Sustainable simplicity and the future of exterior wall for research and education buildings

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Abstract

Today, there is a shift towards sustainable simplicity in facades, embracing material innovations and thermal design strategies for long-term sustainability. Trends in material science and technology suggest a return to historic design thinking through advancements in materials science and engineering performance. From our collective experience as architects, we anticipate a trend towards simpler facade design compositions with vastly embedded technology and material science to highlight this façade of the future. This is particularly acute with federal and state government institutions that focus solely on their rate of return (ROI) in these long-term asset investments. Public universities are uniquely concerned about the value of building and façade expenditure that supports an environmental value without being overly ornamentation-al or self-aggrandising. The complex facades of current research, science, and institutional buildings are a unique opportunity for exploration for public institution budget investments due to of the correlation between highly controlled performance facades and the desire to provide value to institutions and their constituent budgets.

The 140-year history of the curtain wall façade provides valuable guidance on the evolution of material technology, material science, operational, and environmental considerations to suggest the future trajectory of the building enclosure – a trend towards prefabrication, increased component sizes, carbon reduction, decreased maintenance, and comprehensive cost modelling. As the historical trajectory evolves, vanity in design defers institutional design creativity, leading to a layered composition of material, technology, and aesthetics.

1. Introduction

Over the last century and a half, the façade design has oscillated between simple and complex, low-tech and high performance. In the 25 years of our practice as architects the authors witnessed the façade technology becoming progressively more materially sophisticated and constructability complex. However, the future has turned out to be simpler than the complexities suggest. Drawing from a collective experience as architects, the trend is more durable yet simpler, becoming almost more archaic in composition. This trend is particularly distinguishable in the recent buildings erected by educational and research institutions, driven by their recognition that sustainable investments enhance institutional performance while reducing maintenance and operational costs.

Tracing the history of the curtain wall through the consistent trajectory of the past 50 years, educational and research buildings offer a unique case study for predicting the trends in facades for 2040. Beyond the technical aspects, this research delves into the hidden agendas, declared goals, and actual outcomes of both owners and architects, as well as the use of environmental narratives to serve institutional vanity and commercial marketing. The facade - the "face" of the building - reveals all of this, for those who know where to look.

2. History matters

Early façade development began with the novel “suspended” façade system of Chicago’s 1895 Reliance Building, which established a unique milestone in design and building construction that brought together a revolutionary moment in the vanity of the building façade. Early material and manufacturing experiments lead to excitement in technical innovations including the 1950 essentials innovative facades of Mies’ Seagram Building and SOM’s Lever House. These mid-twentieth century constructions reflected the 'less is more' aesthetic but lacked the energy performance required in modern enclosures. Facade design at the end of the 20th century responded to vanity considerations competing against limitations in material performance by adding extra layers – layers of technology and layers of materials. Ad-hoc environmental performance assessment tools of the time also encouraged a complex response of shades, screens, cabling, and connectors that added cost and complexity while restricting maintenance needs and ultimately long-term durability.

Technical innovation transitioned into technical ornamentation, providing the backdrop for the current façade innovation and a framework for the future. Current design practices and client requirements value 'sustainable' simplicity, with material innovations and composite systems thinking. Material science innovations include prefabrication opportunities, composite materials, and thermal design strategies that promote long-term sustainability without undue layered complexity of earlier façade systems. The future of building enclosures references a heritage of innovation in curtain walls by radically advancing the design innovation through materials science and engineering performance.

With a common experience at SOM in the early 2000s, there is a collective recognition that the future of facade compositions is simpler reflecting on early career work. As building façade design leaders, the authors represent both the Owner and Architect of educational and research buildings. The research and education clients recognise that simple sustainable investment enhances institutional performance while reducing maintenance and operational costs. Current case studies will include a variety of institutional projects with facades designed for enhanced ROI’s that value public money. Today's designs promote sustainable solutions focusing on the environment and the beauty of innovation in material science, leading to the reduction of carbon while enhancing an institution’s long-term value.

3. Milestones in façade “vanity”

3.1 The Early Innovators - 1880’s

Burnham and Root established a high bar with the steel framed 1889-95 Reliance Building, integrating a system of layers of four standard sections riveted together in cantilever bays that focused on reduction in weight from earlier masonry systems. These early systems took advantage of primitive industrial mass production assembly elements with craftsman that fabricated complexity through traditional craft, timely materials, and three-dimensional shapes.

- Mass fabrication suggested ornamentation in respect to the basic design aesthetic of the day, noting that any innovation might result in technical failure.
- The kit-of-parts material modules were the prefabrication technology at the time, acknowledging that prefabrication was human scaled to the ability of the construction labourer.
- No consideration of thermal and environmental infiltration because of the lack of building science and thus of understanding in how the building provides an environmental envelope for its occupants.
- Early occupant comfort gained importance over aesthetics as single pane glass facades faded to the thermal protections that thickness in materials (falsely) provided – while reducing window sizes and reducing visibility and transparency.
- 1932 technological innovations in glass block provided daylight along with thermal protection but forgot the desire of views and visibility.
- Early insulated glass units emerged to satisfy occupant comfort at the behest of material thickness, exterior visibility and basic design aesthetics, including the thermal glass designs of Charles D. Haven’s patent of 1932.

