches
#6 thru #18 bar exposed to weather.....		2 Inches
#5 or less bar exposed to weather.....		1 ½ Inches
#14 thru #18 bar NOT exposed to weather.....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



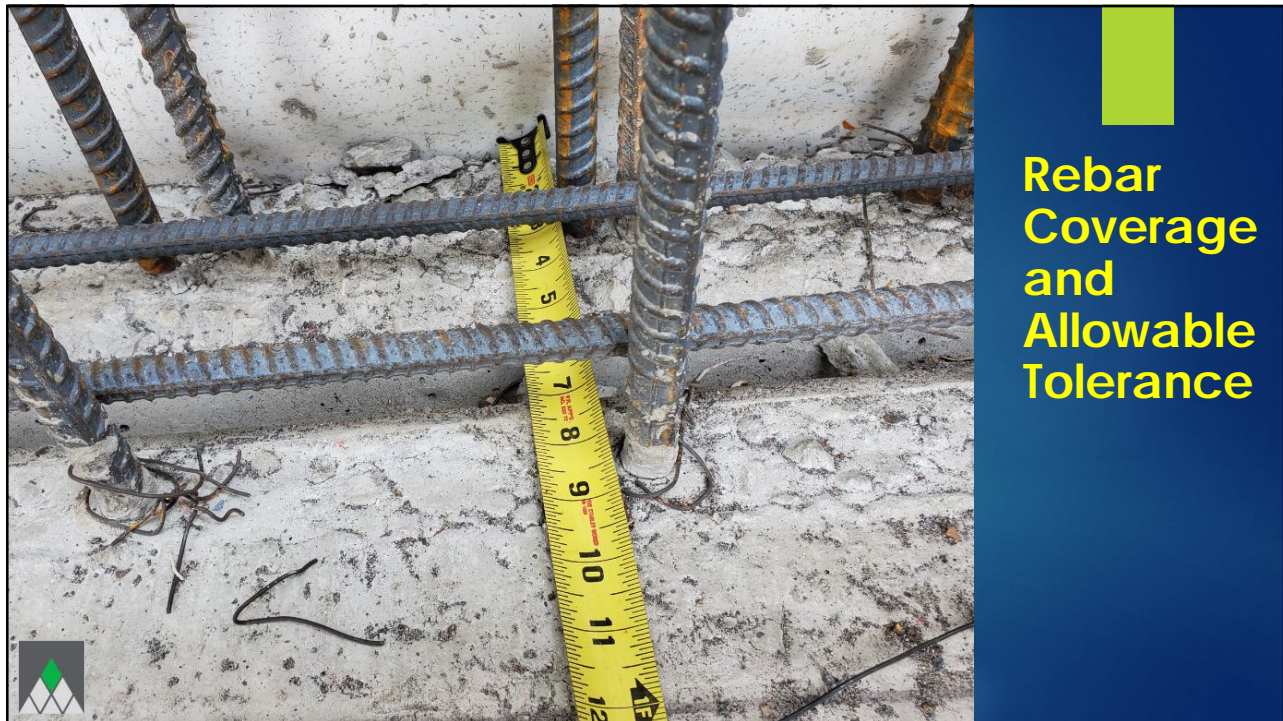
Specified Cover

Tolerance



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

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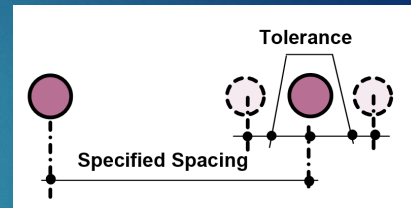
CONCRETE TOLERANCES: Reinforcing

Non-prestressed Reinforcement

Member Depth (or Thickness) is $< 4" = \pm \frac{1}{4}"$

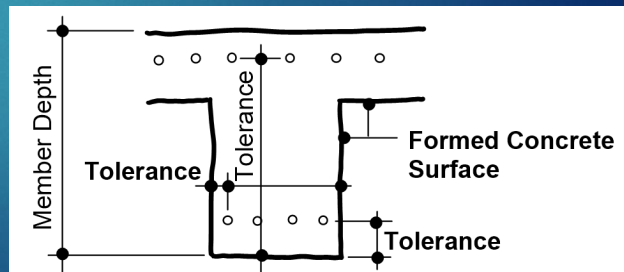
Member Depth (or Thickness) is $4" < 12" = \pm \frac{3}{8}"$

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



Per ACI 117, Rebar Installation Tolerances:

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

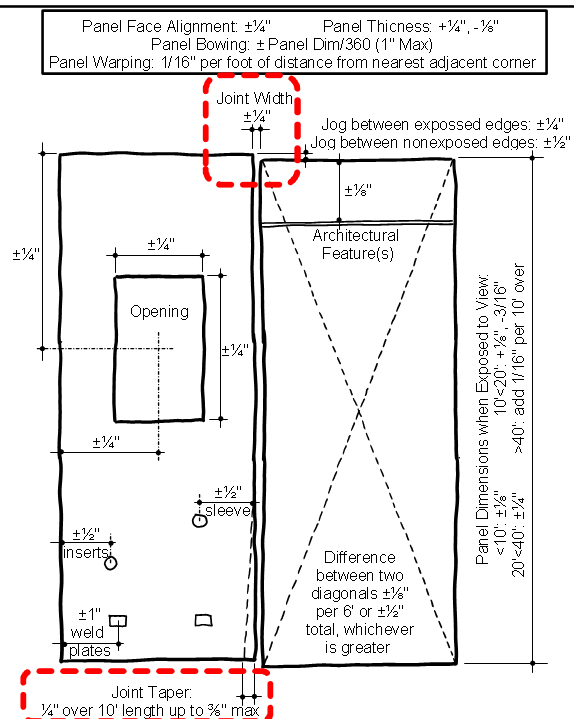


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PRECAST CONCRETE



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Architectural Precast Concrete Panel Fabrication Tolerances *MNL 117*



