Evaluating Contemporary Glazing Utilized in a new Tadao Ando-designed Private Museum

Daniel Joseph Whittaker

Abstract—**The proper integration of the latest approved glass and insulated glazing unit (IGU) products for architectural use in precisely designed buildings is always a challenge. This paper examines the newest methods by which a recently opened private museum, built in Lincoln Park, Chicago, integrated tested and approved glazing materials inside and out, which provided æsthetically vetted solutions. Designed by Osaka, Japan based architect, Tadao Ando, and constructed using mostly American building products and American Union labor, Wrightwood 659 marks a serious achievement of integration of Western building technologies to provide a contemporary Eastern spatial experience. Architect Ando san, having completed a series of private and public museum designs across America, makes a serious leap forward in the use and advancement of new building technologies incorporated into Wrightwood 659. Several comparative case studies including former Ando projects such as the Pulitzer Arts Foundation building in Saint Louis Missouri (2001), provide compelling contrasts in glass and glazing technologies over the past seventeen years. Through these case studies, the engineer and architect shall learn about advancements in building glazing technologies along with the proper application of new to market products in dynamic thermally challenging situations.**

Index Terms—**Condensation, Insulated Glazing Unit, Laminated glass, Engineered Thermal Breaks, Triple Glazing.**

I. Introduction

THE premise behind the proper engineering of a building's thermal envelope is the creation of appropriate thermal breaks between surfaces to prevent the onset of condensation and formation of excess moisture. Water vapor, when situated within a building containing higher humidity than outside on the exterior, tends to naturally migrate from a high humidity enclosure towards the drier environment. In typical winter weather climactic conditions of the American Midwest, winter time environments tend to bring with them low humidity conditions as the temperature falls towards below the freezing point of water (32° F or 0° C). Challenging these outside conditions, standards for museum environments mandate that a safe temperature and humidity 'window' (acceptable range) be set for the storage and display of works of art. Artificially controlled indoor museum climates, maintained by mechanical heating, ventilation and air conditioning (HVAC) equipment, are engineered to perform to pre-set expectations. In the case of Tadao Ando's Wrightwood 659 gallery, located in the Lincoln Park neighborhood of Chicago, Illinois, Affiliated Engineers Incorporated's (AEI) Chicago headquarter office was contacted to perform all engineering services for the building. They worked closely with both design architect Tadao Ando Architect and Associates of Osaka, Gensler Chicago architect of record and Vinci|Hamp, construction administration and detailing architect in Chicago, to complete all necessary drawings and documents for this complex museum building project.

The Smithsonian Institution's standards[1] for indoor climate control were referenced for the points of maximum and minimum indoor temperature and humidity. These standards, recognized by museums worldwide (and their insurance companies) as adequate and appropriate values, allowed an interior climate control range as follows: 37% ~ 53% relative indoor humidity coupled with 68° ~ 72° F (20° ~ 22.2° C) indoor temperature is stipulated must be maintained. For a fickle Chicago environment, known as 'the windy city,'[2] this is quite difficult to achieve given the wide range of temperature and humidity fluctuations that are taking place outside on the exterior of the building. To illustrate the severity of the phenomenon of changeable weather, winter time temperatures can plunge to -27° F (-33° C) below zero approaching 0% humidity. This extreme arctic-like condition occurred on 20 January, 1985. Summer time temperatures can swell up to 106° F (41.1° C) with a dew point of 81° F (27.2° C), which occurred as recently as July, 1995 [3]. As climate change takes place and envelops the globe, more extreme hot and cold weather systems can be expected to become a normal quotidian pattern and not a rarity. What steps were taken to deal with this unpredictable future?

II. Precedent Study: The Pulitzer

A. A Review of 2001 Technology

Situated 304 miles (489.2 km) south southwest of Chicago, Saint Louis, Missouri possesses only a slightly more mild winter climate when compared to Chicago. Located in the region of America that is still considered part of the Midwest, Saint Louis is an older city located on the western bank of the Mississippi River. In September of 2001, Emily Rauh Pulitzer opened the Pulitzer Arts Foundation in a new building designed by Tadao Ando, and curiously constructed by the same general contractor, Zera Construction, based in the Chicago suburb of Skokie, Illinois. The reason for this out of town outfit to come to

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Saint Louis was purely based upon possession of recently learned knowledge. Zera had just a few years earlier finished building a home for the owner of Wrightwood 659, in an adjacent set of three lots to the west, numbered with the street address of 665 West Wrightwood. Construction took place approximately 1993~1997, and Zera Construction was the third construction company on the project and successfully completed Tadao Ando's first residential project ever built outside of Japan for the same private client who commissioned, in 2013, the creation of Wrightwood 659 in Chicago, about a decade and a half later.

