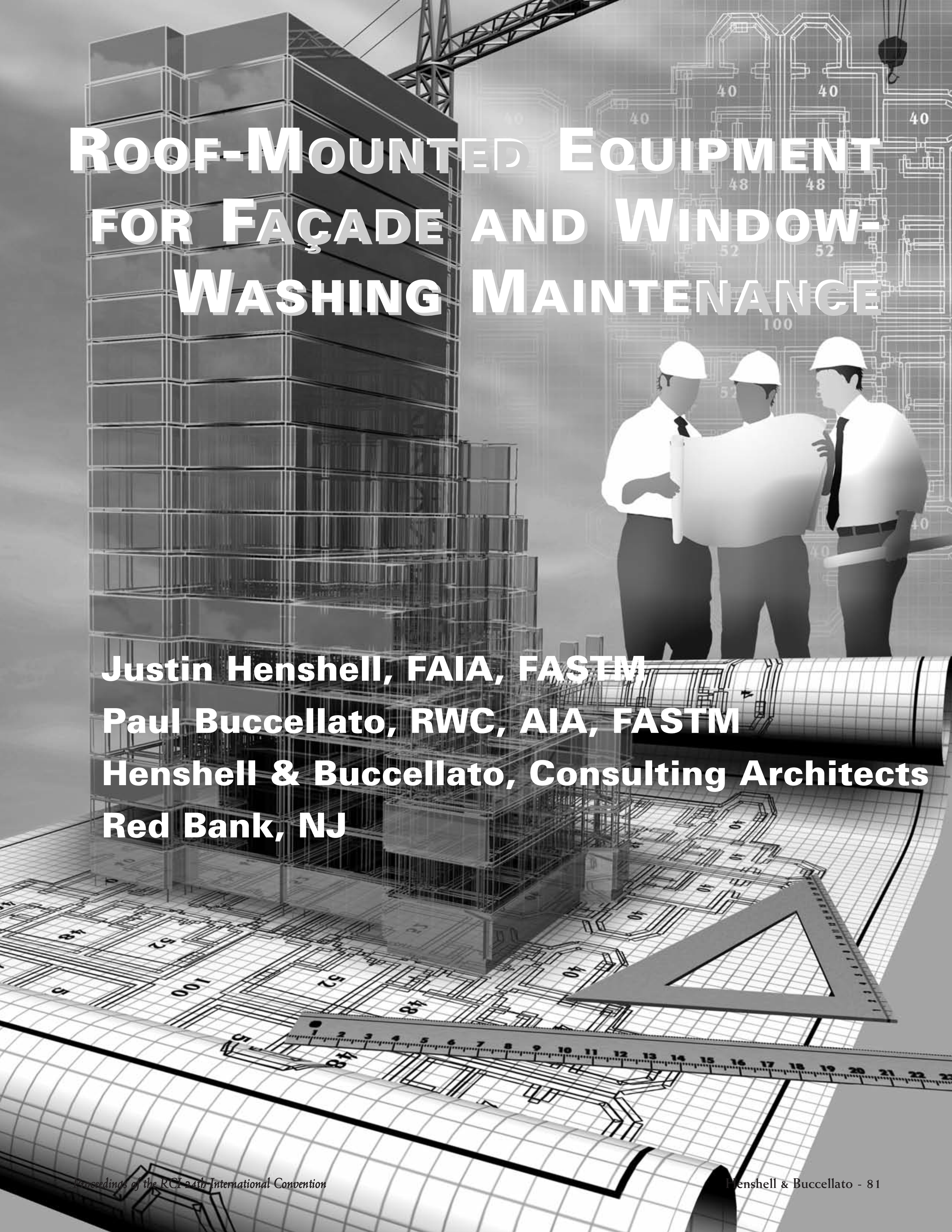

Roof-Mounted Equipment for Façade and Window-Washing Maintenance

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ABSTRACT

Metal and glass curtain walls proliferated after WW II, facilitated by the widespread use of air conditioning and development of sealant technology. Fixed glass required the use of suspended platforms to wash the windows and maintain the curtain wall components. The predominant systems for suspending platforms were self-propelled carriages that ran on parapet or roof-mounted rails and concrete runways and fixed or portable davits. Penetrations multiplied as flashing rail supports, tieback anchors, electric conduits, and code-mandated fall arrest systems became critical. Moreover, the rooftop traffic generated by maintenance personnel threatened the watertight integrity of the roof system. This paper reviews the various window-washing systems and recommends methods to reduce damage to the roof systems. It discusses the use of pavers, walkways, and precast concrete runways. Minimizing penetrations is also discussed. The need for coordination between façade maintenance consultants, structural engineers, and architects who design roof systems is stressed herein.

