A Sustainable Repurposing of the Aging Facility

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ABSTRACT

This case study documents the complete repurposing of an existing, 1970's era, 9 story critical care patient tower in an urban hospital complex. A key element of the repurposing is the incorporation of a new thermal over-cladding that retained much of the existing building's exterior masonry envelope while maintaining internal critical hospital operations. The comprehensive approach used by this project to develop a high-performance enclosure for an aging structure began with developing strategies for hybrid thermal over-cladding and "recycling in-place" to achieve passive temperature regulation, air compartmentilization, and increased thermal mass. Over-cladding with a thermal high-performance envelope improved energy performance through improved insulation, moisture mitigation strategies, and resilient materials, in addition to providing an aesthetic improvement that successfully positioned the aging building as a viable part of the hospital's master plan for future decades.

INTRODUCTION

Building owners and facility managers are increasingly confronted by an aging inventory of building stock. These structures generally retain sound structural frames but have failing, poorly insulated, and antiquated building enclosures. The dilemma owners are confronted with is the decision to either remove these structures and design and construct new facilities, a fairly disruptive and costly path, or to attempt to retain some or all of the aging structures and embark on a renovation to repurpose these facilities. Both choices involve careful planning, scheduling, and a significant investment of capital funds.

Hospital administrators particularly are reluctant to remove their aging existing structures due to the often-limited availability of open areas to erect new buildings and because in many instances the existing facility must remain fully, or partially, operational during renovation. Selecting a strategy that retains the existing structure in part, or in whole, and plans for repurposing that existing structure can begin to address these concerns. One such repurposing approach is termed thermal over-cladding, which essentially involves encasing the aging existing structure with a new exterior insulating envelope system. This strategy can allow aging, existing structures to meet contemporary energy conservation and indoor environmental quality concerns, overcome schedule and budget hurdles, and can create opportunities for older healthcare buildings to have new life in hospital master plans.

This case study focuses on the implementation of such an over-cladding strategy for the 118,500-square-foot Nelson Harvey Building; a 33-year old, nine-story patient care building that occupies a densely urban site in Baltimore, Maryland. The building is situated in the heart of the Johns Hopkins Medical campus and serves as a nexus of circulation and clinical/service support for the adjacent and adjoining medical buildings, see Figure 1. Hospital

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administrators elected to renovate the existing structure in lieu of building new to reduce initial capital costs and because the building houses vital shared facilities used by the eight adjoining buildings as part of daily hospital operations.

Figure 1: Johns Hopkins Medical Campus view from the west with the Nelson Harvey Building in the background

The interior portion of the renovation program encompassed the complete demolition of the interiors on eight patient floors and the first-floor lobby and public waiting areas. First floor renovations were limited to a new first floor entry vestibule and lobby, public corridors, and a plaza restaurant. The basement, first and second floors of the Nelson Harvey Building were required to remain occupied during the extensive interior and exterior renovation. New HVAC, electrical, fire protection and plumbing systems were upgraded and/or replaced throughout.

The exterior renovation program focused on the failing exterior envelope including walls, roofs, and glazing and targeted those features to be replaced and/or repurposed if possible. The existing entrance canopy structure was intended to be removed and replaced by a more gracious, open, and welcoming entry that would also provide better thermal isolation between public lobby and the primary entry. The project scope also included landscape and hardscape additions to the entry forecourt and insulated plaza deck over the hospital's imaging center.

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Figure 2: Johns Hopkins Medical Campus aerial view with the Nelson Harvey Building project scope highlighted

EXISTING CONDITIONS

The existing construction of the Nelson Harvey Building prior to the renovation reflects an all too common assembly of systems for late 1970s buildings – steel framed superstructure with cast-in place concrete over metal deck floor plates, and for the vast majority of the building, a simple, uninsulated, masonry cavity wall cladding. The exterior wall cladding includes a nominal 2-1/4" x 4" x 8" face brick, a 2" air-space, and cement parged coating over nominal 4" x 8" x 16" cored concrete masonry units, see Figure 3. Horizontal ladder reinforcing incorporating eye and pintle masonry ties were used to support the brick veneer. The interior framed walls consisted of 5/8" gypsum board on 3-5/8" 20ga. metal studs to provide a finished interior surface over the concrete masonry units of the exterior wall assembly. The only insulation provided in the wall assembly was unfaced-fiberglass batts between the metal studs, which is subject to R-value reduction due to the thermal break at each exposed metal stud.

Selected areas on the first and second floors featured an insulated metal panel wall assembly attached to miscellaneous structural steel angles and channels with interior framed walls of 5/8 gypsum board on 3-5/8″ metal studs to provide a finished surface to the interior.

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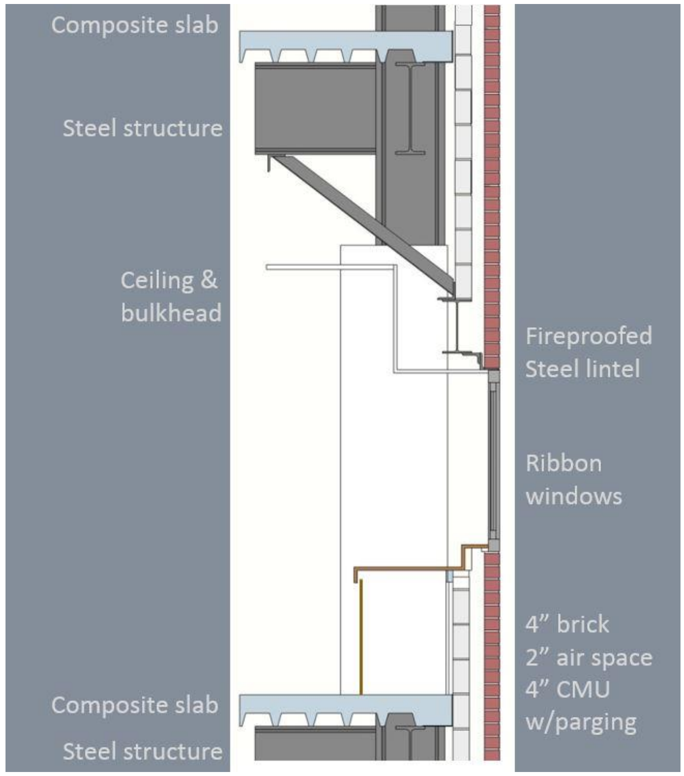

Figure 3: Existing wall section

The roof assembly over the composite construction of 6" concrete and metal deck consisted of white PVC roofing membrane fully adhered to the concrete deck. The roofing membrane was protected with 2' x 4' tongue and groove insulating roof pavers comprised of 2" extruded polystyrene topped with a ½" layer of concrete as a wearing surface.

The Nelson Harvey Building's existing fenestration was characterized by long expanses of aluminum ribbon windows with the masonry spandrel above carried on a system of structural steel lintels, with the structural framing braced to the concrete floor slab. Large expanses of aluminum curtain wall were used at public lobby spaces. The window frames and curtain wall were not thermally improved and lacked a water management system and/or a pressure equalization chamber within the framing system. The vision glazing was single-pane bronze glass.

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Figure 4: Existing east elevation of the Nelson Harvey Building and adjacent adjoining buildings

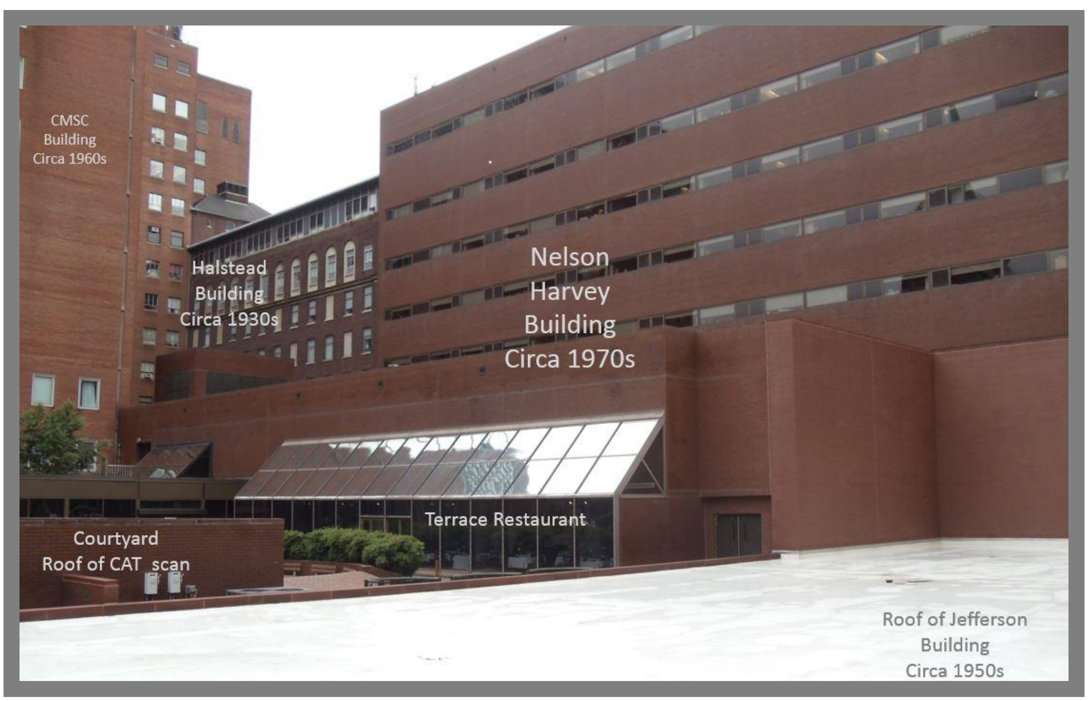

Figure 5: Existing west elevation of the Nelson Harvey Building and adjacent adjoining buildings

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Investigation

Prior to the design team's involvement in the project, Johns Hopkins Hospital commissioned a building envelope analysis of the existing exterior walls to assess existing conditions. Through this analysisit was determined that structural stabilization as well as repairs to the exterior envelope would be required.

Structural Analysis

The structural analysis included a visual inspection of the exterior walls, a lateral analysis of the walls based upon the current building code, and a review of the existing building drawings. The analysis revealed lateral loading and thermal failures in the building envelope, including the following:

- Cracking in the brick veneer
- Horizontal displacement of the brick veneer
- Horizontal bowing at the parapets and various other masonry locations
- Vertical bowing at some of the full height masonry walls

It was suspected, based upon the existing drawing details and visual inspection of the exterior walls, that a soft joint was not installed below the steel shelf angles or along vertical control joints. This was confirmed through the forensic investigation. At the locations investigated, the control joints at the brick were mortared solid. Therefore, areas of cladding were structurally failing causing the bowing and displacement to occur. The walls were also structurally analyzed based on the current adopted code requirements for wind load. It was determined that the exterior walls were significantly overstressed and in order to restore the structural integrity of the exterior envelope, lateral reinforcing would be required.