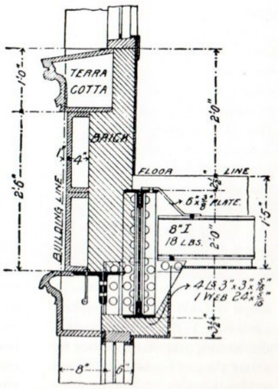

Image: Reliance Building Chicago Façade, 1889-95

Image: Reliance Building facade detail, from Cecil D. Elliott, Technics and Architecture, MIT Press, 1992

3.2 Mid-century Renaissance – 1940’s

In the early part of the 20th century material science evolved, construction techniques matured, and fabrication processes benefitted from increased size, capacity, and volume, allowing for more appropriate “building scale” fabrications. However, there was still a lack of material technology to bridge the divide between comfort and durability, especially around glass performance. Occupants and owners realized the simple storm sash provided improved thermal protection with minimal effect on transparency, visibility, and daylight. Unfortunately, the wide gap between the glass panes of storm windows allowed dirt and condensation to accumulate, thus reducing the thermal and aesthetic benefit.[1] Early Experimentation in insulated glass between 1939-1943 resulted in “Thermopane®” a prototype in material layering that proved the reliability of the new soldered metal seals. The Thermopane insulated glass of the1939-1940 Byrd Antarctic expedition was a public relations success in increasing interest in material science and technology. Notable architect, Eliel Saarinen, experimented with this innovative technology at Cranbrook Academy of Art Library (Bloomfield Hills, Michigan) correct a nagging condensation problem in 1941. All these emerging technology and fabrication techniques were of interest to other notable modern architects of the time but lacked the design flexibility and aesthetic (vanity?) desires of the frame simplicity of the early designs of the Chicago School[2].

- Boston 1949, Art Deco, John Hancock Building (Berkeley Building, Cram and Ferguson) was the first tall building to employ Insulated Glass Units (IGU) of Thermopane throughout its exterior skin including over 17,000 double-glazed units that complemented the building’s pioneering use of air conditioning in the northeast U.S.

- Chicago 1952 – The 860-880 Lake Shore Drive Apartment Towers by Mies van de Rohe considered the vanity of the “visible structural role” of the exposed artificial vertical “I” beams up the façade. The search for simplicity of “less is more” resulted in good design minus thermal performance - with less glass technology resulting in more heat and air conditioning.

- New York 1951 – The Lever House designed by Skidmore, Owings, and Merrill (SOM), imagined as a weightless dematerialization of main vertical supports, used polished, shimmering and semi reflecting glass to achieve an aesthetic of vanity, devoid of consequence. SOM worried about the technological risk in high-rises and opted not to install Libbey-Owens-Ford Glass (LOF Glass) Thermopane windows, skeptical of the 10-year warranty in the unproven welded glass seal caps of their IGU, and instead relied on another innovative technology of 1950 - air conditioning.

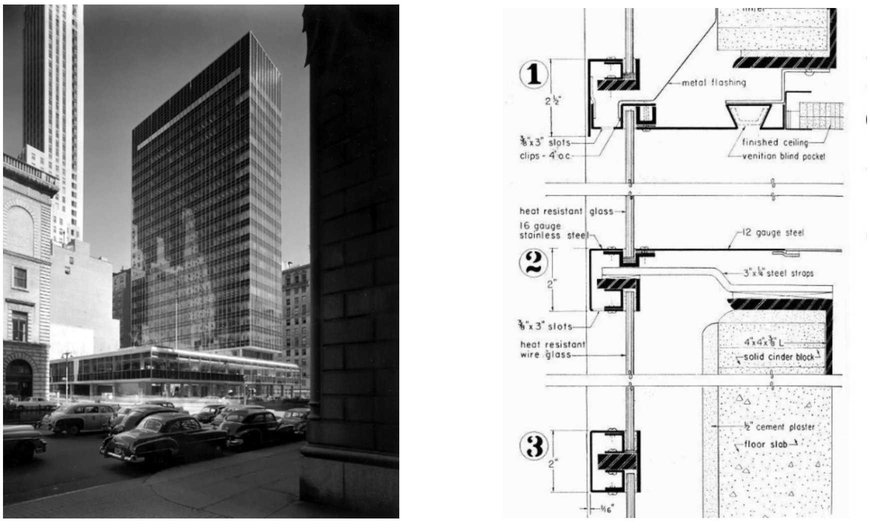

Image: Photo Esra Stoller and vertical section detail, in “Architecture of Skidmore, Owings & Merrill, 1950-1962," The Monacelli Press, 1962

3.3 Energy Crisis and the pivot of 1970’s

[1] The design aesthetic enthusiasm of the 1960’s was tamped down by the energy crisis of the 1970’s. Material and prefabrication innovations took a backseat to energy scarcity. Earlier desires of owners to deliver innovation in “high design” at lower costs resulted in all constituents paying minimal attention to the large amount of energy consumed by the building designs of the time and the lack of durability

in these inherently cheap material compositions.[3] Quickly code officials changed requirements to suggest minimum levels of insulation to meet, yet, undefined “energy budgets.”

- Niagara Falls, NY 1978 - CannonDesign in association with HOK designed the Occidental Chemical Centre, also called the Hooker Office building as an environmental response to the energy crisis. When this innovative use of glass and curtain wall technology was completed, it was considered the first modern instance of a glazed double skin facade incorporating master architect Le Corbusier’s 1930’s ideas in ventilation.[4]
- Philadelphia, 1971 - Other early innovations in reducing energy load of the 1950’s glass box, came in the form of the United Fund Building, which earned praise from the energy conscious innovators of the time. Architect Romaldo Giurgola described this building as “a glass box surrounded by concrete sunscreens where they are needed,” suggesting that the site and placement of the building do matter in improving the occupant experience.

