Structural Silicone Glazing at 50 years

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Introduction

The first building to use silicone sealant in a four-sided structurally glazed application marked its 50th anniversary in 2021. This innovative design was utilized to renovate the decades old Cass Building located at 455 West Fort Street in Detroit, Michigan. Although concerns over the integrity of the glazing using this breakthrough technology led to the installation of secondary "Spider" support systems, earliest mockup testing for the building confirmed the durability of the silicone as a standalone support for glass. In the last 50 years, structural silicone has been successfully used in unsupported four-sided structural applications. This manuscript provides a closer look into the history of the building, which paved the way for this success, including the original design intent. Additionally, a comparison between original installation and today's observations will be made. Finally, this manuscript provides an overall case study as to the long-lasting durability and performance of silicone in structural glazing applications.

History of the Building

The world's first four-sided, silicone structurally glazed (SSG) project dates to 1971 with the renovation of the sixty-year-old Cass Building in Detroit, Michigan, which has been referred to as the "Granddaddy" of structural glazing. The Cass Building was originally designed by Smith, Hinchman and Grylls (SH&G, now SmithGroup) in 1910 to 1913 for Col. Frank Hecker as an investment property that was occupied by multiple offices and light manufacturing companies throughout its life. The building's original primary street facing façades were constructed from heavy masonry clad walls over a reinforced concrete frame with wood framed double hung punched windows. In 1970, SH&G purchased the building and were ready with a design to renovate it as their new headquarters. At the time, silicone structural glazing was being developed in the American Society for Testing and Materials (ASTM) Committee C24 on Building Seals and Sealants with contributions from SH&G's architectural technical staff. To demonstrate and accentuate the firm's technical innovativeness and competence, SH&G's Chuck Parise looked to incorporate the emerging four-sided SSG technology in the design of the building's exterior.

Figure 1. Original Cass building (left) and structurally glazed redesign (right). Photos courtesy of SmithGroup (Holleman & Gallagher, 1978).

The building was stripped down to its original concrete superstructure and fitted with an aluminum framed and monolithic glass custom curtainwall along its north and west façades. A structural silicone sealant was, for the first time, used to retain all four sides of each glass panel to achieve a dramatic transformation (Figure 1). This was just six years after the first two-sided SSG system, the PPG Industries Total Vision System (TVS), was developed and installed (Dow, 2019). As the pioneering re-design of the Cass Building glass curtain wall did not have the benefit of other time-proven systems, there were some initial concerns raised by code officials about the retention of the glazing. To address these concerns, the design was modified to include cast aluminum "Spiders" at the intersections of the vertical and horizontal mullions (Figure 2). These Spiders are essentially decorative in nature while the sealant is functioning properly; however, they offer supplemental support of the glazing in the event of a sealant failure. Additionally, they provided temporary support of the glazing while the structural sealant cured. SH&G staff have indicated that "in retrospect, the Spiders add a pattern that has enriched the glass facades of the building." (Holleman & Gallagher, 1978)

Figure 2. Typical Spider fittings. Photo courtesy of Dow.

Original Design

A full description of the SH&G building's framework is provided by Hilliard et al. in Sealant Technology in Glazing Systems (Hilliard, Parise, & Peterson). This manuscript builds upon that description and juxtaposes the original design with modern day considerations.

The curtain wall for this building is a stick-built system composed of custom aluminum tubular extrusions that were assembled in the field. The glazing system consists of an aluminum grid spanning the north and west elevation from ground to roof. Typical construction of a structurally glazed frame today would consist of box shaped extrusions to add functionality, like fastener rails or fins, to stiffen the construction of the frame to meet deflection criteria. However, in this design, the extrusions are tubular with two fins projecting from the tube via a stem. The fins were oriented towards the face of the building and where the glass was glazed. Furthermore, the tubular sections were inserted into aluminum corner connections to form the grid pattern.

The extrusions include a fin that protruded through to the exterior on both the vertical and horizontal mullions. However, the fin is only necessary at the horizontal mullions to support the dead load of the glazing. The use of the fins at the vertical mullion adds to the aesthetic value and aids in protecting the edge of the adjacent glass units whenever broken units must be replaced. The mullions are connected with cast aluminum connections/nodes that are mechanically attached to the building's structure at each floor line. To accommodate building movement and differential thermal movement of the curtain wall frame, custom expansion joints were also cast and implemented where required (Figures 3-6).