During the construction process, 1998-2001, the Pulitzer Arts Foundation building was designed and built with standard aluminum window mullions outfitted with standard double-pane insulated glazing units. These were in complete conformance with building codes and energy use standards present during time of design in the late 1990s. The type of aluminum mullions used received a custom "Ando gray" paint color. However, in all other respects standard glazing technology was used. This included the use of non-thermally-broken (also known as non-thermally isolated) aluminum mullions. At the time of design, it is not known if expected humidity levels for a museum environment were taken into consideration for window frame design.

B. Contemporary Performance

Observing the glazing system today, seventeen years after the building opened to the public, several issues have been under notation and continual observation:

Fig. 1. Condensation upon narrow slit window at Pulitzer Arts Foundation, Observed February 2015.

First, the image shown in Fig. 1 is not simply an improperly installed window, leaking during a heavy rainstorm, which may be the assumption made upon first glance. Instead, what is occurring is internal building humidity, contained within the gallery rooms, disbursed in the air by the building's *properly* functioning HVAC equipment, is condensing on the cold glass *and* the cold aluminum window frames. Figure 1 conveys that such profuse amounts of water is condensing that it is flowing down the surface of the glass and surface of the frame and accumulating on the aluminum window sill, pooling out onto the concrete floor. As expected, adjacent gypsum board wall surfaces are also being affected, the porous wallboard covered with paper easily absorbs water and will subsequently discolor and swell producing gypsum crystal efflorescence.

Secondly, windows glass surfaces and aluminum frames were not the only areas collecting water on this particular cold winter day (measuring 18° F / -7.8° C). Aluminum doors and door frames, also lacking thermal breaks, easily conducted the cold temperatures indoors and also produced condensation 'sweat' on the surface of the door and frame.

As Fig. 2 shows, a non-thermally broken door itself, made of aluminum and painted, is equally susceptible to extreme temperature and failure in the form of condensation on the interior. Note that lockset cylinder on the interior, for this non-egress door, is also sweating condensation. Major performance issues occur when the condensation re-freezes within the interior of the lockset, barring all functionality of the lock, freezing its tumblers and subsequently, eliminating door access.

Fig. 2. Condensation upon door side stile and lockset at Pulitzer Arts Foundation, Observed February 2015.

C. Beyond the Pulitzer

Many culpable parties may be blamed for the absence of incorporation of proper thermally performing products within the Pulitzer Arts Foundation. Beyond assigning lack of due diligence regarding climate research and performance criteria for the Saint Louis, Missouri region, a secondary building, built by the same general contractor just a few years earlier must be first examined. This is the aforementioned private home at 665 West Wrightwood, for the same client at Wrightwood 659, and built between 1993~1997. Here, local Chicago architect of record Larry Booth's firm, Booth Hansen, performed their proper research, having designed many large-scale private homes in Chicago for over a decade. Familiar with the city's local climate extremes made them well aware that thermally broken aluminum window frames were absolutely necessary for this Tadao Ando designed private home.

While the home was in the design phase in the mid 1990s, one design pro forma they received was to create so-called 'frameless doors.' Such doors, whether used for the main entry or side ramp access were designed to fit a set of specific æsthetic performance criteria which overrode thermal performance. Hence, near 'frameless doors' were designed, a manufacturer was found (Wausau Doors of Wisconsin). Visual performance standards requiring the doors to disappear when closed and completely match the adjacent windows was paramount above thermal performance conditions. Hence, while the entirety of aluminum frames composing the fixed windows in the residence (665 Wrightwood) possess thermal breaks and securely hold in fixed double-pane insulated glazing units (IGUs), the adjacent doors matching the fixed windows in appearance, are actually *not* thermally broken. As a consequence, during harsh winters, when there are a series of extremely cold days in Chicago, the same occurrence of a 'thermal short circuit' produces, just like at the Pulitzer building, excessive condensation on the door's thin side stiles, head rail and bottom rail. Water substantially pools on the door sills. In spite of this functional failure, this was the best solution the various teams involved in the home's design could produce, to simultaneously satisfy the design pro forma while subjugating thermal performance, in order to accomplish the primary goal: æsthetic performance in compliance with Ando's design vision.