3.4 The 1990’s - Layered reaction

Growing energy costs and environmental concerns in Europe in the 1990s led to developments in facade construction aimed at preventing heat transfer through the envelope by separating the facade into multiple layers introducing venting in the resulting cavity. A new version of the layering of the sash window? Simultaneously it became possible to achieve an increased transparency of each layer by replacing the primary facade structure (load bearing posts and mullions) with cable support structures and secondary (glazing frame or mounting structure) with “frameless” structural glazing. Obligatory in many European countries, exterior solar shading was often concealed behind the veneer of smooth structural glazing. Cavity venting and solar protection became automated, driven by new technology in temperature and solar sensors, as Jean Nouvel’s 1987 Arab World Institute in Paris thoughtfully demonstrated. Elaborate custom vanity in facade details generated a highly photogenic, memorable image of the buildings. The marketing impact, however, outperformed the moderate advantages achieved in energy performance of the buildings, that relied on transistors and technology to perform. The diaphragms of the Arab World Institute continued to be photographed long after many had stopped opening and closing in response to the sun's movements, the resulting benefits displaced by technological shortcomings.

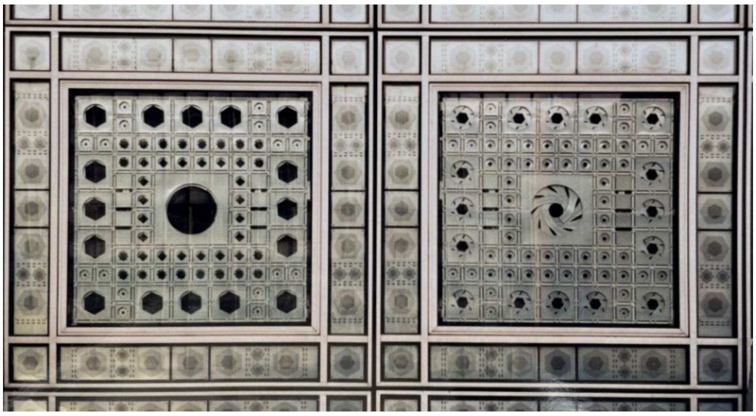

Image: Arab World Institute in Paris with non-functioning solar diaphragms, photographed by A. Koshelev in 1995.

Bonn, Germany 2002 - Helmut Jahn's Deutsche Post Headquarters, whose complex double facade aimed to reduce energy consumption by half in comparison to a standard office building of the time, reportedly only saved 10-15 percent when the post occupancy enthusiasm settled.[5]

Regardless of their actual performance, complex layered facades allowed the clients to address two objectives: they demonstrated that clients wanted to address these pressing energy and environmental goals, and they valued the importance of design in projecting a progressive, forward-looking, media-friendly image, thus presenting the owner and institution in a positive light. The strength of image in a technically complex “energy-saving” façade projecting a positive, future-forward image was quickly recognized on the other side of the Atlantic away from French and German innovation.

In the late 1990s - early 2000s, as young architects in the Chicago office of SOM, we worked on a few such projects. The implicit need to address the reticent environmental concerns allowed us to employ every newly available technical solution in facade design of the day, progressively increasing technical complexity and growing numbers of distinct system layers and assembly parts of these facades. The complexity of a vented double facade was ubiquitous in the early design phases, checking the environmental box and promptly rejected for excessive cost by conscientious institutions that did not see the economic value.

During this time, design examples included highly technical solutions like structural glass bonding, cable-supported glazing, and frameless attachment methods used as surrogates in the environmental benefits to the occupant. The demonstrative use of cables, struts, spider connections evolved into its own architectural language of layers, lots of layers. Energy efficiency, environmental goals and the practicability of maintenance remained a secondary concern for the architect and the owner. If energy transfer through the envelope did occur, it was mitigated with simple insulated glass units with nascent low emission coatings, the rest of the facade design complexity was purely representational. A progressive, photogenic image achieved at a reasonably low cost constituted the primary agenda of architect and their client.

- London 2002 - Bank of America, Canary Wharf, a banking and trading building, designed in the Chicago office of SOM in 1998-2000, reflected this architect-client relationship. Two atria cut into a deep cubic volume brought daylight into the core. Cable-supported (gravity loads) rigid horizontal trusses (lateral wind impact) glazed with spider-connection mounted frameless structurally glazed units to enclose both atria. Total atrium facade system depth including the horizontal trusses exceeded a healthy 2-meters. Apart from the atria’s traditional “light-well” function, no other environmental envelope or design features increased the quality of interior space or reduced the overall energy consumption. Environmental vanity was clearly expressed through a robust budget dedicated to the complexity of cable and spider supports and a lot of stainless steel.

