A COMPARISON OF THREE ENERGY/ENCLOSURE RETROFIT STRATEGIES

MARTIN HOUSTON, AIA, LEED AP

WALSH CONSTRUCTION COMPANY
2905 S.W. 1st Ave., Portland, OR 97201
Phone: 503-222-4375 • Fax: 503-274-7676 • E-mail: mhouston@walshconstruction.com
Abstract

From 2015 through late 2016, Walsh Construction Company executed three different and distinct enclosure energy retrofits. Each retrofit featured different structural systems, water-resistive/air barrier approaches and thermal control strategies. The projects had the common goal of providing a durable and energy-efficient enclosure. The speakers will examine the decision-making process for each enclosure to demonstrate how decisions were made as related to existing structure and project goals. The presenters will analyze specific assemblies, products and details in terms of design and execution and deliver objective information about the performance of each.

Speaker

Martin Houston, AIA, LEED AP – Walsh Construction Company, Portland, OR

Martin Houston is the quality director for his firm. He received a bachelor’s degree in architecture from the University of Cincinnati. He is a LEED-accredited professional and a certified Building Science Thermographer. Houston’s professional focus includes ensuring overall building quality while concentrating on high-performance enclosures. He has presented extensively throughout North America on the contractor’s experience and process in building highly energy-efficient and durable buildings.
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With increasing frequency, clients have been executing building restoration projects that focus on upgrading both the durability and energy efficiency of their building stock. The vast majority of clients with whom Walsh Construction Company (WCC) works create affordable housing for low-income tenants, and those clients own and operate these projects for many years. These clients have come to the realization that their operational costs are exceeding their income. The durability issues they are experiencing are costing precious operational capital to repair, and the operational costs are far exceeding the income provided by contracts with governmental agencies. Operational costs include salaries for staff, maintenance costs, and energy costs for operation of the buildings. As their facilities age, durability issues arise with increasing frequency, requiring increasing expenditures to repair these issues over time. At the same time, energy costs are increasing at a faster rate than contractual payments from governmental agencies. Our clients have realized that to reduce their annual operational costs, they must reduce the annual costs associated with exterior enclosure durability issues and reduce their energy consumption.

This paper presents three case studies from two different clients detailing retrofits (both interior and exterior) that address both exterior enclosure durability issues and energy consumption improvements. The three projects are Gallagher Plaza Apartments, Sellwood Tower, and the Westmoreland Union Manor.

The three projects were delivered using a construction manager/general contractor (CM/GC) method, which provided the opportunity for the contractor to provide both constructability and pricing feedback at key milestones in the design process. Because the contractor was involved in the design phase, a guaranteed maximum price (GMP) contract was used, eliminating cost escalation during the construction process through the change order process. The contractor interface with the design and owner team began early with initial investigation of existing conditions. The investigation included destructive investigation of exterior enclosure components; visual assessment of mechanical, electrical, and plumbing (MEP) systems; and operating cost analysis.

DESIGN AND OWNER TEAMS FOR THE PROJECTS

The Sellwood Tower and Gallagher Plaza projects were both executed for Home Forward (HF), formerly known as the Housing Authority of Portland. HF provides safe and affordable housing for people challenged by income, disability, or special needs. A long-time client of WCC, they own and operate their facilities as opposed to developing projects and then selling them. They therefore have a vested interest in creating durable and energy-efficient buildings, as both contribute to affordable housing and low operating expense. The prime consultant on the Sellwood and Gallagher projects was Holst Architecture, a Portland-based firm known for very high-quality architectural design, which had worked with HF previously on a number of projects, including, most notably, the Bud Clark Commons, a homeless housing and resource center that is arguably among the finest pieces of architecture in Portland. It should be noted that the Sellwood and Gallagher projects were part of a larger project called the Four Towers project, which was comprised of retrofits of four housing projects within the Portland city limits for HF. MEP design on the Sellwood and Gallagher projects was provided by a subcontractor through a design build contract.