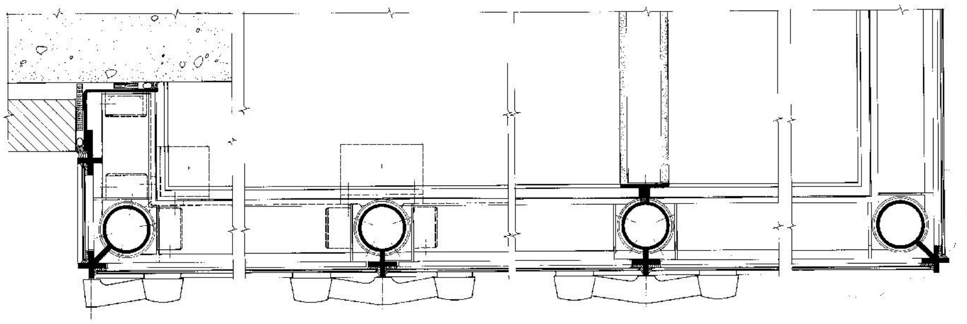

Figure 4. Horizontal section through curtain wall system. Image courtesy of SmithGroup.

Figure 5. Typical floor line attachment connector (image left), typical vertical/ horizontal mullion connector (right three images), Photo courtesy of SmithGroup.

Figures 6. Typical mullion and connector interface displayed at different angles to show details. Photo cortesy of SmithGroup.

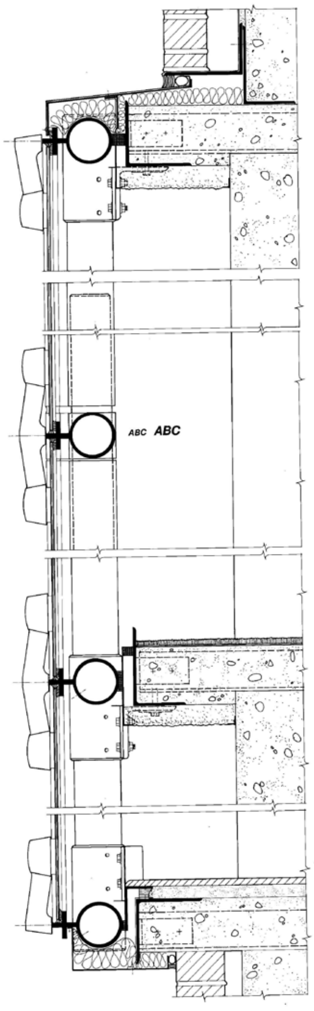

Figure 3. Vertical section of curtain wall system. Image courtesy of SmithGroup.

Original target joint sizes can be seen in Figure 8. The monolithic glass used was sealed on the edge and back to an aluminum T-shaped frame, as shown in the snapshot of a glazing detail (Figure 7). Furthermore, setting blocks were used to support the deadload weight of the glass. This monolithic glass (6.4 mm in thickness) comprised of a reflective bronze coating on glass side #1 possessed a standard dimension of glass measured 1524 mm by 2133 mm. A few lites of smaller dimension exist at the corner returns where the glass wall terminates into the masonry façade (Figure 8). On the exterior of the glass, cast aluminum Spider fittings were fastened with metal screws into the center hub of the corner connections. At each end of the fitting, a hard rubber puck was inserted into a cup section of the fitting.

Finally, the original structural silicone that made this design possible was Dow Corning 781, which was an acetoxy-based cure chemistry and is no longer sold in North America. The sealant reacted with moisture in the atmosphere and released acetic acid as the sealant turns from a paste to a rubbery elastomer. This was the same silicone sealant chemistry that was used in the original weatherproofing applications in 1958 (Kimberlain, Laureys and Harres). Since its initial design, some of the lites in the building have been replaced due to damage (BelCher). For the repair of these lites, neutral cure sealants were likely used, which react to form neutral pH species, like methanol. The structural bite dimensions for the original silicone were designed to be 12.7 mm based on a windload of 1.44 kPa. In today's design methodology, a similar windload would be utilized based on the size and location of the

Figure 8. Smaller glass lites shown in return at corners. Photo courtesy of Dow.

