By C.C. Sullivan, Contributing Editor

FOR GLASS OPENINGS, HOW BIG IS TOO BIG?

PHOTO BY RENE MUELLER, COURTESY SEELE

A production facility for the glass manufacturer seele offers a glimpse of jumbo size panel fabrication from offices set behind a full-height interior glass partition.

LEARNING OBJECTIVES

After reading this article, you should be able to:

- **DESCRIBE the trends leading to large glass panel sizes and the design and implementation strategies to ensure successful project delivery and performance.**
- **DISCUSS the qualitative and quantitative performance considerations for building façades and interior spaces when using larger glass exposures or glass interior walls.**
- **LIST considerations for the use of advanced glazing technologies, in particular fire-rated glass and vacuum-insulated glass (VIG).**
- **EXPLAIN how the use of interior glass partitions, VIG, structural glass, and other glass elements have solved key building design requirements.**

Advances in glazing materials and glass building systems offer a seemingly unlimited horizon for not only glass performance, but also for the size and extent of these light, transparent forms. Both for enclosures and for indoor environments, novel products and assemblies allow for more glass and less opaque structure—often in places that previously limited their use.

For exterior systems, jumbo glass and high-span curtain walls are pushing the limits of monolithic panel sizes seen in recent years. Many experts credit Apple's supermodern, glass-enclosed stores for igniting this trend, says John Ivanoff, Associate Principal, Façades with multidisciplinary consultancy Buro Happold. "Apple had the right budget to create stores with floor-to ceiling glass and structural glass stairs, and their building teams partnered with manufacturers such as sedak in Germany, known for bending and strengthening panels, as well as NorthGlass in China, two of the largest suppliers for extremely oversized glass," says Ivanoff.

From Apple's influential, over-the-top storefront conditions to today's widespread jumbo applications, some fundamental challenges, from fabrication to installation, restrict the dimensions of glass openings. "While the length of the glass panels can continue to grow, the furnaces used tend to limit possible widths and the ability to curve larger panels," says Ivanoff, noting that today's largest glazed spans exceed 72 feet (22 meters) in length and 13.75 feet (4.2 meters) in width. "So, it's gotten a bit crazy over the years," he adds.

Other influential works include Apple's headquarters in Cupertino, Calif., with its meticulously crafted, curved glass panels up to 47 feet long and 10 feet tall, with weights exceeding three tons per unit. Produced by glass manufacturers sedak and its sister company seele, the Foster + Partners-designed building employs more than 3,000 sheets, including 872 cold-bent panels of safety glass, cured five at a time in an extra-large furnace built specifically for the task.

A newer project, the 39-story recladding of 660 Fifth Avenue designed by Kohn Pedersen Fox and installed by Island Exterior Fabricators, replaces a memorable mid-century patterned cladding (by architects Carson & Lundin) with the largest class curtain wall openings possible for the structure, utilizing the full span between each perimeter column.

According to seasoned design and construction firms, unit prices for jumbo glass panels present less of an issue today. Instead, it's the cost of installing the panels that far outweighs materials budgets in terms of project impact. Building teams are challenged in identifying competent specialty contractors, first, and then in evaluating logistics for delivering the massive panels to constrained urban jobsites. The weight of the glass is also quite problematic, both in erection and in designs for today's applications favoring fewer mullions and less structure.

On the other hand, supply is strong. "More suppliers are available to provide large glass units than in the past," says David Frey, FAIA, LEED AP BD+C, Technical Principal with HOK. "As availability has increased, costs have come down, so architects are more comfortable designing façades with larger glass sizes."

PHOTOS FROM LEFT BY TREVOR MEIN AND ANDREW MEREDITH; COURTESY LANDINI ASSOCIATES

Experimenting with larger panel sizes, more tint colors, and varied shapes, storefronts for retailers such as McDonald's use extensive glass façades for their brand flagships in New York City, left, and Sydney Airport.

DESIGN OBSTACLES FOR EXPANSIVE GLASS

That said, Frey offers some words of guidance for architects and building teams considering larger glass sizes: "First, modern energy codes make it more and more challenging to achieve greater than 50 percent vision glass on a building. Consequently, meeting the U-value of an assembly is more difficult," he says, alluding to the thermal transmittance of, or rate of heat transfer through, a building material or assembly.