The Westmoreland Union Manor (WUM) project was executed for the Union Labor Figure 1 – Example of constructability review comments.
Retirement Association (ULRA). ULRA similarly provides housing for income-challenged and senior residents, as well as retired union members at many different facilities across the Portland metropolitan region. Many of ULRA’s facilities are quite old and include such notable buildings as Chaucer Court, originally an Odd Fellows Hall—a ten-story building renovated in 2012 by WCC and Michael Willis Architects (MWA). Similar to HF, ULRA owns and operates its facilities over the long term and, therefore, shares the goal of creating durable and energy-efficient buildings to keep the housing affordable and to reduce operating expenses. The prime consultant on the WUM was MWA Architects. They are a San Francisco-based architecture firm whose well-established Portland office has a significant portfolio of work with nonprofit housing agencies. MEP design on WUM was provided by Interface Engineering as a consultant to MWA.

### ENGAGEMENT WITH THE DESIGN TEAM DURING PRECONSTRUCTION

A significant part of the quality process at WCC includes engagement with the design team to provide both cost information and constructability feedback during the design process. While we view our role as being guardians of the project budget, we use the constructability feedback mechanism as a way of assuring the quality of the project being delivered. This results in a high-quality project that manages our own risk, as well as that of the owner and the consultants. Quality metrics are ultimately determined by the client, but WCC establishes a baseline for our own quality expectations. The constructability feedback process uses the owner’s quality metrics as the reference standard for our feedback. During various different stages of design, while our project managers and estimators are working on providing cost feedback through the estimating and value engineering processes, our quality managers and project managers provide constructability feedback, with the quality managers primarily focusing on the building enclosure.

As seen in Figure 1, the feedback addresses the various control layers of the enclosure assembly and, therefore, the hygrothermal performance of the enclosure, as well as specific installation methodologies and manufacturer installation requirements. Our reviews are intended to improve the documents from which we build during construction and specifically avoid addressing aesthetic concerns, except as they relate to durability. These reviews are typically conducted at the end of schematic design and design development and at 50% completion of contract documents (CDs) to provide the design team with constructability feedback in a timely manner so that it can be addressed and incorporated in subsequent documents issuances. We similarly review the project’s specifications, focusing on Divisions 1-8 as they most specifically address building enclosure requirements. The reviews focus on material selection, warranty and installation requirements, and quality control activities. Our input is informed by our experience with the product, including installation nuances and product performance, as well as compatibility with other adjacent materials.

This engagement with the design team took on a slightly different form for the WUM project, where we used a very preliminary mock-up to design the enclosure system (Figure 2). Our typical process starts with constructability feedback to help assist in the development of project details, which is followed by the construction of a mock-up to practice the construction of the details, understanding the sequence between trades and verifying performance through testing. However, for WUM, we constructed the mock-up across the street from our office during the design phase to help in development of the details. This means that we not only worked as a team, including ULRA, MWA, and our subcontractors, but our material suppliers were involved as well, confirming installation methodology and compatibility, as well as sequence.

For instance, a silyl terminated polyether (STPe) liquid-applied, weather-resistant air barrier (WRB/AB) was selected for the wall, which needed to tie into the polyurethane deck traffic coating. We used the mock-up as early verification of chemical compatibility and adhesion of the two materials and to understand which one needed to be installed first. ULRA also required that only union labor be used on the project. Because we were unable to find a cost-effective sheet metal subcontractor for the installation of the WRB and cladding system, we decided to use our own self-performed trade crews (our sister company, known as RDF Builders) for the construction of the vast majority of the building enclosure. The mock-up process is shown in the photos below and includes engagement from all of the project team members, including the owner, general contractor, enclosure consultant, and window manufacturer.
ADDITIONAL CONSIDERATIONS AFFECTING THE DESIGN PROCESS

Because of the way that the housing contracts are structured, housing providers, such as HF and ULRA, are required to provide continuity of housing, which means that during the renovation/retrofit process, tenants must be provided housing continuously and can only be asked to vacate their units for a maximum of eight hours during a typical day. This requires the construction team to determine how to remove and replace the exterior enclosure within a single working day or how to isolate the tenant from the construction activities while keeping them in their apartment unit. As an alternate, tenants are moved to vacant units and “shuffled” to allow for work to be completed with maximum efficiency. At Gallagher and Sellwood, temporary walls were built inside the units to effectively isolate the tenants from construction activities. At WUM, the window wall system was removed and a new fire-treated, wood-framed wall was installed within an eight-hour period. In order to meet this schedule, wall panels were prefabricated on the ground and coated with the STPe liquid-applied WRB/AB prior to being lifted into place. All of this was determined through the mock-up process for the WUM project. During construction, the prefabrication process had to be modified because of weather conditions: As the weather turned colder and wetter in the fall, a curing “oven” was constructed to ensure that the WRB/AB was fully cured before the panels were lifted into place.