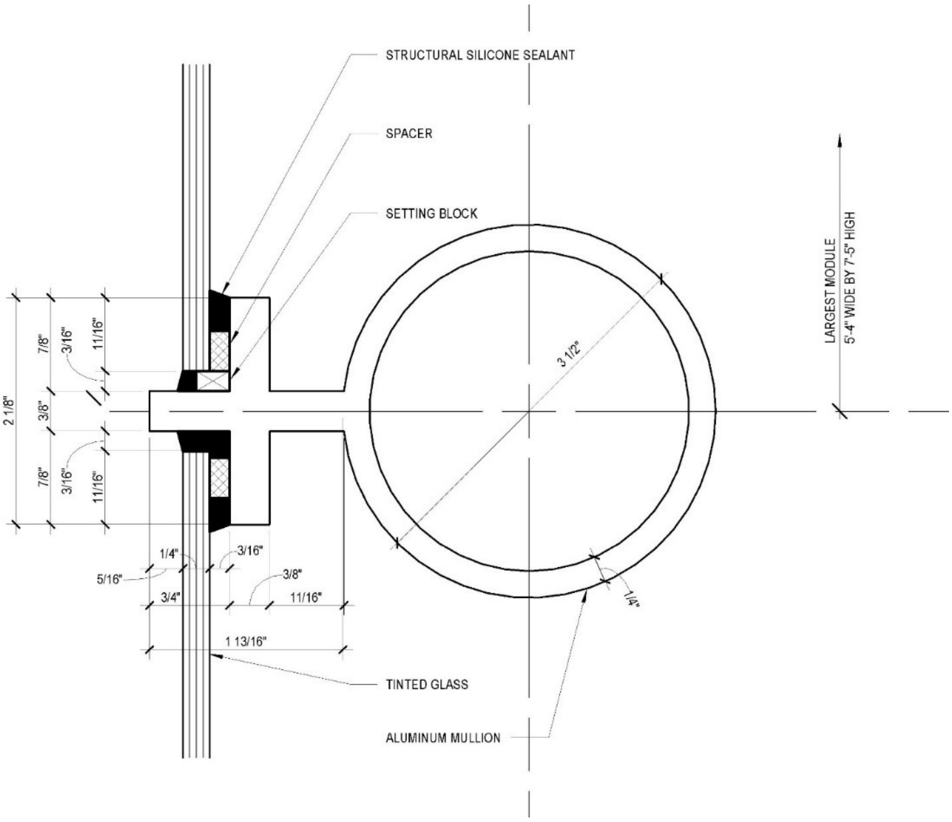

Figure 7. Glazing detail of structural silicone attachment. Image courtesy of SmithGroup.

building. Moreover, to design a structurally glazed bite dimension today with the trapezoidal loading theory (Haugsby et. al.), a design strength of 140 kPa, and windload of 1.44 kPa the typical bite dimensions would be calculated at 5.1 mm. Most sealant manufacturers today would require a minimum dimension of 6 mm, roughly half of the originally designed dimension.

Early Mockup Testing

Early mock-up testing for the SH&G building provided a look into the long-term performance of this four-sided, structurally glazed system. After testing to destruction according to ASTM E330, "Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference" at 3.34 kPa positive windload, it was observed that only the central portion of the glass was destroyed (Figure 9) (Hilliard, Parise, & Peterson). The silicone sealant, in contrast, still supported the glass along the perimeter demonstrating the continued strength of the sealant after glass failure. Although cast aluminum Spiders were installed to the aluminum frame to provide additional support in the event of sealant failure, this mock-up testing revealed that they were not structurally required (Figure 10) (Hilliard, Parise, & Peterson). This initial design concept paved the way for unsupported four-sided structural silicone applications only five years later (Dow, 2019).

Current Condition of the Building

50 years since the building's recladding has given insight into the durability of structural silicone adhesives. The former SH&G headquarters is located at 455 West Fort Street in Detroit, Michigan 48226 (42.3286°N 83.0515°W) and stands at 19.55 m and 5 stories tall over 11,148 m2 of property (Emporis, 2000-2021) (CommercialCafe, 2021). Currently, the building is unoccupied and owned by a local investment/development firm (Figure 11 and 12).

