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Examining Steel Foundation and Thermal Break Construction Methodologies in new Museum by Tadao Ando

Daniel Joseph Whittaker, Ph.D.
Illinois Institute of Technology (IIT)
email: dwhitta1@hawk.iit.edu

Abstract

In an effort to enable typically high energy consumption museum buildings to perform more efficiently in a northern non-coastal climate zone, several technologically sophisticated building materials were utilized along with innovative construction methods to create Tadao Ando's newest semi-public gallery project in Chicago, Illinois. Several technical hurdles were overcome while designing and planning an entirely new sealed building within the extents of a 1930, 38-unit, 3,530 square meter apartment building enclosed by a three wythe thick masonry shell, averaging 19.2 meters tall. This paper shall explore the finer points regarding the smart use of steel and stainless steel thermal breaks in the planning, design and construction of a wholly-Japanese designed museum built with American Union labor using domestically sourced tools and building components primarily from the U.S. and Europe.

How can Ando's design vision be faithfully translated by a team of engineers, architects and laborers far away in the Midwestern plains of America? Due to the unique wet sandy soil conditions of Chicago, a new rigid steel-frame structure was required. This armature was then encased in a fire-protective and sometimes decorative concrete sheath. Due to special live-load structural bearing capacities required by the client to accommodate future heavy artwork, an entirely new foundation system was necessary to augment the existing non-reinforced concrete perimeter footings. Chemical grout was temporarily injected at high-pressure into the wet sand to facilitate support of both the existing masonry wall and old rubble stone basement of an adjacent 1880s rowhouse. This entirely new foundation system rests upon a combination of water-jet drilled micro-pile clusters and perimeter jack-piles. This paper shall investigate many fine construction aspects related to the new footing, foundation and thermally-broken steel frame system supporting the significant weight of this four-story private art gallery building in Chicago.

Keywords: Chicago, Private museums, Steel bearing construction, micro-piles, Tadao Ando.

1. Introduction

Unlike many of Mr. Ando san's newly constructed projects, this particular building located about 4,224 feet (1,287 meters) inland, due west from the current engineered and reinforced shoreline of freshwater Lake Michigan, can be simply characterized as a new four-floor, plus basement, steel and reinforced concrete building within an existing masonry shell, with a top-level reinforced concrete addition. The extant structure, a four-story, 38-unit apartment building constructed between 1929-1930, consists of a three-wythe thick Chicago common brick body, with a front façade of wire-screened red face brick and Indiana limestone detailing imitating a mild American Federal-revival styled street-front (complete with classical-revival vestiges including a triangular pediment, acroterial vases, brick quoining, fluted pilasters, and tripartite neo-Palladian window groupings). The footprint of the building is approximately 174' long (53 m) and I-shaped. The finished first floor level lays about 3' (~1 meter) below grade, which is a configuration commonly called an 'English basement' style. Composing the first floor, hollow clay tile and brick partitions demarked fire separations, along with a hollow clay tile ceiling only at the first floor (due to the presence of a boiler-mechanical room). Above the first floor, wood floor joists rested upon interior masonry walls forming a double-loaded corridor, whereupon each apartment unit was accessed. Additional vertical full-height fire-breaks separated each unit, while interior non-load bearing partitions were comprised of wood studs covered in typical wood lath and plaster. The building, as constructed, contained no fire-suppression sprinkler system, which at the time was (and still is) not required. At a later date, in the 1980s, natural-gas fireplaces were added by a different owner to most of the units as an aesthetic amenity garnering greater rental income.

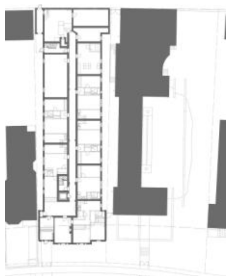

Figure 1. First floor plan of former apartment building.