GALLAGHER PLAZA

Gallagher Plaza was originally constructed in 1980 for the Housing Authority of Portland. It is a six-story residential building housing low-income tenants (Figure 3). The floor system is a pre-cast concrete cored plank system, and the original exterior walls are framed with steel studs sheathed with gypsum and an exterior insulation and finish system (EIFS). The exterior windows are a non-thermally broken aluminum window system and perform poorly in terms of water penetration and thermal flow resistance. The existing roof appears to be the original built-up roof, which has been covered repeatedly with an aluminum roof coating membrane. Preliminary investigations revealed significant water intrusion around the window rough openings as evidenced by Figure 4. Note also the microbial growth on the inside surface of the exterior paper-faced gypsum sheathing below the window rough opening.
framing. It was noted that although an EIFS system was used, only 1 in. of exterior insulation was installed, resulting in a poorly performing thermal enclosure (Figure 5).

Ventilation into the units was originally provided through vents in the window units, which at the time of the preconstruction investigation had been blocked (Figure 6). This was likely due to tenant complaints about cold air drafts during winter months, but resulted in poor indoor air quality within the units.

GALLAGHER PLAZA RETROFIT COMPONENTS

The Gallagher Plaza exterior wall assembly consisted of metal stud framing and fiberglass mat gypsum sheathing coated with an acrylic, liquid-applied WRB/AB (Sto Gold Coat® and associated flashings and reinforcements). The insulation is 3-in.-thick mineral fiber insulation (Roxul®) at an R-value of R-12.3, and the cladding system of fiber cement plank (Oko Skin) is attached through a double metal girt system (Figure 7).

For performance balanced with cost-effectiveness, reinforced vinyl windows were chosen for this project (VPI 800 Series horizontal sliders). Horizontal sliding windows are being increasingly requested by nonprofit housing authorities, because they are easy for the tenants to operate and generally require less maintenance by personnel. Because there are fewer moving parts, hardware replacement is less frequent. Although a horizontal sliding window provides less resistance to water penetration and airflow, the improved durability (in the reduced maintenance) is a trade-off acceptable and desired by our clients.

From the existing concrete deck up, the new roof assembly consists of a torch-down SBS-modified base sheet followed by two layers of staggered polyisocyanurate insulation. Note that the initial base sheet functions as a vapor and air control layer and as a temporary roof to protect the occupied units below. This is followed by a gypsum cover board, an SBS-modified base sheet, and an SBS-modified granulated cap sheet. PMMA resin flashing is included for detailing of difficult conditions, such as penetrations and door threshold integration with the main roofing assembly. The SBS roofing system is preferred due to the robustness of the membranes, the redundancy of the waterproofing layers, and the fact that the roofing and mechanical system installation can be sequenced (i.e., the base sheet can be installed and the roof is essentially waterproof while mechanical systems are installed). Once mechanical system installation is complete, the base sheet can be inspected and repaired, and the cap sheet can be installed without damage from mechanical system trades.

Two large boilers located on the roof were replaced with high-efficiency water heaters located on the first floor. Existing make-up air units were replaced with new units that included a heat recovery ventilation (HRV) system using heat exhausted from bathrooms and kitchens to temper fresh air, which was distributed to the corridors. Additional ventilation air to the units was provided through trickle vents in the new windows in each apartment unit.

The retrofit measures have resulted in an 18% reduction in electrical consumption in the first calendar year following completion. In the first-floor common spaces alone, the annual savings exceed $14,000.