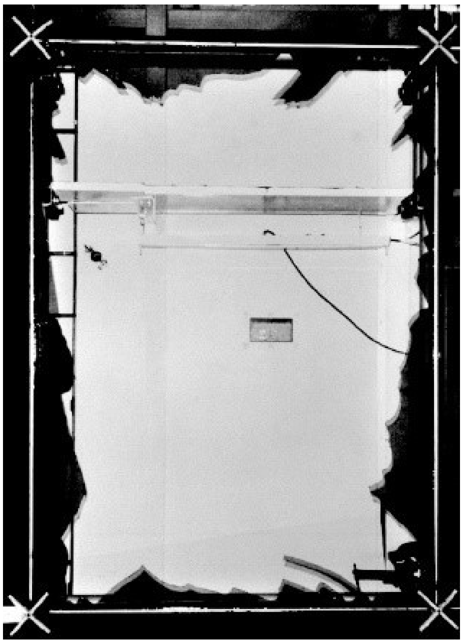

Figure 9. Early mock-up of four-sided structural glazed system for SH&G Building. Shards of glass are seen attached to metal frame even after glass failure. Photo courtesy of Dow.

Figure 10. Cast aluminum Spiders deemed unnecessary in the system but added for additional safeguards. Photo courtesy of Dow.

The building experiences yearly temperatures ranging from -8 °C to 28 °C according to the National Oceanic and Atmospheric Administration (Figure 13) (Climate & Weather Averages in Detroit, Michigan, USA, 2021). Highest temperature recorded for the area reached 40 °C in June 1988 with a record low of -29 °C in January 1984 (Current Results , 2021). Detroit experiences windspeeds and gusts from 14 to 40 kph (Winderfinder, 2021), precipitation averaging at 23 cm per year, and has had over 80 tornados since 1950 along with several tornados in the direct vicinity of the building (Figure 14) (Detroit's NPR Station, 2021) (Home Facts, 2021). The SH&G building structural silicone glazing system has stood the test of time through various weather conditions and an occasional glass breakage. In 1977 when a large wing nut fractured a lite of glass, it retained its structure for three days until a replacement lite was reglazed (Figure 15). This repair was easily completed without disturbing surrounding glass (Hilliard, Parise, & Peterson).

A July 2021 inspection of the building found several of the Spider fittings missing or loose (Figure 16). The Spiders at the top of the building were missing, and it was speculated they were removed for roofing activity and never replaced. Also, some of the rubber pads that protect the glass from the Spiders were missing from the cup ends of the fittings and others appeared to have been permanently deformed resulting in no contact between the rubber pad and glass.

Several lites appeared to have been replaced, and the silicone applied dimension and adhesion appearance did not look to be consistent with the original workmanship nor the expected workmanship outlined in today's standard (ASTM C1401-14). Figure 17 shows one such example where an area of sealant was not fully adhered to the glass. The area may have been a result of insufficient fill so that an air void formed during the application or lack of cleaning where separation may have occurred over time. Figure 18 illustrates a smaller dimension of sealant than typical of the original installation; however, based on the above design assumptions, the bite would approach a dimension that would be adequate today. Figure 19 further illustrates what appeared to be significant smearing of a sealant, perhaps indicative of poor attention to detail as the sealant was installed during glazing replacement.

A final observation on the condition of some of the interior materials was interesting considering environmental exposure for over 50 years. Coating on a wood stud, shown in Figure 20, degraded to the point of cracking and peeling due to UV exposure. Despite the unknown age of the coating, this observation provides a noticeable contrast in performance and reinforces the inherent durability of silicone sealant when exposed to UV light.

Figure 11. Recent photograph of the glass facade. Photo courtesy of SmithGroup.

