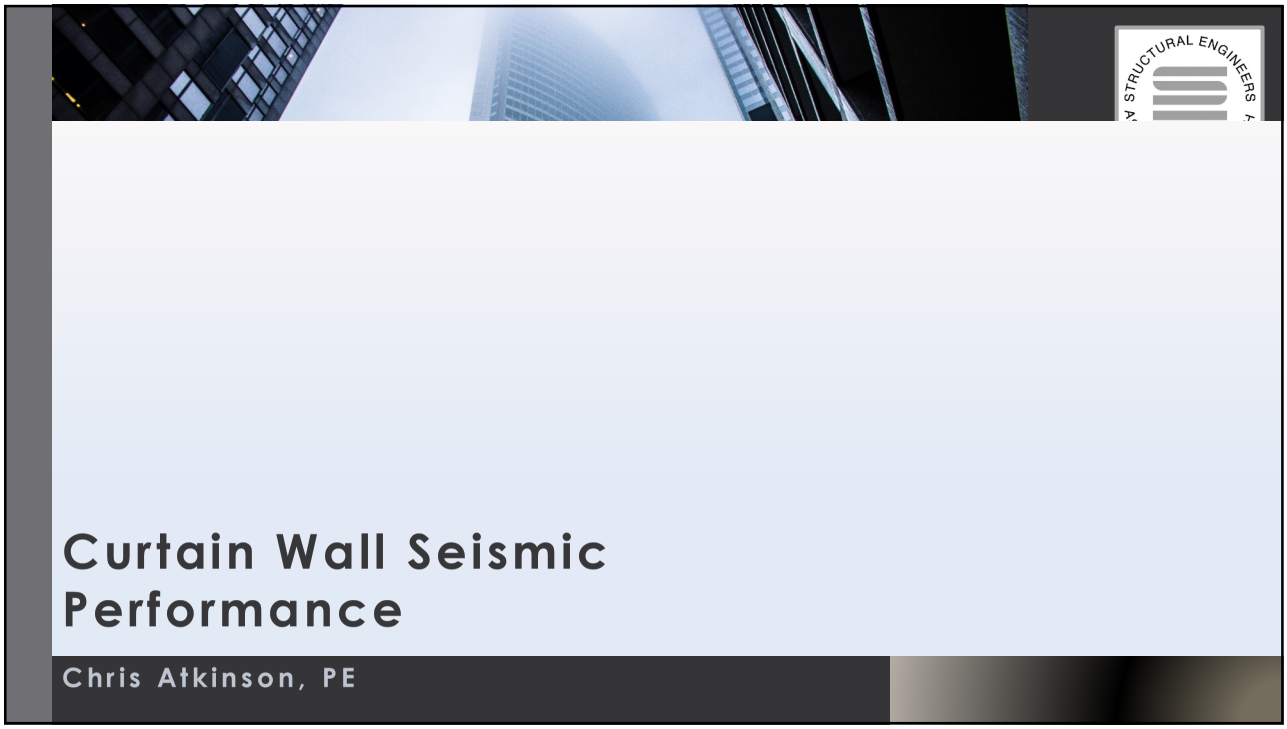


Curtain Wall Seismic Performance

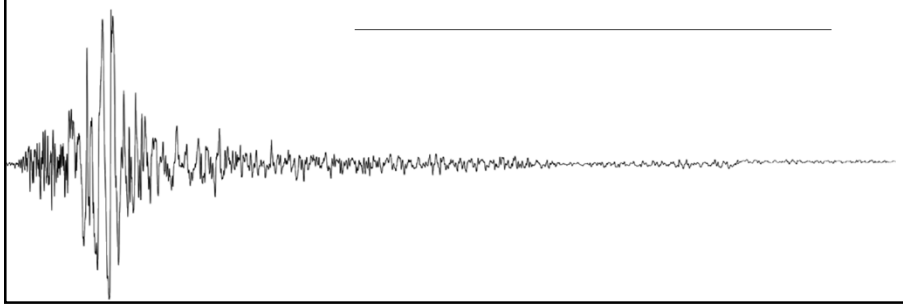
Chris Atkinson, PE

1

WORLD VIEW

of a glazing engineer

Minute tolerances, lighter forces and members with non-standard shapes.