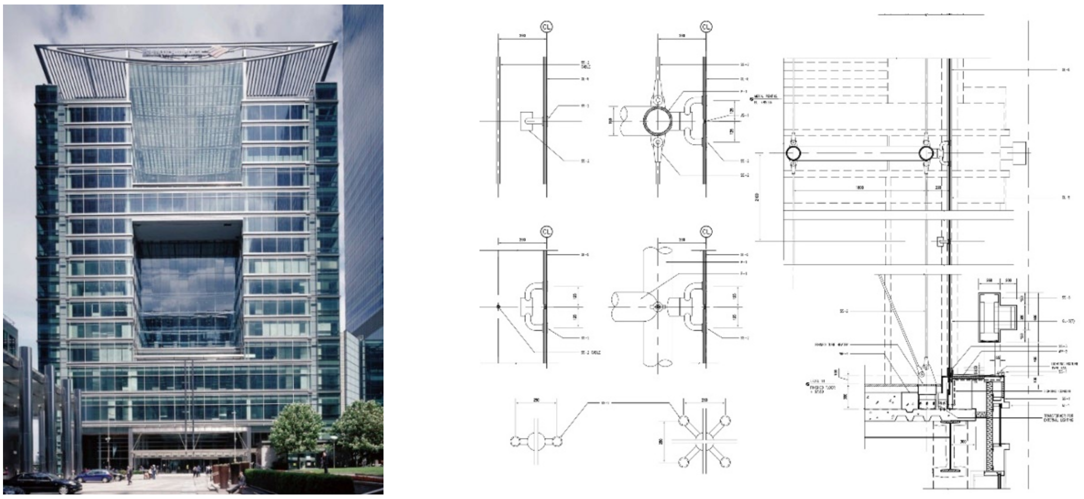

Image: Bank of America Canary Wharf in London, facade details, SOM

- Virginia Beach, 2007 - Designed by SOM in 2001-2003, the Virginia Beach Convention Center features an extensive day-lit pre-function event space clad with laminated insulated low-emission coated glass units mounted on 22.8m (75ft) high inclined cable trusses. The lobby welcomes convention attendees by providing an impressive event space unique to Virginia Beach. To achieve the design aesthetic, the maximum total facade system depth including the load-bearing trusses is an impressive 3.15m with the totality of the pre-function glazed all oriented south in the humid mid-Atlantic. The absence of exterior or even interior solar shading ignores enormous heat transfer through the envelope mitigated solely by the properties of the vintage 2007 insulated glass unit and air conditioning… lots of it. The vanity of the façade design and its complexity completely missed the environmental opportunity for long term economic viability.

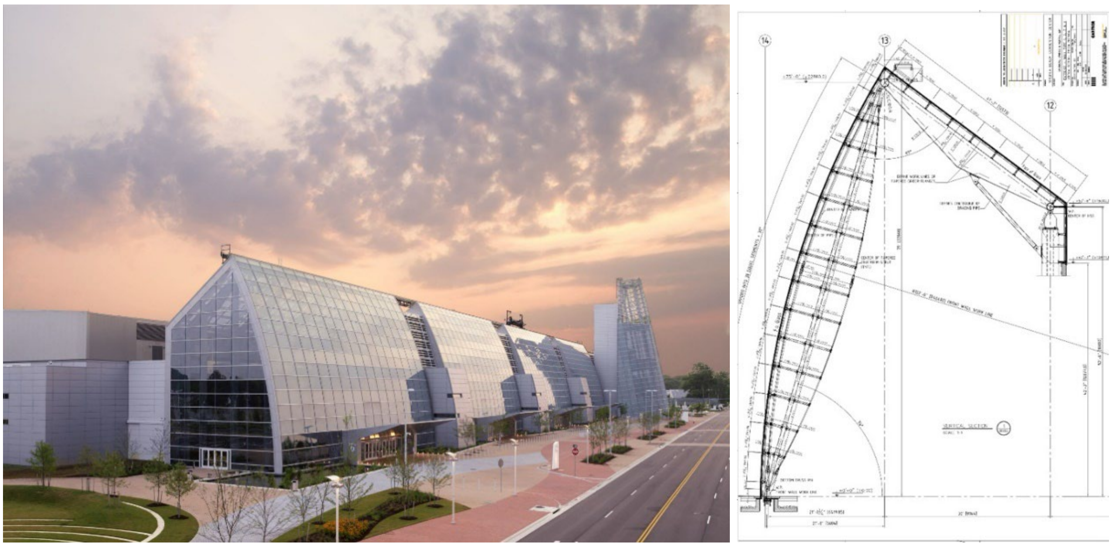

Image: Virginia Beach Convention Center, facade section, SOM/Gartner

4. Educational and research buildings’ facades - 2024

Today, in 2024, we represent both the client and architect working on educational and research building projects in Europe and North America. While many conditions are requirements of the market and the local construction industry, there are certain common patterns in today’s facade design development shared by institutions on both sides of the Atlantic.

University institutions, particularly those with a focus on sciences and technology, expect their new buildings to embody their future-oriented mission of advancing research in environmental and materials science while being good stewards of the building cost to shape the construction industry in the next decade. Public institutions often have a mandate from state or federal governments to serve as beacons for industry and society. For example, ETH Zurich, the Swiss Federal Institute of Technology, has a federally mandated "*Vorbildfunktion*," or “role model function,” requiring the Institute to demonstrate the highest standards in environmental stewardship, energy consumption, workplace practices, and more. ETH is expected to meet these standards within its base budget, without added funding. The juxtaposition of elevated requirements and limited budgets compels institutions to act prudently but creatively. In addition, educational and research clients expect architects to deliver pragmatic, high-performing, durable facade solutions that also project the image of the institution held to higher standards. Recently completed research and educational buildings begin to demonstrate these emerging trends in the future of façade design.

4.1 ETH GLC Life Sciences Laboratory Building, Zurich, Switzerland

The ETH Zurich GLC life sciences laboratory building, completed in 2023, features a vented cavity facade. In winter, when closed, it serves as a thermal buffer, while in summer, air enters at the bottom and carries warm air from the cavity extracted at the top of the facade. Glass blocks in the outer layer’s spandrels disperse intense summer sunlight, while the low winter sun enters the clear glazed zones unobstructed. The glass blocks give the flat, easily maintainable facade a visually rich textured appearance. The vision zones consist of an inner triple-glazed layer and an outer laminated glass layer, with retractable fabric exterior sun shading concealed between them. Floor-high, 3.6-meter-wide facade units were shop-fabricated and mounted 80% complete, with only the spandrel glass block elements installed onsite. The resulting assembly is durable, requiring minimal maintenance.