Frey also points to the importance of window-to-wall ratio (WWR) analysis, which—in conjunction with preliminary energy modeling—now "occurs very early in the design phases." In addition, structural engineers and other façade designers must collaborate closely to address tolerances and critical variables such as elastic and inelastic seismic movement, he says, which allow for the minimum level of ductility structures require in some earthquake-prone jurisdictions.

WWR and U-value analyses also help building teams address questions about the relative benefits of daylighting and thermal gain through larger glazed openings, says Antonia Walker, Project Architect and Manager with Body Lawson Associates Architects and Planners (BLA). Natural light benefits occupant health and can reduce heating costs, but it also raises HVAC

RENDERINGS COURTESY BROOKFIELD PROPERTIES

In reconstruction projects, many older curtain walls are being replaced by dramatically increased glass opening sizes, as at KPF's redesign of 660 Fifth Avenue in New York City, where glass panels span from column to column.

operations costs in the cooling season, she notes. In her firm's affordable housing developments, Walker's design teams are pushing for larger openings and more apertures, such as at the Peninsula, a new, 740-unit mixed-use campus which just completed its first residential tower. The project features 164 units on 14 stories wrapped in a textural brick façade in the Bronx, N.Y., designed by WXY architecture + urban design and BLA.

Studying the U-values and completing energy calculations, BLA's Walker and WXY Senior Associate Tom Offord worked to maximize window area; fortunately, the best mechanical solution did not use packaged terminal air-conditioning units but instead a ductless, variable-refrigerant-flow (VRF) system. With no grilles needed in the openings, the uninterrupted full-height windows employ double-glazed IGUs with a low-emissivity coating and argon fill set in polyvinyl chloride (PVC) window frames—a spec that also benefits interior acoustics for residents living adjacent to an industrial area. "The noise factor was a big consideration," says Walker, "and the windows work well, even on the third floor."

In a departure for affordable housing, these full-height windows flood public interior zones with maximum daylighting, too, "serving as a reorientation device and as a way to passively introduce natural light in hallways, which otherwise would rarely have natural light," adds Victor Body-Lawson, FAIA, Founding Principal of BLA. Adding to the natural illumination theme, WXY and BLA located circular fire-rated windows in entrance doors to the building's fire stairs, all at an ideal height for visibility for children and wheelchair users.

The portholes offer a glimpse at another growing trend: the expanding use of fire-rated products into building enclosures and, even more prevalent, in interior spaces. From stairwell enclosures where glass walls help entice occupants to use the stairs, to elevator enclosures and other vertical shafts, larger wall areas with fire-protective glass are being seen in entry zones, areas of egress, and surrounding atriums for public gathering.

FIRE-PROTECTIVE, RESISTIVE SOLUTIONS

Increased use of fire-protective glazings also helps optimize daylight illuminated, open interiors. Those specialized glass assemblies can incorporate basically any high-performance, low-e, dynamic glass or sun control devices without impacting their capacity for fire ratings, says Tim Nass, a Vice President and fire glass expert with Safti First. "Fire protective products are considered protected openings by code, meaning they compartmentalize the visual elements of a fire—smoke and flames—but do not address the issue of radiant energy or heat generated by a fire," says Nass. By contrast, fire-resistive assemblies are essentially considered walls: "It is important to understand that the code does not distinguish between transparent and opaque. Nonetheless, fire-resistive assemblies compartmentalize visual elements of fire while also stopping the transfer of radiant energy or heat generated," he adds.

In this way, building teams no longer consider transparent but fire-resistive partitions as "openings." In compliance with the key standard ASTM E119, these glass separations that control heat flux are walls, pure and simple. "In situations where two buildings are close to adjacent property lines, fire-rated glass provides opportunities for increased vision glass in proximity to that property line," says HOK's Frey. "Fire-rated structural glass floors can also give the appearance of visual connectivity vertically between floors."

