Case Study: Carleton Lodge – Recladding for a Better Environment

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ABSTRACT

Carleton Lodge, situated on the banks of the Rideau River, is a 160-bed long-term care facility that opened on April 8, 1989. The structure is light wood frame construction with insulated stud walls, vertical aluminum siding, and pitched roof trusses. The Lodge, with a central core and four 2-storey residential wings, has private rooms with en suite bathrooms, which project beyond the face of the main walls, and vent directly outside. There is perimeter hot water heating and ventilation from central make-up air units. Since construction, problems have existed with water infiltration, condensation and mould within the exterior walls. The residential wings were cold and drafty in winter and hot in summer. Whenever mould has been encountered since the building was completed, the City of Ottawa (and formerly the Regional Municipality of Ottawa Carleton) has taken immediate action to remove and remediate and conducted frequent air testing to ensure residents and staff were safe. The project objectives were to solve the problem of water penetration into the exterior walls, carry out mould decontamination, and re-clad with a system that will provide trouble free service with a reasonable degree of maintenance. A holistic approach was applied using integrated design and assessment techniques to investigate and design solutions for the building envelope problems. Remediation considered the possibility of mould, potential for salvaging materials and buildability of the details. A mock up was constructed during the design process to verify constructability and test the improvements to the exterior walls. As residents could not be relocated during construction, the project's greatest challenge was limiting disruption and noise. Construction areas were tarped and negatively pressurized to eliminate dust infiltration. Following exterior inspection and wall reconstruction, interior remediation proceeded on a room-by-room basis and generally without displacing residents. The existing un-vented aluminum cladding assembly with minimal capillary break was replaced with a new rain screen pre-finished aluminum cladding system, consisting of high permeance membrane air/moisture barrier, galvanized z-girts and exterior insulation, new windows, ventilation grilles and dampers, and pre-finished metal siding. Exterior sheathing was improved to act as the primary air barrier, and a continuous thermal barrier was achieved with sprayed on foam insulation at difficult locations. Despite many fixed elements of the building, the project has corrected water penetration problems, decontaminated exterior walls, greatly improved the interior environment, and reduced heating and air conditioning costs. Energy use data is still being collected. Client feedback indicates that the project objectives were achieved.

INTRODUCTION

Carleton Lodge is a 160-bed long-term care home situated on a 12-hectare waterfront property overlooking the Rideau River in South Ottawa. The current facility is the second facility on the site, constructed in 1988 and 1989, and opening its doors on April 8, 1989. The original Lodge was opened in 1960, and was the first municipal long-term care home in Ottawa-Carleton.

Carleton Lodge has a three-storey central core, with a large central atrium and a fourth level mechanical room. The central core is a reinforced concrete structure with insulated steel stud or concrete block exterior walls. Connected to the central core are long 2-storey multi-unit residential wings that are denoted "West" and "East", as shown in Figure 1. The residential wings are wood frame construction, with insulated wood stud walls and pitched shingled roofs. The residential wings have mainly private resident rooms, with some double rooms, nursing stations and assisted bath areas. Each resident room has an en suite bathroom projecting beyond the main building (Figure 2) with standing seam metal shed roofs. The second level bathrooms cantilever beyond the ground floor. The entire building is clad in pre-finished vertical aluminum siding. Two central boilers and perimeter radiators provide heat for the residential wings. Make-up air and conditioned air in the summer is ducted to the residential corridors.