D. *Preliminary Precedent Conclusions*

Today's building technologies offer, to some extent, a

Fig. 3. Condensation upon non thermally broken aluminum sill of combination door and operable window, Wrightwood 665 Private Residence, Chicago, Observed Winter 2014.

greater degree of options that were not either within the designer's access in the early to mid-1990s nor available in the proverbial toolbox of the window and door fabricator or master metalsmith carpenter during that era of construction. For example, a contemporary solution today may entail the incorporation of a heat source integrated into the sill of the thermally unbroken door in order to heat up the cold metal surfaces to prevent condensation from forming to begin with, and also to help heat the metal surface to aid in the quick evaporation of any accumulated moisture. This heat could be supplied either via hydronic means with a closed loop of propylene glycol [4] or a well-made, long-lasting electric resistance heating cable. Neither were incorporated into the door sills nor surrounding frames in the 1990s construction of the house at 665 West Wrightwood, nor the Pulitzer Arts Foundation. Retrofit applications would require both the complete removal of the door and frame under remediation and the creation of a trench or chase to bring power or tubing to the area in need, both of which would be entirely too disruptive to the exiting home which now has been lived in by the owner for over two decades.

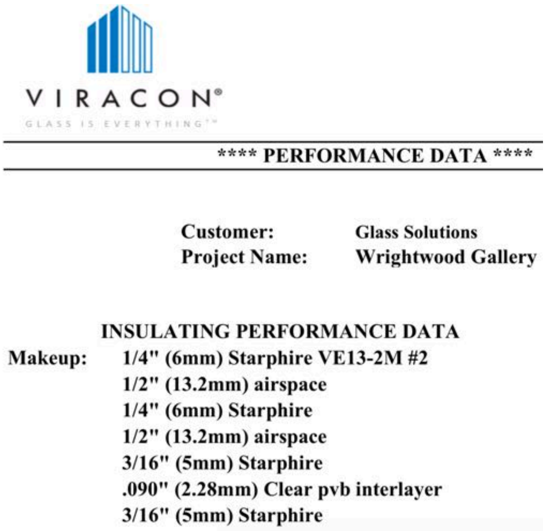
III. Contemporary Thermally Broken Glazing Systems

A. *Tested Technology Incorporated into the private gallery in Chicago: Wrightwood 659*

The use of the latest thermally broken aluminum window glazing systems as incorporated into Wrightwood 659 gallery building, which included high-performance glazing which exceeded any Tadao Ando museum project built to date. This was accomplished for this private museum, due to an edict the client ordered to both acoustically and thermally isolate the chaotic urban exterior environment from the inside. The interior was to be the most placid and contemplative gallery environment technically possible, in the city. In order to do this, and accomplish a whole host of other design criteria, a third layer of glazing was incorporated into the IGUs in addition to a lamination. This laminated layer, made of a special plastic material, succeeded in eliminating over 99% of ultraviolet (UV) radiation from penetrating through the windows. It is well known that UV radiation contributes to the dissolution of dyes in a wide assortment of natural and artificially colored substances, found in both artwork as well as building products. The testing agency of Wiss, Janney, Elstner Associates of Chicago performed third party UV testing to verify the manufacturer's claims and found them virtuous [5].

B. *Triple-glazed IGUs: A special combination*

To achieve the sophisticated performance that was demanded of the exterior windows at Wrightwood 659,


VIRACON®
GLASS IS EVERYTHING™

**** PERFORMANCE DATA ****

Customer: Glass Solutions
Project Name: Wrightwood Gallery

INSULATING PERFORMANCE DATA
Makeup: 1/4" (6mm) Starphire VE13-2M #2
1/2" (13.2mm) airspace
1/4" (6mm) Starphire
1/2" (13.2mm) airspace
3/16" (5mm) Starphire
.090" (2.28mm) Clear pvb interlayer
3/16" (5mm) Starphire

Fig. 4. Viracon's window glass Performance Data sheet (excerpt) [6].

more than simple triple glazing was specified. As mentioned, the addition of a polyvinyl butyral (PVB) interlayer achieved UV suppression performance. The three layers of glazing achieved the exterior sound-deadening performance. The use of Pittsburgh Plate Glass's (PPG's) Starphire-branded glass which contains a patented formula known to contain a special 'low-iron' glass ingredient content mixture, reduced the so-called 'Coke-bottle-green' tinge that thick glass panels or multiple sheets of glass tend to stray in color, tainting the

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occupant's view through to the other side. Figure 4 lists the specified glass layer composition and thicknesses.