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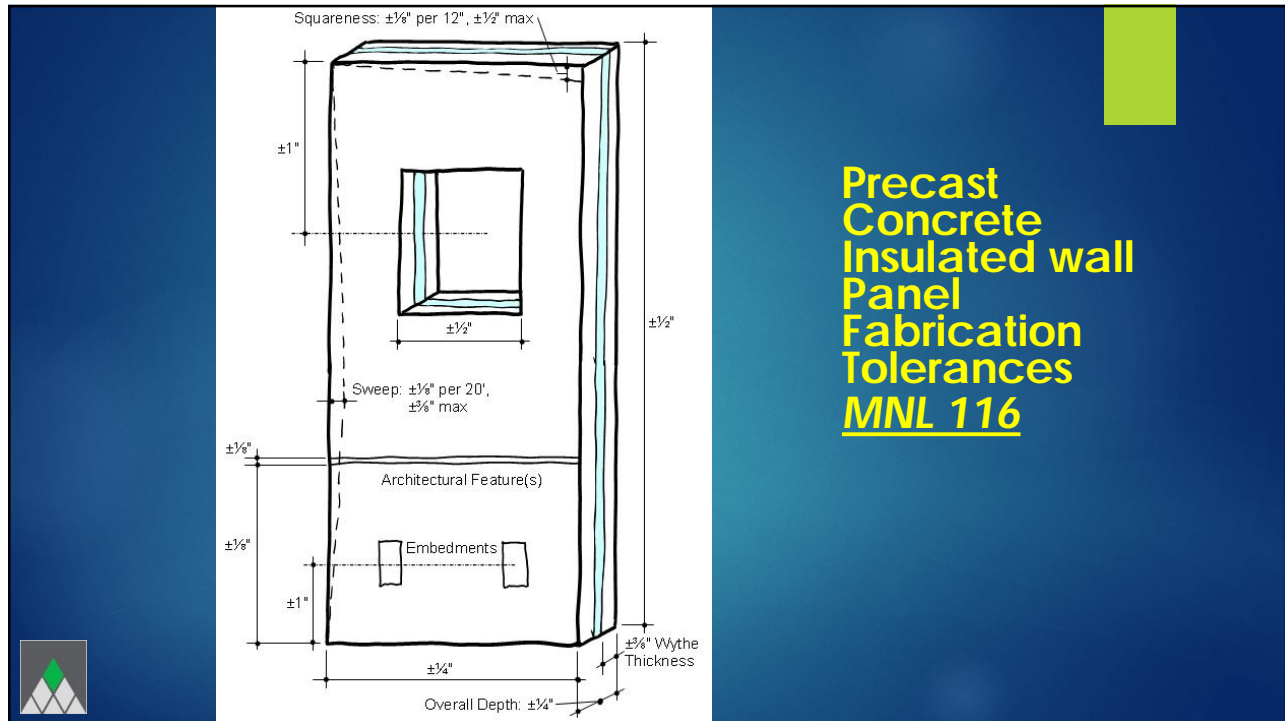
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MNL 116 TOLERANCES

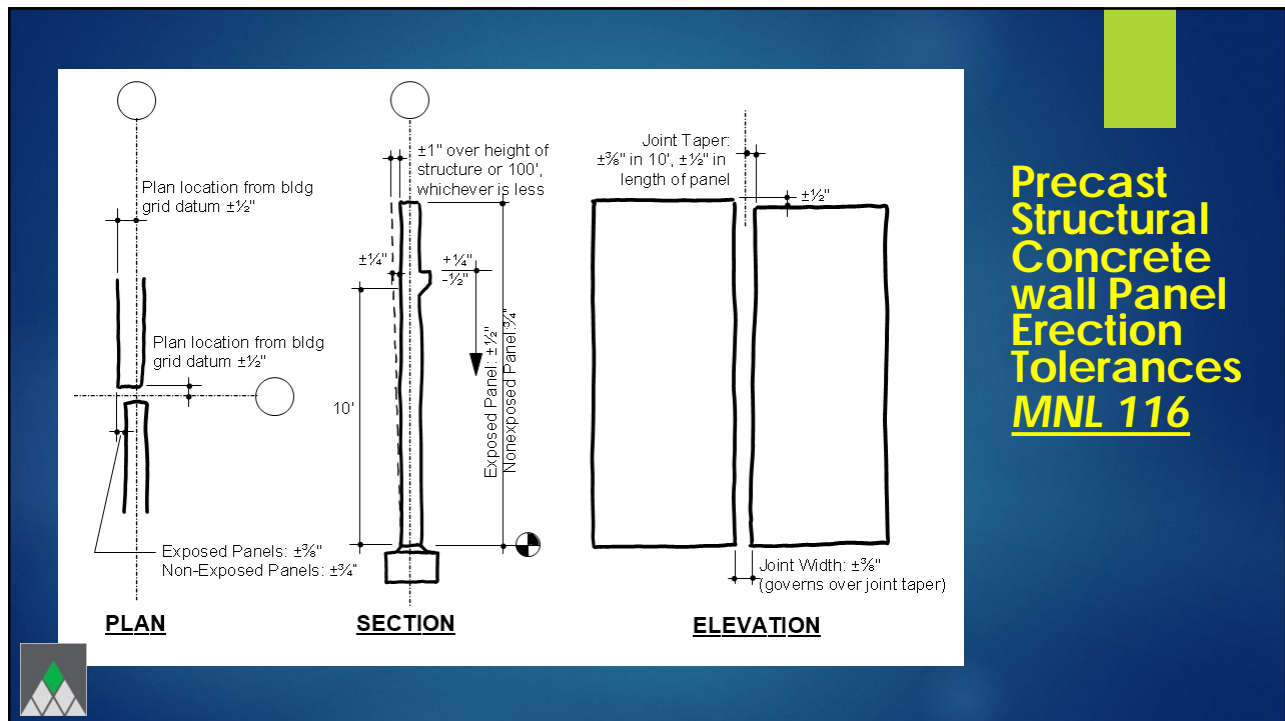
- 1) $\pm 1/4''$
- 2) $\pm 1/2''$
- 3) $\pm 1''$

What is the tolerance for opening vertical location?