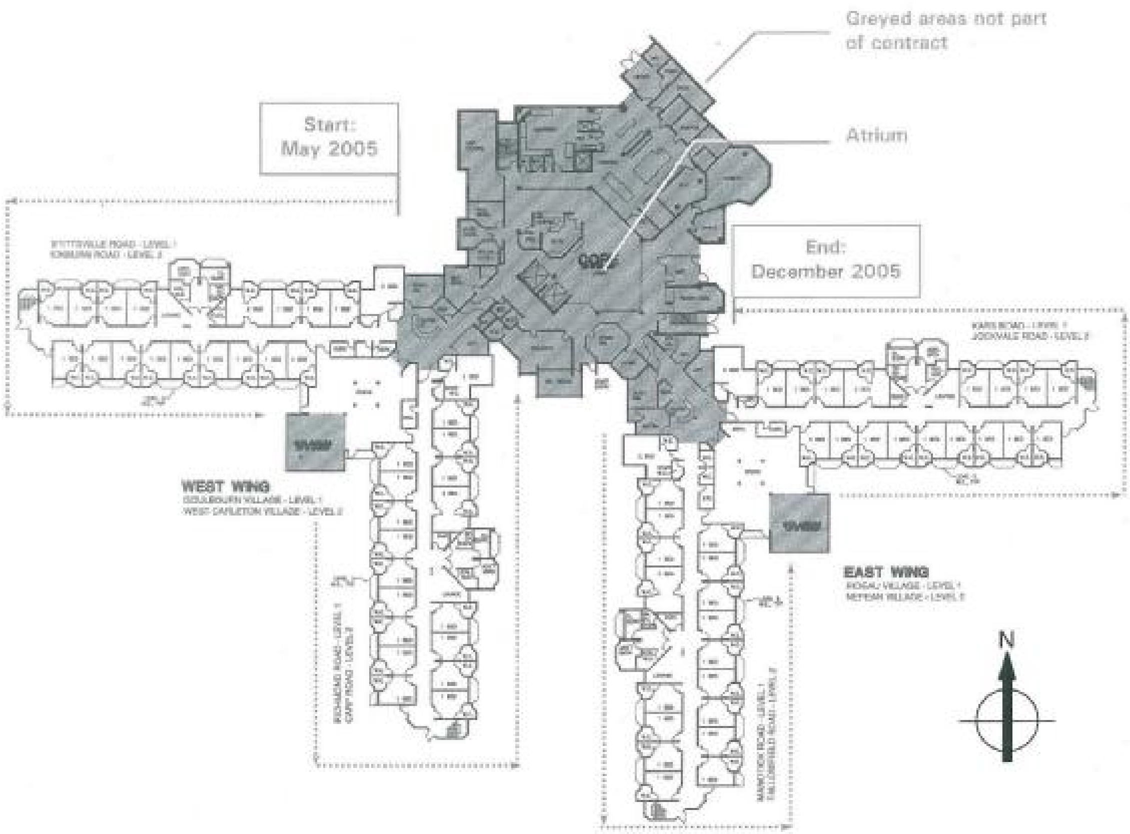

Figure 1: Building Plan

Figure 2: Retrofitted Building Elevation

Since its completion in 1989, there has been a number of building envelope problems reported by staff, including water infiltration, mould at various locations, excessive icicles at the eaves, sprinkler freeze-ups, and cold, drafty interiors. Building modifications done prior to this project include:

- The original residential roofs were constructed with no overhang, thus eaves were flush with the exterior wall or stopped short in some locations. Water infiltration caused deterioration of some exterior wood frame walls, previously repaired.
- Eavestroughing that was provided on the original structure was removed several years later due to excessive ice build-up at the eaves. Foundation drainage was added except on one wall.
- Mould abatement was performed on the ground floor exterior walls, as well as at some isolated upper floor exterior walls.
- The roofs on the residential wings were replaced in 2000, including small roof projections that were added to direct roof runoff from the base of the walls.
- New parging was also applied in 2000 at the base of the walls.

With no soffits, attics had isolated vents in the soffit over the second floor windows. Attic ventilation was poor and icicles formed. Due to lack of an adequate overhang, roof runoff fell to the ground either directly along the wall or by cascading over the shed roofs over the residential washrooms. Some of this water infiltrated the wall assembly through vulnerable areas at the shed roofs, windows, and joints in the siding, and backsplash at the base of the wall (Figure 3). Moisture also infiltrated the wall cavity from the building interior due to spillage of water in bathrooms, leakage from plumbing pipes, and condensation on pipes and exhaust ducts. Condensation in the exterior wall due to high interior humidity was most critical in the common assisted bath areas, where the majority of the fans were not functioning, and not vented to the building exterior. Whenever mould has been encountered since the building was completed, the City of Ottawa (and formerly the Regional Municipality of Ottawa Carleton) has taken immediate action to remove and remediate and conducted frequent air testing to ensure residents and staff were safe.