Architectural Analysis

Through forensic examination and test cuts, several major construction issues with the envelope were revealed. These conditions had contributed to the envelope's deterioration over time and it was evident that some form of remediation would be required. The following conditions were observed:

- Inadequate insulation – with no insulation in the cavity, the only existing thermal barrier was located between internal studs. Without a continuous insulation system in the masonry cavity the concrete masonry units of the backup wall and the edge of the concrete floor slabs became major contributors to heat loss due to thermal bridging in the exterior wall system. With the exterior assembly uninsulated, the interior framed wall realized heat loss through thermal bridging due to the metal studs exposure to the uninsulated concrete masonry units.
- Control joints were too few, mortared solid, and incorrectly located at the locations investigated. Therefore, areas of cladding were structurally failing causing the bowing and displacement to occur.
- Air infiltration was observed in the cavity walls due to the lack of an air barrier and gaps in the walls. There were broken and missing portions of the parge coating on the concrete masonry backup wall that were noted in the test cut locations. Air leakage in the building contributed to significant energy loss.
- Non-thermal, single pane glazing with deteriorating gaskets in the existing ribbon windows were contributing to significant energy loss.
- Wall flashings were not constructed to industry standards which can contribute to moisture accumulation resulting in moisture issues, such as leaks and material deterioration. The following flashing installation defects were discovered:

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- Improper location of sealant
- Improper lapping and sealing of adjoining flashing pieces
- Lack of end dams
- Flashing edge ending within the veneer
- Buildup of mortar in wall cavities
- Lack of weeps

These flashing defects may have contributed to many moisture problems within the building, but there was no record of any reported. It was suspected that any moisture issues were mitigated due to the high volume of internal air exfiltration through the cavity wall which would have inhibited its accumulation.

As a direct result of the structural and architectural analyses, a critical component of the project during the design process was the completion of an extensive digital laser survey of the exterior of the building. The digital laser survey data was collected from 37 different locations over a two-day period allowing for the construction of an accurate 3-dimensional model of the exterior building surfaces. This made it possible to map in detail the actual physical dimensions of the building including all dimensional deformities due to the thermal movement. The high-degree of accuracy conveyed by this in-depth digital survey was necessary to properly construct a new enclosing envelope over the existing building envelope with minimal removal of that existing envelope.

THE OVER-CLADDING DESIGN APPROACH

A number of design approaches were evaluated in the concept phase for rectifying the envelope problems. All the options proposed new insulated roof and glazing systems, but differed in how to deal with the failing masonry envelope. An initial option proposed removal of all existing brick veneer and CMU backup walls in order to construct new thermally improved masonry wall assemblies on the existing structure. Another option suggested repairing and stabilizing the exterior brick masonry and reinforcing the existing CMU backup wall with 16ga. cold-formed metal framing (CFMF) to satisfy code requirements for lateral loading to the building envelope. The third idea was to over-clad the existing masonry with an insulated metal panel system supported on a cold-formed metal stud frame connected back to the building's main structural steel frame. This last option would first require repairing and stabilizing the existing masonry prior to any over-cladding. All of these early proposed options were rejected for reasons of cost, schedule, and aesthetic. The removal of all masonry walls and the construction of new masonry infill walls was deemed too costly, logistically challenging, and would result in vast amounts of debris and airborne dust as a result of the demolition process to remove all of the existing masonry. The approach to internally reinforce the CMU in the exterior walls with CFMF would result in a net loss of valuable square footage for patient rooms already deemed under-scaled by industry standards. Insulated metal panel was undesirable as a primary exterior material aesthetic for the prominent building as voiced by the hospital's board of directors who desired to maintain a campus composed of predominantly masonry buildings.

After thoughtful consideration of a number of different design approaches, the design team decided that the most promising strategy was to over-clad the building, as illustrated in Figure 6, provided that the proper materials and structural systems could be found. The selection of over-clad materials and assemblies would have to address several important requirements as set forth by the owner, architect, and structural engineer. The owner stipulated that the predominant material expression be brick to complement the medical campus in general and the adjacent historical buildings in particular. The structural engineer required that any over-clad assembly be self-supporting, transfer lateral and gravity loads to the buildings existing structural frame only, and not exceed the overall building's structural lateral dead load capacity by 10% or an individual column's structural dead load capacity by more than 5%.

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The architect desired to develop a high-performance enclosure that met the former criteria while being aesthetically modern, minimizing on-going energy use of the building post-occupancy, using new materials sustainably, and maintaining high indoor and outdoor environmental quality through demolition and material re-use. It was also desirable to enhance the building's resiliency given the vital mission of the hospital and the operation of this building as a center for the treatment of highly infectious patients.

The design approach formulated by the design team is a concept termed *recycle-in-place*. Key to this concept is the notion to encapsulate the existing building envelope and incorporate the existing materials together with the new over-cladding materials into a hybrid thermal over-cladding that will achieve passive temperature regulation, exterior wall convective air compartmentalization, and increased resistance to fire and sound transmittance through tapping into the potential of thermal mass. The new over-cladding envelope meets contemporary energy conservation and indoor environmental quality concerns through improved insulation and moisture mitigation with a double-sealed barrier wall system. The minimal demolition required to implement this strategy limited airborne dust and debris on-site and decreased the volume of construction materials hauled and dumped miles away. This approach reduced, and in some cases eliminated, airborne pollutants in both the hospital's sensitive environment and in the community at large. Applying this strategy will have a significant impact on both the short-term and long-term sustainability of the Nelson Harvey Building.

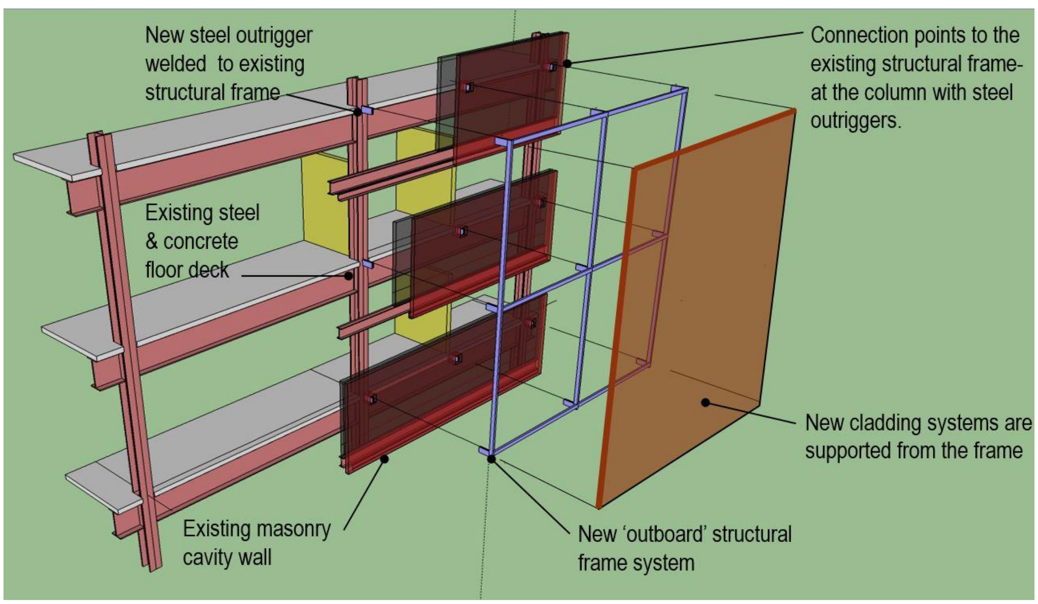

Figure 6: Preliminary over-cladding concept design (Feasibility Study)

As previously described, forensic and observational investigations indicated the existing Nelson Harvey Building had adversely aged and begun failing to a point that the exterior construction conditions were not accurately represented by the project's as-built drawings. Establishing an accurate three-dimensional model of the existing building in order to design an over-cladding system that would essentially "slip-over" the existing building envelope was critical, but presented numerous challenges. Prior to the three-dimensional scan of the building, as-built documents from the original 1970's construction documents were used to construct a three-dimensional model using

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Autodesk's Revit software that represented at a minimum how Nelson Harvey was originally intended to be constructed. Field surveys were conducted by the design team to ascertain the general completeness of the as-builts as well as to document evident deviations that may have resulted during the building's construction, or any subsequent additions and alterations in the years that followed. The deviations were numerous and included the bowing and displacement of the masonry veneer resulting from the lack of provision for material thermal expansion in the original design and construction. The back face of the over-cladding system, as envisioned by the design team, would be held off the face of the existing envelope walls by 1" in order to limit the cantilever of the new structural system and to reduce the size of the resultant cavity between the existing wall and the new over-cladding. This meant that the design team needed to establish the out-most control points of the existing envelope, including any thermally displaced veneers, in order to slip the new over-cladding over the existing envelope.

A conventional surveying program to establish the existing control points would have been daunting for the size and complexity of the existing building. Instead, digital laser surveying was employed to scan the entire exterior envelope in order to create a digital point cloud file that provided an extremely accurate digital model that could be compared with the Revit model created from the less than accurate as-built info. The accuracy of the digital point cloud is within +/- 1/16." The variances between the two models were several inches in most cases with some areas identified as being several feet off, see Figures 7 and 8. Once the point cloud file and the Revit model were overlaid, the Revit model was adjusted to reflect the true field conditions of the building. Having this very accurate digital model enabled the design team to create the new over-cladding envelope that would "slip over" the existing envelope with confidence that the new envelope would both fit and absorb the building's deflection anomalies. In addition to the irregularities of the existing building envelope that the digital survey accurately recorded, the digital survey was also crucial in modeling the physical building connections that the existing Nelson Harvey Building had with no less than eight adjoining buildings. Any proposed envelope over-cladding required close coordination with the adjoining buildings to properly create the necessary wall and roof expansion details between the buildings. The Nelson Harvey Building's renovation could not succeed at the expense of comprising any of its adjoining neighbors.