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2018, in Anchorage, Alaska (AP Photo/Mike Dinneen)

SEISMIC RISKS

MAINTAINING LIFE SAFETY

- Glazing, like many façade materials can be a **risk to life** and limb in an earthquake event.
- The risk is caused primarily by **building drift** which racks glass framing or rocks then racks unitized systems.
- With some of the tightest of tolerances, glass lites can **impact** their frames or are **pinched** by racking.

4

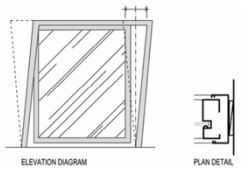


Figure 4-1: Seismic frame

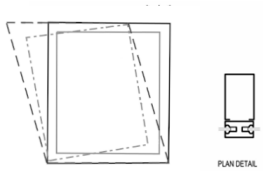


Figure 4-2: Glazing pocket

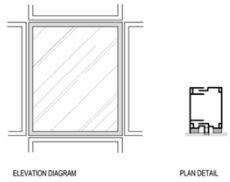


Figure 4-4: Unitized system

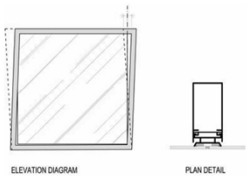


Figure 4-3: Structural silicone

With few exceptions the name of the game is protecting the glass with very little room to move.

Architects crave thin joints and the smallest glazing frames they can find.

Engineers have developed many methods to accommodate seismic movements, but mean little if.

SEISMIC DRIFT

ACCOMODATING THE MOVEMENT

5

ITEMS ADDRESSED

IN NO PARTICULAR ORDER

CODE STANDARDS

WHAT THE SEOR SHOULD PROVIDE

REVIEWING THE GLAZING CALCS

6

CODE PROVISIONS

ASCE 7-16 Section 13.5.4

"Glass in glazed curtain walls…shall be designed and installed to accommodate **without breakage or dislodgement** the relative displacement requirement of Section 13.5.9"

ASCE 7-16 Section 13.5.2

"Architectural components that could pose a life-safety hazard shall be designed to **accommodate** the seismic relative **displacement** requirements"

7

SAFETY FACTOR

ASCE 7-16 Section 13.5.9.1

- $\Delta_{fallout} \geq 1.25 D_{pI}$

Section13.3.2

- $D_{pI} = D_p I_e$

What they were trying to say is

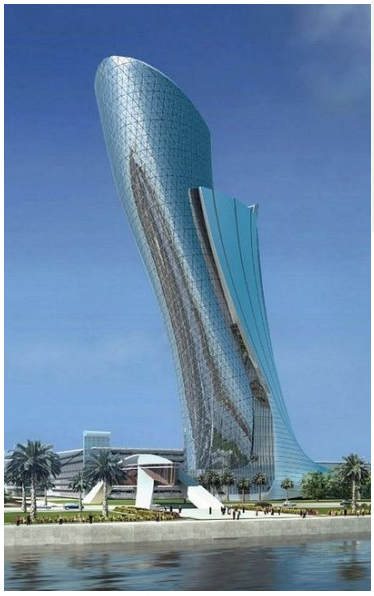
- $\Delta_{fallout} \geq 1.25 * \Delta * I_e$

Section 13.3.2.1

- $D_p = \Delta$

Where:

- Δ = Story Drift Per Section12.12



8

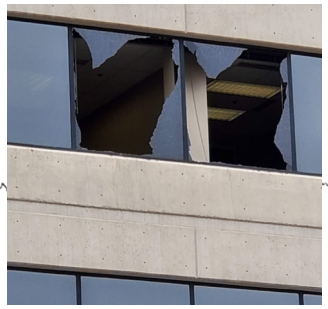
DESIGN DRIFT

The code wording is not clear about what is the "design drift" the glazing must accommodate.