1.1 Why Adaptive Re-Use of This Building?

Between 1992 and 1997, the owner of this project was the first person outside of Japan to commission Mr. Ando san to have full design control for a new single-family residence using Ando's traditional idiom of reinforced concrete. However, due to the cold climate of Chicago, all exterior walls and planar roof surfaces are so-called 'sandwich-walls' with an internal center core of 4" (10.2 cm) of extruded rigid polystyrene, completely enveloped on all sides by site-cast reinforced concrete totaling 15" (38.1 cm) thick. This formidable private home is situated adjacent (west) of the apartment building, which formerly had about 19 apartments peering over towards the Ando-designed home. Initially published as 'The Eychaner-Lee residence,'[1] the home is still inhabited by the owner (Eychaner), who in 1997 purchased the 38-unit apartment building and continued operating it as such through the end of June, 2013, when all leases naturally expired. Throughout this early time period, other Chicago architects and designers had performed preliminary studies for various re-use scenarios which included an art gallery plus a reduced number of dwelling units (including what could be termed as a temporary live-in 'artist in residence' unit), stacked on top of a small quantity of garden-level car-parking spaces (including an automobile turntable) in the partially-subterranean basement vehicular access occurred via a communally shared rear alleyway. In 2013, the owner and author of this paper, working as owner's representative, traveled to Osaka and approached Mr. Ando san, who graciously agreed to the commission; albeit its unusual nature. It is speculated that the recent completion (June, 2009) of the comprehensive renovation of the Punta della Dogana, in Venice, for Mr. Francois Pinault [2] aided in Mr. Ando san's expert-level familiarization of the nuances presented in old-building re-use for art-gallery re-purposing scenarios; although the Venice example is in a 327 year old building, and the Chicago structure was a mere 83 years old when this project began in 2013. It must be noted actual physical connections for personnel movement between the still-private residence and the new publicly-accessible art gallery, in the form of bridges or tunnels, do not exist in this first phase of completed construction work. However, in anticipation of the future, the entire first floor level of the new gallery building was set to be co-planar with the existing first floor level of the adjacent home. The first floor level however was not planned to contain art, and hence, has a ceiling set at 9' (2.74 m) tall. Galleries on floors 2, 3, and 4 all possess 12' (3.66 m) or greater height ceilings. An existing at grade level entrance into the lobby of the gallery building facing Wrightwood Avenue was re-used. The original extant entrance possessed a fairly grand carved limestone-detailed entrance topped with a triangular pediment. However the original doorway itself was fairly low; the agreed upon solution was to raise the header about one foot (30.48 cm). This original at-grade front (public) entrance proved to provide convenient ADA-compliant wheelchair access into the building. A new passenger elevator provides vertical access to all four levels plus a new basement. As mentioned, an elevated first floor level is situated co-planar with the corollary first floor of the adjacent residence. A monumental reinforced concrete vertical 'fin' supports cantilevered reinforced concrete staircase, which rises in the north-facing atrium, connecting levels one, two and three. The fourth floor art gallery is reachable via passenger elevator, or two east-side emergency fire-egress staircases, as proscribed by code.

2. Permanency and Expected Live Loads

The desire for long-term structural fidelity was paramount in this project, as it is in most buildings. However, the particular time frame envisioned was to create a base structure that would last in excess of 300 years, like that of the Venetian Dogana. The live-load requirement for this building was pre-determined by the client at 300 pounds per square foot (14.36 kN per square meter)! This high quantity was not to ready the structure for any particular large, dense and extraordinarily heavy artwork or sculpture—but instead, to guarantee some degree of longevity and permanence due to the 'heaviness' of the stalwart structure. Any pre-meditated destructive act in the distant future, it is wished, would be rendered economically un-viable. Note: a typical art gallery space would factor in live loads at about only one-third the performance rating of this building, that being around 100 pounds/ft^2 (4.78 kN/m^2).

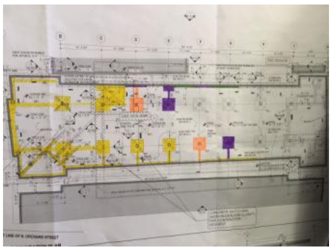

Figure 2. Plan showing pile clusters, highlighted as installation progressed.