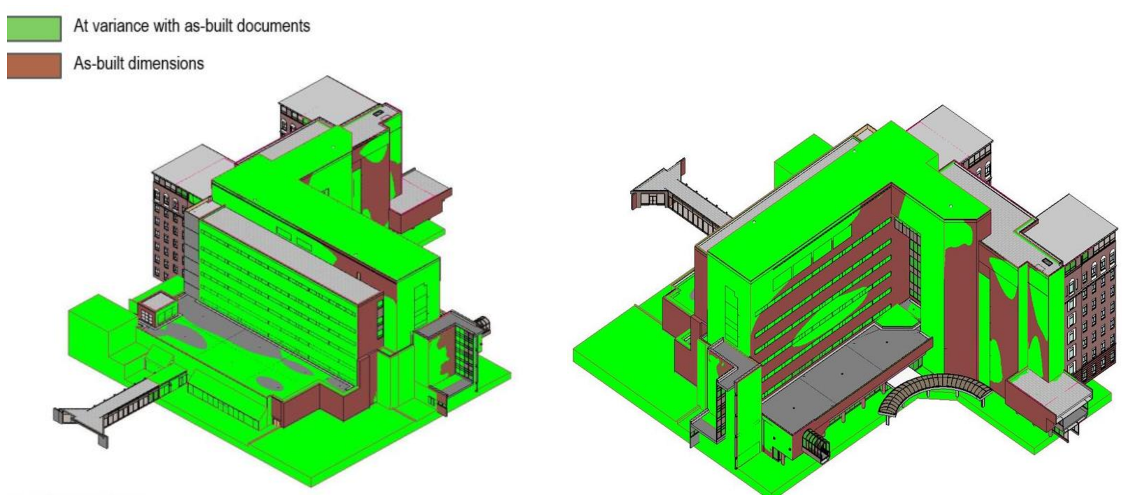

Figure 7: Point cloud model overlaid onto the Revit model of the existing building

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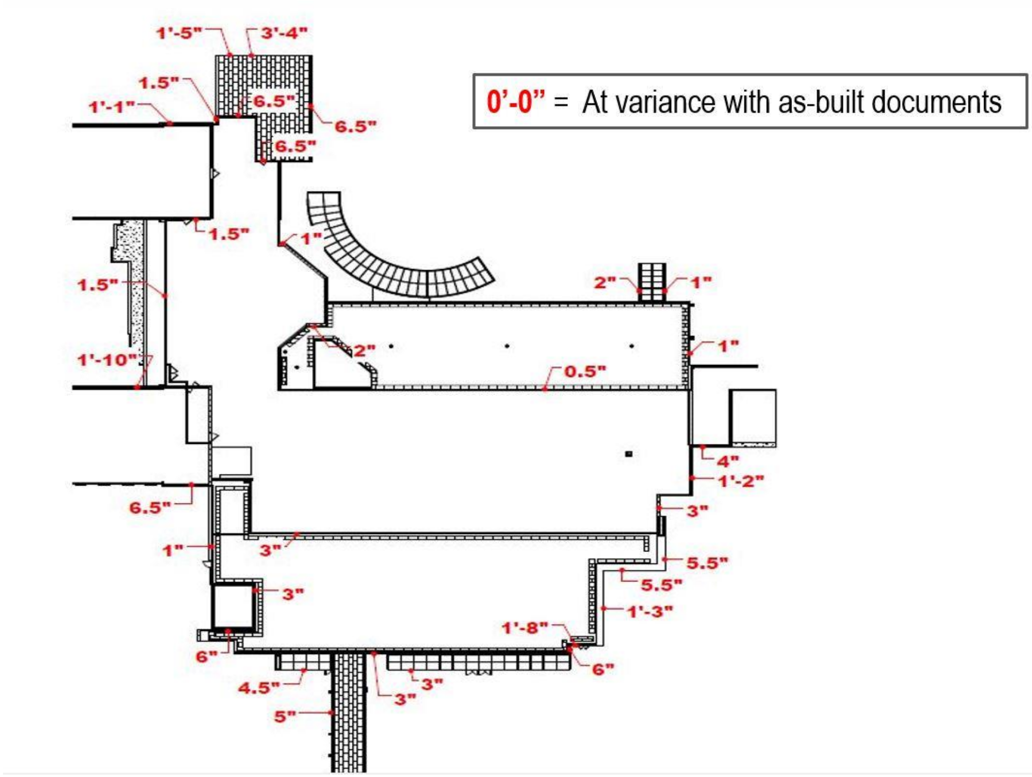

Figure 8: Variations between the point cloud model and the existing building as-built documents

Design and Execution

With reliable data regarding the Nelson Harvey Building's on-site condition, the design team was able to move forward with designing and documenting the new over-cladding systems that would revitalize the building. In evaluating the available systems for the over-cladding materials, the following systems were identified as most capable of fulfilling the project's established design critieria:

Over existing masonry portions of the existing envelope:

- Wall panels of thin-brick cast into thin-precast concrete panels, reinforced by thermally broken, cold-formed metal framing with sprayed polyurethane insulation between the concrete and framing members, between the framing members, and between adjoining precast panels.
- Wall panels of prefinished, insulated, interlocking aluminum panels, with insulated joints attached to cold-formed metal framing. This system was also used at exterior soffits.
- Thermally improved, aluminum-framed and glazed curtain wall using insulating and fritted, low-E coated spandrel glazing, backed with mineral board insulation.

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At existing vision glazed portions of the existing envelope:

- Thermally improved, aluminum framed, and glazed curtain wall using insulating and low-E-coated, low-iron glass.

At existing roofs of the existing envelope:

- Fully adhered PVC roof membrane over multi-layered rigid insulation and protected with concrete topped, insulated roof pavers.
- At roof areas exposed to public view an extensive green roof system was installed over a fully adhered PVC roof membrane over rigid insulation.

The new envelope system required careful planning and detailing for incorporation into an over-cladding system. Each system was selected based on aesthetic appeal, structural integrity, light weight, thermal capability, and moisture resistance.

Precast Panel System as Over-cladding

The thin-precast panel system selected as the primary cladding system for the Nelson Harvey Building embodies many favorable attributes for envelope design: aesthetic expression (brick), good weight to size ratio, weather and hazard resistance, continuous insulation, limited thermal bridging, air/vapor barrier, moisture resistance and management, and thermal mass. The precast panel system permits shop fabrication with better quality control, an accelerated construction schedule, and good life-cycle costing.

The thin-precast panel system at 32lbs/sf conformed to the structural engineer's weight limit of a maximum of 35lbs/sf for any over-cladding system in order to remain within the code dictated 5% maximum dead load and 10% lateral load addition to the building's overall structural frame (see Figure 9). Each panel spans from column to column (22' on average) and has a maximum height limit of 12 feet. Each individual panel is supported at four points on steel tube outriggers "needled" through the existing masonry envelope and welded to the existing steel columns. Two mid-panel connections are used for in and out adjustment of the panel for optimal alignment. The six connection points limit the surface area of thermal bridging between the precast panel and the internal construction. Once the connections were made, the masonry removed to allow access to make the steel connections was infilled with new masonry to provide the desired fire and acoustic resistance. The precast panel as designed and fabricated incorporates a thermal break between the concrete and the cold-formed metal framing via the use of intermittent steel Nelson anchors that provide a ½" standoff between the two. Sprayed-on polyurethane insulation (SPF) of 4" minimum thickness, medium-density, and closed-cell foam between and around the steel framing provides a high degree of insulation and also performs as an air/vapor barrier. See Figure 10.

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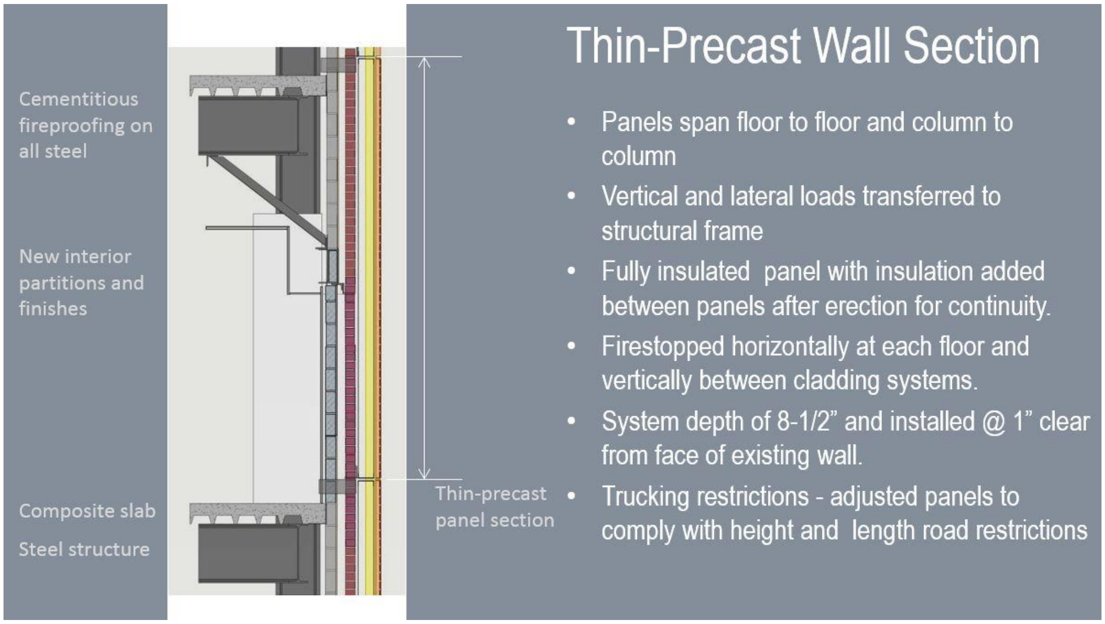

Figure 9: Thin-brick precast wall section

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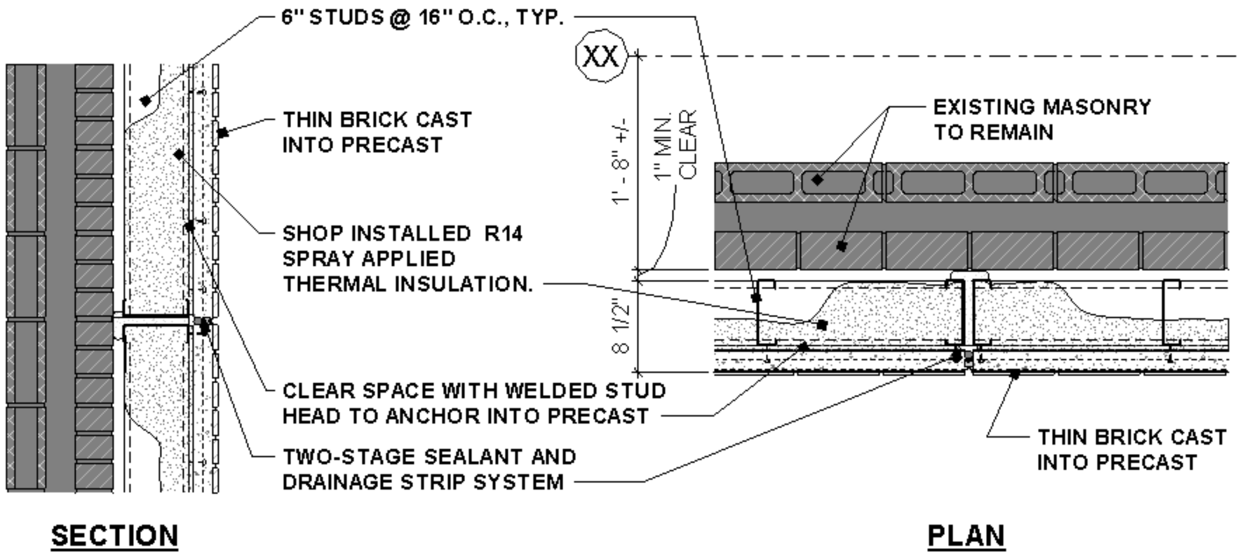

