Glass Informational Bulletin **GANA PGC 03-0809**

Performance Criteria for Glazing Subjected to Seismic Events

Introduction

Shaking and twisting buildings, uplifting of the earth, people screaming, running and trying to avoid falling debris. This can be a typical scene during a damaging earthquake. Significant research has been done on the causes of earthquakes; less work has been done on how to keep buildings intact and functioning during these events. Engineers and architects must follow code requirements for the structural performance of buildings in seismic zones. This glass information bulletin will focus on the use of glass and glazing as non-structural components installed in buildings in seismic-prone areas.

What is an Earthquake?

An earthquake is a rupture in the earth's lithosphere or crust. Typically starting deep in the earth's mantle, convection currents can build pressure over time under the tectonic plates. When the plates can no longer contain the pressure, a rupture occurs as a mechanism to release the pressure. This causes the crust to move and slip, shaking the ground for several miles from the earthquake's epicenter.

According to the United States Geological Survey (USGS) there are over 500,000 detectable earthquakes in the world every year. Of those, one-fifth can be felt and only a small number actually can cause damage. An earthquake will typically occur along a "fault" line where edges of tectonic plates intersect. There are three famous fault lines in North America (See Table 1); however an earthquake can occur anywhere.

Table 1
Major Fault Lines in North America

Fault Line	**Location**
New Madrid	Central United States: Illinois, Kentucky, Missouri, Tennessee and Arkansas (mid continental, possible caused by the Farallon slab)
San Andreas	Pacific Coast of California (Pacific and North American Tectonic plate intersection)
Denali	Alaska (North American and Pacific Tectonic plate intersection)

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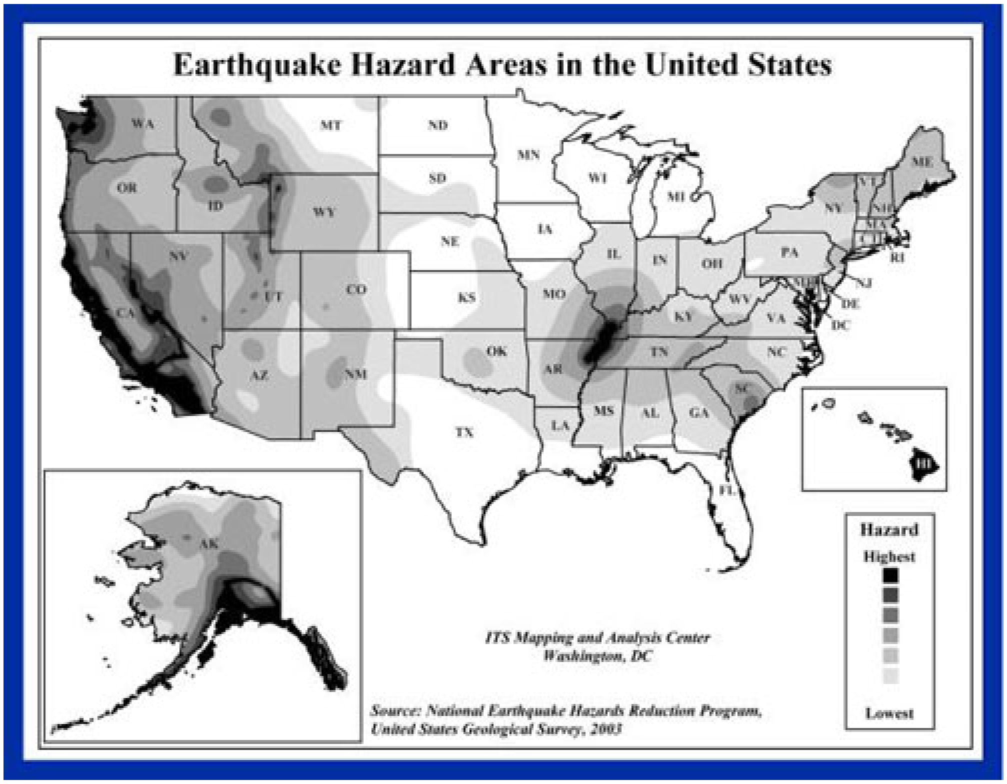

Earthquakes are rated on basically two scales - Richter Magnitude Scale and the Modified Mercalli Scale. The Richter Magnitude Scale rates the magnitude of the earthquake, the higher the number, the more severe the earthquake. The rating does not relate to how far the earthquake reaches from its epicenter. The largest recorded earthquake in the world occurred in Chile in 1960 and was a 9.5 on the Richter Magnitude Scale. The Modified Mercalli Scale rates the level of damage to an area. A comparison between the two scales is outlined below in Table 2.