It could be $1.25D_{pI}$, D_p, or Δ.

For clarity in communicating with the glazing consultant, **specify Δ per 12.12.1 in either percent of story height or inches.**

Otherwise, be careful in specifying the drift the glazing must accommodate based on the characteristics of the wall.



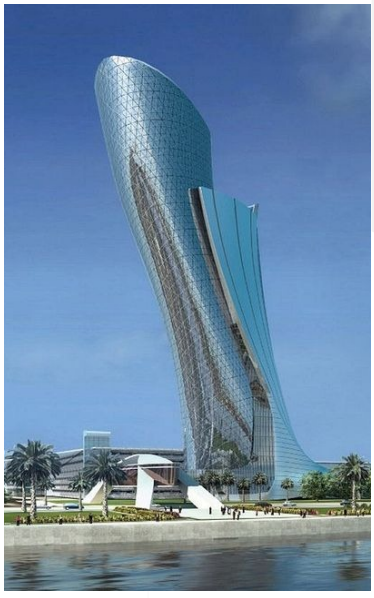
9

CODE PROVISIONS

Given $\Delta_{fallout} \geq 1.25 * \Delta * I_e$ the allowable drifts of Table12.12-1

For most structures

- Cat. I & II: $\Delta_a \leq 2\%$ → $\Delta_{fallout} \geq 2.5\%$
- Cat. III: $\Delta_a \leq 1.5\%$ → $\Delta_{fallout} \geq 2.34\%$
- Cat. IV: $\Delta_a \leq 1\%$ → $\Delta_{fallout} \geq 1.88\%$



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AAMA Standard

The industry standard, that is frequently required by spec, simply applies a factor of 1.5 to the design drift for **testing**. This gives:

- Cat. I & II: $\Delta_{fallout} \geq 3\%$ → 3% is typically what systems are tested to
- Cat. III: $\Delta_{fallout} \geq 2.25\%$
- Cat. IV: $\Delta_{fallout} \geq 1.5\%$

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WHAT IS $\Delta_{fallout}$

ASCE 7-16 Section 13.5.9.2:

"$\Delta_{fallout}$, the drift causing glass fallout from the curtain wall, storefront, or partition, shall be determined in accordance with AAMA 501.6 or by engineering analysis."

AAMA 501.6 is a rarely performed test and an expense most architects avoid.

12

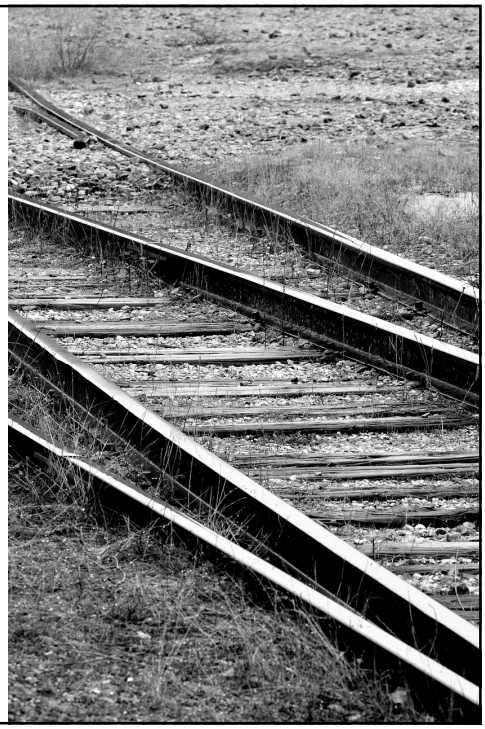
WORKAROUND

For system that have a mechanical hold on the glass, the code kindly provided the following allowable clearance to substitute for $\Delta_{fallout}$