Figure 10: Thin-brick precast assembly detail

An average of eight precast panels were erected per day during construction, as shown in Figure 13, with each one being craned into place and adjusted using the six anchoring points provided for each panel. Once the panels were installed, the ¾" gaps between panels were completely filled from the exterior with expanding, closed-cell, polyurethane foam to provide for continuous insulation of the thermal envelope. The joint is ultimately capped with a double sealant barrier encasing a preformed pressure equalizing drain strip completing the barrier wall over-cladding system. The 1" minimum air space between the back of the precast panel framing and the existing masonry wall was horizontally firestopped at every floor. The firestopping afforded a means of compartmentalizing the vertical chase between the new and existing envelopes to not only limit the spread of fire and smoke in the event of a fire, but also provide a means to limit the stack effect of convective air movement in the cavity that can have an adverse performance effect on the envelope's ability to limit air infiltration and exfiltration. The 1" void space was also periodically firestopped vertically for the identical reasons. See Figures 11 & 12

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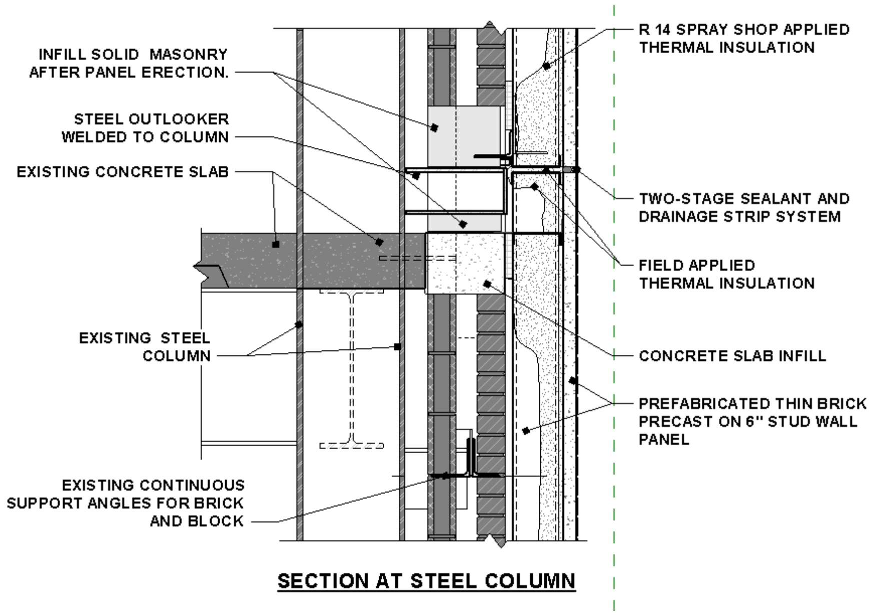

Figure 11: Thin-brick precast - column support section

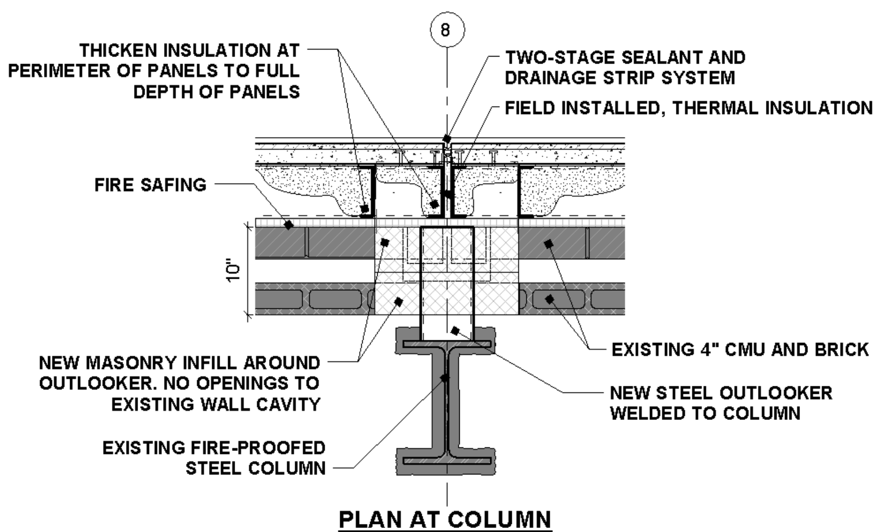

Figure 12: Thin-brick precast - column support plan

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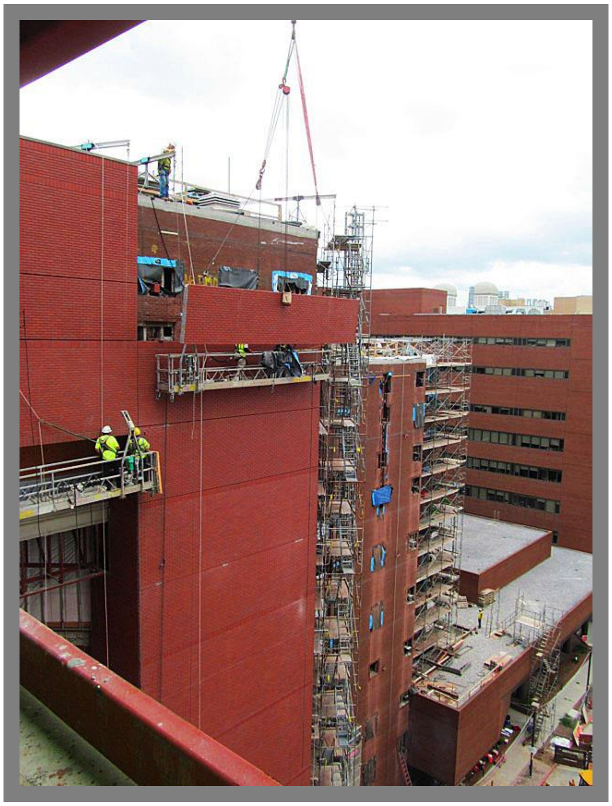

Figure 13: Thin-brick precast wall panel installation – southeast elevation

Prefinished Insulated Aluminum Wall Panel System as Over-cladding

The light-weight insulated aluminum wall panel system was selected as a secondary over-cladding system to be installed over the existing masonry wall in select areas of the building where construction access by the crane was restricted and the weight of precast panels would have exceeded the safe loading reach distance for the crane's boom, see Figure 14. In these areas, see Figure15, cold-formed metal framing was installed 1" off of the existing face of masonry, spanning floor-to-floor and connected back to the building's structure along each floor line by means of a structural angle connected to steel tube outriggers "needled" through the existing masonry to make connections at the columns. The aluminum panel system has an excellent weight to size ratio, is weather resistant, provides continuous insulation when installed in conjunction with insulated joints between panels, limits thermal bridging, acts as an air/vapor barrier, and provides moisture resistance and management. The aluminum panel system permits shop fabrication with better quality control, accelerated construction schedule, and good life-cycle costing.

This light-weight cladding systemaided in keeping the aggregate over-cladding within the code defined limits for added deadload to the building structural frame. The 1" minimum air space between the back of the aluminum panel framing supports and the existing masonry wall is horizontally firestopped at every floor. The firestopping afforded a means to compartmentalize the vertical chase between the new and existing envelopes to limit the spread of fire and smoke in the event of a fire and provided a means to limit the stack effect of convective air movement and the resulting impacts on the envelope's ability to prevent infiltration and exfiltration. The 1" void space was also

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periodically firestopped vertically to complete the compartmentalization. The insulated aluminum panel system was also used in a limited capacity in soffit areas.

Figure 14: Metal wall panel and curtain wall installation – west elevation

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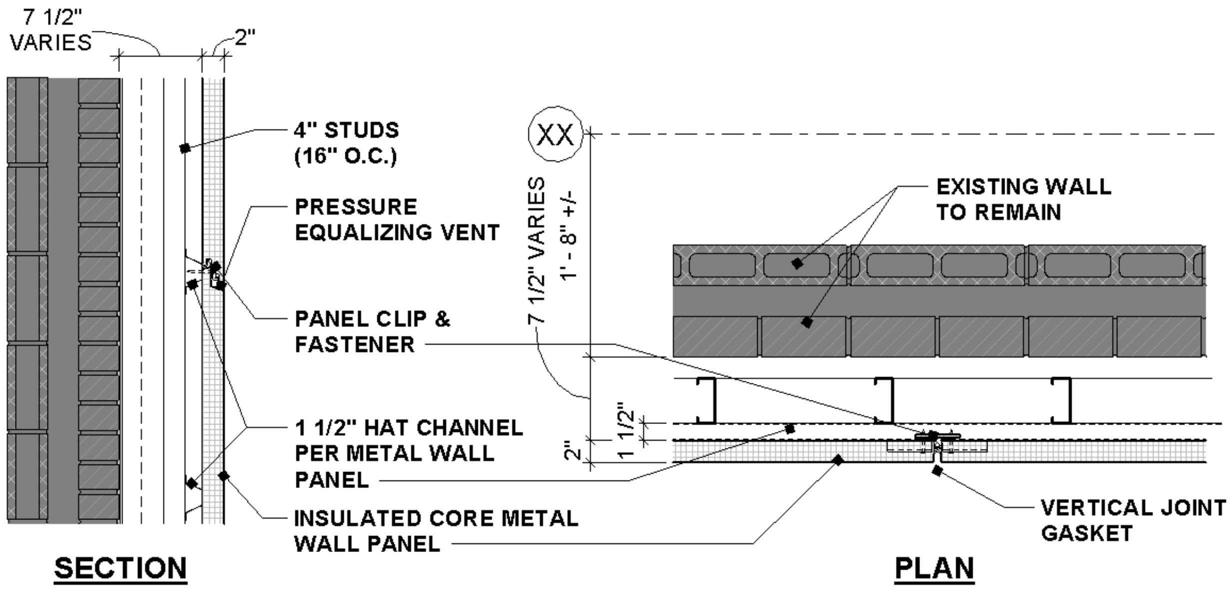

Figure 15: Insulated aluminum wall panel assembly details

Aluminum Curtain Wall System as Over-cladding

The thermally improved aluminum curtain wall system was selected as the primary cladding system for the patient tower portion of the Nelson Harvey Building to provide a viable vision glazing strategy coupled with an aesthetic expression to reduce the visual mass of the building, as originally designed. With its alternating horizontal bands of heavy masonry and narrow windows, the existing building did not project a welcoming sight to patients. The new curtain wall system permitted shop fabrication of some components with better quality control, accelerated the construction schedule, and provided good life-cycle costing.