Image: ETH GLC Building, photo by A. Koshelev

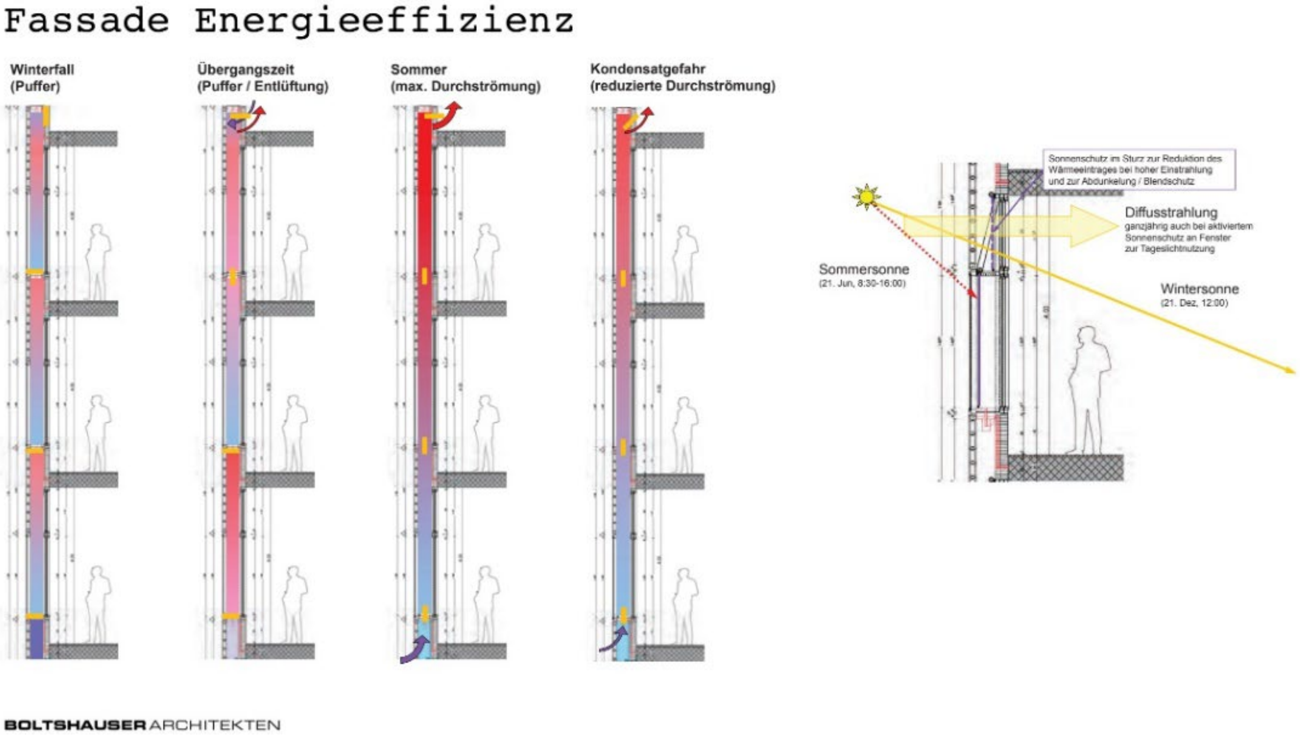

Image: ETH GLC Building, Boltshauser Architekten

4.2 ETH HPQ Physics Laboratory Building, Zurich, Switzerland

Currently in construction, ETH Zurich's new HPQ physics laboratory building features 30-meters of below grade *low noise* labs and an extraordinarily stable concrete structure above ground, designed to reduce in-lab building vibrations. The facade will also be unusually stable by shielding the sensitive labs inside from external acoustic, vibration, and electromagnetic disturbances. The conventional triple-glazed vision section of the facade is complemented by a 15-20mm thick cast-iron column and spandrel cladding, which will also conceal retractable external fabric solar shading. The standardised, prefabricated cast-iron elements ironically follow the fabrication and mounting logic of the 1890 Reliance Building's terracotta panels. In both cases, a durable, form-cast material is designed with a particular profile to lend visual depth to a thermal envelope that, from a purely technical standpoint, could otherwise remain flat.