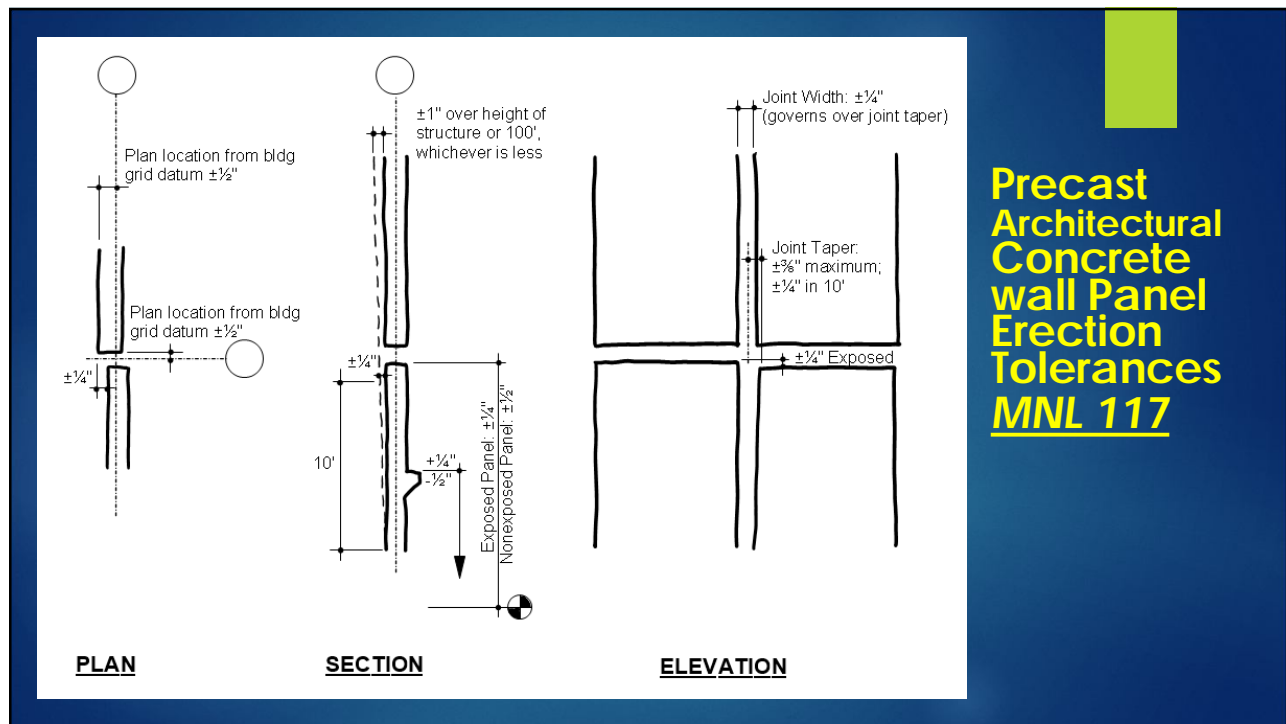
32



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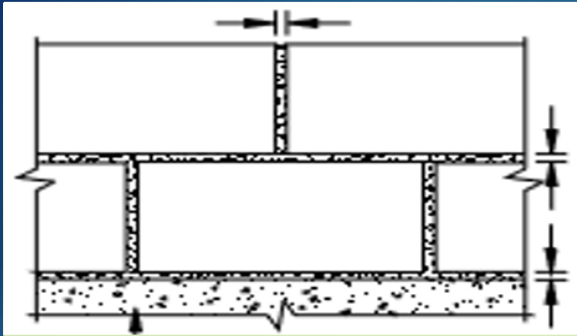
MASONRY

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 ACI 530 and ACI 532.5)
TMS 602-16 Specification for Masonry Structures (formerly also designated as ACI 530.1 and ACI 532.6)
and Companion Commentaries

THE MASONRY SOCIETY
The Masonry Society
www.masonrysociety.org

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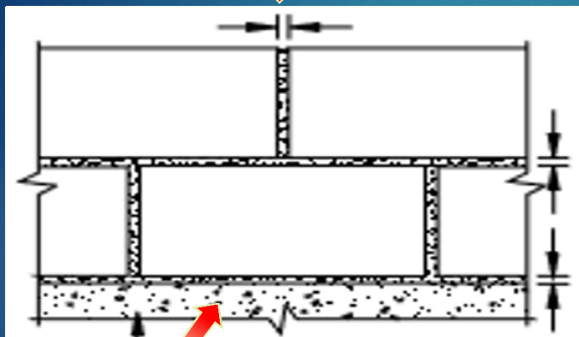
WHAT IS THE ALLOWABLE TOLERANCE OF THE THICKNESS OF A TYPICAL CMU BED JOINT?

- 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 $1 \frac{1}{4}''$ max

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

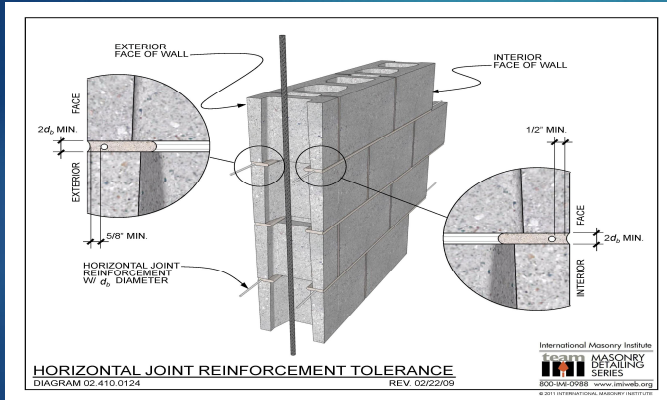


Note: TMS 402-6.1.2.3...Max wire size = $1/2$ joint thickness

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HORIZONTAL JOINT REINFORCEMENT