$$D_{clear} = 2c_1\left(1 + \frac{h_p c_2}{b_p c_1}\right)$$

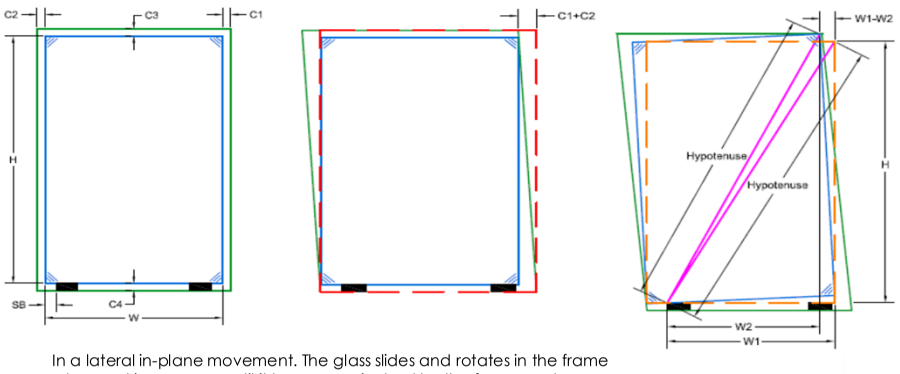
This calculation is based on the height and width of the glass "lite" and the average clearances between the glass and frame.

The concepts used in this equation are part of the "engineering analysis" that consultants perform to satisfy Section 13.5.9.2 to determine $\Delta_{fallout}$.



13

WORKAROUND



In a lateral in-plane movement. The glass slides and rotates in the frame when racking occurs, until it becomes pinched by the frame and subsequently breaks.

These clearances are typically between 1/4" and 1/2" sometimes up to 1"

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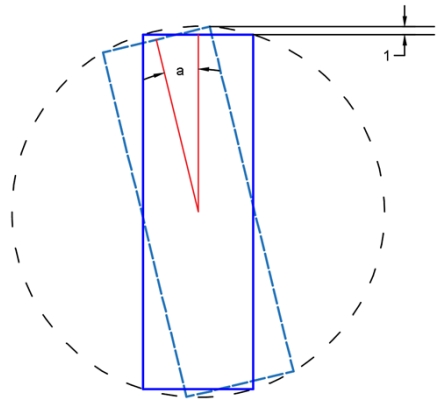

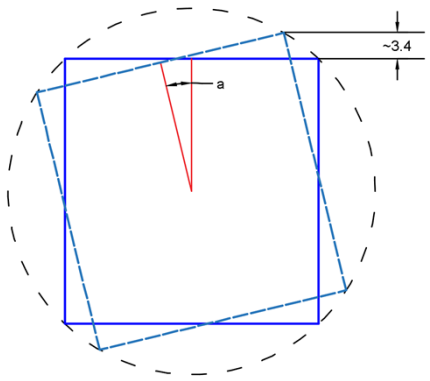

Regardless of the system or method, the clearance needed for the glass is usually controlled by the gaps at the top and bottom of the glass.

Be aware that when architects choose huge individual panes the 1/4" to 1/2" gap is eaten up quickly with the rotation of the glass in frame.

To maximize lite size and minimize frames, an architect should be advised to increase the building stiffness if the desired look is worth paying for.

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TIP: Always keep story drift below 2% even with 2.5% possible for some structures.

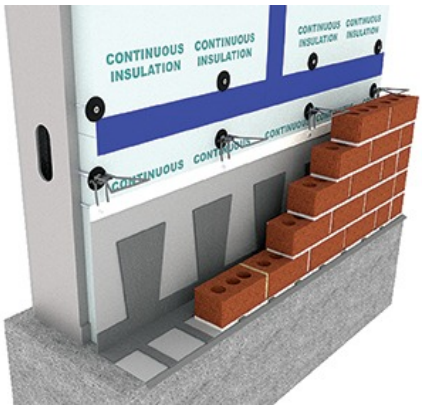
ACTUAL DRIFT

It may greatly impact enclosure costs to simply give the code allowed drift tolerances for the structure.

Always provide the real (calculated) story drifts.

