SIMPSON GUMPERTZ & HEGER
Engineering of Structures
and Building Enclosures

30 January 2012

Jeffrey Martin, AIA
McGinnis Chen Associates Inc.
2386 Fair Oaks Boulevard
Suites G & H
Sacramento, CA 95825

Project 060230 – Spandrel Glass Stress Measurement, 450 N Street, Sacramento, CA

Dear Mr. Martin:

Per your request, we have reopened the above-named project to assist with assessment of the cause of a recent spandrel glass break at the building.

Past Assignment

In 2006 you retained us to measure the residual surface compressive stress (RSCS) in spandrel glass in the building, and in certain samples of glass provided by Mr. Jeff Chen.

The results of those measurements are recorded in a letter from Simpson Gumpertz & Heger Inc. to Mr. Chen dated 27 March 2006 (copy attached). In summary:

- RSCS varied from 7,509 psi to 10,970 psi.
- RCSC average was 9,492 psi.
- RCSC varied within individual lites or samples by as much as 994 psi.

Current Assignment

You sent me photographs of a broken lite of spandrel glass and shards of glass from an area where a number of cracks emanate from a point.

The photographs show the following:

- A horizontal bar that is attached to the vertical members of the curtain wall framing and sits slightly outboard of the outside surface of the glass, casts shade onto the glass (Martin Photo 016).
- A closely spaced series of fracture lines emanate from a point in the vicinity of the horizontal bar (Martin Photo 022).
- Another confluence of fracture lines is shown in Martin Photo 005 emanating from what appears to be the sill glazing pocket.

- The spandrel insulation appears to be in contact with the inboard side of the glass (Martin Photo 033)

The fracture surfaces of the shards of glass that you sent to us show the following:

- Crushed glass at the tip of the most projecting shard. No features consistent with an origin of fracture.

- Surface roughness along the mid-plane of the glass is consistent with heat strengthened glass.

- Fracture surfaces away from the pointed end of the shards are clear and consistent with low stress fracture propagation.

Discussion

We do not have a piece of the broken glass that contains the fracture origin, so the cause of this fracture cannot be determined definitively. Possible causes of fracture, along with our assessment of the likelihood that each mechanism is active, are as follows:

- **Projectile Impact:** We cannot assess the likelihood of this cause based on the information we have.

- **Thermal stress:** The shadow cast by the horizontal bar and the insulation in contact with the inboard side of the glass can create reasonably high thermal stress. Heat strengthened glass, however, is very resistant to thermal stresses of the magnitude likely imposed by these features. Excessive thermal stress is not a likely cause of the fracture.

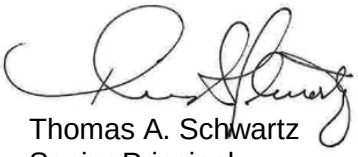
- **Spontaneous Fracture from Nickel Sulfide Impurity:** The RSCS measurements of the spandrel glass that we conducted in 2006 show that much of the glass has residual stress sufficient to make the glass susceptible to breakage from a Nickel Sulfide (NiS) impurity. This impurity can undergo a change in its solid state (i.e., a phase transformation), which is accompanied by slight expansion. If the particle exists near the mid-plane of fully tempered glass, or the mid-plane of highly tempered heat-strengthened glass, the particle expansion, in combination with the residual tension that exists near the mid-plane of the glass, can propagate a fracture in the glass. The phase transformation of NiS is triggered by the cumulative effect of thermal energy on the particle since the time of manufacture. The time to the phase transformation can be days to decades.

- **Excessive Bending:** We have no information to suggest that excessive wind loads (or any other lateral load imposing force) were present at the time of fracture.

Our 2006 measurements show that the spandrel glass on this building generally has high residual stresses. (Current heat strengthened glass is limited by ASTM Standards to an upper limit of 7,500 psi, many years ago the limit was 10,000 psi). This level of built-in residual stress makes this glass susceptible to NiS-generated fractures. The fact that fractures of the spandrel

glass on this building have apparently occurred over a long period of time, without any obvious external source of stress, further indicate NiS impurities as the most likely cause.

Sincerely yours,



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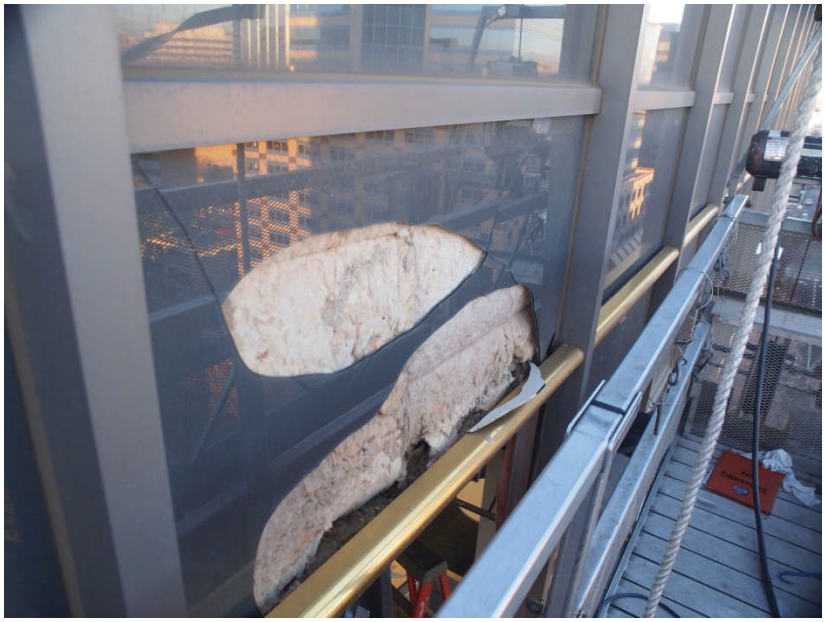

Martin Photo 016

Martin Photo 022

Martin Photo 005

Martin Photo 033