Note: TMS 402-6.1.2.3...Max wire size = $\frac{1}{2}$ joint thickness

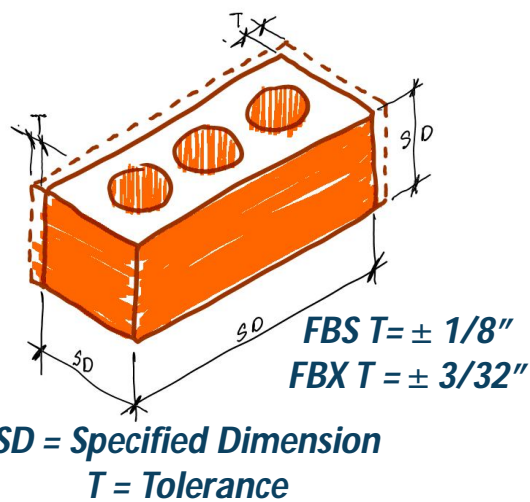


So, based on the Code and allowable tolerances...

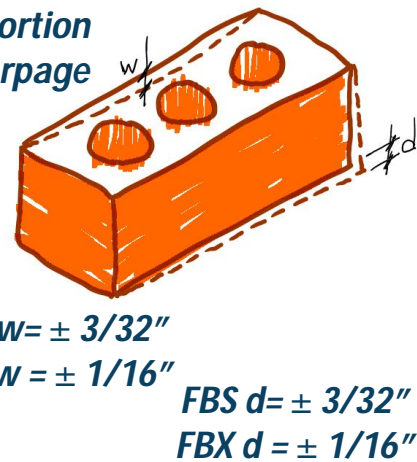
Does a 3/16\"

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MASONRY TOLERANCE *ASTM C216 – FBX & FBS*



$d = \text{Distortion}$
 $w = \text{Warpage}$



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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 $\pm 1/2"$ (ACI 117)

MASONRY TOLERANCE ASTM C216 – FBX & FBS

$d = \text{Distortion}$
 $w = \text{Warpage}$

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

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

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

$SD = \text{Specified Dimension}$
 $T = \text{Tolerance}$

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

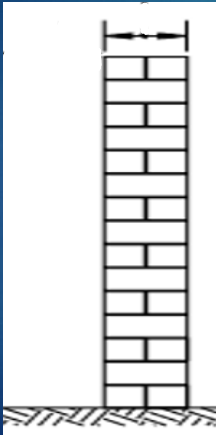
INITIAL BED THICKNESS = $1/4"$ min to $1 1/4"$ max

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

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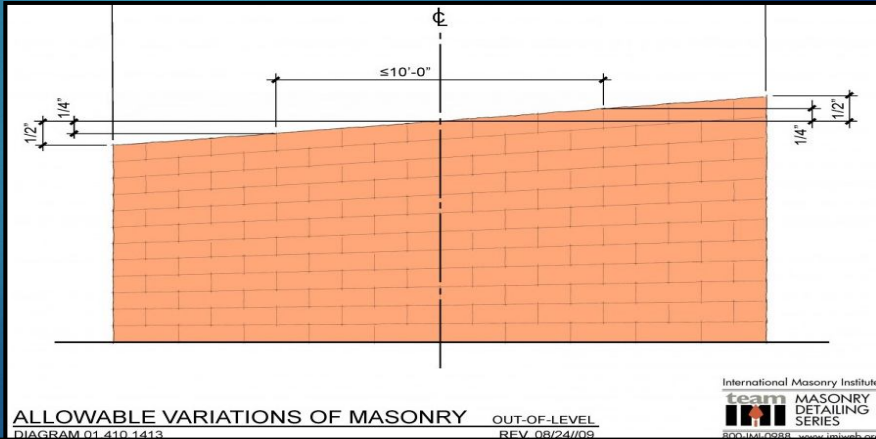
MASONRY WALL TOLERANCE

CROSS SECTIONAL
- $\frac{1}{4}$ " to + $\frac{1}{2}$ "