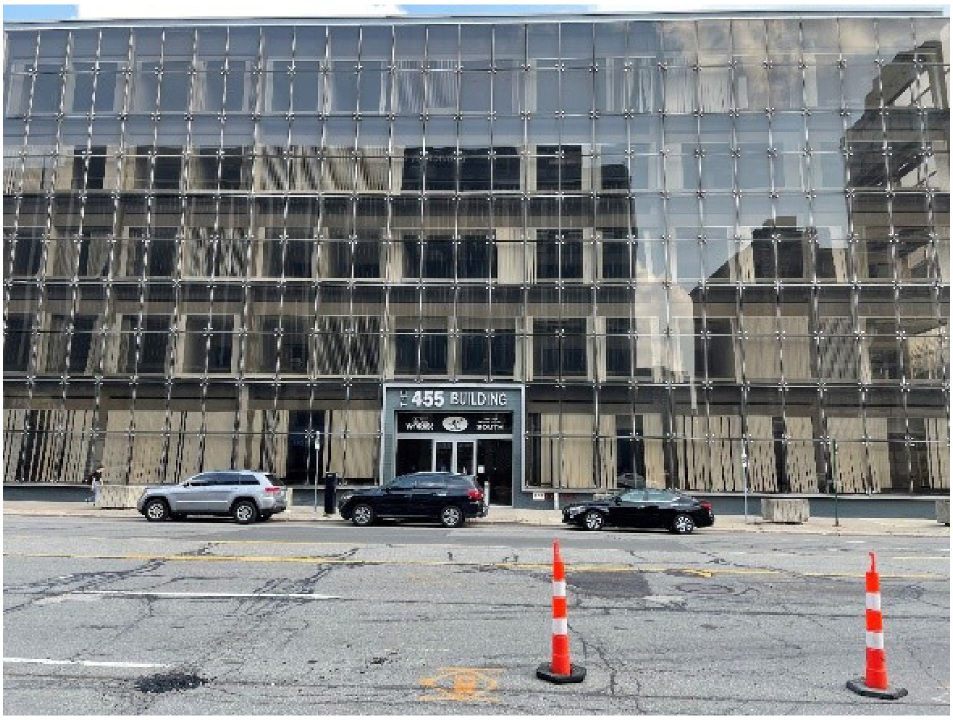

Figure 12. 455 W Fort St on July 2, 2021. Photo courtesy of Dow.

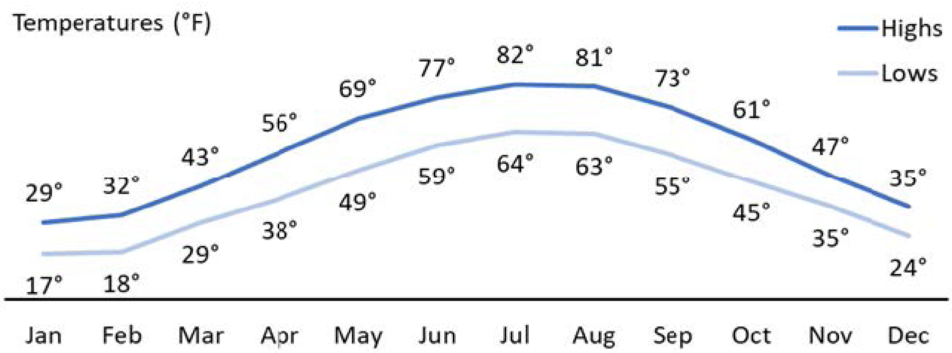

Figure 13. Typical temperature extremes for Detroit. (Graph prepared from data on NOAA Website 7/22/2021).