Figure 3: Stained Sheathing Around Windows

The previous repairs did not correct the cold, drafty interiors. Washrooms were particularly cold, especially on the windward faces of the building, furthest from the central core. Pipes up to three feet inside the building would freeze in winter in the residential wings. This was caused by a number of interrelated factors.

- Fans in the washroom exhausted through vents in the soffit of the adjoining windows or the cantilevered second floor washroom floors. In the winter on cold, windy days, strong winds would blow cold air back into the building through these vents.
- The ground floor ceiling is dropped below the second floor for mechanical services, so the soffit just below the cantilever floor of the second floor washrooms was directly connected to this space above the ceiling. These soffits were not sealed nor insulated, and cold air blew in through the bathroom vents and above the ground floor ceiling.

- The stack effect created in the high atrium of the central building core aggravated the problem. Air moving upwards in the atrium, through the elevator shaft and mechanical room vents, created negative pressure relative to the connecting residential wings, increasing the infiltration of cold air through the exhaust vents, other openings in the siding, and cantilever floor projections.

Adjustments to the mechanical system were required to provide adequate heat to the residential rooms, especially in windy winter weather. The mechanical systems could not adequately cool the residential wings in summer.

REPAIR APPROACH AND METHODOLOGY

In 2004, it was determined that despite previous attempts to alleviate building envelope challenges at Carleton Lodge, major issues remained to be resolved. A plan was developed to remediate and restore the indoor environment at Carleton Lodge to acceptable levels. A holistic approach was applied. There were many fixed conditions; however, there was adequate flexibility to modify enough elements for a profound improvement to the interior conditions. A multi-faceted approach was undertaken, as outlined below

WATER INFILTRATION AND ATTIC VENTILATION

Roof projections were added with eavestroughing and downspouts to direct water away from the building. Siding interfaces were designed and constructed to properly shed water. In addition, continuous soffit venting was installed, improving attic ventilation.

AIR, VAPOUR AND THERMAL BARRIERS

The walls were reconstructed by removing all exterior siding, sheathing and batt insulation. Repairs to the existing 6-mil polyethylene vapour barrier could not be completed due to complexity in the exterior wall design (Figure 4). Since a comprehensive air barrier could be constructed, all efforts were taken to ensure that it was achieved. A new redundant air barrier was constructed with sealed sheathing and a high permeance membrane. The high permeance membrane also acts as a secondary moisture barrier. Batt insulation in the stud cavity was replaced. Based on dynamic hygrothermal modelling by WUFI, additional rigid mineral wool insulation was installed outside the sheathing. Hours per year when conditions support mould growth on the inside face of the exterior sheathing were less than 1% in the analysis. Spray-foam insulation was installed in areas where the vapour barrier could not be reinstated. All of these techniques were aimed at increasing thermal resistance, reducing air leakage, and moisture penetration into the wall cavity, essentially reducing energy consumption and increasing resident comfort.

Figure 4: Discontinuous Poly Layer Between First and Second Floors

INTERIOR HUMIDITY AND HVAC SYSTEMS

To reduce humidity build-up, new fans were installed in each residential bathroom and the common assisted bath areas. However to reduce air leakage through these fans, motorized dampers were added to every fan. High quality dampers were selected and connected to the fan switches, opening the dampers after a delay from the time the fans started, to ensure that air infiltration was minimal. The dampers were installed in the soffit above the ground level windows and sealed to the exterior sheathing to minimize air barrier discontinuities.

LOGISTICS

Exterior cladding reconstruction was only performed on the wood framed residential wings of Carleton Lodge. The central core and two solarium areas, shown in grey in Figure 1, were not part of the contract. The central core houses the administration offices, kitchen, dining rooms and gathering areas for the residents. Reconstruction was conducted commencing at the North Elevation of the West Wing, and progressed counter-clockwise around the building, ending at the North Elevation of the East Wing. The exterior work was completed within a seven-month period from May 2005 to December 2005.