ELEVATION

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



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VARIATION IN PLUMB

H = Wall Height
D = Allowable Variation

When $H < 10'-0''$

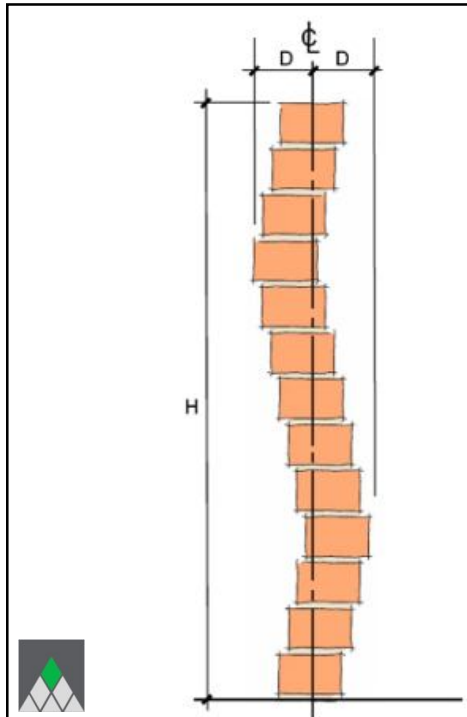
$D < \frac{1}{4}''$

When $H < 20'-0''$

$D < \frac{3}{8}''$

When $H > 20'-0''$

$D < \frac{1}{2}''$



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MASONRY REBAR TOLERANCE

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



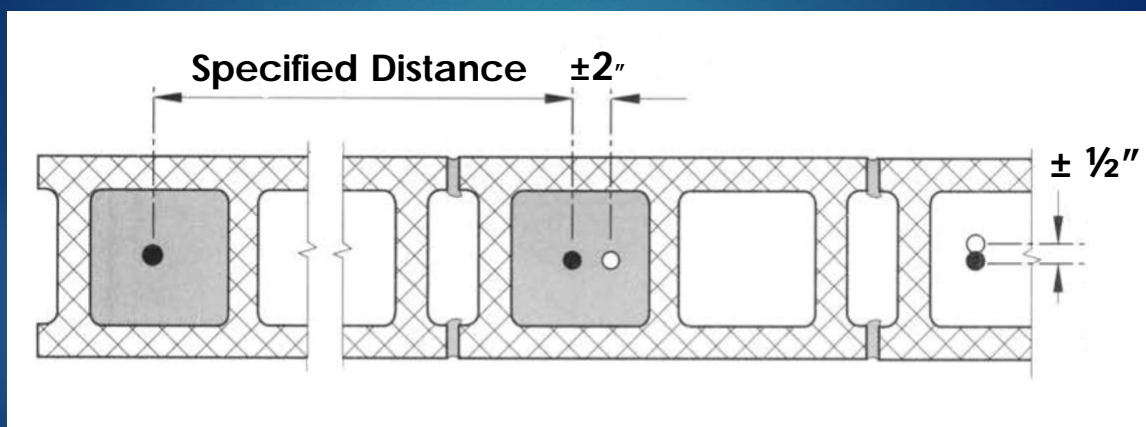
What is vertical rebar tolerance in depth location in an 8" CMU wall?



ACI 530

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MASONRY REBAR TOLERANCE

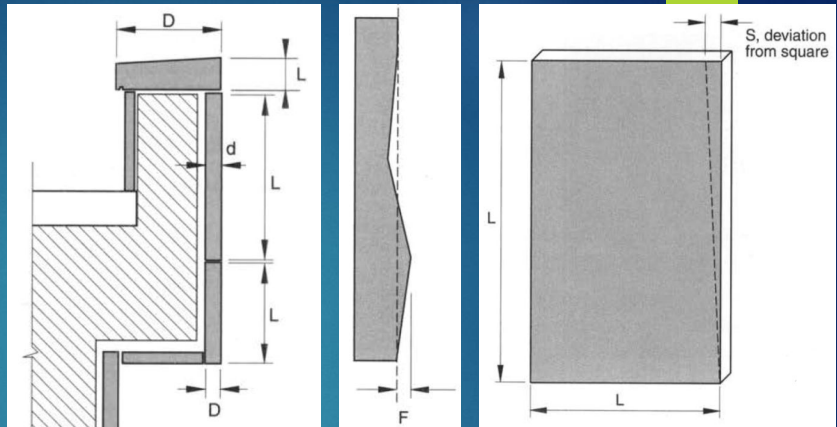


ACI 530

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LIMESTONE FABRICATION TOLERANCES

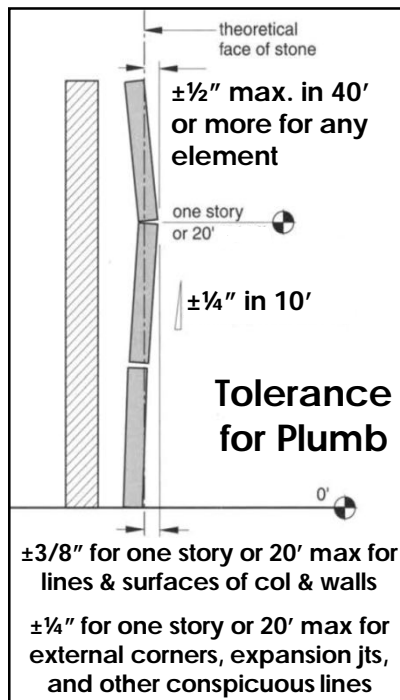
Specifying how the limestone is cut is important for tolerances.



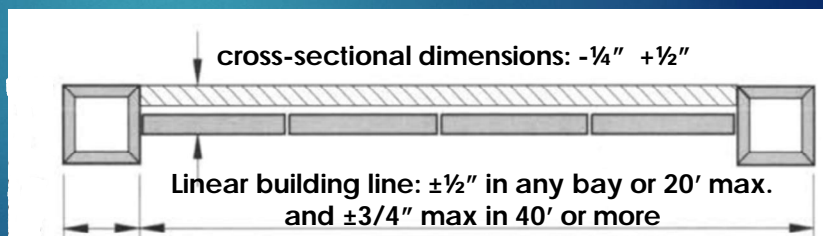
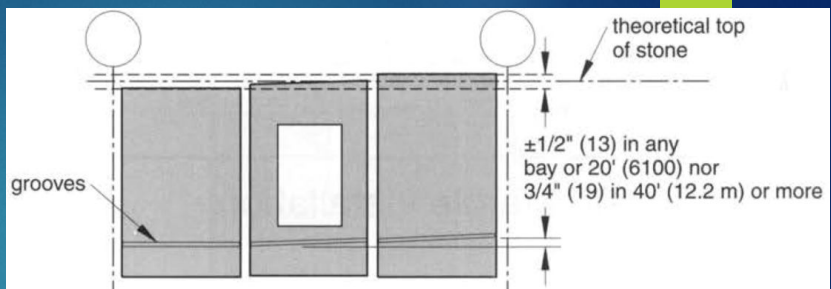
Finish type	Length, L, in (mm)	Deviation from flat surface, F, in (mm)	Critical depth, D, in (mm)	Non-critical depth, d, in (mm)	Deviation from square, S, in (mm)
Smooth machine finish	$\pm 1/16$ (2)	$\pm 1/16$ (2)	$\pm 1/16$ (2)	$\pm 1/2$ (13)	$\pm 1/16$ (2)
Diamond gang finish	$\pm 1/16$ (2)	$\pm 1/4$ (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, 21st ed. Indiana Limestone Institute of America, Inc.

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LIMESTONE INSTALLATION




Source: Indiana Limestone Handbook, 21st ed. Indiana Limestone Institute of America, Inc.