SPEAKERS

Mr. Justin Henshell has been a registered architect for 55 years, is licensed in NY, NJ, PA, VA, MA, FL, and Puerto Rico, and holds a certificate from the National Council of Architectural Registration Boards. He has headed his own firm since 1956. He is a Fellow of the AIA and a member of the New Jersey Society of Architects, CSI (past president Metropolitan New York Chapter), and The Masonry Society (past director). He also is a Fellow of ASTM and the recipient of the Walter C. Voss Award for 2000. He is a member of ASTM Committees D08 Roofing & Waterproofing (past chairman of Subcommittee D 08.20 Roofing Membrane Systems), C 15 Masonry Units, and E 06 Performance of Building Constructions. He serves on the International Council for Building Research Studies & Documentation, Commission W086 Building Pathology. Mr. Henshell was a faculty member and regent of RIEI. Justin Henshell has authored more than 35 technical articles and papers and presented them in the U.S., Canada, and Europe on a variety of subjects relating to construction materials. He is the principle author of an ASTM standard on waterproofing design and a co-author of an NCARB monograph on Built-up Roofing. He is also the author of *The Manual of Below-Grade Waterproofing Systems,* published by John Wiley & Sons. In 2008, he was awarded the first William C. Correll Award by RCI for “outstanding actions beneficial to professional development of the industry.”

Mr. Paul Buccellato attended Pratt Institute and is a registered architect in New York, New Jersey, Pennsylvania, and Virginia and holds a certificate from the National Council of Architectural Registration Boards. He is also an RWC with RCI, Inc. He is a member of the AIA, the New Jersey Society of Architects, CSI, RCI, and ASTM, Committees D-08 Roofing & Waterproofing (chairman subcommittee D08.20 Roofing Membrane Systems, past vice chairman of Subcommittee D08.22 Waterproofing), and C 15 Masonry Units and recipient of the Award of Merit and a Fellow of ASTM International. He is a member of the Masonry Contractors of New Jersey. He has authored several technical papers on waterproofing and roofing, five ASTM standards on roofing and waterproofing, and has lectured at Brookdale College, NJ and presented papers to various organizations. He wrote a column on roof design for *The Roofing Specifier* and is a co-author of an NCARB monograph on built-up roofing. Mr. Buccellato is the mayor of Matawan, NJ.

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ABSTRACT

Metal and glass curtain walls proliferated after WW II, facilitated by the widespread use of air conditioning and development of sealant technology. Fixed glass required the use of suspended platforms to wash the windows and maintain the curtain wall components.

The predominant systems for suspending platforms were self-propelled carriages that ran on parapet- or roof-mounted rails and concrete runways, and fixed or portable davits. Penetrations multiplied, as rail supports, tieback anchors, electric conduits, and code-mandated fall-arrest systems became critical. All of these penetrations required roof system openings and flashings that weaken the waterproofing system. Moreover, the rooftop traffic generated by maintenance personnel threatened the watertight integrity of the roof system.

This paper reviews the various window-washing systems and recommends methods to create and maintain the watertight integrity of the roof systems.

It discusses the use of pavers, walkways, and precast concrete runways and how to minimize penetrations. The need for coordination between façade maintenance consultants, structural engineers, and architects who are involved in the design of roof systems is emphasized.

INTRODUCTION

Prior to the advent of the metal and glass curtain wall, medium- and high-rise buildings were constructed with punched windows separated with masonry-clad columns and spandrels. Windows were operable because air conditioning was not in widespread use and operable sash was required for ventilation.

These windows were washed by men equipped with safety belts which were secured to window-cleaner anchor bolts. Their design was controlled by both FM, UL and local codes.

Window washers worked from boatswains' chairs, swing stages, or scaffolds secured by C-hooks over parapets or from cables connected to rings through the membrane secured to the roof deck framing.

With the widespread introduction of air conditioning, operable windows were no longer required for ventilation. As air-conditioned buildings proliferated, metal and glass curtain walls with fixed glazing became more feasible.

Fifty years ago, Lever House (*Figure 1*), the New York City "glass box," ushered in the era of high rise buildings clad with metal and glass curtain walls. Soon, similar buildings became a part of the landscape in every major city. Accelerated by the rapid improvement of HVAC systems, these buildings had few, if any operable sash which presented a problem for cleaning the glass and maintaining caulking.