The portion of the existing masonry wall located from the existing window sill to the floor line was removed to aid in the reduction of the overall dead load of the building, allowed the installation of new steel structure to support the curtain wall system, and provided additional floor space for the patient rooms, see Figures 16 and 17.

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Figure 16: Location of masonry (red) and glazing (blue) demolition – east elevation

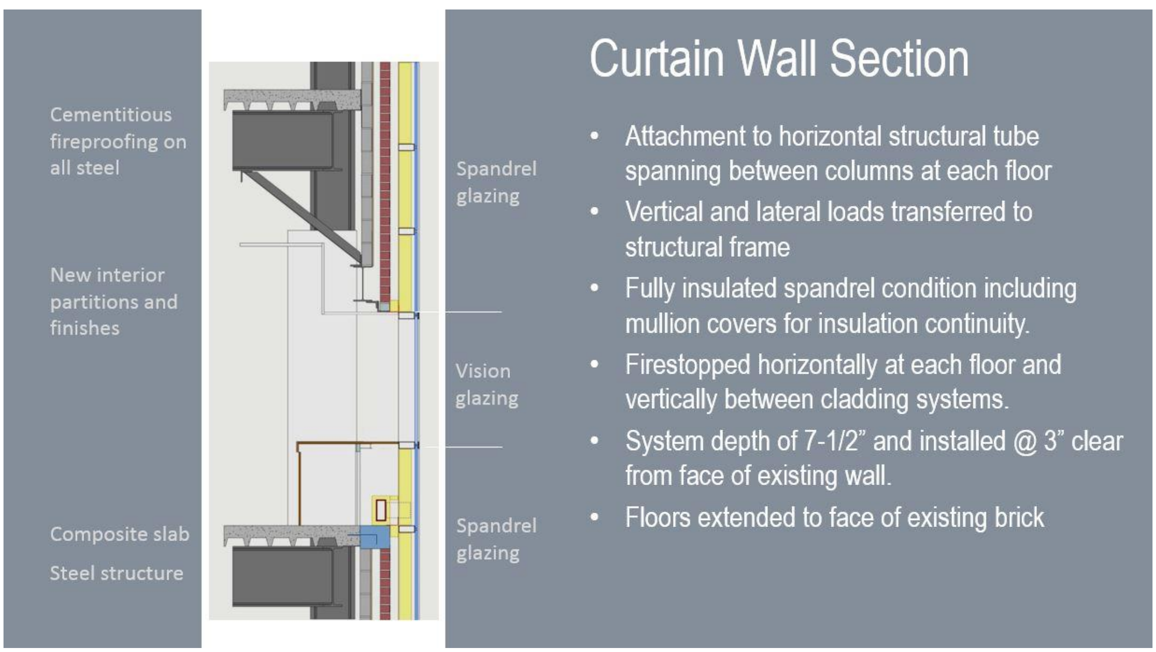

Figure 17: Curtain wall section

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A new concrete floor extension was added to the existing concrete floor slab bringing the face of the new slab to the exterior face of the existing brick. This created a 2-hr rated floor slab to the back face of the curtain wall and effectively capped the former wall cavity. A new structural steel tube spans between existing structural steel columns and is held 1'-0" above the existing floor slab to provide a connection point for the vertical curtain wall members. See Figure 17 & 18. The structural tube is supported at the column connections, in addition to third points along its length by stub-up tubes from the existing concrete floor, designed to limit vertical and horizontal tube deflection. This structural arrangement of a horizontal steel tube to provide curtain wall support has the added benefit of limiting the thermal conductive path between the building frame and the curtain wall mullions that is the bane of more traditionally framed curtain wall systems.

Where the curtain wall system is installed as over-cladding of the existing masonry wall, the resultant void is insulated with 4" of mineral board insulation and firestopped at the head and sill of the vision glazed areas of the curtain wall system, as shown in Figure 19 below. The portions of the aluminum curtain wall framing mullions that are concealed from view are fully wrapped in mineral board insulation. The steel support structure is fully insulated against thermal conductance in the event of fire and also serves to enhance the wall's R-value as well. The curtain wall system is vertically firestopped where the system interfaces with the precast and aluminum panel systems.

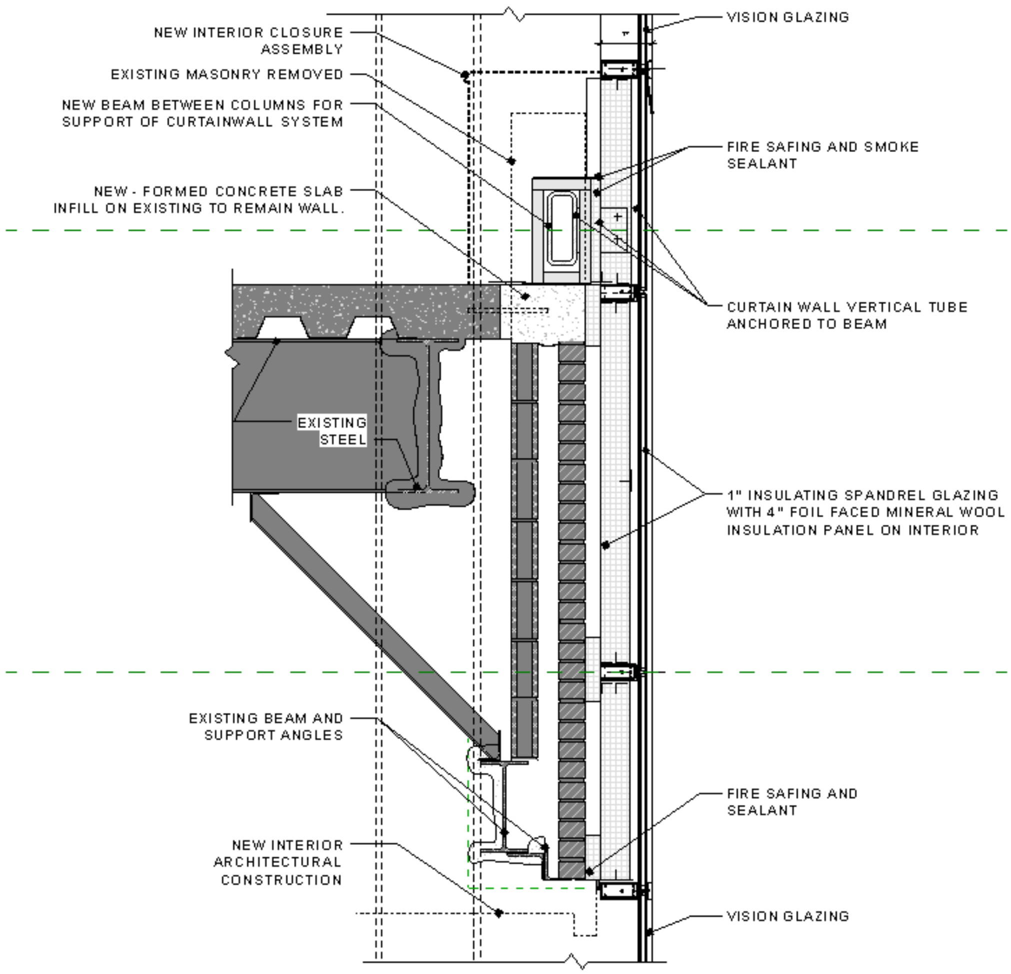

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Figure 18: Curtain wall support section

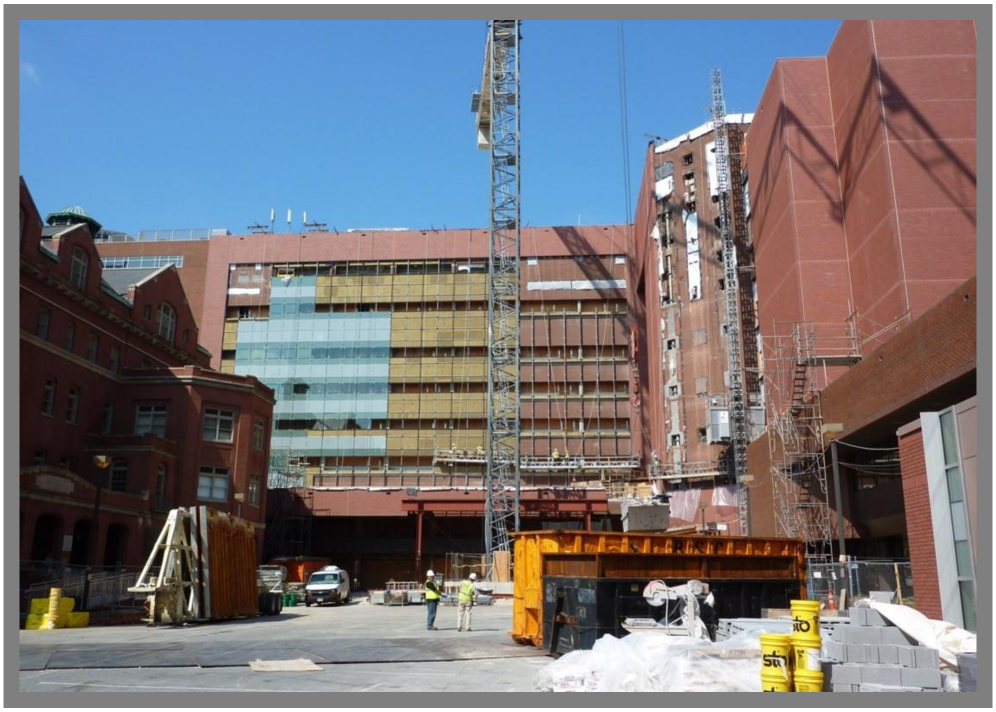

Figure 19: Installation of curtain wall and thin-brick precast wall systems over the existing facade – east elevation