16

COLLISION AVOIDANCE



Besides accommodating drift, a structure may have rigid elements such as a masonry veneer, GFRC or precast that do not rack with the structure.

If not designed properly, a glazing system that must rack may collide with the rigid wall elements.

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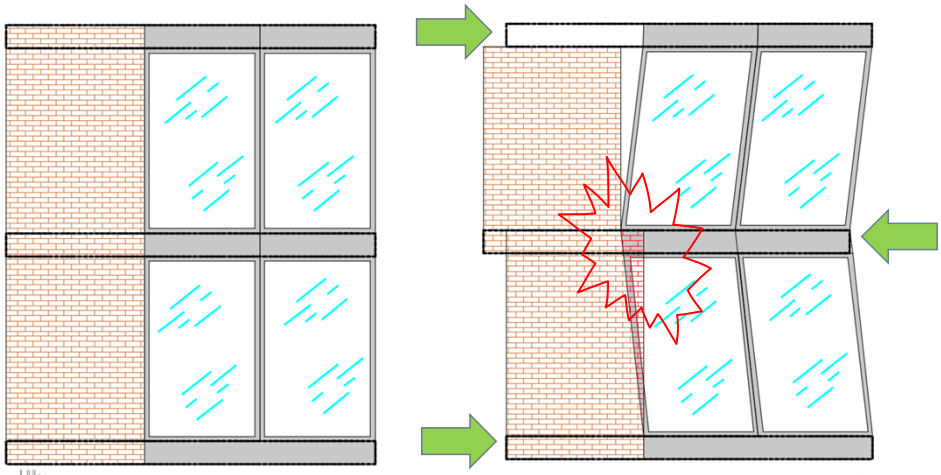
COLLISION AVOIDANCE



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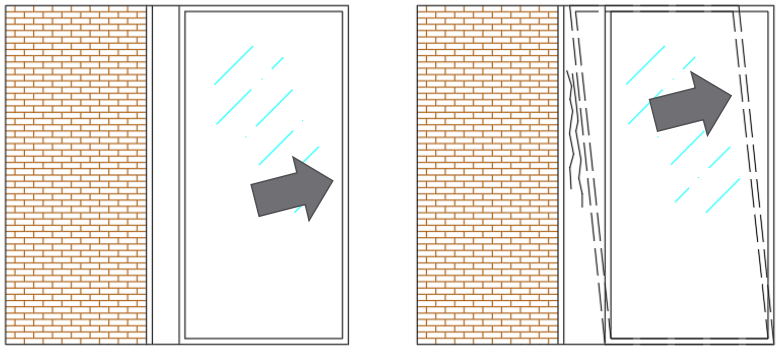
COLLISION AVOIDANCE

One option is to make the anchor points at the head of the window slide, but this leads to other technical difficulties.

The second optionsto prevent this is to use a crush zone. Architects usually hate the idea if it shows.



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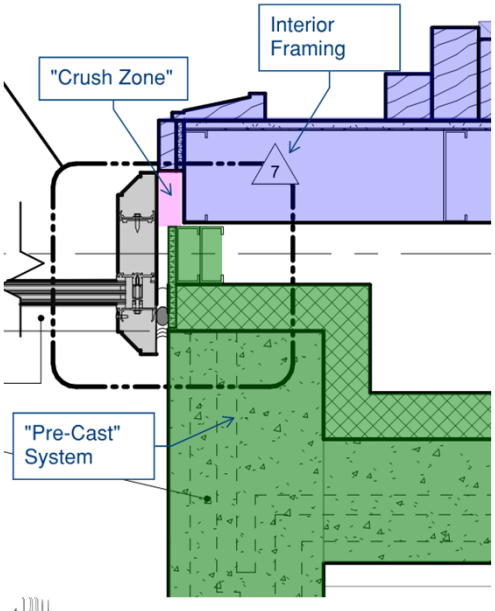

COLLISION AVOIDANCE

Crush Zones can be hidden with a two layered wall. The curtain wall moves behind the inner or outer wall while being attached to the other.