The Chicago office of Thornton Tomasetti served as the structural engineer for this project and was immediately contracted to meet with a representative (Mr. Masataka Yano) from Ando's office in order to devise a viable structural grid. An elegant double set of eight bays, on about a 20' (6.1 m) grid, marching from North to South, through the length of the structure, created a basic support framework for the new gallery building. A traditional (typically early twentieth-century industrial or factory) reinforced concrete pan-joist construction method was chosen for economically providing uniform heavy-load-bearing capacities with no post-tension (P.T.) cables in the floor (however two major unequal-length skylight-roof beams do contain an asymmetrical quantity of P.T. cables; these cables and the thermally-separated cantilevered roof structure are examined in a separate investigative paper by this author). It must be noted that the one-way reinforced concrete pan-joist floor slab structural system has been in use for industrial buildings carrying extraordinarily heavy floor loads for over a century; this system was not especially re-invented for this project. Its application however came as a very structurally efficient method by which to solve the live-weight floor load requirement. The pan-joist system acquired such a moniker through the incorporation of re-usable upside-down U-shaped sheet metal formwork pieces, called 'pans.' These pans create a large-gauge ribbed hollow 'void,' 2'-6" [76.2 cm] wide x 1' [30.48 cm] deep, stretching the length of a full bay—in most cases approximately 19' [5.8 m].

Figure 3. One-way pan-joist construction showing reinforcement bars.

3. Reinforcing the Existing Footing

Aforementioned extant masonry perimeter walls were constructed of three-wythe thick (equivalent in total to 12" or 30.48 cm) Chicago common brick, which is typically a variegated beige color. This 80-some year old wall, un-insulated, would in deed play a major role in providing bearing strength for the new gallery building. However, in order to do this, its existing un-reinforced concrete, spread-type footings, extending less than 6 feet (1.83 meters) deep, needed to be reinforced. Three major reasons existed for this reinforcement: a) Extant footings could only bear 3,500 pounds/square foot (167.5 kN/m^2) [3], and b) The requirement for a deeper, fully-functional basement to contain some mechanical equipment necessitated under-cutting the old foundations, and c) The excavation work for the new, deeper gallery building basement was adjacent to an 1880s row house (to the east), which was situated atop an old and potentially fragile ruble stone foundation.

GEI (Geotechnical Environmental and Water Resources Engineering) of Chicago were contracted to investigate, via numerous soil-bore samples, the composition of the sub-surface soil conditions. Chicago, whose downtown core is a well-known home to many of America's once world's-tallest skyscrapers, is a metropolis built upon a thick swath of long-compacted wet sand, inundated by the fresh water of adjacent Lake Michigan. The results of analysis of the drill samples indicated an elevated underground ridge of 'Niagara Limestone' existing 38'~43' feet (11.58~13.1 meters) below grade, which was, from their experience, a full 20' (6 meters) shallower than elsewhere in the city.[4] This was fine news, for it meant that shallower rock-socketed micropiles could be used in the creation of the sixteen main bearing pile clusters.

Figure 4. Hydraulic drilling rig installing a set of micropiles.

4. Perimeter Improvements

The elongated I-shape of the existing building measuring 174’ linear feet (53 meters) at it maximum length, possessed a perimeter of 474.5 feet (144.6 m) of unreinforced concrete footings, which necessitated the introduction of 170 bracing push piles (also sometimes referred to as jack-piles or push piers). About two-thirds of which were configured in pairs, connected to brackets positioned on both sides of the original concrete foundation wall just above the footing. Each push pile consisted of a 4” (10.16 cm) diameter hollow pipe, inserted through the wet sand about 40’ (12.2 m), with a 1” (2.54 cm) reinforcing bar down the center, which lastly was grout-filled. This near-palisade of push piles (spaced on average 3.5 feet apart, or 1.067 meters), in combination with a new basement interior reinforced concrete wall, comprised the new perimeter footing system, able to bear the weight of this extremely heavy structure. However, it could not immediately be installed on the northeastern-most corner of the building due to the close proximity, (varying 6” to 3’, 15.24 cm to 0.91 m) of an existing fragile 1880s masonry structure resting upon its original unreinforced, loosely- mortared ruble stone foundation.