The insulating glazing in the spandrel portion of the curtain wall system consists of an inner and outer unit of low-iron glass. The outside glass unit has a white silk-screened dot frit pattern in 20% and 60% densities on the #2 surface, in addition to a low-E coating on the same #2 surface, thus improving the unit's heat gain resistance and shading coefficient. The #4 surface has a grey uniform opacified coating. (See Figure 20 illustration)

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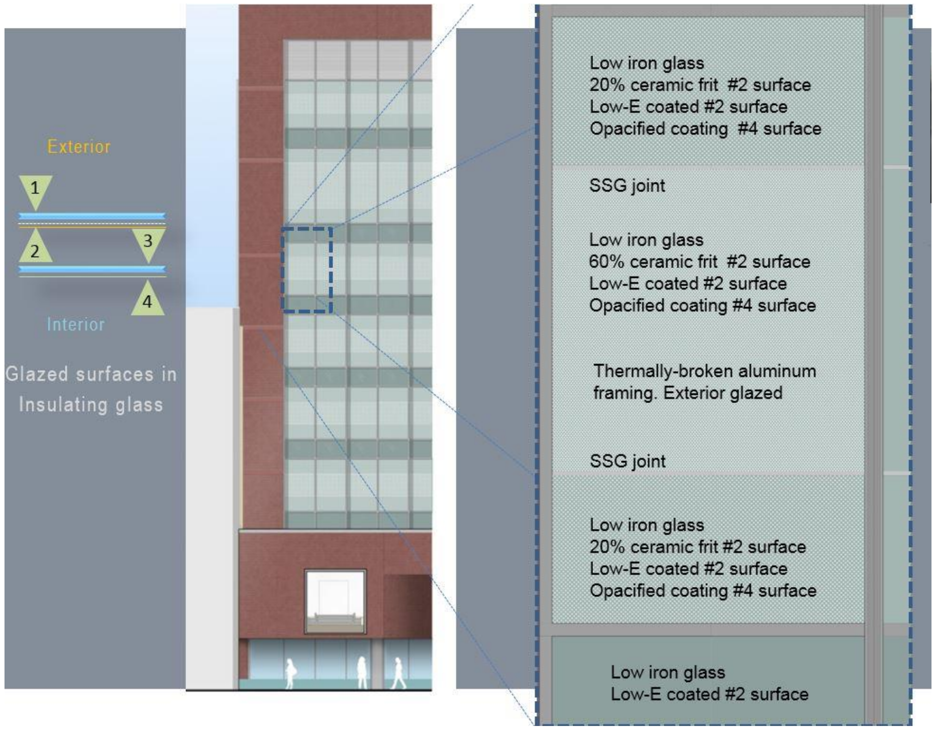

Figure 20: Glazing types at the curtain wall system over-cladding

Roofs

Based on the point cloud data and on-site observation, existing parapets were removed as these exhibited the greatest displacement and bowing. All new roofs and parapets have continuous thermal insulation with continuous air/water barriers. The white PVC roofing membrane with heat-welded seams is fully adhered to a glass-mat faced coverboard over two staggered layers of polyisocyanurate insulation. The PVC membrane is protected from above by both new and salvaged, tongue and groove concrete topped insulating roof pavers that serve to enhance the insulating value of the roofing system, in addition to providing protection of the roofing system. A highly reflective surface coating was added to the pavers to enhance heat reflectivity. See Figure 21.

Extensive green roof systems consisting of drought tolerant sedums are used where patient rooms and public spaces have direct views to the roof areas. The green roofs serve as a means of lowering reflective heat while providing a natural setting that is conducive for patient and staff wellbeing. A large skylight installed within the green roof area, located above the main lobby, augments the natural light permeating the lobby area through the glazing along the forecourt entry. See figure 22 & 23.

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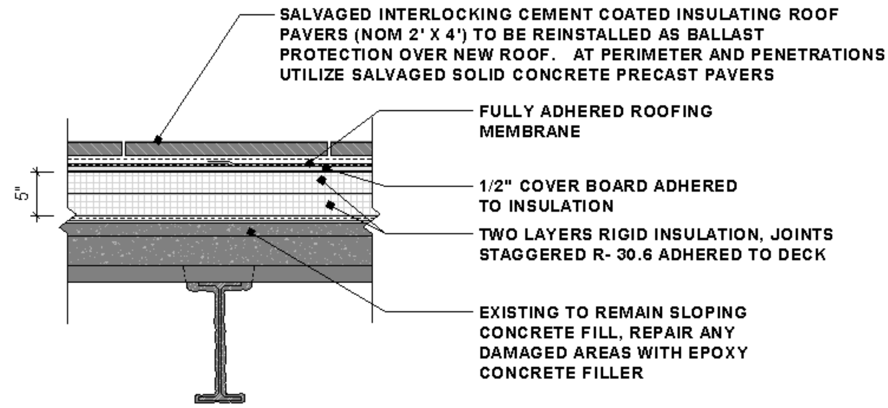

Figure 21: Salvaged paver roof

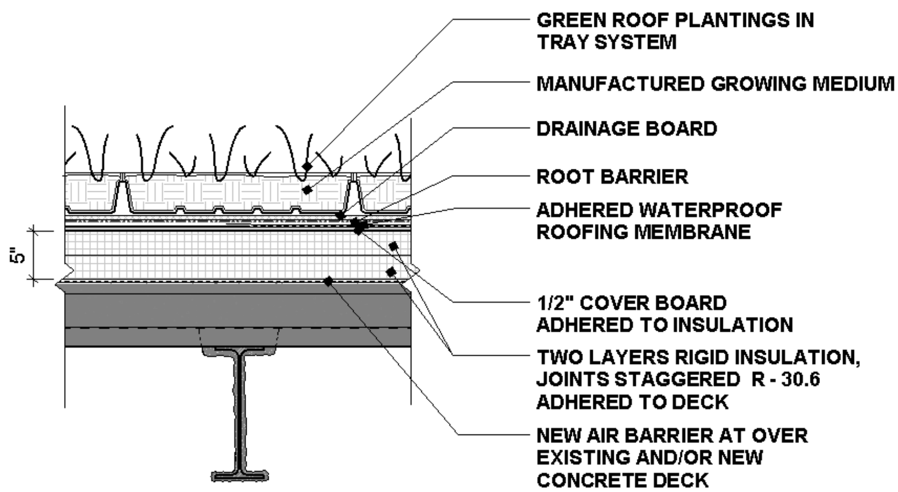

Figure 22: Green roof

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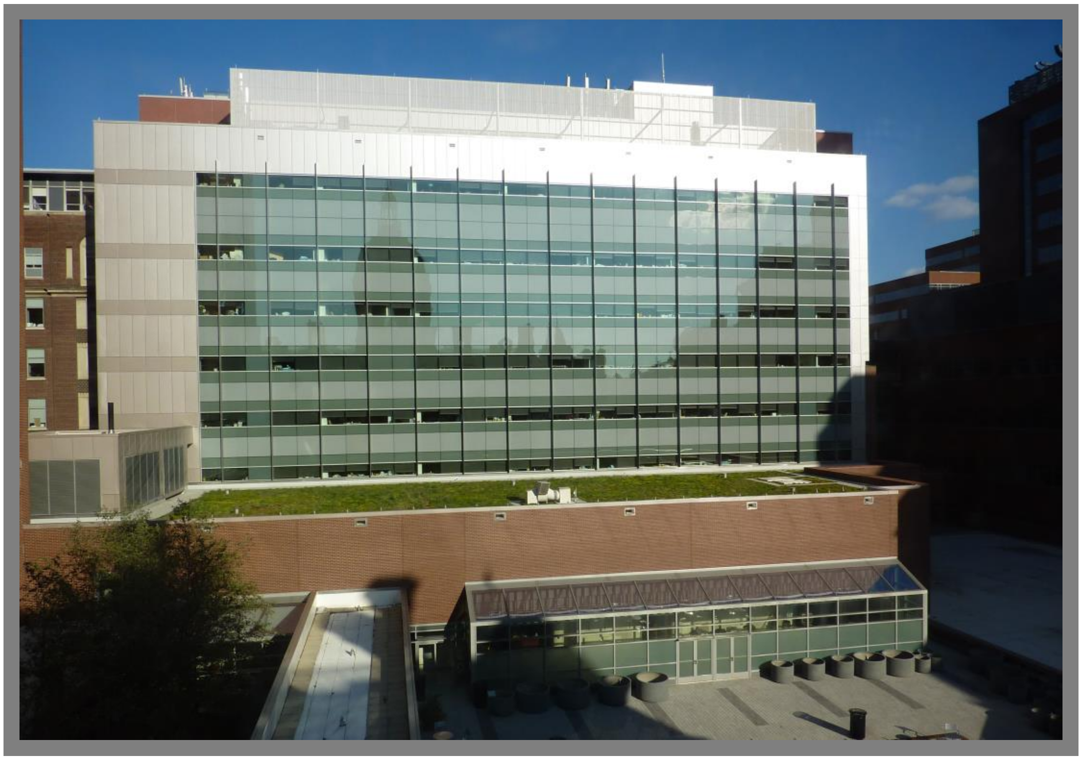

Figure 23: West elevation of the main patient tower (metal panels, curtain wall, and green roof)

Installation of Over-cladding Systems

Selective cutouts of the existing brick masonry cavity wall occurred over much of the building exterior in order to install new structural outriggers designed to support the over-cladding from the existing steel columns. The new steel framing was "needled" through the existing masonry façade through these small access ports cut into the masonry to afford anchorage points for the new façade systems. Once the existing façade was stabilized the new insulating façade systems and roof systems were installed to encapsulate the existing masonry walls and roof areas. Demolition also included the removal of all existing roofing and glazing on the building, in addition to attached pedestrian covered walkways connecting the Nelson Harvey Building to adjoining buildings. Most of the existing concrete topped insulating roof pavers were salvaged for reuse over the new roofs. The existing exterior canopy on the building was removed and replaced by a new entrance structure that includes a large metal canopy roof over a glazed entrance vestibule. The existing masonry parapets were removed due to pronounced bowing and deflection from thermal expansion. Masonry knee walls on patient floors 3 through 8 were removed for reasons previously mentioned. The removal of the existing masonry aided in shedding deadload weight from the building frame that permitted the extensive over-cladding by the precast panels. Maintaining the vast majority of the exterior wall system had the additional effect of enabling interior construction work to proceed without the necessity of erecting extensive

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temporary walls. This strategy allowed for faster dry-in time and improved the overall duration for scheduled construction activities.