The Viracon IGU assembly described above produced a high-performance windows and skylights admitting a generous 67% of the visible light spectrum while only allowing 32% of solar energy through, yielding a Solar Heat Gain Coefficient factor of 0.36. All values were tested at centerpoint of IGU, as per industry standards [7]. The difference between standard 'wide-window' vertical window fenestration glazing in this project and the narrow 'Ando-trademark' windows, is that the wide exterior windows possess an internal tempered pane of glass due to the safety code requirement. These so-called 'floor-to-ceiling' glazing conditions must either have a horizontal pedestrian occupant safety bar present, or be tempered, to protect the from a potential walk-through and breakage hazard. Likewise, due to safety code requirements, skylights present at the fourth floor ceiling/roof also possess a tempered layer enabling the skylight glazing to be entirely in compliance.

IV. Implementation of Design 'Performance' Æsthetic

A. Seldom-noticed new-to-the-market IGU Product Enhancements

There have in fact *not* been an avalanche of new performance perks or products in the realm of IGUs in the last decade. The only main new enhancement is the addition of a black plastic interlayer, covering up what typically is a bright, shiny and highly-specular interior inter-layer which contains a perforated aluminum spacer bar containing within a granulated spherical silica gel desiccant crystals. Traditional aluminum spacer bars have, since the 1950s when IGUs came to the marketplace, always been shiny unfinished aluminum. Recent developments enabled these spacers to be coated with a black tape layer, eliminating their shiny and overly reflective surface, which often times collected sunlight and bounced it randomly (and distractingly) within the space it enclosed. See Fig. 5, a close-up photograph of the IGU at the Tadao Ando designed Clark Art Institute in Williamstown, Massachusetts, completed in 2015.

As Fig. 5 illustrates, the triple-glazed IGUs at the Clarke possess the standard aluminum spacers, which are uniformly perforated like teeth on a zipper to allow any excess moisture between the panes of glass to be absorbed into the desiccant crystals which are packed within the interior of the two bars separating the three sheets of glass. Translucent insect left in photograph indicates the rural nature of the Clarke, and what its large bodies of terraced water attract in outdoor Western Massachusetts.

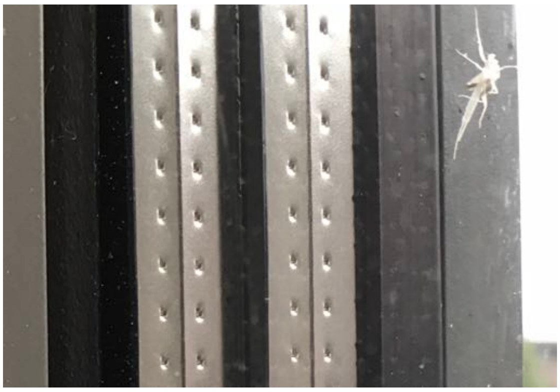

Fig. 5. The Clark Art Institute's IGU, zoom-in detail image.

While not a major æsthetic violation or compromise, the bright aluminum nonetheless is distracting to what otherwise is a rather dark color palette of black silicone window seals and Ando-gray painted aluminum mullions, indoors and out. What is hidden from view is the plastic resin thermal break, contained concealed within the aluminum window frame. The Chicago design team working on Wrightwood 659, observing nearly countless numbers of window assemblies and IGU configurations, went ahead with the design challenge and engaged window manufacturer Viracon to use one of their newest product enhancements, a material which covered the aluminum and made it visibly disappear from view by masking it in a minorly-reflective black coating. See Figure 6.

As figure 6 shows, the black coating still contains the necessary perforations to enable any stray moisture to be absorbed into the desiccant contained within, however gone are the harsh rays of reflected sunlight. The black interlayer works in particular rather well in a triple-glazed configuration, to eliminate multiple unsightly distractions.

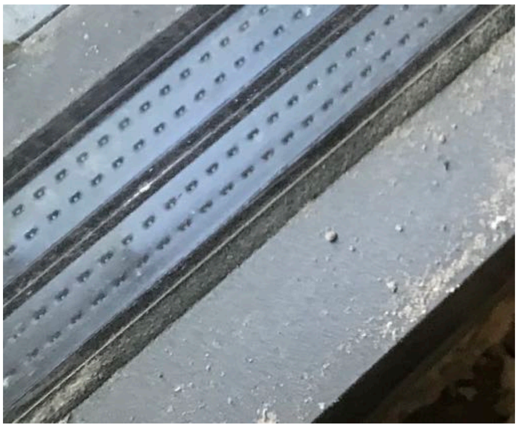

Fig. 6. Wrightwood 659: IGU window glass zoom-in detail, while site was dusty and under construction..