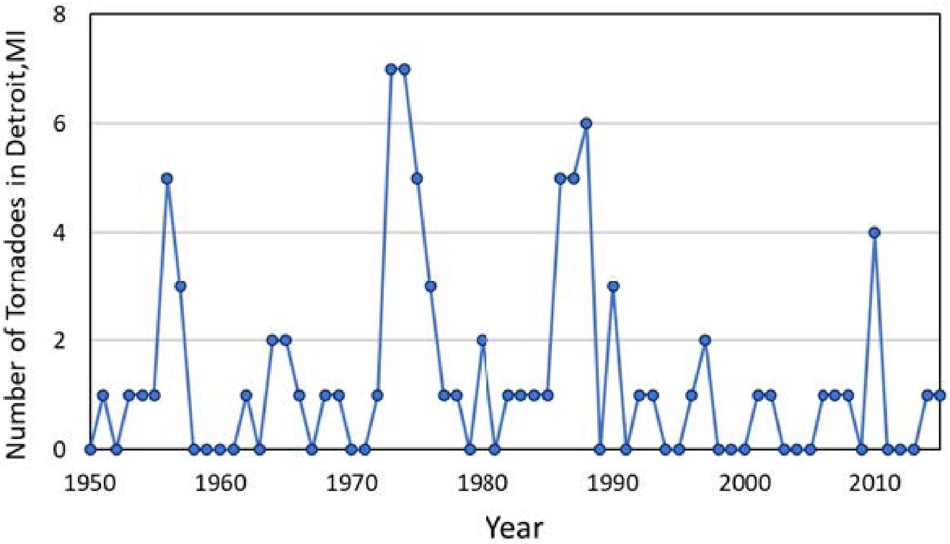

Figure 14. Number of tornadoes in Detroit, MI from 1950 to 2015. (Graph prepared from data retrieved from Homefacts website, Tornado Information for Detroit, Michigan 8/26/21).

Figure 15. Picture of broken glass circa 1977. Photo courtesy of Dow.

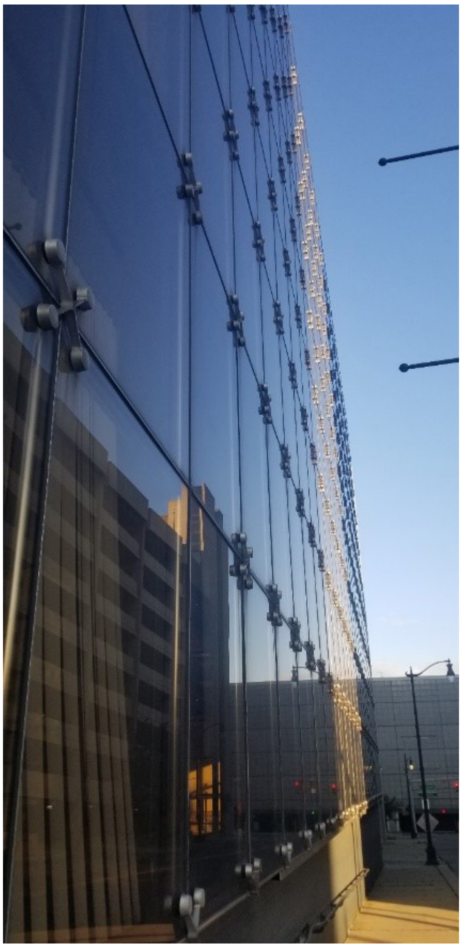

Figure 16. Missing Spider fitting shown on first row of glass lites – July 2021, Courtesy of SmithGroup.

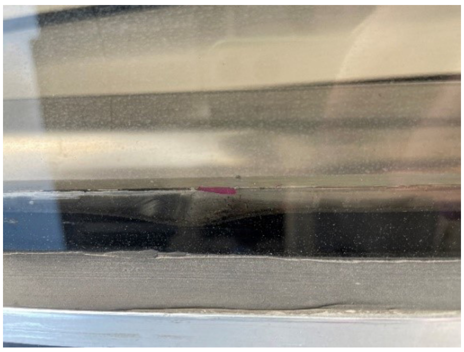

Figure 17. Section of sealant appearing to lack full adhesion – July 2021. Courtesy of Dow.

Figure 18. Smaller Bite dimension compared to original intent – July 2021. Courtesy of Dow.

Figure 19. Appearance of smeared sealant – July 2021. Courtesy of Dow.

Future

Contact with ownership has been made to consider further access to the building with intent to more closely evaluate the interior sealant according to ASTM C1394-20, "Standard Guide for In-Situ Structural Silicone Glazing Evaluation". Further consideration is underway to propose the addition of this building to the National Historic Register.

Conclusion

Silicone sealants continue to be crucial components in structural glazing applications. This 50-year history highlights only one example of the durable and proven

Figure 20. Degradation on interior acrylic coating that receives significant UV exposure. Courtesy of Dow.

performance of silicones. The integrity of the façade has continued after decades of UV exposure, temperature extremes and other significant weather events. Even though there are areas which appear to be less than desirable regarding the application, the original and current design practices, rooted in industry standard, continue to ensure a robust performance even in less-than-ideal conditions. As such, the use of silicone materials should continue to be considered in the development of sustainable innovative technologies for building facades.

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