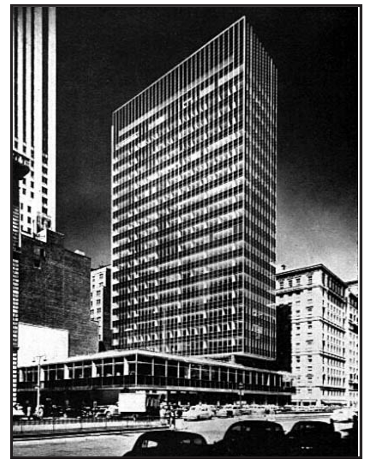

Figure 1

Today, most of the metal and glass curtain walls on high-rise buildings are maintained from scaffolds or platforms suspended from window-washer carriages that circumnavigate the perimeter of the roof, traveling on concrete runways or rails. Buildings with many setbacks are equipped with permanently mounted davits or davit sockets to receive portable davits. For nonwindow-washing maintenance, if required, portable outrigger beams are often specified.

Currently, OSHA/ANSI standards require compliant fall protection and suspended maintenance equipment on all buildings. Two anchors are required: one for a tieback, and the other for a fall arrest line. This poses a challenge to roof designers who must design systems that will resist the potential for water infiltration at these numerous penetrations and from abuse by maintenance personnel.

One of the most common building maintenance systems is an electric-powered, self-propelled carriage with a scaffold suspended from its davits. The scaffold may be swinging or equipped with fittings to engage guides that are integral to the vertical curtain wall mullions. By raising or lowering the scaffold and moving the carriage, the entire façade is accessible for cleaning and maintenance. The carriage travels on a concrete runway or is mounted on tracks that may be secured to the parapet or supported on pedestals. It is commonly housed on the roof in "garages" for protection and maintenance.

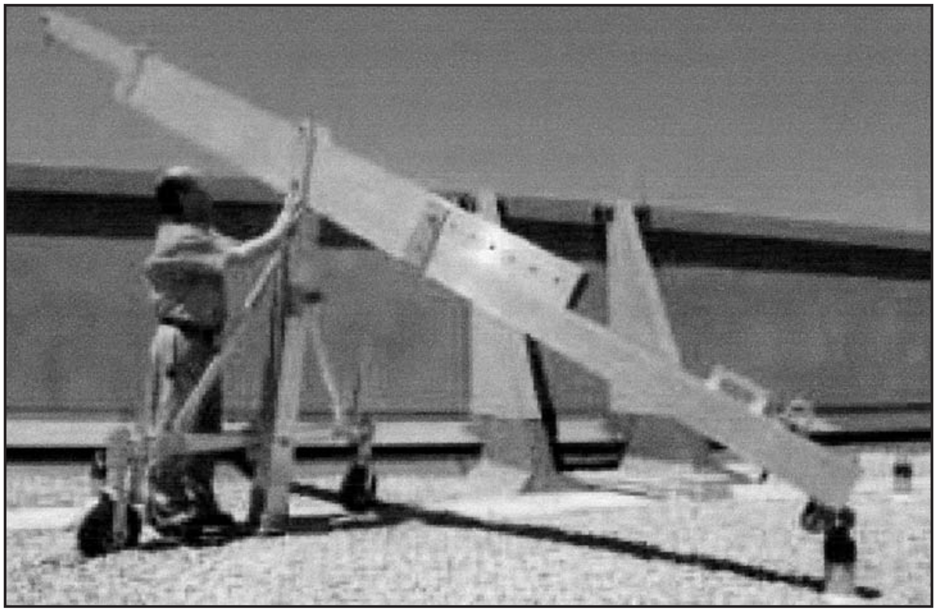

Figure 2

WINDOW-WASHING SYSTEMS

PORTABLE ROOF OUTRIGGER BEAMS

Description

This is one of the least sophisticated maintenance systems. It consists of two portable, extendable outrigger beams with a fitting on one end to secure to the tieback anchor and a pair of wheels mounted on a tripod and located near the eave or parapet (*Figure 2*).

The beams are carried or sometimes dragged across the roof, positioned, and secured at the inboard end to the anchor fitting.

Problems

Portable Roof Outrigger Beam systems present the following concerns:

- The wheels on the tripod can cut into the roof membrane or force aggregate into it.
- Smooth-surfaced and single-ply membranes are subject to abrasion.
- Loose-laid membranes will wrinkle from the wheel shear.
- Insulation below the membrane may have insufficient compressive strength to resist the point loads of the tripod wheels.