V. Exterior Glass Railing Failures

A. Factory oversight conveys problem to the job site

The exhaustive use of Oldcastle's laminated SentryGlass-brand glass enabled the clearest and least-tinted view outward, as possible on this project. Exterior railings, code-compliant built to a pre-specified height of 42" tall (106.68 cm) were specified to be made of two layers of tempered glass. Sandwiched together, bonding the two layers of 3/8" (10 mm) glass was a standard vacuum-adhered PVB interlayer. What arrived on the job site, and initially installed, however was anything but standard. See Fig. 7.

Three of the eight tempered laminated glass panels which compose the 67'-11" (20.7 m) long guardrail at the southern terrace had been installed containing failed laminations that were not caught by quality control as they

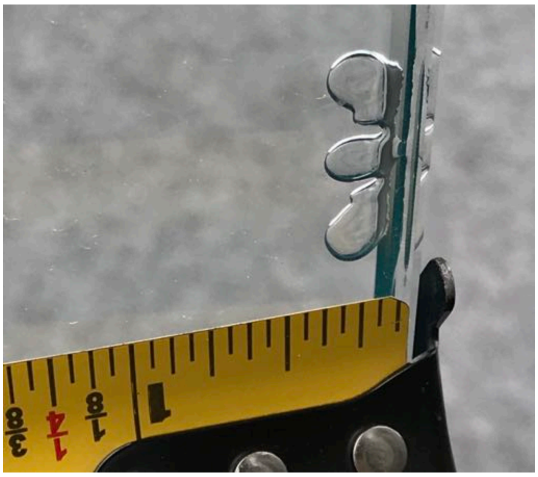

Fig. 7. Zoom-in detail example of three air bubbles located at an edge.

exited the factory. These remained in place for some weeks, serving their function as a safety barrier, while new pieces, cut and laminated to replace the failed ones, were fabricated and shipped to the site.

B. *Searching for other lamination issues*

Close inspection of the extensive number of laminated glass exterior window IGUs revealed no issues.

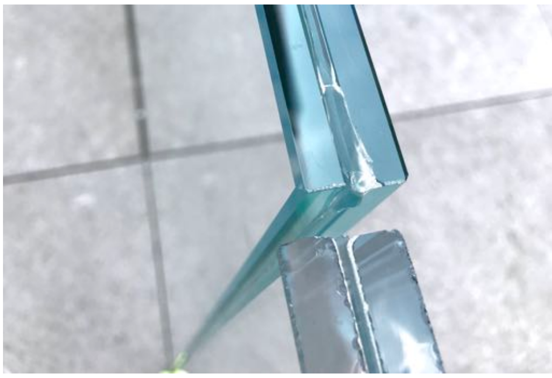

Fig. 8. Oldcastle low-iron glass, showing center PVB lamination.

Fortunately, the nine pieces composing the two main skylights admitting light into the fourth floor and above the

Fig. 9. Dendritic patterns of air intrusion in failed laminated glass panels. Asia Society building in Admiralty district, Hong Kong, S.A.R. China. Condition observed on site by author, 24 February, 2013.

art display platform mezzanine (between the third and four floors) revealed no lamination issues.

Improper lamination or contaminated or un-pure PVB interlayers can spoil a proper lamination job; examining Tod Williams and Billie Tsien's Asia Society building, constructed in the Admiralty neighborhood of Hong Kong, and opened on 9 February 2012 [8] demonstrates this. This building faced a plague of improperly laminated glazing panels. The intrusion of air between the two layers sandwiched together with a faulty PVB interlayer, is clearly visible as delamination creeps across the surface of the glass. Replacement is presented as the only operative solution; there does not technically exist a reliant on-site solution to 'fix' a tainted laminated glass failure, in situ.