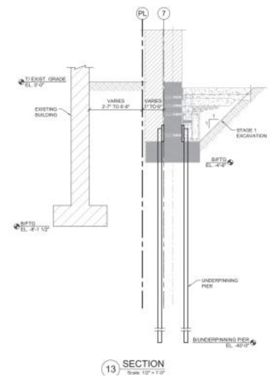

Figure 5. Push-pile section drawing, bracing existing unreinforced foundation. (Diehm & Laverack, GEI Consultants, 26 June 2014.[5])

The solution which appeased the neighbor’s exacerbated fears of (unlikely) basement wall cave-ins (failure or collapse), was the introduction of a self-curing grout injected in successive underground vertical cylinders, about 24” diameter x 7’ deep (61 cm x 2.1 m). Commonly referred in the industry as ‘chemical grout,’ a pre-ordained slurry mixture of cement, sand, water and bonding add-mixtures (enabling submerged, under-water curing or setting to take place quickly; hence the alternative term ‘jet grout’), is injected at incredibly high pressure into wet sand located beneath the apartment building’s old footings, and adjacent to the neighbor’s rubble stone foundation walls. After hardening, this injected grout forms a sort of load-bearing palisade of intersecting tubes beneath the existing footings. Time consuming as this was, it was a stipulated requirement by the governing municipal body in Chicago, known by the aptly arcane and intimidating name: *‘The Bureau of the Underground.’*

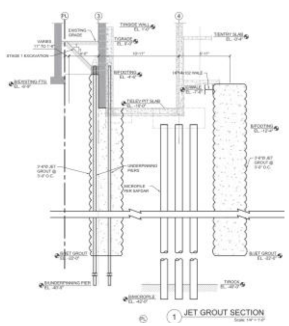

Figure 6. Injecting cylinders of chemical (jet) grout (drawn as bubbles).

(Diehm & Laverack, GEI Consultants, 26 June 2014.[6])

Once the chemical grout had cured underground, the wet sand comprising the old basement floor could be excavated, and parts of the hardened chemical grout could be chipped away, piecemeal. Secondarily, new push piles could then be safely inserted into place. This complex choreography of equipment and manpower fortunately only occurred on the easternmost side of the building, due to the close adjacency of the neighbor's foundations. Had their delicate nineteenth-century structures not been present, conventional gradually-sloping inclined earth-cut planes would have been allowed to be excavated (preventing any risk of soil cave-in) for this relatively shallow basement excavation. 'Over-kill' is a common colloquial term which could be applied to this particular segment of construction, due to the uniquely-needy and overly-litigious nature of well-resourced entities in Lincoln Park, Chicago.

The aforementioned underground Niagara Limestone ledge comprises 'geologically stable bedrock' in this area, and has been documented as varying in thickness from 240 to 425 feet (73.1~129.5 meters) thick (beneath the surface sand layer)[7]; this is what the entire building is effectively resting upon. This weight is transferred through a series of eight pairs of pile caps. Each 8' square (2.43 m^2) pile cap is comprised of the tops of five rock-socketed micropiles, hydro-jet drilled 38 to 43-feet deep (11.58~13.1 meters) to reach the limestone bedrock. The ends were subterraneanly drilled about 3' (1 m) into the bedrock. The hollow steel micropiles, after hydro-jet drilling, had a 1" (2.54 cm) rebar inserted into their full length, and then were solidly filled via a pressure-grout method, with neat cement grout with a typical compressive strength of 4,000 to 5,000 psi (281~351 kg/cm^2).[8] Hayward Baker of Roselle, Illinois, possessed the hydraulic drilling equipment and skilled manpower to complete this formidable task.