Carleton Lodge operates 24/7/365, caring for full-time higher risk residents, many confined to the building. The Lodge is fully occupied with a substantial waiting list. As a result, there was little opportunity to relocate residents overnight during construction. The project's greatest challenge was limiting disruption and noise, and separating the construction area from the residents. Interacting with the residents and staff with a high degree of sensitivity was essential for success of the project.

Figure 5: Tarp Enclosure

In order to ensure that the exterior work area was negatively pressurized relative to the interior of the Lodge, each elevation was completely enclosed with scaffolding and a tight tarp enclosure. Large fans through this tarp enclosure operated continuously, creating the negative pressure required to prevent any contaminants from entering the building interior (Figure 5). The interior polyethylene and drywall were maintained during all exterior repairs to keep a defined, exposed separation between exterior and interior. The enclosure also protected the exposed wall construction from rain and extreme temperatures. In instances where the new batt insulation would be left exposed overnight, the contractor took the additional step of providing a second layer of tarps directly over the wall insulation. In the infrequent instance where water penetrated the overall tarp enclosure, the leak would be immediately fixed in the tarp, and the timber framing and sheathing left to dry out.

The negatively pressurized tarp enclosure was also essential to the mould remediation. After removal of the batt insulation, the presence of concealed mould on the exterior face of the drywall was recorded in detail. Following completion of the exterior re-cladding, the interior mould remediation was carried out. The detailed recording of the mould on the exterior face of drywall that was concealed from the interior enabled a very targeted remediation, without significant internal disruption. Drywall was removed and replaced according to standard mould remediation procedures. It was essential to carry out mould remediation after cladding rehabilitation.

In the summer and fall, exterior remediation was carried out one half-wing at a time. Thus, for this time, only half of the residents on one elevation had scaffolding set-up and construction occurring outside of their rooms. As the end of the construction season neared, and concerns of cold, rainy weather were impending, the contractor modified the exterior reconstruction schedule so that a lesser length of wall was open at one time. In this way, the length of wall exposed to the harsh elements was minimized, and resident comfort could be maintained.

Interior mould remediation was carried out on a room-by-room basis after the exterior tarp enclosure was removed. Based on the magnitude and location of the deterioration, the interior remediation was classified into four general categories.

- **Remediation of structural elements in the exterior wall.** This work was the largest magnitude of the remediation. When it occurred in a resident room, it required relocation of the resident and tarp enclosure of the entire resident room.
- **Remediation of interior bathroom of resident rooms.** When the remediation was totally within the bathrooms, the doors to the bathroom were sealed and the work done without relocation of the resident.
- **Remediation of interior living area of resident rooms.** When the remediation was within the living room area, a tarped enclosure was installed to separate the wall from the room. Residents were relocated during the work day while work was carried out, but they were returned to the rooms overnight.
- **Remediation in non-resident areas.** This type of work did not require resident relocation. In these cases, the work area was sealed off and the work carried out in the most effective way to reduce the interference time. Normal staff activities in these areas were shifted to adjacent areas for the period of the work. As a result, in the case of assisted bath areas, only one of these rooms could be remediated at a time. Conversely, remediation of the stairwells and ends of corridors had little impact on the operation of the Lodge.

A highly proactive and cooperative interaction between the construction team and the staff of the Lodge was essential to the success of the project. A resident satisfaction survey conducted during the summer months after the construction revealed that concerns over construction noise and inconvenience registered minimally in resident complaints. Thus this approach was deemed successful. The main project objective was to improve the conditions in the Lodge; so respecting this during construction was also critical.

CLADDING REPLACEMENT

For reference purposes, Figure 6 provides a schematic of a building section illustrating the newly constructed cladding system.