VI. Fire-Rated Glass

A. *Searching for a code-compliant solution*

Design architect Tadao Ando created a very intriguing area on the fourth floor, near north end of the building: neighboring a termination of an acute-angled concrete wall, he placed a floor-to-ceiling vertical narrow glass window,

Fig. 10. Site meeting whereupon a product sample was inspected.

looking into an egress fire-exit staircase. Within the staircase, he then placed two floor-to-ceiling vertical glass windows, even more narrow than the penetration adjacent to the concrete wall. These two narrow glass windows, looking due east, however are *not* in alignment with the wider interior window. Ando's office indicated that all glazing was to be clear, and *not* contain any wire—that is, the traditionally accepted and approved method for glass to be inserted into any fire-exit staircase. This glass is made with a grid of stainless steel wire sandwiched in the middle. This is to ensure that in a fire condition, for a set period of time, the glass may crack due to the intense temperatures of accumulated super-heated smoke, but will not fall out of place and let smoke, flame and super-hot gasses pass into the protected staircase, which is meant to provide a safe harbor for building occupants to descend within. Numerous other designers and architects have called on manufacturers and building product testing agencies to find better-looking solutions to this problem. Wired glass has been around and recognized for over a century; originally hexagonal chicken-wire was the standard; eventually a square grid superseded this antiquated fire-glazing. However, even a modern stainless steel wire square grid is a far cry from clear glazing.

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B. *Chemistry to the rescue of architect's demands*

Early products touting wire-free, fire-rated glazing were made of special sodium-silicate interlayers which, while cost-prohibitive for all but the most premium of architectural projects, solved the pressing æsthetic solution in search of clear, wire-free, fire-rated glass. The product ultimately selected for this application which also passed muster with the Chicago city fire department, building inspection department and by Intertek Warnock Hersey testing agency of New York and London. Safti*first* is the manufacturer and branded their glass product as 'Pyran Platinum L' fire-rated glazing. Based in Brisbane and Mercer, California, their product, as shown, is offered in numerous incremental fire-rating levels, ranging from 20 minutes up to a maximum of 180 minutes.

Fig. 11. Egress stair interior at northwest corner of core; view showing window placement at 'end' of concrete wall behind.

Although not anywhere as near as clear a Starphire glass, this product was better than any wired glass available. A recessed reveal was created in the concrete wall to accommodate the thickness of the IGU and also to hide the unsightly black sealing compound that is present in all IGUs, lining the perimeter of the unit.

VII. Security Vestibule Glazing

Due to the nature of the museum building housing future exhibitions containing rare and important pieces of art, artifacts and archeological finds, the building necessitated a means of access control. A front vestibule, normally associated with cold and hot air control, was adapted to serve double duty: functioning both as an 'air-lock' and a 'sally port' where only one set of doors are to be open at any given time. Stopping short of being a panopticon, the security guard's booth is stationed in a securely locked room fully observant of the vestibule, and equipped with necessary closed-circuit surveillance monitors collecting the supernumerary high-resolution digital video feeds from the museum building's interior and exterior cameras.

Early layout and elevation versions of this room depicted a long horizontal movable sash which would be electrically raised and lowered, falling in to base cabinet below comprising the security desk. As the project was further refined, such an electric moving sash proved improbable to meet the security demands of the space. The design then progressed towards a very large single piece of security glazing, which was specified to perform at Underwriters'

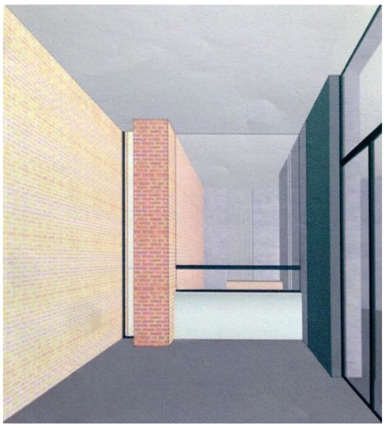

Fig. 12. Interior rendering issued by Tadao Ando's office showing original intent of front security vestibule, as seen by a visitor at entrance [9].

Laboratories (UL) 752 Security Level 1, indicating it could stop three shots of a 9 mm caliber traveling at a maximum speed of 1,293 feet per second (394 meters per second), was un-manufacturable, according to American vendors bidding on the project [10]. Ando's office created a very clean monolithic design (a later version, different than the initial rendering shown in Figure 12), and called for a single piece of clear glass to fill an opening 7'-6 1/8" wide x 9'-10" tall (2.289 m x 2.997 m). A secondary option was to align the larger glazing piece's horizontal seam with a pre-existing concrete form flush joint; however manufacturers stated the largest size possible would fall short of aligning with this joint, 75 1/8" tall (1.908 m). Not wanting to visually show such an alignment inconsistency, especially given this was the first interior room the visiting public would witness, the decision was made to divide the entire piece of glazing into equal halves, which manufacturers could accommodate without fail.