Technical specifications for the micropile pipe sections called for either new billet steel or 'mill secondary' steel. Recycled steel pipe for micropiles was declared not code compliant.[9] 5.5-inch (13.97 cm) outer dimeter rock socketed micropiles were installed, each yielding 130 kips (58 metric Tonnes) vertical compression capacity.[10] The outer annulus between the pile and the bore hole are filled with non-structural cement grout. The terminus of the pile was requested to be anchored a minimum of one foot (30.48 cm) deep into solid bedrock "to minimize the potential for shear failure along natural bedding planes."[11]. The cluster of five piles yielded a combined bearing capacity of 650 kips (290.2 Tonnes).[12]. This is an incredibly tough foundation system.

The actual act of steel placement within an existing building proved to confront the steel fabricator (Scott Steel of Crown Point, Indiana) and installing sub-contractor (4 S Erection, a Union job shop, also of Crown Point) with a whole host of problematic positioning issues to solve, as well as the luxury of working within an existing structure which conveniently supported the manpower. Steel columns and beams, once delivered to the job site, were placed upon low-lying dollies (low-bed carts) and wheeled through holes hammered through the building's few remaining masonry non-bearing fire-break walls. Vertical column pieces were not easily dropped in by crane due to the existence of specimen trees worthy of preservation at the front (north) street façade as well as 'constant-on' exposed high-voltage electric power lines present in the alley. Hence, most all steel was delivered through the alley at grade-level and threaded through a maze of internal floor and ceiling openings. The existing old hardwood floor atop a wood-joist system provided enough support for individual steel pieces and steelworkers. A visually delightful hybrid condition developed within the building, as the steel frame grew up within (and through) the existing wood floor joist and brick wall building; ultimately extending up past the original roof to form elements of the new fourth floor substructure.

In total, 220 U.S. (short) tons (199.58 Tonnes) of steel beams and columns were delivered to the site. All steel used on this job was manufactured in the USA. Additionally, 165.5 U.S. (short) tons (150.139 Tonnes) of reinforcing steel[13] were delivered and fit for this project. The largest size was US#10 (Metric #32)! Gerdau Ameristeel of Belvedere, Illinois performed the shaping and installing of all the reinforcing rods (commonly called "rebar"); it came from Knoxsville, Tennessee.[14] This includes complete rebar of a variety of sizes for columns, a one-way pan-joist floor slab support system, two full-height structural shear walls, architectural (visible) walls and structural (hidden) walls, along with an exposed exterior ceiling system (including both cantilevered areas and reinforcement within the two giant post-tensioned ceiling-skylight beams). To put these amounts in perspective, a common engineering practice is to calculate the average amount of structural steel product used in a building per unit floor area, to determine the efficiency of the structure. Typical low-rise buildings may have 8 pounds of steel/square foot (39 kg/m^2). This building contains 20.8 pounds of steel/square foot (101.5 kg/m^2), a 2.6-fold increase over an 'average building.'

The specifications for quality, strength and type of steel installed on this project was all made by structural engineers at Thornton Tomasetti's Chicago office. As per typical, American Society for Testing and Materials (ASTM) standards were used; A992 carbon steel alloy was specified for the steel columns and beams, which possesses a tensile strength of 50 ksi (344.7 MPa). A992 steel "has been the standard for Wide Flange shapes since the 1990s. Other shapes are still A36 (36 ksi {248 MPa}) steel, such as angles and channels."[15] As aforementioned, local American Union labor, sourced from Illinois and the neighboring state to the east, Indiana, was utilized not only for fabricating and installing the steel, but for the near-entire assembly of this building. This being a 100% private self-funded project actually had no requirement to hire Union labor; however it was determined the best course of action to take, in order to produce this quality of a building in the city of Chicago within Cook County, Illinois.

Upon completion of the steel frame and supernumerary temporary diagonal support struts, demolition of the remainder of the original apartment building's masonry fire-break walls and wood floor joists commenced. This act dramatically unveiled a solitary space-frame-like armature: the new three-dimensional steel grid was left alone, visually stunning, supporting the old exterior perimeter masonry carapace. Now the 'only' remaining part was to frame and support formwork for floor slabs, install copious amounts of rebar, pour concrete, and eventually form both structural and architectural concrete floors and walls.