Exterior Wall: Cladding repair/replacement began with teardown of the existing aluminum siding, which allowed for the extent of water infiltration through the cladding to be observed. The majority of water damage was limited to around windows, along the sloped sills of recessed windows, as well as localized areas where openings in the siding allowed for direct water infiltration. All existing batt insulation was then removed to the polyethylene vapour barrier. Black staining of the exterior face of the drywall was observed and tested around the building perimeter, usually in the order of 1 to 3 square feet, with the exception of some larger affected areas. The common assisted bath areas were also a location where significant black staining was observed on the drywall, which was attributed to the high-use and high humidity of these areas, and the lack of ventilation available in these rooms.

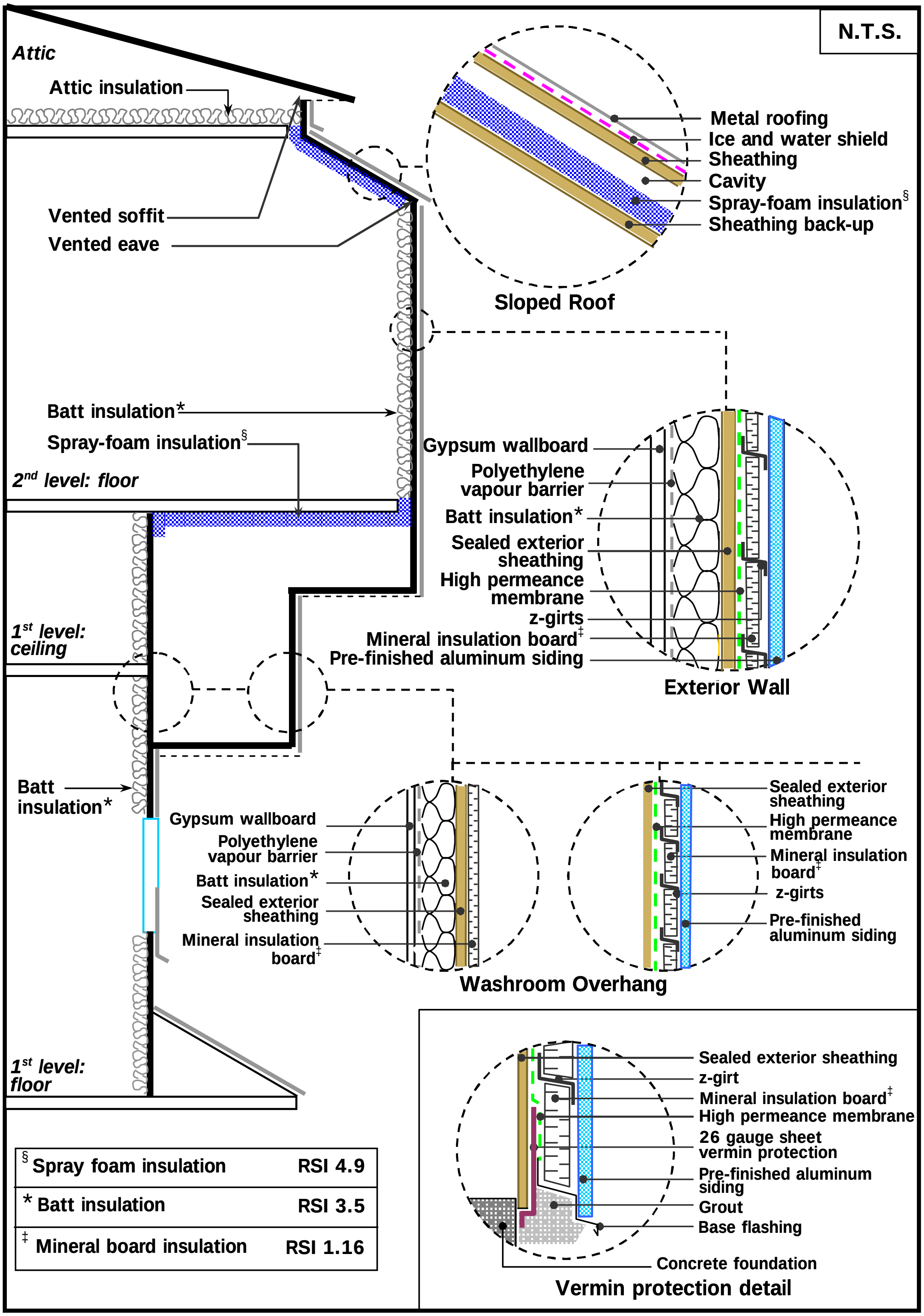

Figure 6: Schematic of Building Section and New Cladding System

The vapour barrier was repaired by sealing holes and providing additional polyethylene where it was missing, prior to any further remediation. Due to the complexity of the exterior wall construction, there was some limitation on the completeness of the repairs to the vapour barrier. New batt insulation (RSI 3.5) was then installed between studs.