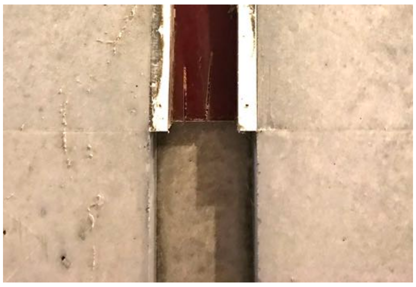

Fig. 13. Interior elevation of vertical embedded 'groove' in architectural finish Ando concrete wall; horizontal joint line subtly stretches across center of image. Dark maroon FinnForm formwork with white epoxy-adhered edge banding is visible; lower portion of formwork has been removed prior to taking this on-site photograph on 5 December 2017.

Further changing the initial design issued by Ando's office was the presence of a slightly dropped ceiling soffit with reveal, which was not present in the original design but was necessitated because of a boxy and too-large building exhaust air duct above the ceiling. This duct blows out stale building air towards the east, through a secure louvered vent. The initial long, thin horizontal dimension proved to be too taxing on the load-bearing exterior masonry wall, and to avoid further cost complications of adding a structural header just for a vent opening, the dimensions were changed to a more boxy, squat rectangular form. This change unfortunately,

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unbeknownst to the team, intruded upon the plane of the finished acoustical cellular ceiling board material, which was hung from a metal spline framing system. In order to accommodate this lower ceiling elevation, a soffit with reveal was added above the security glazing. This reduced the vestibule ceiling height 5.5” (13.97 cm) from its pre-designed and pre-set window header height of 13’-4 1/2” (4.064 m) above finished floor (AFF). It was highly undesired to introduce soffits or reveals that Ando did not design, but in this case, near the end of the project and with great demand to complete the building, this change was quickly instituted on site to speed up the ultimate finishing of the project. The front vestibule was the last room to be completed in the building.

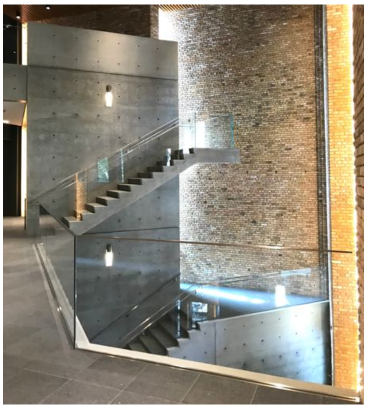

Fig. 14. Interior view from the second level, towards the south west facing fin wall supporting a monumental cantilevered concrete stair.

The glazing initially considered for the security window was a 100% clear laminated acrylic material, which contained two thin exterior layers providing reasonable scratch resistance, laminated onto a thicker core acrylic base. Armour-G Bullet by Guardian Industries and LP 750 by Total Security Solutions were both considered in the original building specifications created by Gensler. Later, upon more thorough product review, a conventionally laminated glass and plastic security glazing product was ultimately used. In spite of the dimensional limitation of the product, it was the best suited material for this application, and fit into the aforementioned pre-formed vertical concrete ‘grove’, which could not grow wider due to the pre-set dimension cast into the concrete wall.

VIII. Interior Glass Guardrails

Commensurate with Tadao Ando’s smooth-finish architectural concrete idiom is the use of glass as both a weather barrier and as a visually clear boundary marker. In the case of stair and balcony guardrails, they also serve a safety purpose in addition to marking a boundary between occupiable space and large voids of un-occupiable space. As is expected in his spatial experiences is the near-absence of unnecessary color. As mentioned earlier, contemporary float glass contains iron impurities which tinge the view through, and especially pronounced at the edge, creating what is seen as a ‘Coke-bottle green-tinged’ color. Aforementioned PPG Starphire product, utilized in Viracon glazing, was also used in the interior guardrails. Tempered and then sandwiched with a PVB-interlayer, this laminated safety glazing satisfied all code requirements for a stable and sturdy guardrail along the stairs and two balconies overlooking the museum building’s three story internal atrium at the north end of the structure.

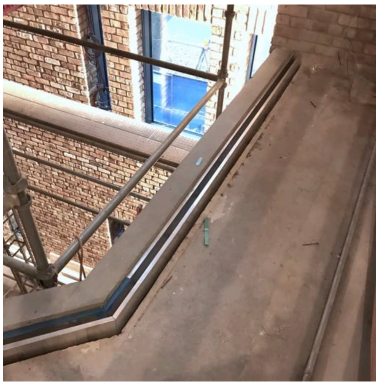

Fig. 15. Aluminum ‘shoe’ which will later receive the glass handrail. Note it is butted up against the site-cast, smooth-finish architectural concrete balcony edge. It will later receive stone up to the opposite side.