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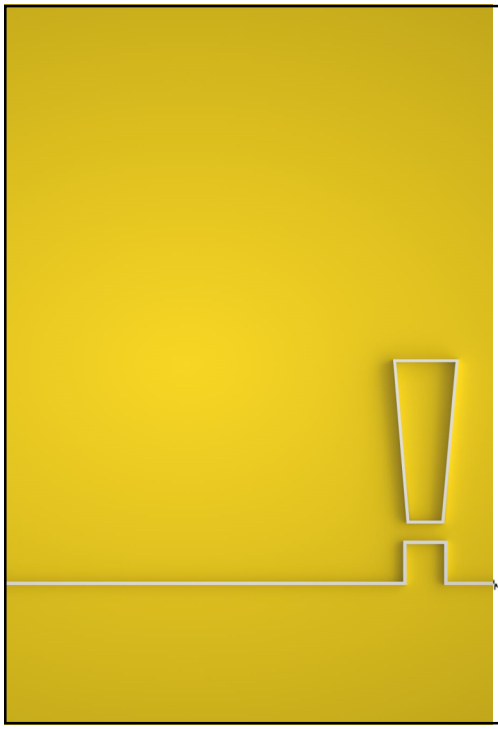

SEISMIC BEHAVIOR

Make your intentions clear with the seismic behavior cavity walls.

Clarify how the GFRC, Masonry or Stone Veneer, or Precast Façade is intended to move.

Will the system rock or slide? How will it "slide"?

With threaded rod or slip tracks on framing etc?

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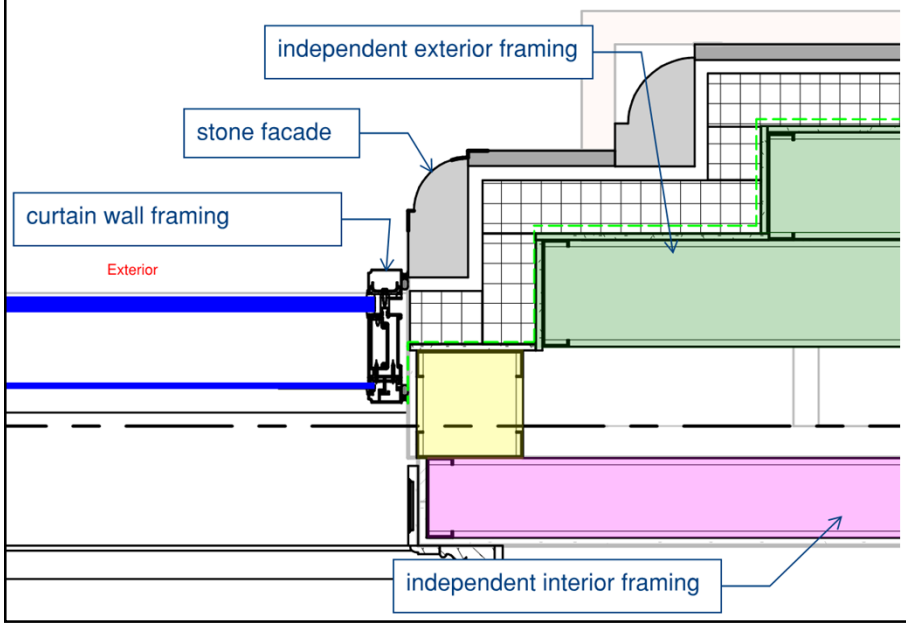
COLLISION AVOIDANCE