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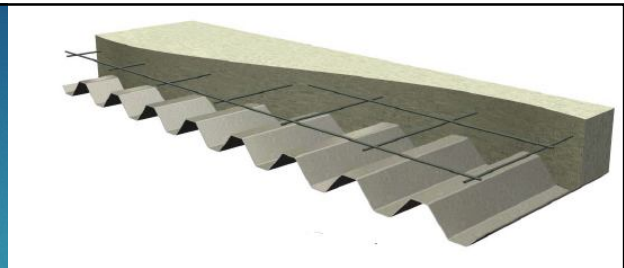


STEEL



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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 $\pm 1/2$ " tolerance (minimum overlap is 1 1/2" to 2 1/2"...However, overlaps greater than 2 1/2" are acceptable.

Minimum edge distance of a fastener for the deck is 1/2".

ASC Steel Deck Fabrication Tolerances

Length of Panel:	$\pm 1/2$ "
Coverage Width:	$-3/8$ " , $+3/4$ "
Sweep of Panel:	1/4" in 10'
Square of Panel:	1/8" per foot width
Height of Panel:	$\pm 1/16$ "

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Steel Angle Manufacture Tolerances

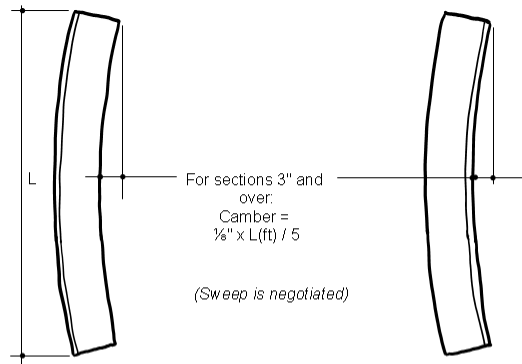
Variation in sizes (length) for Angle

	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"

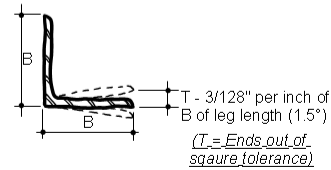
Unequal Legs, longer leg determines classification

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



SWEEP AND CAMBER TOLERANCES

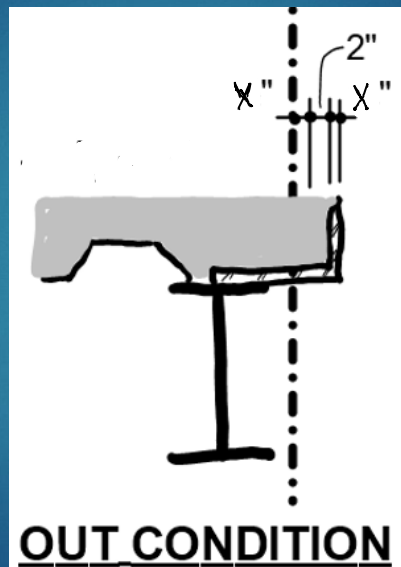


CROSS SECTIONAL TOLERANCE

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SLAB EDGE TOLERANCE

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

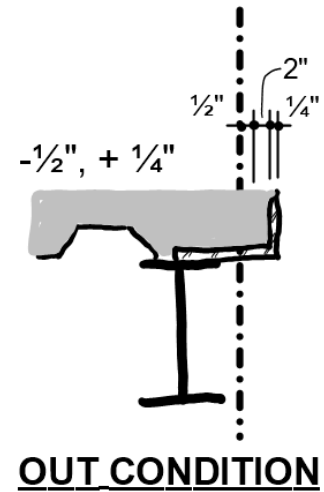
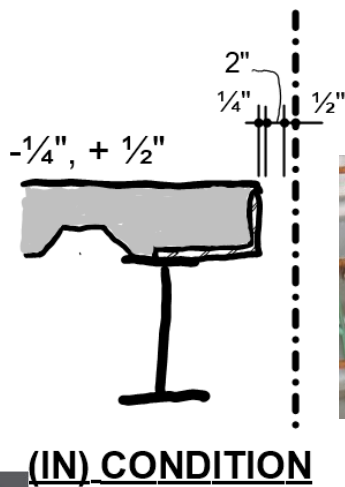


What is the tolerance for the slab edge out condition?

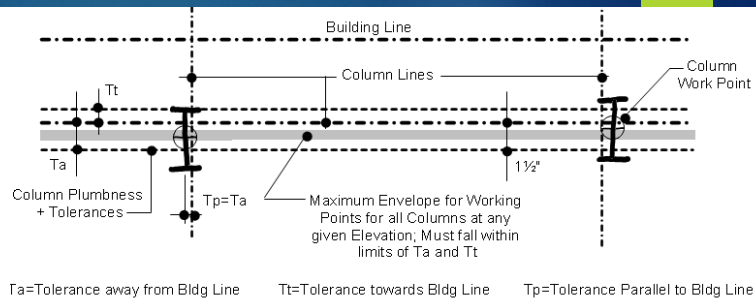
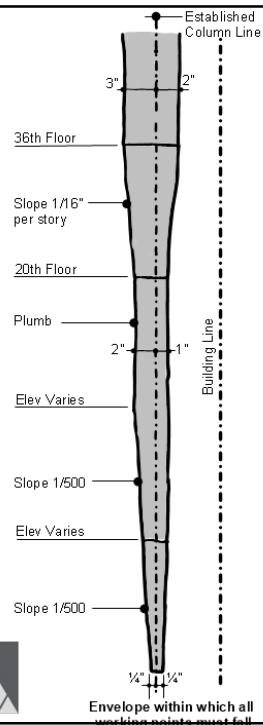


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Steel Angle Installation @ Slab Edge Tolerance