Once again, like the aforementioned south exterior terrace, all interior guards at the staircase and balconies are code-compliant 42” tall (106.68 cm) and capped with a brushed stainless steel C-channel along the top edge. All glass is made of two unequal thicknesses of laminated and tempered Starphire glass with a PVB interlayer. The outer (atrium side) layer being thinner at 7.5 mm and the inner (person side) is 9 mm thick. Including the clear laminated center core (2 mm), the overall glass guard thickness is 18.5 mm.

This glass panel is friction-fit into an extruded aluminum ‘shoe’ which was previously anchored and fit onto the concrete slab subfloor prior to the installation of the gray granite flooring. The actual aluminum shoe along with plastic shims and the friction fitting is not æsthetically pleasing, so solid stainless steel bar stock (18 mm wide face x 24 mm deep) recesses into an indentation below the finished stone flooring surface or stone tread. The stainless steel has a brushed finish and is positioned on top of the shoe, to cap the recess and also to time-out flush and co-planar with the finished flooring: that being stone in most cases.

The third floor mezzanine level (technically called the art display platform) possesses the building’s one concrete

Fig. 16. First floor glass guardrail, as it starts, anchored into the lobby floor, prior to the first riser step rising up the angled monumental three-story staircase. Note the plastic laminate internal strip is visible.

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and wood stair which aflights up to the fourth floor. This staircase exemplifies the one condition in the museum building where wood treads and risers are used, along with an architectural finish concrete 'stringer.' In spite of the change in staircase materials, an identical glass railing was specified and installed in this area.

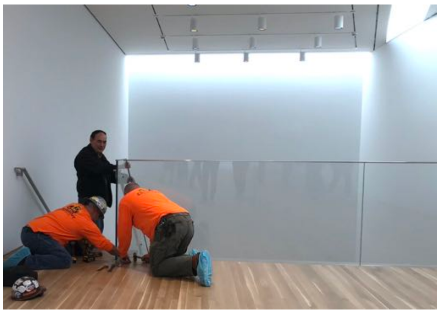

Fig. 17. Fourth floor gallery view south. Laborers are working at more securely anchoring the wedge slips stabilizing the glass guards.

Throughout the Ando building, the panels of glass composing the guards are *not* joined together. An air space gap, approximately 1/4" (6.35 mm) is present throughout the building. Other designers often times call for this gap to be caulked with clear silicone, which after application in reality is more transluscent. Ando's office specified that these gaps be minimized, and when absolutely technically necessary, to leave them open and un-caulked. This means that the occupant, when looking closely, can see the PVB interlayer edge laminating the two sheets of glass together. This edge is more apparent at 45° angled railing intersections. However, this reveal gap and laminated interlayer overall is quite negligible, while comprehending the spatial experiences of the gallery and its dynamic interior spaces.

Fig. 18. Exterior view looking north, from roof of owner's home towards northwest corner of Wrightwood 659 gallery building. Note filled-in window openings of former apartment building, along with new fourth-level of gallery building, being clad in floor-to-ceiling reflective glazing.

IX. Conclusion

In conclusion, a complex array of contemporary glazing products were assembled by the local team of architects, in order to completely fulfill the design architect's vision. Tadao Ando set forth a complex hierarchy of layers varying from complete transparency to relative opacity, which were fulfilled using a wide variety of American-sourced glazing products. Overlaying this intense and unforgiving (non-compromising) set of æsthetic requirements of the project was an equally strict set of building fire life safety codes necessitating strict fire separation boundaries. In several instances, highly developed glazing products played a major role in achieving the maintenance of proper fire boundaries, with the addition of fire-rated frames and localized deluge sprinkler heads. No possible solution was left unexplored, and all potentially beneficial combinations of products which would yield the intended design appearance were placed under consideration and evaluation for incorporation. The latest advancements in insulated glazing units, fire rated glass, laminated glass and bullet resistant glass were employed in this project. Design architect Tadao Ando and project construction administration architect, Vinci|Hamp, worked in tandem to develop the highest-performing solutions fulfilling both design-driven mandates as well as American and Chicago municipal fire life safety and building code requirements. The final outcome raises the level of expectation for thorough and well-developed design excellence in the Midwest and across the world for all of Tadao Ando's institutional museum projects.

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