PERFORMANCE AND METRICS

Energy Modeling

To measure the efficacy of revising the Nelson Harvey Building's envelope, the baseline and proposed conditions were analyzed using Sefaira, a SketchUp plug-in. In both cases, the HVAC and hot water heating components were modeled identically to isolate the impact of the building envelope changes on energy usage. Both models were run as a healthcare occupancy and located in Baltimore, Maryland to accurately represent the impacts use group and location have on energy usage.

In the baseline case, a glazing U-factor of 0.61 BTU/h*ft^{2}*°F and a solar heat gain coefficient (SHGC) of 0.83 was applied to both façade and skylight glazing in all orientations. The exterior wall was uniformly defined to have an R-value of 9.20 h*ft^{2}*°F/BTU. The structure was assumed to have a leakage rate of 0.54 cfm/ft^{2} at 75 Pa per ASHRAE 90.1-2013 and a surface reflectance of 0.5. Because testing data for leakage rate and surface reflectance was not available, these values were maintained in the proposed model as well so that their impact in comparing the performance of each model would be similar. It should be noted that the existing building likely had a higher air leakage rate than modeled owing to its age and exterior envelope failures. The hybrid envelope, conversely, likely has less air leakage than was modeled. ASHRAE 90.1 now includes guidelines about how to account for variable leakage rates between baseline and proposed conditions. In future, similar work should reference the most recent ASHRAE guidelines and incorporate air leakage rates accordingly. The baseline roof was defined to have an R-value of 11.17 h*ft^{2}*°F/BTU.

Because Sefaira offers a limited number of opportunities to define materials, approximations were made in the representation of the proposed case that introduces uncertainty in the results. The modeling program allows only one glass and one exterior wall R-value to be defined per cardinal direction and required our team's best judgment to determine how to most accurately represent a materially complex exterior envelope that features multiple assemblies on each exposure. The exterior assemblies in the proposed design are: thin-precast panel, vision glazing, spandrel glazing, metal panel, stucco, green roof, and non-green roof.

To generate the most accurate proposed model, each elevation's glass and exterior wall R-value were defined independently. The north elevation, featuring stucco and vision glass, was modeled using an exterior wall R-value of 16.8 and the vision glazing properties for the high-performance glazing install on the project which carried a U-factor of 0.29 BTU/h*ft^{2}*°F and a SHGC of 0.29. The south elevation, featuring metal panel as well as thin-precast in addition to vision and spandrel glazing, was defined using the exterior wall R-value of the thin-precast assembly and the vision glazing properties. All spandrel glazing was assumed to have the properties of the vision glazing because of the small quantity of spandrel glazing on this façade and all metal panels were assumed to have the same R-value as the thin-precast because of the minimal variation in R-value between these two assemblies. The thin-precast assembly has an R-value of 33.17 while the metal panel assembly has an R-value of 31.66. The south elevation's two material were therefore defined using the vision glazing properties, a U-factor of 0.29 BTU/h*ft^{2}*°F and a SHGC of 0.29, and the exterior wall R-value as 33.17.

The east elevation features vision and spandrel glazing as well as thin-precast panels on the tower and metal panels on the first two levels. Because the quantity of metal panel was minimal compared to the quantity of thin-precast panels, the east exterior wall was defined with an R-value of 33.17 to match the thin-precast assembly. Vision

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glazing was defined with a U-factor of 0.29 BTU/h*ft^{2}*°F and a SHGC of 0.29. The spandrel glazing was defined as the thin-precast exterior wall assembly because of the 4" of mineral wool insulation provided behind the spandrel glazing and the existing brick cavity wall that was preserved in place. Given the components, the spandrel assembly had an R-value of 29.15 which is far closer to the performance values of the thin-precast assembly than it is to the vision glazing.

The west elevation features vision and spandrel glazing as well as metal panels on the tower and thin-precast panels on the mechanical penthouse. Because the quantity of metal panel is significantly greater than the quantity of thin-precast panels, the west exterior wall was defined using the metal panel assembly and modeled using an R-value of 31.66. Similar to the east elevation, spandrel glazing was treated as having the same performance characteristics as the metal panel assembly because of the similarly in their performance. Vision glazing was defined with a U-factor of 0.29 BTU/h*ft^{2}*°F and a SHGC of 0.29.

The roof assembly was uniformly modeled without a green roof because of the overwhelming quantity of non-green roof area compared to the area that included a green roof assembly. The roof's R-value was defined as 43.04.

Because the proposed building has a mulit-layered envelope that must be approximated in the energy analysis tool, the predicted energy use intensity (pEUI) of the proposed building is of limited usefulness. The comparison between the proposed building's pEUI and the baseline building's pEUI, however, is a reasonable estimation of the proposed project's improvement over baseline. The proposed model resulted in a pEUI 17% lower than the baseline case suggesting the improvements made to Nelson Harvey's building envelope resulted in significant energy savings.

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Existing Cladding

Material	R-value	% of cladding	Weighted Average
Brick/CMU Cavity Wall	9.20	88	8.10
Brick/CMU Parapet	4.00	2	0.08
Metal Panels	14.34	10	1.43
		100	9.61 AVG R-value

There was a 227% increase in the insulation value of the building walls with the over-cladding.

New Hybrid Cladding

Material	R-value	% of cladding	Weighted Average
Thin Precast Panel	33.17	35	11.61
Thin Precast Panel Parapet	24.00	2	0.48
Type C1-Spandrel	29.15	6	1.75
Type C2-Spandrel	29.60	6.5	1.92
Type D-Spandrel	29.60	15	4.44
Metal Wall Panels	31.66	35.5	11.24
		100	31.44 AVG R-value

Existing Roofing

Material	R-value	% of Roofing	Weighted Average
PVC w/ insulated pavers	11.17	100	11.17 R-value

New Roofing

Material	R-value	% of cladding	Weighted Average
PVC adhered insulated	43.04	60	25.80
Green Roof	35.54	40	14.22
		100	40.00 AVG R-value

There was a 258 % increase in the insulation value of the building roofs with the new roofing.

Window to Wall Ratio (WWR)

Vision glazing total = 14,281 SF 17% of total wall SF

Wall area (including "glazed" wall) = 82,808 SF

WWR = 17% vision glazing

Figure 24: Comparison of insulation values of new and existing wall and roof systems

Post-Occupancy Observations

The Nelson Harvey Building has been in operation for over three years since construction activities were completed. The new hybrid envelope of insulating over-cladding systems combined with the attributes of retaining the existing masonry wall system has greatly improved the building's resistance to heat transfer and moisture transmission. As a general rule heat and moisture travel with infiltrating and/or exfiltrating air, and as materials get wet, the insulating properties are less effective. As a result, the relative humidity of the air moving in the wall system increases and the temperature of the materials at which the dew point is reached are lowered. The new envelope as a whole with

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its improved thermal and moisture resistant over-cladding manages heat, air, and moisture much more effectively than the previous construction. The mass walls at the exterior, and especially the mass wall at the interior, have greater inherent capacity to absorb excess moisture within the wall system and to release that moisture slowly over a period of time, either to the exterior, or to the interior, depending on location within the wall assembly.

An inherent property of precast concrete and masonry is the thermal mass. A wall system with high thermal mass has high heat capacity and will absorb and release heat slowly. The exterior over-cladding precast panel system stores heat energy during the hot and humid summers in Maryland. Combined with the proper insulation and with minimal thermal bridging, the over-cladding precast system slows down heat transfer, which reduces the energy needed to heat and cool the structure. When combined with the thermal mass of the retained existing masonry wall inboard of the insulation, a portion of the internal thermal energy is stored and made available passively to help maintain the desired indoor temperature. This further reduces the amount of energy needed to heat or cool the structure, thus improving energy efficiency even more. This translates to reduced operating costs for the hospital and more comfort for patients and staff. Johns Hopkins Hospital Facilities staff report significantly fewer complaints from patients and staff regarding thermal comfort conditions in the building than what occurred prior to the renovation. In addition to reducing operating costs of the building itself, this also translates into fewer maintenance visits to adjust HVAC equipment to meet occupant needs.

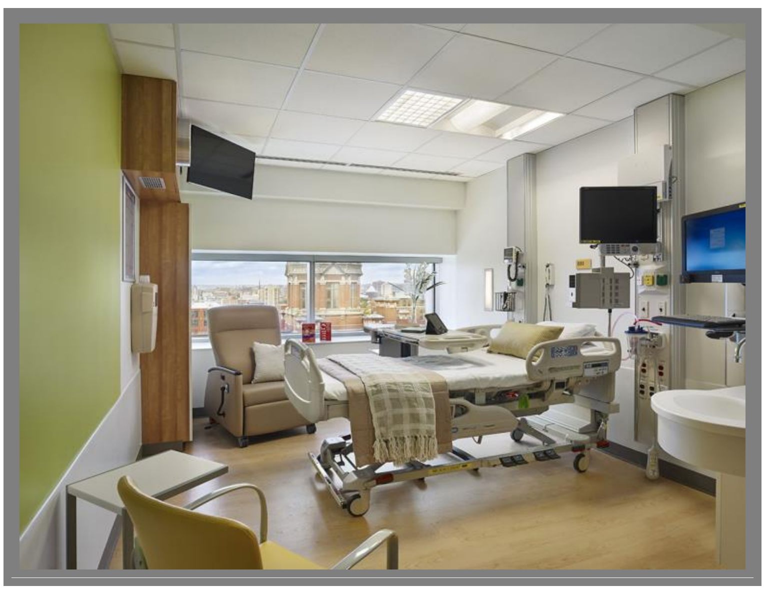

Figure 25: Patient room in the main tower portion of the building, facing west, Halkin Mason Photography

The thermal mass also aids in delaying when the inside peak heating and cooling times occur. This is the result of thermal lag, or the time it takes for heat to transfer through the materials of the wall assembly. As temperatures cycle throughout a 24-hour period, there is a point when the outside temperature reaches the peak high and low. The inside of the building generally has a temperature variance with the outside conditions and is always trying to equalize with the outside temperature. The greater the variance in temperatures, the more energy is required

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to maintain the indoor temperature at the desired level. If the interior building peak times can be altered to coincide when the variance in temperatures are less, then less energy will be required to maintain the desired interior temperature.

For the Nelson Harvey Building, the thermal mass effect of the combination of the exterior over-cladding precast with the interior thermal mass of the existing masonry adjusts the inside temperatures peak by several hours relative to when the outside temperature peak occurs. This effect of the double thermal mass wall on the precast portions of the over-cladding reduces the variance in temperature and the amount of energy required to maintain the interior temperature at the desired level. The benefit of the thermal mass effect holds true for both the aluminum panel and glazed curtain wall over-cladding where those systems are installed over the existing masonry wall of the building, albeit not to the same degree that the precast concrete over-cladding areas over the existing masonry have, due to the lower mass of those systems. The insulating value of the hybrid building wall system has been improved in excess of 200% over the existing building envelope. The overall result is that the HVAC system for the Nelson Harvey building should be able to perform more efficiently and economically to maintain the desired indoor temperature.