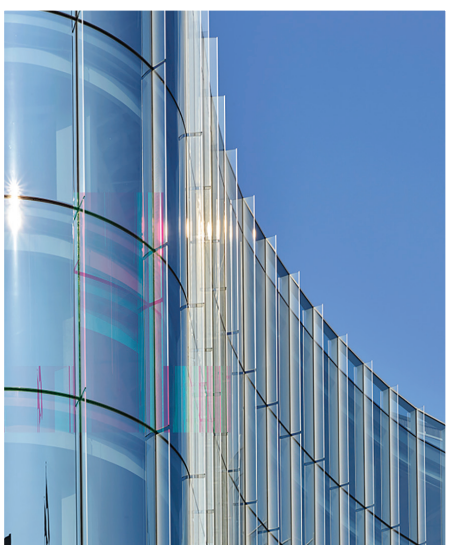
Other building teams find they are expanding their uses of interior storefront, says Lauren LoPresti, NCIDQ, Interior Designer with The Architectural Team, known as TAT. "We've looked at interior storefront and using more glass, which is an effective and impactful way to separate spaces and separate functions without totally enclosing them." Examples include the adaptive reuse of Cliftex Mills in New Bedford, Mass., where the historic, 115-year-old brick building with river views is being renovated into multifamily housing for 55-plus active seniors.

"The mill building has long, wide corridors, and the client envisaged amenity spaces off the corridors while still maintaining clear sight lines throughout from the front to the back of the circulation volume," says TAT's LoPresti. "To optimize the layout for both occupant circulation and functionality of the amenity zones, on three levels we used a storefront with glass above an opaque three-foot base."

INTERIOR GLASS, TRENDING UP

Interior glazing is described as "extremely valuable" for building design, as it allows layouts that separate certain functions and spaces while still maintaining a desirable degree of visibility between the two functions, says TAT's Scott E. Maenpaa, a Project Manager. Yet, interior glass partitions may afford *too much* visibility in certain applications, he adds. "To fix this, we try to ensure none of our glass sections are too large, since oversize pieces can be more prone to shattering in transportation or too difficult for installers to handle," says Maenpaa. "Also, we often specify a frosted or tinted glass type, such as a glass film, or we try to be creative with the mullion applications so we have smaller areas of glass where privacy is most desirable."

Among those solutions are electrochromic glass and "smart glazing" products that adapt to changing conditions. "For south-facing building façades," says HOK's Frey, "large glass expansive walls—in airport boarding areas, for example—electrochromic glass is a very effective method of controlling daylight and increasing occupant comfort."



With more suppliers available for large glass units, costs have dropped, leading to more façades with larger, full-height glass openings, as at the HOK-designed 1771 N Street NW in Washington, D.C., with renovation installation by Pioneer Glazing.

One challenge with these electronically controlled openings, says Buro Happold's Ivanoff, is working to avoid their getting value engineered out of the design. "On top of that, electrochromic technology changes about every two years, in terms of their appearance or switching time, for example, which improves significantly year after year. Some systems have the ability to connect to an app, like a smartphone, which is fantastic." Yet at the scale of a building, leaving the owner or developer with what may be considered an outdated product speaks to the challenge of adaptability of the electrochromic glazings. They may also present challenges for replacement of the smart IGUs in an effort to adapt to changes in technology. Interior glass replacements, on the other hand, are easier and tend to be less costly and disruptive.

Reflecting the fast pace of technological advances, product makers are changing as well. French glass giant Saint-Gobain acquired electrochromics innovator SageGlass in 2012, for example, with large-scale fabrication capabilities in Minnesota. The company View Glass, with its vaunted machine-learning technology for tinting control, announced a merger last year with a financial backer, effectively going public. Clearly, the appetite for applications of super-clear glass that can adapt for varying conditions—on different elevations and different times of day—is seen as a growth industry. Ivanoff and Body-Lawson also point to project examples where electrochromics eliminate façade components such as sunshades or interior solar control while still resolving issues of glare and thermal comfort for occupants.

Smart glazings are also finding applications on storefronts and glass entry areas, where changing conditions and visibility needs benefit from their unique control. These ground-floor solutions often serve as testbeds for the newest glass design ideas, too, whether for jumbo glass panels, fire-rated separations, or unique glass aesthetics.

STOREFRONTS AS TESTBEDS

For projects such as New York City's 111 West 57th Street, for example, building teams are employing the largest glass panels with minimal visible mullions and frames for their lowest floors, including retail spaces. Public spaces like Boston's The Exchange designed by Perkins and Will and Mikyoung Kim Design create new "living rooms" that welcome the public into steel-framed and glass-enclosed atriums full of retail and hospitality offerings. Built by Turner, the prismatic form with angled glass walls trumpets the availability of new amenities in the city's bustling Financial District.