SELLWOOD TOWER

Sellwood Tower was originally constructed in 1970 for the Housing Authority of Portland (Figure 8). It is an eight-story residential building housing low-income tenants. The floor system is a poured-in-place concrete slab on the first and second floors and precast slabs on the upper floors.
Exterior walls, beams, and columns on the first floor are poured-in-place concrete, while interior structural walls above the first floor are stacked bond CMU. The original design included a nonthermally broken aluminum storefront system spanning from slab to slab on the north and south elevations. During the late 1980s, a steel-framed wall sheathed with gypsum and EIFS was installed over the exterior of the storefront system. When the EIFS was added, the storefront framing was left in place, and in some locations, even the glazing of the storefront system was left in place. Exterior punched windows were installed into the EIFS system. The exterior windows were a nonthermally broken aluminum window system that performed poorly in terms of water penetration and thermal flow resistance. The existing roof appears to be the original built-up roof, which has been covered repeatedly with an aluminum roof coating membrane. Preliminary investigations revealed significant water intrusion around the window rough openings, as evidenced by Figures 9 and 10. It was noted that although an EIFS system was used, only 1 in. of exterior insulation was installed, resulting in a poorly performing thermal enclosure. There is evidence of water intrusion from pitch pockets on the roof and through the CMU enclosure of the stair towers.

SELLWOOD TOWER RETROFIT COMPONENTS

The Sellwood Tower exterior wall assembly consisted of metal stud framing and fiberglass mat gypsum sheathing coated with an asphalt/butyl hybrid self-adhered membrane (SAM). The insulation is 3-in.-thick mineral fiber insulation (Roxul) at an R-value of R-12.3 (as opposed to the XPS indicated on Figure 11), and the cladding system

Figure 8 – Sellwood Tower prior to renovation.

Figure 9 – Water intrusion at windowsill.

Figure 10 – Water intrusion from roof at window head.
still underway. This will result in energy savings in excess of $200,000/year at the Sellwood project, despite the addition of air conditioning to the common areas on the first floor of the building.

WESTMORELAND UNION MANOR

Westmoreland Union Manor was originally constructed in 1966 for the Union Labor Retirement Association (Figure 12). It is a seven-story residential building housing senior tenants. The floor system is a slab on grade at the first floor and one-directional post-tensioned slabs above grade. The three stair towers are cast-in-place concrete and function as the shear cores for the building. The remainder of the exterior is clad with a single glazed window wall system, which comprises over 70% of the wall area. This system is a cement composite panel is installed to girts attached to a fiberglass spacer, which significantly reduces thermal bridging between the cladding and building structure.

The window and roofing systems on the Sellwood Tower are identical to those used at the Gallagher Plaza. It is important to note that the original scope of work did not include roof replacement, but due to cost savings during the construction phase, the roof replacement was added back into the project scope.

Wall-mounted electric-resistance heating units within each apartment were replaced with new electric-resistance heating units. HRVs were added to the make-up air units, which delivered make-up air to the corridors of the building. No changes were made to the domestic water heating system, as significant plumbing upgrades had occurred five years prior to this retrofit. Similar to Gallagher Plaza, additional ventilation air to the apartment units was provided through trickle vents in the new windows in each apartment unit.

Total building energy consumption was reduced from $3.62/1000 sq. ft. to $.42/1000 sq. ft. while construction was faced sealed system with no drainage capacity and is a very poor thermal performer, being only single-glazed and nonthermally broken.

There was significant evidence of a lack of occupant comfort discovered during the initial investigation through occupant surveys that mentioned poorly performing window wall systems and drafty balcony doors. In addition, there were complaints of poor indoor air quality and the unintended sharing of odors between units. The existing roof has been covered repeatedly with layers of asphalt patching compound. Preliminary investigations revealed significant water intrusion around the perimeters of the window wall system and at balcony entrance doors.

WESTMORELAND UNION MANOR RETROFIT COMPONENTS

The Westmoreland Union Manor exterior wall assembly consisted of 2x8 fire-treated wood stud framing at 24 in. O.C. to maximize insulation effectiveness by reducing thermal bridging (Figure 13). The 2x8 stud depth also allows for R-28 blown-in batt insulation increasing the thermal resistance of the assembly. Note that a proprietary vapor control layer is provided on the interior surface of the framing between the framing and interior gypsum wallboard. This material is a 2-mil polyamide film that changes permeability, depending on relative humidity, allowing the wall to change vapor permeability as needed. The exterior sheathing is fire-treated plywood, which caused some minor issues in the adhesion of the liquid-applied WRB/AB. Because the

Figure 12 – Westmoreland Union Manor prior to renovation.
salts that are part of the chemical structure of the fire treatment sometimes migrate to the surface of the wood, sporadic areas exhibited poor adhesion. At those areas, the WRB/AB was removed, the salts scrubbed off the surface, and the WRB/AB was reinstalled. The cladding system is a fiber cement composite panel that is attached with a proprietary clip system.