At roof areas, the thermal mass of the existing concrete slab serves to reduce the transfer of heat much as the precast panels and existing masonry do for the wall systems. In addition, the reuse of the concrete topped insulated roof pavers over the new PVC roof membrane and primary roof insulation further limits heat transfer through the roof. Mass walls and roof systems have a greater effective R-value than the sum of their material R-value and contribute significantly to the buildings ability to resist temperature transfer through the envelope. The insulating value of the new building roof system has improved by as much as 250% over the existing building roofing insulation value.

Thermal mass combined with limited thermal bridging can aid in the sizing of HVAC systems and thus aid in reducing the first costs of a project. Having reduced exfiltration and infiltration of air by employing a newer, tighter envelope over the existing building will certainly contribute to improving HVAC performance.

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Figure 26: "Before" view of Nelson Harvey Building from the east

Figure 27: "After" view of Nelson Harvey Building from the east, Halkin Mason Photography

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Field Thermal Imaging Analysis

The design team conducted a thermal imaging analysis of the exterior of the Nelson Harvey Building to ascertain the actual field performance of the envelope. The thermal images were taken in the month of January when the outdoor temperature was at the lowest and the differential between outdoor and indoor temperatures exceeded 30 degrees Fahrenheit. The testing occurred at dawn to allow stored heat in the thermal mass of the building from the previous day to release in the overnight so as to not compromise the thermal readings. The result of this testing confirmed that the thermally improved envelope is performing as expected.

The thermal images of the east and west elevations of the curtain wall indicate heat transmission from conductance through the aluminum mullions as would be expected, however, the images also indicate the reduction in heat loss through conductance at the spandrel locations due to the added insulation between and around the aluminum mullions, see Figure 28a & b. It is interesting to note in the thermal images how the vertical aluminum fins on the curtain wall increase thermal transmission due to their increased surface area.

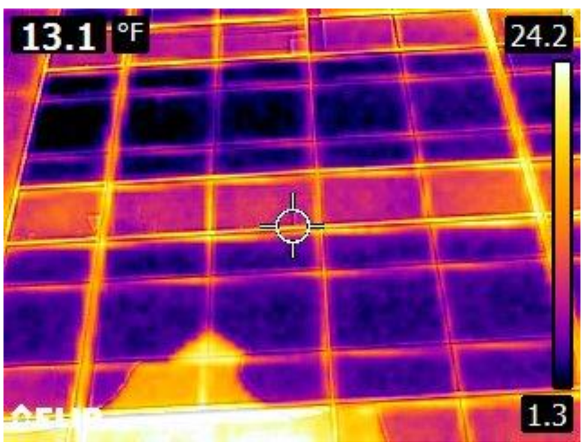

Figure 28a & b: Thermal & Visible imaging of the new east curtainwall system

The insulated precast panels are performing well with very limited thermal conductance through the actual panel, see Figure 29. The cold-formed metal framing of the precast panels are held off from the concrete via spaced Nelson studs and these appear to be quite successful at limiting thermal conductance between framing and the concrete facing. There are limited locations where a structural connection is evident behind the panel as revealed by the thermal images.

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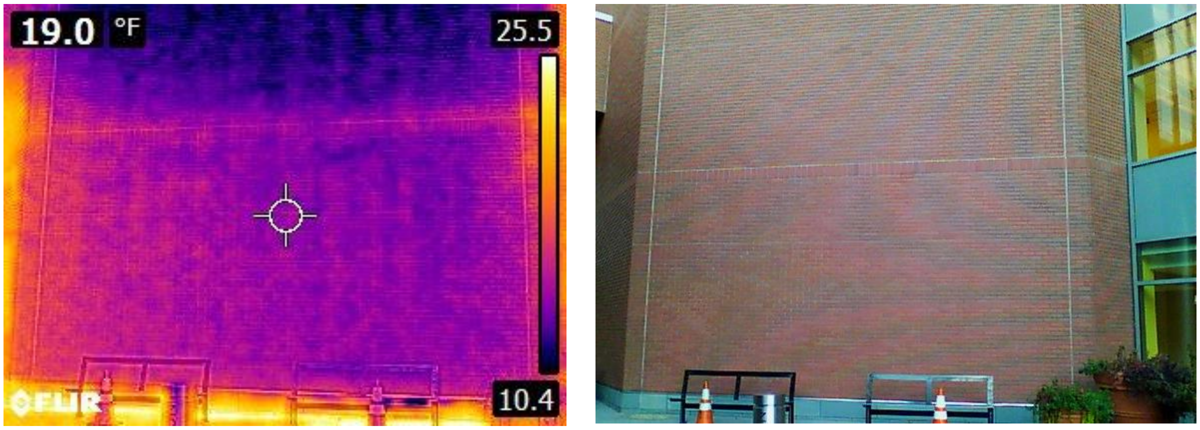

Figure 29a & b: Thermal & Visible imaging photos of the thin-brick precast wall panel system

There is limited thermal conductance through the metal panel system over-cladding as illustrated in Figure 30. As expected, the greatest thermal heat transfer occurs at the panel joints where there is limited insulation, in the case of vertical joints, and no insulation in the gasket or sealant joints.

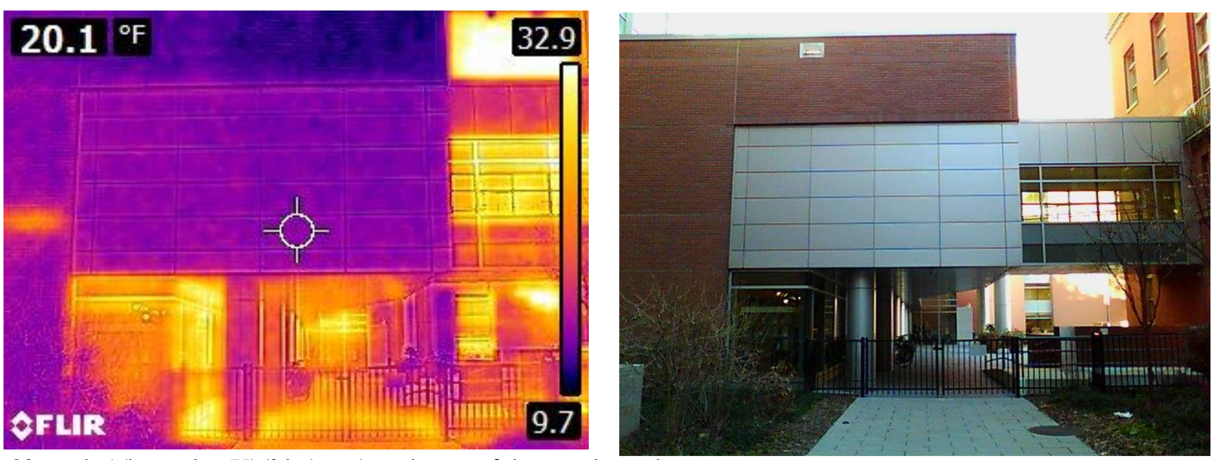

Figure 30a & b: Thermal & Visible imaging photos of the metal panel system

The original masonry parapets of the building that were the source of so much thermal heat loss and movement were removed in the demolition phase of the project and replaced in the new construction by extending the vertical height of the precast panel over-cladding to form a parapet. The new parapet is fully insulated on both sides and horizontally through the panel at the roof. The thermal images show little heat transmittance at the parapets.

Air exfiltration was evident in the thermal images at building entrances where door seals were being

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compromised. The thermal images of the east elevation exhibits substantial air exfiltration around the intake louvers at the mechanical penthouse level at the top of the building. The interior of the plenums are fully insulated at the level so the exfiltration of warmer air from around the louver is not fully understood at this time, but may be attributed to loss of air around the annular space between the ducts and the insulated plenum panels. The thermal images show a uniform heat loss around the tops of each louver despite the plenum being compartmentalized from each other. Another area of exfiltration that is evident is the horizontal connection between the curtain wall and the metal panel system on the west elevation at the top of the building. This is likely attributable to an improperly sealed joint that is creating a breach in the insulation envelope. The thermography image revealed that the joint between the curtain wall and the metal panel was not correctly installed at this isolated location. These types of testing support the principle that a combination of on-site visual inspections during and after construction, in combination with post-installation field testing, is paramount for quality control and quality assurance in validating envelope performance.

CONCLUSIONS

Design began March of 2011 and was completed June 2012. Construction began October 2012 and was completed October 2014. The final project construction cost was substantially below the Hospital's initial projected construction budget estimate and this enabled the Hospital to expand upon the original project scope to include a new forecourt and plaza deck for the Nelson Harvey Building. The project achieved a Green Star 2 Level under the Baltimore City Green Building Certification Program. (LEED silver certification level equivalent)

Figure 31: New envelope - east elevation, Halkin Mason Photography

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The design and owner team's intent at the outset of this project was to deliver a project that improved the aesthetic, thermal, and structural elements of the existing building through the execution of a design approach that would minimize capital costs, have minimal impact to the daily operations of the hospital during the renovation and employ sustainable practices both in the building design and construction. The design concept of installing a new thermal envelope over-cladding system that incorporates the existing masonry envelope into a new hybrid building envelope, exploits the potential of the existing building's infrastructure. Resiliency, sustainability, thermal control and moisture resistance are all enhanced through the process of recycling-in-place. Beyond the apparent benefits of improved building performance, the retention of a significant portion of the existing masonry envelope aided the construction process by contributing to shorter construction schedules and the limiting of demolition debris. Retaining the existing buildings walls provided a more secure construction environment that shielded the interior materials and mechanical equipment from exposure to moisture and dust from the exterior construction site activities. To underscore the contribution that recycle-in-place has on sustainability is the realization that an estimated total of over 2,130 tons of debris that would have been hauled by an estimated 71 dump trucks to landfill sites was avoided. Most importantly, critical care patients within the Nelson Harvey Building and adjacent buildings were not subjected to construction noise and air-borne pollutants that extensive demolition would have wrought.

The comprehensive approach towards developing high-performance enclosures for aging structures that this case study illustrates began with developing alternative strategies for a hybrid thermal over-cladding and "*recycling-in-place*" that enabled the Nelson Harvey Building to successfully be positioned as a viable part of the Medical Center's master plan for decades to come.

Figure 32: New envelope – entrance canopy and vestibule, Halkin Mason Photography

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PROFESSIONAL PHOTOGRAPHY

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