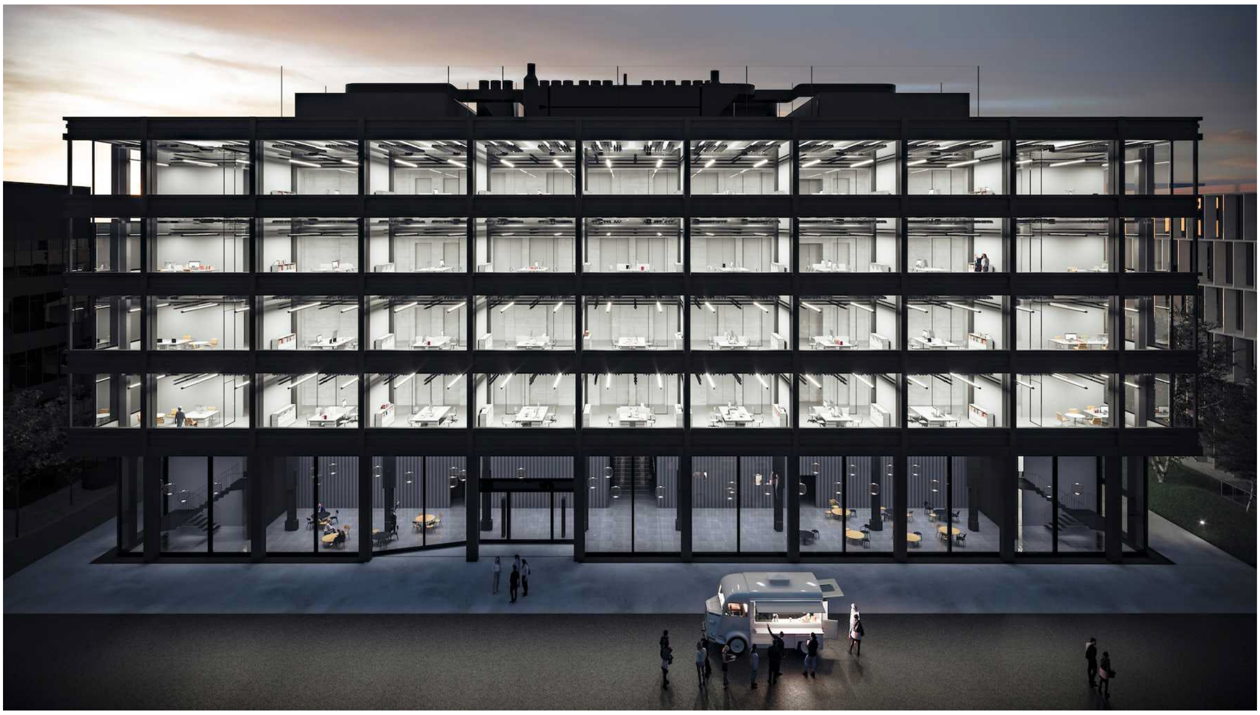

Image: ETH HPQ Building, Ilg Santer Architekten

Image: ETH HPQ Building, facade mock-up photos by A. Koshelev

Textured, heavy, rough, and almost archaic in appearance, the facades of both GLC and HPQ project an image decidedly different from the sleek, dematerialized, expressionless skins often seen on the increasingly flamboyant high-rises in booming "Big Oil" and Far East cities. Although the two buildings were designed by unique architects, they both reflect the pragmatic, long-term-focused agenda of their ETH client. The historic arc from the pragmatic, durable, yet expressive approach of the Reliance Building to that of the HPQ Building is evident in the comparison of their facade section details below.

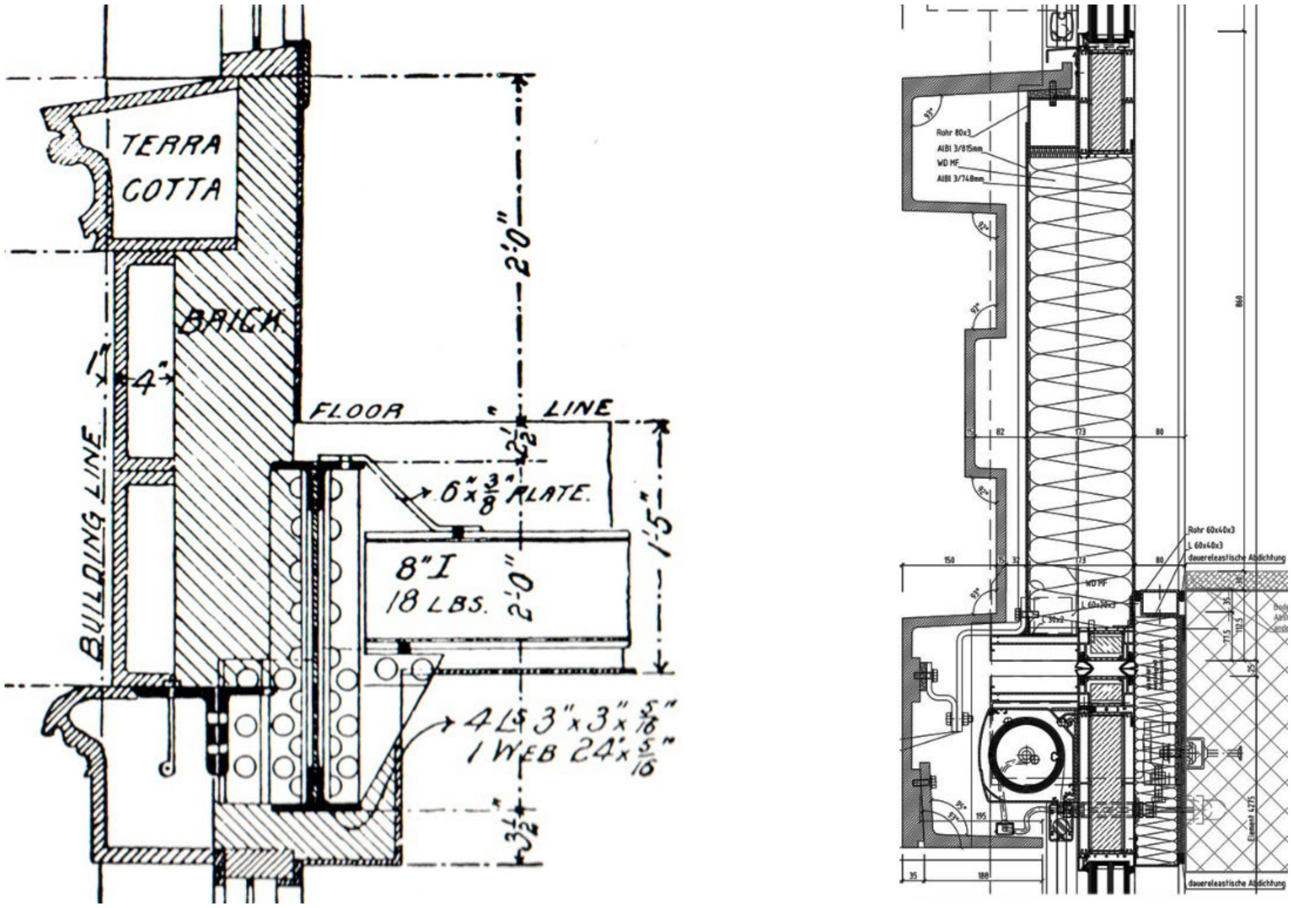

Image: Reliance Building facade detail, from Cecil D. Elliott, Technics and Architecture, MIT Press, 1992, HPQ Building facade detail Ilg Santer Architekten / GKP Fassadentechnik AG

4.3 University of Virginia, Gilmer Science Hall, Charlottesville, VA

Like most other buildings of its time, 1961 Gilmer Hall concealed research and discovery behind opaque brick walls and accessed science only though dimly lit internal corridors. The 2022 redesign and renovation seek to redress these legacy issues through an environmental-economic lens of new high-performance curtain wall enclosures that increase the amount of daylight into classrooms, while providing a building envelope that significantly improves the enclosure performance and sustainability goals of this public university asset.