Figure 7: Sealed Joints in Sheathing

The Ontario Building Code (OBC) requires a gap to be provided between sheets of sheathing for new construction. The gap between plywood sheathing boards was sealed with acoustic sealant to the full depth of the edges (Figure 7). Where the acoustic sealant did not appear to fill the entire sheathing joint depth, the joint was taped to maintain the seal. In this way, the sheathing would be the primary air barrier for the building envelope with structural integrity to withstand the pressures developed across the air barrier. Sheet type air barriers can tear or become loose over time. However, since a moisture barrier was needed, and to provide redundancy to the air barrier system, a vapour permeable sheeting was installed over the plywood sheathing and clamped in place with z-girts (Figure 8).

Figure 8: Tyvek Installed Over Sheathing

Next, horizontal galvanized z-girts were installed with a slight slope away from the wall to drain any water away from the wall surface. Rigid mineral insulation board (RSI 1.16) was anchored to the sheathing between the girts to provide a more continuous thermal barrier against heat loss and reduce condensation within the stud cavity (Figure 9).

Figure 9: Installation of Rigid Insulation

Vermin protection in the form of a 22 gauge L-shaped galvanized steel sheet 300mm in height was fastened to the sheathing at the base of the wall, and sealed with grout at its base (Figure 6).

The intent of the guard was to prevent vermin from crawling under the base flashing and chewing their way further into the wall cavity behind the sheathing.

The final step of cladding reconstruction was installation of the siding. Pre-finished aluminum siding similar in colour to that of the original core structure was used to maintain a consistent appearance between new and old. The aluminum siding was fastened to the z-girts using steel screws with plastic washers to address galvanic corrosion. At the base of the siding, the moisture barrier was sealed over the top of the lowest z-girt, and base aluminum flashing fastened to the face of the z-girt, directing water within the wall cavity out.

The sloped sills located beneath the recessed windows in the living areas of the residential rooms were reconstructed in a similar manner to the exterior walls. The existing metal and sheathing were removed, revealing evidence of water infiltration and vermin penetration at the first floor. Continuous vermin protection was provided along the perimeter of the base sill. The sills were then reconstructed with framing, sheathing, self-adhering waterproof membrane, and pre-finished sheet steel roofing. Vent holes were included at the top of the sills, and a screened wall vent installed to provide ventilation of the sill cavity. Vents were also provided in the base of the second floor sloped sills.

Beneath the second floor washroom overhangs, the polyethylene vapour barrier and batt insulation was discontinuous. Due to the challenge associated with providing a continuous vapour barrier at this location, and the recorded complaints of cold floors at the second floor washrooms, spray-foam insulation (RSI 4.9) was installed on the underside of the second floor overhangs overlapped with the wall to maintain continuity. A removable vented soffit is provided at the base of each overhang, allowing for maintenance and access to the dampers.

Washroom Sloped Roof Replacement: Beneath the sheet metal and sheathing of the sloped washroom roofs was a discontinuous polyethylene layer, and packed batt insulation. Due to the poor condition of the vapour barrier, and the lack of structure to secure to, plywood sheathing was installed at the back of the sloped roof cavity and spray-foam insulation was applied. This effectively established continuity of the air and vapour barriers.