Retail storefronts such as McDonald's in New York City's Times Square, where three levels of floor-to-ceiling insulating glass create dramatic views outdoors while completely muffling noise and protecting against heat gain. With architecture by Progressive AE and design by Landini Associates, which has created McDonald's flagships in dozens of cities, the three-story glass-fin curtain wall erected by Schimenti Construction projects four feet beyond the existing building structure. Inside, natural daylighting is supplemented by dynamic, integrated lighting controls with dramatic day and night presets.

Landini Associates employed massive glass façades and bright red glazing for other flagships in Tianjin, China, and Brisbane, Australia. Their mullionless yellow

glass panels for the McDonald's "Sky Kitchen" at Sydney Airport transform a kitchen enclosure into "a visible signage beacon and showcase of team and process." It's ranked as one of *Vogue Australia*'s 35 "most beautiful restaurants worth visiting for their design."

Another glass innovation seeing more storefront and similar applications is vacuum-insulated glass, known as VIG. While relatively new, the highly insulating yet lightweight glass units have been used for a 2006 greenhouse project and, by 2011, for a large-scale library. More recently, Boulder Community Health's West Medical Building incorporated hybrid vacuum-insulated glass, or HVIG, windows to improve year-round energy efficiency and comfort by reducing thermal transmittance and convection at its storefront openings and punched windows. In contrast to the U-value of 0.29 for low-e insulated glass, the HVIG panels specified by design firm Boulder Associates tested to a U-value of 0.071 on the north façade and 0.064 on the others, cutting visible light transmittance (VLT) by 13 percent, which perceptibly cuts glare through its façades with higher solar radiation.

VARIED APPLICATIONS AND GLASS SOLUTIONS

VIG glass retrofits can benefit older buildings, says Buro Happold's Ivanoff, where glass units must have a thinner profile of glass but still deliver a higher performing U-value. "This application is trending now, as the construction industry and real estate owners are considering triple-glazed windows, but they are very heavy compared to normal insulated glass units, and now VIG, which is a positive change coming in the future," he says. Investing in the promise of VIG are companies like Vitro Architectural Glass, which last year acquired North American rights to sell tempered VIG products developed by LandGlass and VIG Technologies.

Another trending design concept is structural glass, including for glass stairs and floors—exciting "horizontal applications," says Safti First's Nass. "Fire-rated floors have a dramatic effect on any building's design and can be a unique way of bringing in natural light from above." Yet he cautions that these challenging applications may encounter restrictions on glass size, floor loading, and installation options. "We have designed a floor that incorporates the walkable surface directly into the fire-resistive glass, which allows the glazier to install the floor from above using a crane or glass manipulator." Other systems available rely on installing smaller pieces, adding to the challenge. Yet many can be customized with graphics and are made with nonskid, ready-to-walk surfaces.

For varied building types, larger glass expanses and more application types are the key to successful building solutions, says Rockland Berg, AIA, NCARB, SAGE, ASHA, Principal of design firm three. "For senior living communities, we are responding to a market preference for larger balconies and full-height windows to bring in more natural daylight," says Berg. Yet these settings also require "screening strategies" that reinforce healthy connections to nature and make spaces feel larger—balconies doubling as outdoor "great rooms," for example, adds Berg: "Making the most of the outdoors inspires residents to be more active and engaged."

For hospitality projects, Berg views glass as central to the array of improved amenities expected by patrons. The Cap Rock Members Club complex in Horseshoe Bay, Texas, designed by three, offers members a southwest orientation with extensive glazed zones to maximize sunset viewing in the clubhouse restaurant and lounge. Designed with slender roof openings, gently angled floor-to-ceiling windows, and modern glass overhead doors within the façades of Texas Lueders limestone, the clubhouse draws in sunlight and scenery seemingly everywhere.+

PHOTO: CHRISTOPHER MANN

Opening to expansive views of Texas Hill Country, a new clubhouse designed by the firm three at Horseshoe Bay Resort outside of Austin incorporates slender roof openings, gently-angled floor-to-ceiling windows, and modern glass overhead doors.