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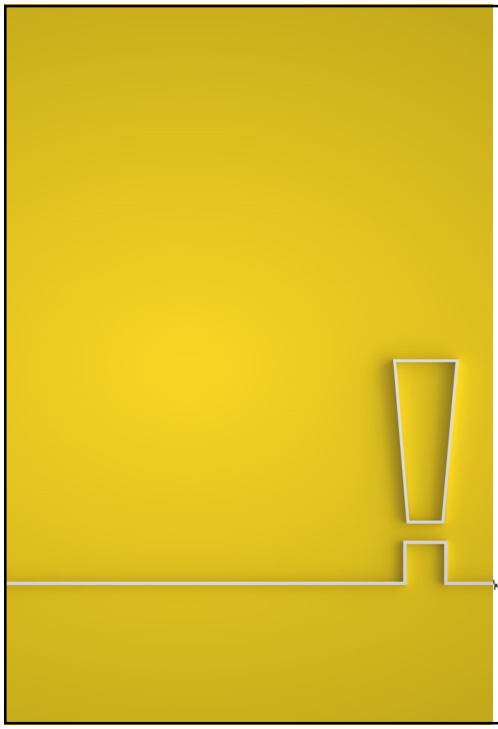

VERTICAL SEISMIC BEHAVIOR

With critical tolerances at the head of a curtain wall, the glazing engineer needs to know the **controlling combination** for slab vertical deflection from three contributing factors.

1. Live load
2. **Seismic Vertical Loads**
3. "Long Term" deflections

"Long Term" deflections as many specs call them, include column shortening, PT relaxation, and/or concrete creep in concrete or composite slabs.

Combined according to ASCE 7-16 chapter 2, these would ideally be no more than 1/2".

However up to an inch or more can be accommodated at increased cost.

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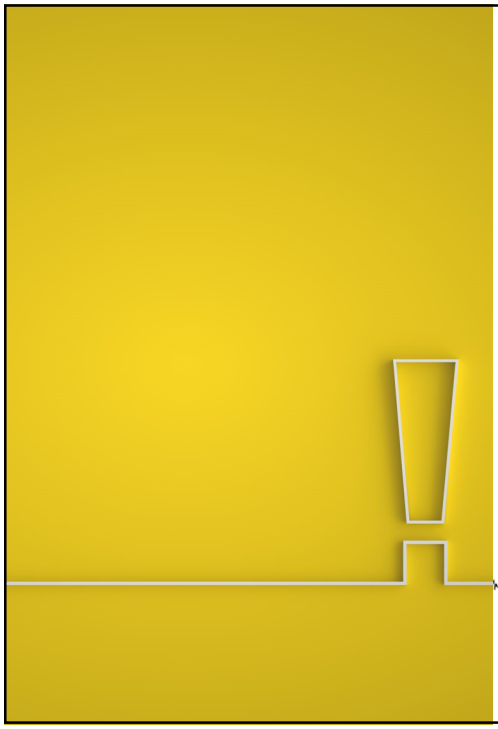

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To put it gently, some of us have witnessed situations where contractors are **unaware** of many of the required steps to build to the code for seismic events. Why wouldn't they if these standards aren't enforced? It's easier and cheaper!

Unfortunately, engineers have unwittingly accommodated them by stamping calculations "**just for the bolts**." These get accepted as a full design.

When reviewing curtain wall calculations **PROTECT THE PUBLIC** and check for the necessary work!

WHAT TO CHECK FOR

GLAZING CALCULATIONS

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Curtain Wall Seismic Calculations **must** include:

1. Statements that all glass sizes have been checked and fit within passing test parameters (referring to an **AAMA 501.6 or 501.4 test**).
   a) Or analysis of glass rotation and clear spaces between the frames and glass lites similar to Section 13.5.9.1.
2. **Scope of work** by the consultant engineer that includes all in-plane and out-of-plane forces on anchors, framing and glazing in all conditions throughout the project.
3. Statements/analysis that **clearances are sufficient** to accommodate all movements according to code loading combinations.
4. If you can, **help the architect specify these things clearly up front!**

WHAT TO CHECK FOR

GLAZING CALCULATIONS

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THANK YOU FOR YOUR INTEREST
Please feel free to contact me at christopher.dkinson@steelencounters.com or by phone at 208-760-9347 if you would like more information about curtain wall standards and what you should expect in your reviews of curtain wall calculations.
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