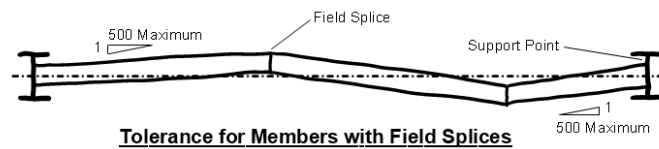


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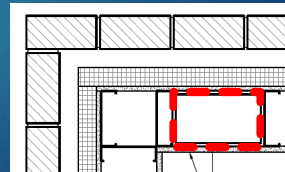
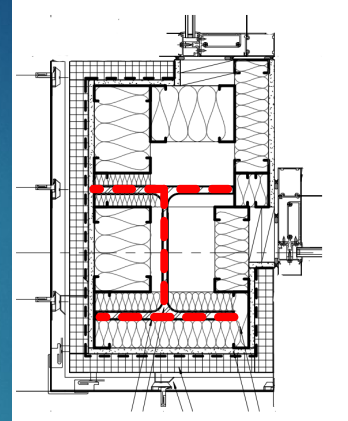
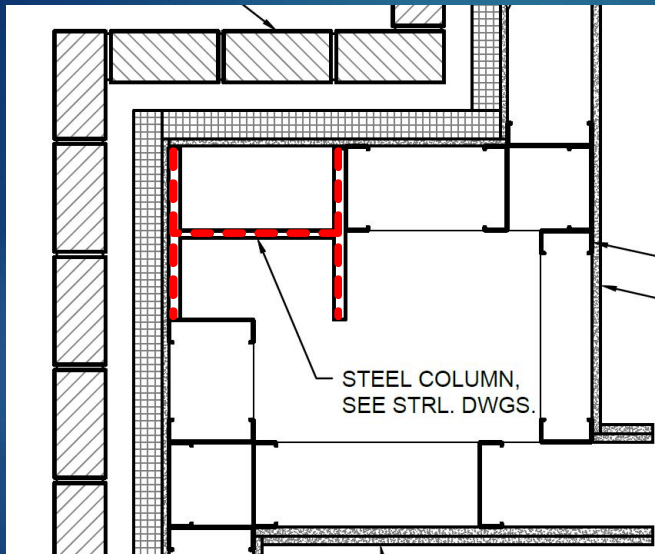
Tolerance for Columns with Continuous Intermediate Beams