The client was particularly sensitive to the poor performance of the original glazing system at WUM and sought significantly improved thermal performance from the glazing system. And although the window-to-wall ratio was reduced from 70% to approximately 45%, the U-value of the proposed glazing system was still of particular concern. The glazing system selected included the EuroLine 4600-Series Goldenline™ tilt-and-turn windows and the 4700-Series swing doors. These are very stout windows, featuring a very robust vinyl extrusion reinforced with steel, which allow for the use of triple glazing and excellent compression of the gasket between the frame and the sash, improving both the watertightness and airtightness and contributing to greater durability and energy efficiency. The U-value of these windows is .17, compared to a U-value of .28 for the dual-glazed VPI windows used on the Sellwood and Gallagher projects.

The roofing system at the Westmoreland project is similar to the system used at both the Gallagher and Sellwood projects. The installation of this system at Westmoreland was made more difficult by a significant number of cell phone tower installations, which needed to be raised because of the added insulation within the roof assembly.

Two large boilers that provided both domestic hot water and water for the hydronic heating system have been replaced. Domestic hot water is now provided by five new gas high-efficiency water heaters. Heating and cooling within the 300 apartment units are provided by Daiken mini-split units. Heating and cooling for the first-floor common areas is provided by three new heat pumps. Make-up air units with HRVs provide tempered make-up air for both the residential floor corridors and the commercial kitchen on the first floor.

Westmoreland Union Manor is still under construction, but initial thermal imaging of the project creates a very clear picture of the thermal effectiveness of the renovated area relative to the completed areas of the building. Figures 14 and 15 are of the existing construction, indicating significant thermal bridging and air leakage at the glazing system. Figure 14 is the original construction, while Figure 15 shows a completed bay of the renovation on the left-hand side and the original construction on the right-hand side of the image.

For comparison, Figure 16 shows the actual surface temperature of the exterior surface of the building glazing, indicating a 10.1°F temperature difference between existing glazing and the new glazing assembly.

The measured energy reduction at Westmoreland is significant. Electrical consumption has remained fairly steady through construction, despite the addition of the mini-split systems for each unit, power for construction activities, and temporary heat for units under construc-
tion. However, gas consumption has been reduced over 43%, as seen in Figure 17. The reduction in gas consumption is largely due to switching from a hydronic heating system for the entire building. Despite switching to an electrically powered heating and cooling system for the building, the steady consumption of electrical energy points to the effectiveness of the enclosure retrofit in reducing the loads on the building imposed by exterior temperatures.

CONCLUSIONS

Energy and enclosure retrofits provide several different but complementary benefits to our clients. The enclosure retrofit creates more durable protection of the building structure by resisting water ingress and vapor flow, thereby extending the life of the building as a whole. At the same time, by creating better control of heat and air flow, the renovated enclosure contributes significantly to reduction of heating and cooling loads. However, an enclosure retrofit alone will not create the greatest reduction in energy consumption but, rather, is best coupled with a retrofit of the MEP systems that address those loads. In apartment buildings, heating and cooling is typically the largest source of energy consumption. That is why the enclosure must first be retrofitted to reduce the heating and cooling loads, and then the heating and cooling system must be redesigned to meet those reduced loads more efficiently. Domestic hot water is the second largest source of energy consumption in apartment buildings and, therefore, also needs to be addressed. Water heating systems currently available on the market are much more efficient than older systems and can contribute significantly to energy consumption reduction.

It is important to be cognizant of the effect of the baseline energy consumption on the scale of energy savings accrued through energy and enclosure retrofits. A very energy-inefficient building, once retrofitted, will result in significant energy savings as compared to an existing building that is only moderately inefficient. At the same time, a retrofit that only addresses the enclosure misses out on the opportunity to greatly reduce energy consumption by meeting those loads more efficiently with newer and more efficient MEP systems. The combination of an enclosure retrofit with an MEP system retrofit offers the opportunity to realize the best energy consumption reduction while providing a long-term durable facility, both of which contribute to significant reduction in operating expenses for the life of the building.