Table 2

The Earthquake Rating Scales

Richter Magnitude Scale	Modified Mercalli Scale		Amount of Damage
≤ 4.3	1-4	Detected to Moderate	No damage reported.
4.4 - 4.8	5	Rather Strong	Damage minor. Small, unstable objects displaced or upset; some dishes and glassware broken.
4.9 - 5.4	6	Strong	Damage slight. Windows, dishes, glassware broken. Furniture moved or overturned. Weak plaster and masonry cracked.
5.5 - 6.1	7	Very Strong	Damage slight-moderate in well-built structures; considerable in poorly-built structures. Furniture and weak chimneys broken. Masonry damaged. Loose bricks, tiles, plaster, and stones will fall.
6.2 - 6.5	8	Destructive	Structure damage considerable, particularly to poorly built structures. Chimneys, monuments, towers, elevated tanks may fall. Frame houses moved. Trees damaged. Cracks in wet ground and steep slopes.
6.6 - 6.9	9	Ruinous	Structural damage severe; some will collapse. General damage to foundations. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in ground; liquefaction.
7.0 - 7.3	10	Disastrous	Most masonry and frame structures/foundations destroyed. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dikes, embankments. Sand and mud shifting on beaches and flat land.
7.4 - 8.1	11	Very Disastrous	Few or no masonry structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Rails bent. Widespread earth slumps and landslides.
> 8.1	12	Catastrophic	Damage nearly total. Large rock masses displaced. Lines of sight and level distorted.

How does an Earthquake cause glass damage?

During an earthquake, a building will sway laterally and rack out of plane. This can cause the glass to crack. Although glass tends to have good in plane and out of plane strength, once a crack occurs, the opening can be compromised. Research done by University of Missouri – Rolla and later by Pennsylvania State University provides insights into why and when glass breaks during an earthquake. The main cause for glass breakage is damaging contact of the glass edges with rigid framing materials. Once a crack occurs, the continued movement of the building can cause the glass to fracture and fall out of the opening unless the glass is a laminated construction or a film has been applied to its surface." It has been determined that laminated annealed or heat-strengthened glass has better retention in the frame structure than fully tempered laminated glass due to the inherent characteristics of their break patterns. Research has also shown that the proper placement of rubber spacers along both the horizontal and vertical edges of the glass, and/or rounding of the corners of the glass lite aid in reducing the potential for the glass to contact the edges of the frame and break.

Test Standards and Guidelines

According to provisions found in section 13.5.9.1 of American Society of Civil Engineers (ASCE) 7 – 05 that are referenced in Chapter 24 of the International Building Code, seismic testing of glazing units is not required provided:

- Tempered glass is not used in openings greater than 10 feet (3 m) above a walking surface;
- Adequate clearance is provided around the glass so that it does not contact the frames during the calculated movement from a seismic event and;
- Annealed or heat-strengthened laminated glass is captured in a glazing pocket and is anchored to the frame by an appropriate structural sealant.

The American Architectural Manufacturers Association (AAMA) has developed two test methods for assessing seismic performance of glazing. These are:

- AAMA 501.4 - *Recommended Static Test Method for Evaluating Curtain Wall and Storefront Systems Subjected to Seismic and Wind Induced Interstory Drifts*
- AAMA 501.6 - *Recommended Dynamic Test Method for Determining The Seismic Drift Causing Glass Fallout From a Wall System*

Conclusion

Glazing that is engineered for earthquakes can perform very well. Sometimes glass breakage may occur after the seismic event due to unseen edge damage that is aggravated by thermal stress. The use of setting blocks and adequate framing tolerances can reduce the likelihood that the glass will break due to edge damage. The use of properly glazed laminated or filmed glass will also increase the likelihood that the glazing will be retained in the frame should breakage occur.

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