Sheathing and waterproof membrane were installed, followed by pre-finished sheet steel roofing similar to that used on the core structure and on the sloped sills, to maintain a consistent appearance around the building. A gap was provided at the eave of each roof, and a wall vent installed at the uppermost section to vent the roof cavity. An additional benefit to the wall vent was that it protected the fasteners that anchor the wall vent/metal roof to the sheathing beneath. By preventing water from falling directly on the fasteners, the wall vents reduce the potential for corrosion at the fasteners, consequently decreasing the possibility for water infiltration into the sloped roof cavity.

Windows: Windows that were exposed to direct water runoff, including windows located in the residential washrooms, assisted tub rooms and ends of stairwells, were replaced. These windows were the site of localized water infiltration due to poor framing and waterproofing details. At the head of each new window, the top of the z-girt was slipped under the moisture barrier and sealed, while the base of the z-girt overlapped and fastened to the flashing. The living room recessed windows were not replaced.

ROOF ENHANCEMENTS

Main Roof: The main purpose of the roof enhancements was to prevent water infiltration into the walls below and reduce icicles. The existing roof projections were small and could not direct water away from the face of the walls sufficiently. Icicles were reduced by ensuring insulation continuity and improving soffit ventilation of the attic space. There were also no soffit vents at the roof eave; the original construction provided attic ventilation through isolated vents over the second floor windows. In winter weather icicles spanning from the roof to the ground had been previously reported. The poor attic ventilation combined with the cold roof eaves at the recessed second floor windows and the second level washrooms were the primary cause of the icicles. Tower vents were installed high on the roof with the roofing replacement in 2000.

The first of the roof enhancements was to install a 300mm extension to the roof eave around the perimeter of the residential wings to direct roof runoff away from the exterior walls. Existing shingles and sheathing were removed in the first 1200mm from the eave, and new framing spliced to the existing roof trusses. This new 1500mm section of roof was then protected with sheathing, self-adhered waterproof membrane, and roof shingles to match those on the existing roof. A vented soffit was provided, and insulation baffles installed to enable continuous attic ventilation along the roof eaves. Eavestroughing and downspouts were installed to direct water away from the building.

Figure 10: Installed Damper

Skylights: Skylights located at the end of each residential wing were replaced with wood rafters, drywall, polyethylene vapour barrier, spray-foam insulation, and completed with sheathing, adhered waterproof membrane and shingles. A wall vent was provided at the top of the new roof. This location was previously plagued by water infiltration due to difficulties in constructing watertight details where the siding and skylights met. Eliminating the skylights allowed a roof to be constructed that reduced water infiltration and permitted much greater control of the interior conditions at the ends of each residential wing, warmer in winter and cooler in summer.

HVAC IMPROVEMENT

To improve and control ventilation in resident washrooms and common assisted bath areas, new fans were installed in each room. Essential to the success of the project, at the location of the vents to the exterior, dampers were installed to prevent back drafts from pushing air back into these rooms. To maintain the integrity of the air barrier, the dampers were sealed with acoustic sealant to the plywood sheathing, and mechanically fastened around their flanges (Figure 10).

The hot water radiators in each resident room were cleaned to improve operating efficiency. No other modifications to the HVAC systems were included in the project.

INTERIOR REPAIR DETAILS

The interior repair was limited to remediation of damaged drywall and drywall that had mould developed on the exterior face. The identification of this drywall was carried out when the outside face of the drywall was exposed during the exterior work. The areas in need of remediation were carefully documented. This procedure maintained a complete separation between the interior and exterior of the building throughout the project. Only at a few locations, where there was deterioration and rot of the wall framing, was the exterior and interior exposed together. In these few cases, the room was vacated and sealed and the remediation completed including framing repairs, prior to re-establishing the separation from interior to exterior and reopening the rooms. In only these cases of significant repair did residents need to be relocated overnight.

Mould remediation in individual resident rooms was carried out on a room-by-room basis after the exterior repairs were completed. This allowed for work to have the minimal impact on the residents and no need to relocate residents overnight except as noted above.

Washroom windows were replaced on a room-by-room basis, by sealing the washrooms from the residential rooms, replacing the window with any repairs to the rough opening and then reopening the room. Washroom fans and wiring of the dampers to the switch were also carried out from inside.