Exterior Steel Column Installation Tolerances



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Tolerances

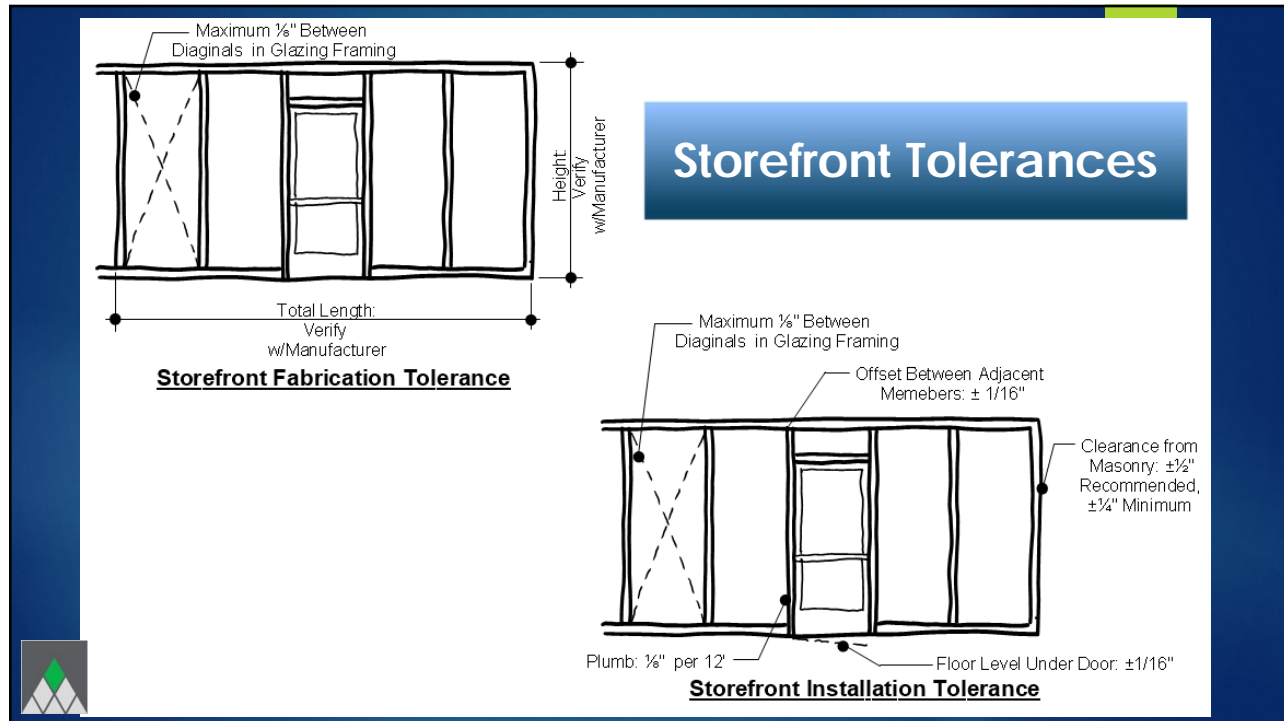


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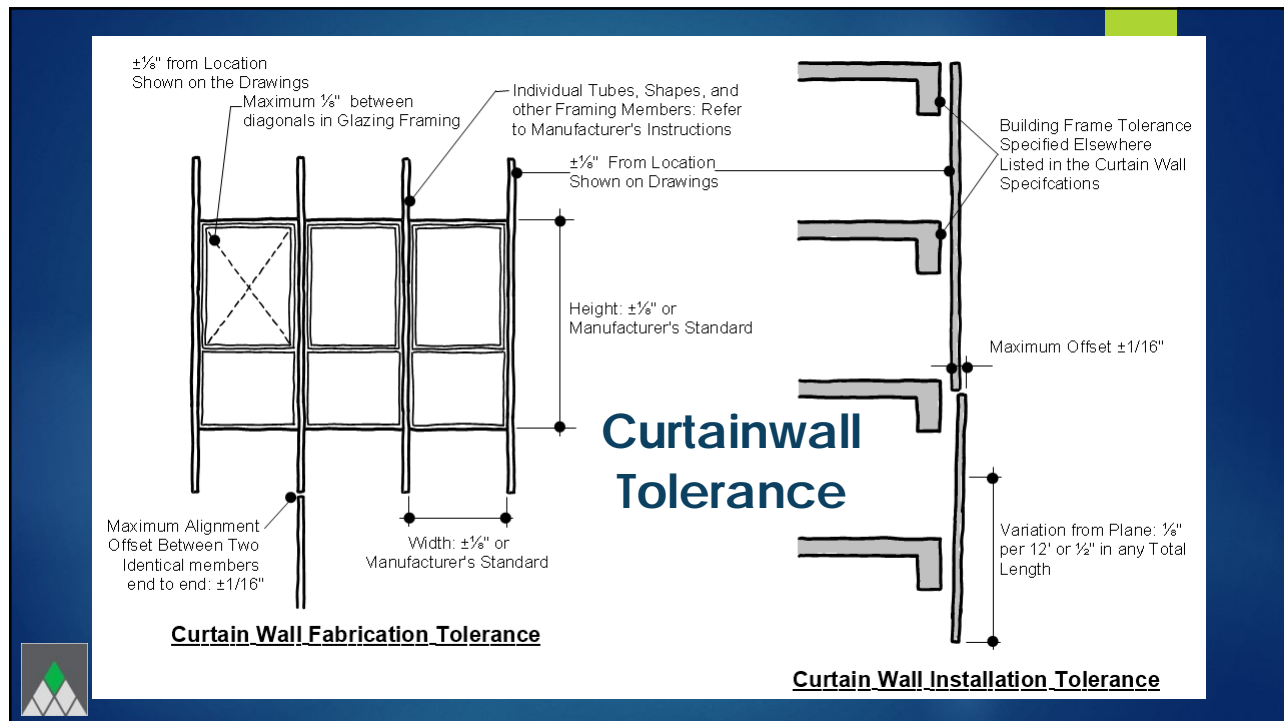
STOREFRONT & CURTAINWALL



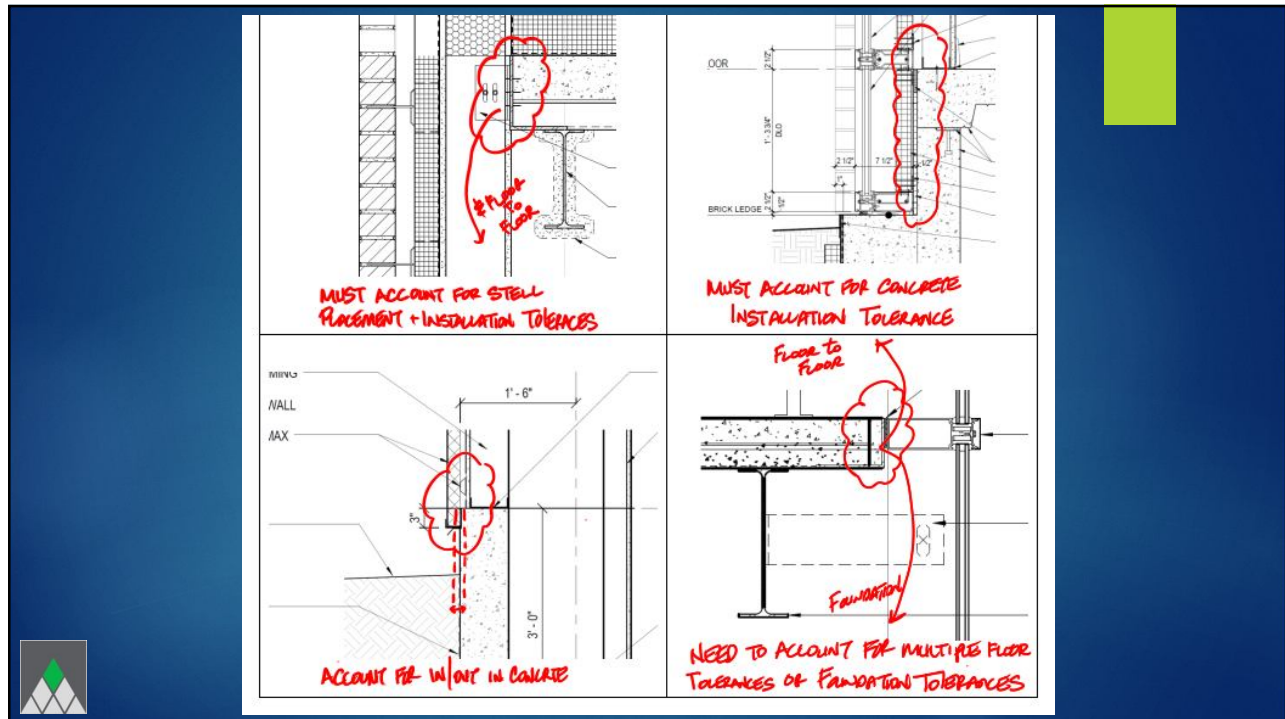
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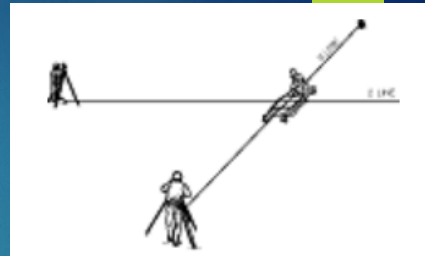


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Construction

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

<p>Building Envelope Tolerances Course # S003-040720TR</p> <p>Corey S Zussman AIA, NCARB, ALA, RBEC, RRC, REWC, RWC, RRO, CDT, CQM, CxA+BE, BECxP, LEED® AP BD+C Level 1 Thermographer, Director of Quality - Illinois & Wisconsin Pepper Construction</p> <p>czussman@pepperconstruction.com</p>		<p>Preventing Pathogen Transmission Through Surface Material Specifications Tuesday, August 25, 11:30am-1:00pm CT By: Linda Lybert, Healthcare Surfaces Institute</p>
<p>Remote Learning Library Live online CEUs from our chapter members and partners.</p>		<p>Remote Learning Library Live online CEUs from our chapter members and partners.</p>

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