Providing a new north and south façade enclosure that proudly puts Gilmer Hall's scientific mission on public display, the repurposing decisions were based on a design strategy that ranked enhancement of the existing building asset and occupant comfort first. Spaces are organized to be flexible with a range of capabilities versus specific uses, while beautiful enclosure details manifested from the complexity of the original facade with obsolete material interface details.

Approximately 95% of the existing floor area was renovated into modernized teaching labs, state-of-the art active-learning classrooms, daylight-filled spaces for informal collaboration, and flexible laboratories that support exciting new interdisciplinary research initiatives. The renovation included a 50% replacement of the technically failing exterior envelope, replaced with a new high-performance curtain wall system. The new facade in combination with the complete replacement of the building's obsolete MEP systems supports a new university asset that is twice as energy-efficient than its 1961 façade enclosure. The improved building aesthetics were a secondary effect in transforming the building from an "energy hog" to an "energy nibbler."

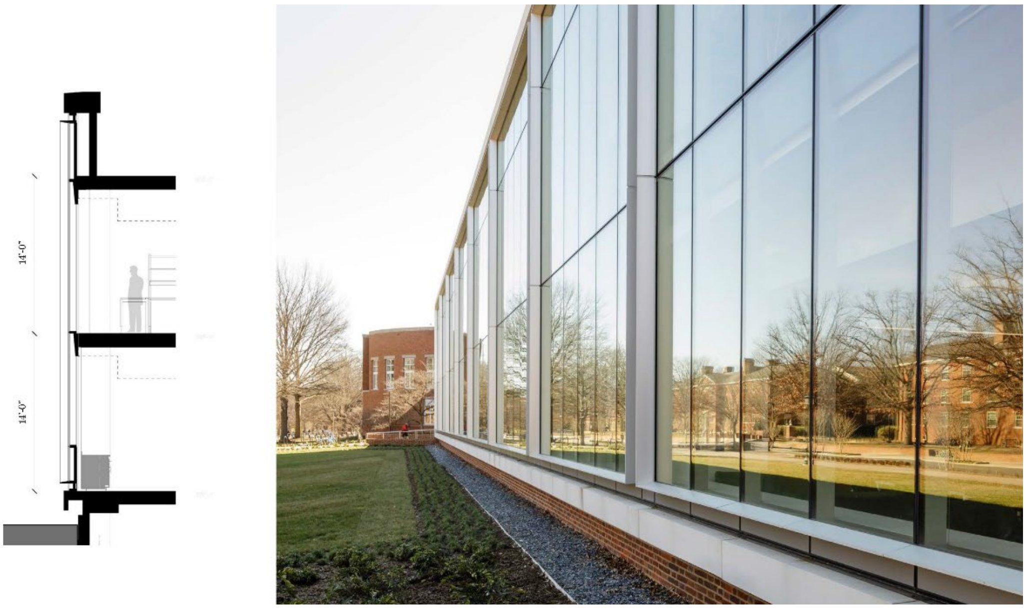

Image: University of Virginia, Gilmer Hall, North Façade, 2022, Perkins&Will, Lincoln Barbour Photography®

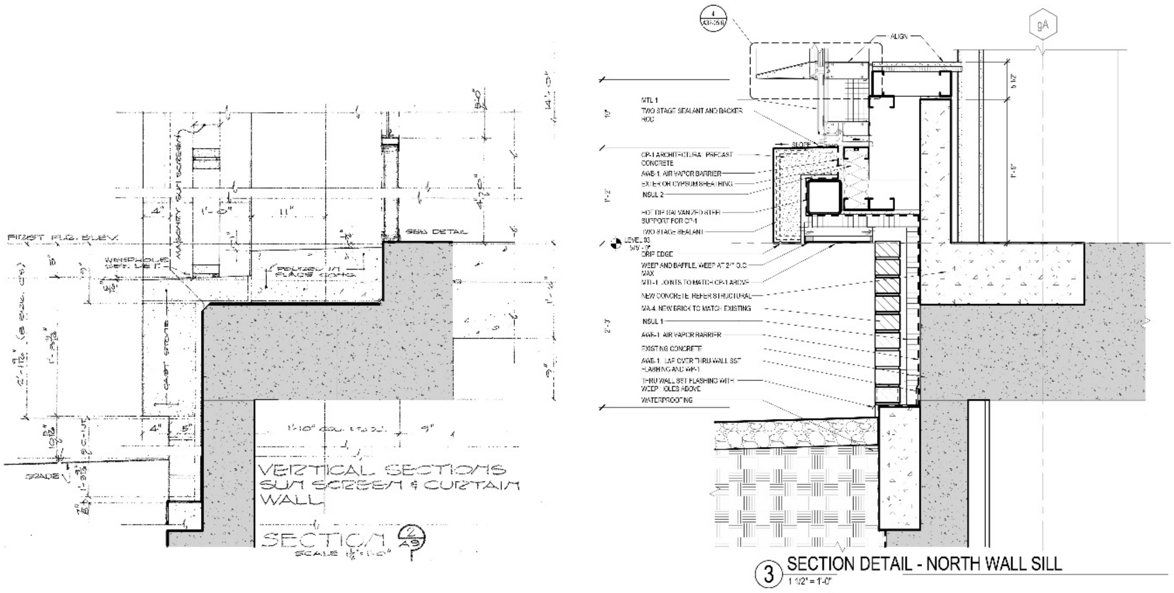

Image: University of Virginia, Gilmer Hall, South Façade Detail, 1961 and 2022, Perkins&Will

4.4 Bowie State University, Communication Arts &Humanities Building, Maryland

The Bowie State University Communications Arts and Humanities (CAH) Building is an integral part of the campus experience - collecting and connecting students across various fields of study into a facility designed to inspire collaboration and undergraduate interaction. The building massing informs the design of the facades, space program needs, views, and environmental orientation. The ground level is visible and connected from exterior to interior while the rhythm of punched windows at the upper levels enhances unique programmatic moments contained within.