ASSISTED BATH AREAS - VALUE ADDED

Repairs to assisted bath areas were carried out with the new fans and dampers that controlled air leakage and provided for ventilation of interior humidity. Prior to the project, the assisted bath fans were generally inoperable. In addition, some remediation to the interiors of these rooms was carried out. The ceiling below second floor baths and showers was repaired and drip pans were installed in the ceiling to protect them from uncontrolled water leakage. Improvements to shower construction, including new flooring and drains were made to reduce water leakage in these areas.

CONCLUSIONS

Since original construction, problems have existed at Carleton Lodge with water infiltration, icicles, condensation and mould within the exterior walls. The residential wings were cold and drafty in winter and hot in summer. The project objectives were to solve the problem of water penetration into the exterior walls, reduce icicles, carry out mould decontamination, and re-clad with a system that will provide trouble free service with a reasonable degree of maintenance. While the City of Ottawa has taken immediate action to remediate areas whenever mould has been encountered in the past, including conducting frequent air testing to ensure residents and staff were safe, a more comprehensive remediation of the exterior envelope was deemed appropriate to reduce the risk of future occurrences.

The construction work needed to consider many logistical challenges including, 24/7/365 operation, caring for full-time higher risk residents, many confined to the building and with no swing space for resident relocation during the construction work. The project’s greatest challenge was limiting disruption and noise, and separating the construction area from the residents. Interacting with the residents and staff with a high degree of sensitivity was essential.

The exterior work area was completely enclosed and negatively pressurized relative to the interior of the Lodge. While the negative pressure was created with large fans, the noise of the fans had to be factored against the need for separation of the construction area and the interior. The walls were remediated; increasing insulation, decreasing air and water infiltration and exfiltration, increasing vermin resistance and controlling ventilation air to the washrooms. In the end, construction is inherently noisy and disruptive; however, the separation of the work area from the interior was successful at keeping disturbances to an acceptable level. Interior mould remediation was carried out on a room-by-room basis minimizing resident and staff disruption and allowing for completion of the entire project with only minor disruption to day-to-day operations, while maintaining a safe environment for residents at all times.

A thermographic scan prior to and following construction revealed exceptional improvement to the exterior cladding, as illustrated through thermal imaging. Thermal anomalies were practically non-existent in the residential wings. The imaging showed that the only thermal anomalies were elevated temperatures at functioning fans and at reflective corners at recessed windows, both of which are expected thermal expressions even with a properly performing exterior envelope. The remainder of the thermal imaging showed the walls to be thermally neutral.

Qualitative results on the improvements to the interior conditions within the residential wings showed that where heating systems previously could not meet demand in cold windy winter conditions, there was no problem meeting that demand after the renovations, with no modifications to the heating systems. Comfortable conditions are now maintained at the Lodge, where this was unattainable prior to the renovations. This was achieved without any other changes to the HVAC systems.

Semi-quantitative results on energy savings showed where two boilers operating with outlet temperatures of 190ºF were required prior to renovation, only one boiler operating with an outlet temperature of 170ºF was required after renovation.

A holistic approach was applied using integrated design and assessment techniques to investigate and design solutions for the building envelope problems. Despite many fixed elements of the building, and no modifications to the central core, the project has corrected water penetration problems, greatly reduced icicle build-up, decontaminated exterior walls, greatly improved the interior environment, and reduced heating and air conditioning costs. The water penetration problems are visually monitored within the Lodge as no sensors were installed with the remediation. The decontaminated exterior walls were confirmed by continuous monitoring during construction. The reduced icicle build-up is confirmed each of the past two winters by visual review. The building operators confirm the reduced heating and air conditioning costs over the time since construction. The greatly improved interior environment is qualitatively reported from the staff and residents of the Lodge. Given the significant improvement to the interior conditions reported in both winter and summer, we have confidence in this reporting.

A resident satisfaction survey conducted during the summer months revealed that concerns over construction noise and inconvenience registered minimally in resident complaints. The main project objective was to improve the conditions in the Lodge; so respecting this during construction was also critical. Client feedback indicates that the project objectives were achieved.

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