Figure 7. A new steel structural frame, un-veiled as demolition proceeds.

Unlike warm-weather sub-tropical conditions found in much of Asia, the climate of Chicago exerts upon a building what some may find to be unusually extreme and variable climatic conditions. The HVAC-R (Heating, Ventilation, Air-Conditioning and Refrigeration) mechanical engineer, AEI (Affiliated Engineers Incorporated) initially designed the building's systems to perform with exterior ambient temperature extremes ranging from -27° Fahrenheit (-33° Celsius) in the winter to 106° F (41° C) in the summer,[16] a swing of 133 degrees Fahrenheit (56° Celsius) in total! While the air handling system's performance, equipment, and delivery methodologies merit a separate investigation, such climatic extremes are discussed here since they affected *how* and *why* various building elements were thermally separated from one another.

5. Thermal Breaks in Structural Steel

It has been a long-standing tradition in commercial glass window frame manufacturing to thermally separate the two pieces of an aluminum frame (interior and exterior) with a low-thermal

conducting polyamide resin (1,000-times less conductive than the commonly used bauxite ore-based frame).[17] Hence, the two pieces of aluminum comprising a window frame are physically not touching, yet still structurally able to hold the weight of an Insulated Glazing Unit (IGU, made by Viracon Glass in Owatonna, Minnesota) and the varying intense wind pressure and suction loads placed on the glass pane. Hence the thermal separation of the window frame prevents the high thermal-conducting nature of the non-ferrous metal (aluminum) from bringing (via conduction) excess heat from a sun-baked exterior into the air-conditioned interior spaces of the building in the summer. In a reverse seasonal situation, the thermal break prevents warm, moist interior air from condensing and freezing on the cold aluminum frame in the winter. This water eventually melts causing water stains, marring interior finishes and altering interior humidity levels. The custom frames for all windows and skylights were post-extrusion fabricated in Elmhurst, Illinois by Glass Solutions, Inc. on CNC-controlled robotic machines. They were all pre-configured to receive 1-15/16" (49 mm) triple-glazed IGUs.
In a similar vein, the tubular structural steel members embedded into the perimeter masonry walls were treated the same way. Any chance of condensation spells not only ruinous aesthetics, but also compromises the insulation system. Condensate water could also cause slow but steady rusting and erosion of the steel supporting structural system attaching the aluminum frames to the building's reinforced concrete structure.

Although this project has been henceforth discussed as a new four-story gallery building, one particular area contains a dramatic three-story void. This is the front (north facing) entry atrium. A 42'-1" tall space (12.8 meters) immediately opens up an incredible volume to the visitor, framing a diagonally-positioned reinforced cantilevered concrete staircase. Due to the nature of this hollow area within the building, being surrounded on two major sides with no lateral support, these 88-year old three-wythe thick masonry bearing walls needed additional bracing in order to overcome adverse exterior wind and buckling forces. This was accomplished through the addition of several horizontal tubular steel beams, anchored to each other and to massive vertical steel bracing columns embedded into purposefully-located (read: hidden) corners in the existing 'break-front'-style façade. The addition of concealed linear LED lights features what now appears like a framed brick proscenium (flat) archway. All of this is the result of Tadao Ando and the structural engineer working in tandem to achieve the intentionally directed result.
The aforementioned horizontal tubular steel braces were embedded into the existing three-wythe thick masonry bearing walls through the removal of several vertical courses of the inner two wythes of bearing brick, effectively transferring the weight of the vertically progressing masonry wall and concomitant elemental (wind) forces onto the galvanized steel member. These horizontal hollow tubular tin-galvanized steel beams were anchored perpendicular to massive vertical steel columns. However, conventional steel plates welded to the wide flanges of the columns were not employed, since the column was situated on the interior of the building, beyond the thermal envelope (which entailed a closed-cell spray foam surface-applied insulation). Thermal separation was proscribed as the solution to prevent a thermal short-circuit in the bearing structure.
This insulation, which dries and hardens in a yellow color, is commonly used in Chicago. It is a polyurethane product, known as Covestro Bayseal CC X-brand (known as 'Yellow Drum'), and achieves an insulating R-value of 24 at nominally 3.5 inches of application (8.9 cm). It provides both a thermal envelope insulating the building and a vapor barrier, preventing the exchange of moisture between the interior and exterior. The construction administration architect, Vinci Hamp, rejected a different proposed spray-foam insulation, Touch 'n Seal, for although it met insulating value requirements, it allowed too much vapor permeance for the specifications set for this museum project.[18]