At critical public junctures in the massing and program, there are featured facades that include large “picture” windows into significant building spaces. These picture window manifest visibility through their simple design and thoughtful detailing. Large glass panels of up to 8’-6”x 19’ (2.6m x 5.8m). are supported by a vertically oriented steel and aluminum structural system. The insulated and laminated glass panels are 1-7/16” (3.65cm) inches thick with an outer glass layer laminated onto the insulated glass unit. A stainless-steel cruciform shelf plate at the centerline of the window mullion supports the glass in just the four corners of the oversized glass. The high-performance glass composition achieves an efficient U-factor of 0.3 providing seasonal comfort throughout the year. Energy modeling in design studied the relationship of solar orientation to façade performance, modeling various options in solar shading from frit patterns to aluminum shading to reduce glare and heat gain. The modeling verified that a simple ceramic frit was as beneficial to the façade performance as more complex solar shading without changing the clean aesthetic and complicating the building maintenance.

The Sentech Versa wall® system design is featured in prominent public building locations including the multiple building entrances for the students, staff, and community. The glass façade height of 48’ (14.6m) does not require mid-span bracing for the prefabricated glass panels of 8’-6”x 19’ (2.6m x 4.8m) tall. Vertical support spacing occurs on module per design at an average 8’-6” (2.6m) The insulated and laminated glass façade supports performance values of 0.3 U-factor (insulation) and 0.34 SHGC for the assembly designed to a 2022 budget of $180/SF.

Image: Bowie State University, Maryland USA, Communication, Arts, and Humanities Building, 2024 Perkins&Will, Lincoln Barbour Photography®

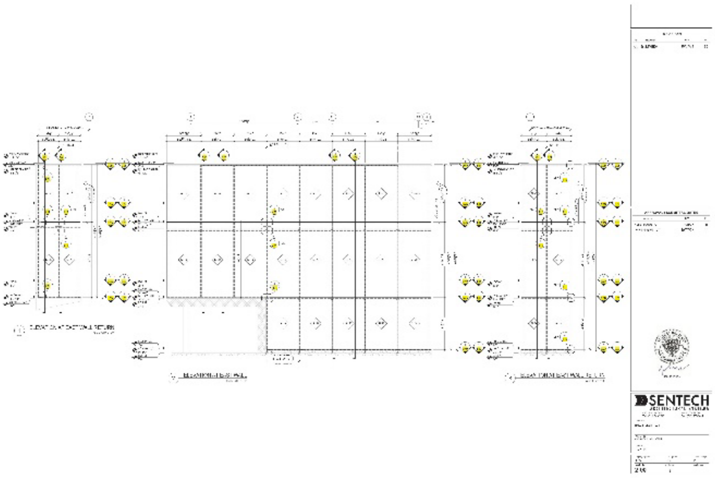

Image: Bowie State University, Maryland USA, Communication, Arts, and Humanities Building, 2024 Façade Detail, Perkins&Will, Sentech Façade

5. Conclusion

The technical aspects of exterior wall design and facade appearance are historically driven by external factors. Their development has not followed a linear progression in a clearly distinguishable direction but rather a “roller coaster,” oscillating between the extremes: substantial depth versus absolute thinness, expressive complexity or minimalistic aesthetics, and technological sophistication pivoting to archaic simplicity. Pioneering façade designs introduced trendsetting breakthroughs that were quickly replicated in diluted form or critically assessed and perfected by a cadre of followers. From the early terracotta curtain-wall imitations of expensive masonry cladding of the Reliance Building to the honest austerity and mediocre environmental performance of the Lever House, to the ornamental complications of double-wall, sensor-driven performative facades of the late 1990s excess, the transition into the next evolution of advanced building skins is now taking place.

Today’s pioneering clients and architects, particularly those in educational and research institutions, are less likely to strive to impress with flamboyant, publication-driven facade imagery. Maturing educational and research institutions recognize the value in adopting a pragmatic approach to cost, long-term durability, and low maintenance. This attitude influences their perception as responsible societal pillars of public money, acutely aware of their limited, fixed financing. Future facades will be simpler solutions with economic rate of returns and life cycle costs influencing design decisions. Advances in material science will prove the demise of complex vented cavity facades. Facade fabrication will increasingly become unitized and shop-fabricated with standardised and replaceable assembly details. Stick systems (post-and-beam) will be relegated to lower economic value building markets. Movable, high-cost, and high-maintenance parts will disappear while anything that can be fixed into a shop-fabricated facade element, such as photovoltaic panels, will have longer durability and thus value. Mechanical, reversible shop assembly methods will dovetail with the disassembly and reuse requirements of a circular economy. Glass will continue its technological revolution remaining the primary light-permeable material of today, while more layered material options will become available for spandrel opaque facade components. Glass will reach maximum dimension when transportation and installation are no longer cost-effective elements.

Beyond the technical and economic considerations, public institution facade design will represent the values of the university it houses with a message that does not contradict the public benefit of the institutional mission. At the intersection of environmental-economic needs, technical trends, and societal aspirations, the façade designs of educational and research buildings will continue to engage technological exploration in an expressive design dialogue.

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