Figure 8. An array of structural thermal breaks separating steel members.

In a warm, moist museum environment (whose interior climate control system was specified to match standards set forth by the Smithsonian Institution in Washington, DC),[19] humidity transfer from the moist interior through the exterior walls towards the drier exterior, is always a concern, and amplified by Chicago's variable winter weather.

Such failures of a building's exterior envelope would lead to internal wall condensation conditions, which in turn, often contribute to exponential mold and fungal growth; hence a 'sick building syndrome' which is unhealthy and unsafe for occupants, and in this case, in particular, downright dangerous for artwork contained within.

The solution for how to structurally bond steel elements to one another, satisfying load transfer requirements proscribed by the structural engineer, while simultaneously pleasing the architect and mechanical engineer with a thermally-isolated building envelope has been achieved in this project through the assistance of a patented German-made product. Schöck Isokorb, a product made in Baden-Baden, Germany,[20] contains a combination of high strength but low-thermal-conducting structural stainless steel elements (threaded rods) combined with pre-formed, compressed open-cell insulating polystyrene material.

Figure 9. Structural thermal break device detail image.

These 'structural' thermal-breaks were utilized in the three-story atrium area where two main supporting columns, due to their dimensional heft, and the architect's vision for them to blend into the newly re-clad brick interior walls, had to be placed within the interior boundary of the building. If they were encased within the conventional closed-cell spray foam insulation, the masonry veneer wall would have had to be positioned proud of the rest of the wall, voiding the original design ethos for the space. Ando's design called for a smooth transition (monumental flat brick wall) to the break-front portion of the atrium; not an ungainly pronounced pair of protruding pilasters. The design team accomplished his vision, and fully supported and exceptionally heavy building constructed to bear even greater (live) loads within.

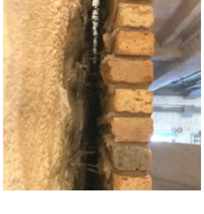

Figure 10. Section through interior masonry wall showing 'veneer' brick.

Conclusion

In conclusion, through the use of these now-hidden structural thermal breaks, the architect, Tadao Ando, and his vision, was preserved, while also achieving proscribed thermal performance goals for insulating the building's envelope. During Chicago's cold and dry winters, warm moist air remains in the interior portion of the building, keeping art work and artifacts preserved within a narrow temperature and humidity range [21], with little fluctuation. There remains no risk that condensation will occur on the inside face of the internal masonry bearing brick wall, for this face is never exposed to the atmosphere, being encapsulated behind spray-applied closed-cell foam insulation. All interior non-bearing partitions, be it veneer brick (of 1 wythe thick) or gypsum board (layered upon plywood blocking, anchored to light-gauge non-bearing steel studs) do *not* touch either the inside face of the insulation nor any concrete-clad steel bearing elements. Instead, all elements are successfully thermally separated and no adverse thermal-bridging occurs in this new private art, architecture and design gallery building called "Wrightwood 659" [22] in Chicago, Illinois.

Acknowledgements

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[22] Owner (refer to text for name). Naming convention "Wrightwood 659" decided / decreed upon the eighth floor roof-top terrace at the Venezia Bauer Hotel. Venice, Italy. 20 June, 2018.