Recommendations

A good design for this type of system should incorporate a row of precast 600-mm x 600-mm (24-in x 24-in) pavers near the eave or parapet that will provide permanent support for the wheels of the tripod. Typically, plywood sheets are utilized to provide protection and to isolate the wheels and equipment from the membrane. However, plywood can deteriorate over time and cause damage to the roof membrane. Careful coordination is required with the façade maintenance engineer to properly locate the anchors and the pavers. Pavers should be sturdy and set solidly on the membrane to resist cracking from the wheel loads.

Figure 3

DAVITS

Description

Davits consist of a telescoping outrigger beam mounted on masts. They are bolted to a socket on a pedestal secured to the roof structural framing system. Hoists and platforms are suspended from the outrigger (*Figure 3*). Davits can be permanently mounted on the roof or are portable and are fitted into permanent sockets connected to the roof structural system. Optionally, masts can be tied back to a roof-mounted anchor, but usually the structural support is sufficient to resist the moment forces from the hoist and platform.

Problems

The davit supports consists of a flat plate welded to a post. The height of the davit is often determined from the top of the structural deck by either the façade maintenance engineer or structural engineer without determining the level of the height above the membrane. Since the membrane level varies when tapered insulation is used, the level of the membrane at each davit may not be determined at the time the post height is selected. Energy Code requirements or Mechanical Electrical Plumbing Engineer (MEP) criteria and future reroofing may result in the top of the post flashing being too low to conform to industry standards or the membrane manufacturer's requirements.

Figure 4

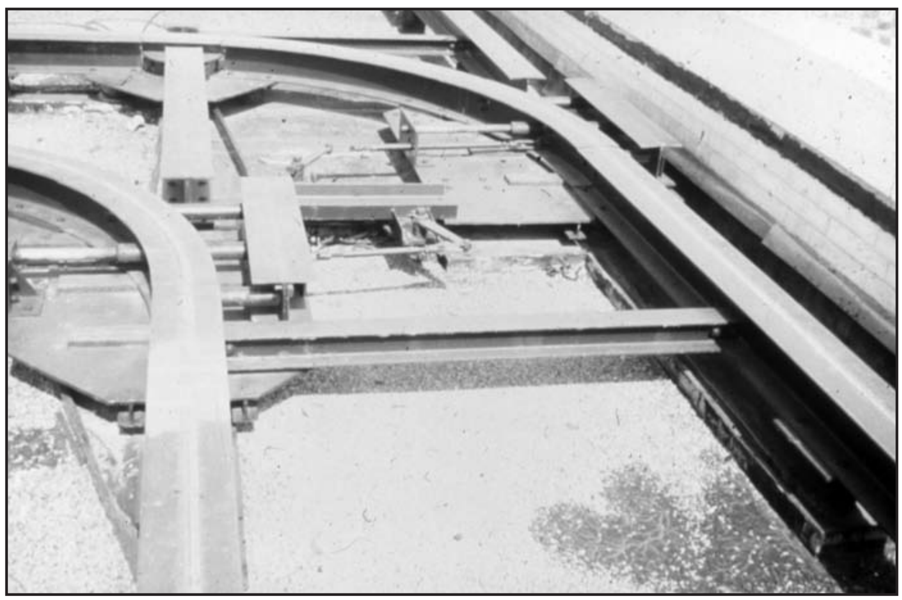

Figure 5

Recommendations

Coordination among the architect, engineer, and façade maintenance consultants at the beginning of the project can eliminate flashing problems from inadequate pipe heights.

Prudent roof designers will provide pavers where davits are to be located to reduce abuse from maintenance personnel. Walkway pads can be used, but protection of the membrane is reduced.

CARRIAGES ON RAILS

Description

Carriages or trolleys are usually self-powered and can be mounted on a monorail secured to the inboard face of the parapet or to pairs of rails mounted on supports above the roof. Roof-mounted rails are usually installed close to the surface of the roof and may incorporate complicated switching gear. They also require local power supplies mounted on the roof and spaced to minimize the length of the cables (*Figures 4* and *5*).

Problems

Parapet-mounted rails rarely pose problems. However, it is desirable to provide pavers for the operators to walk on for accessing the equipment.

Roof-mounted systems with their switching gear can inhibit roof maintenance and pose difficult flashing and reroofing conditions.

Recommendations

If the building design requires or incorporates the use of a carriage or trolley window-washing system, it is best to use a parapet-mounted rail system, in lieu of a roof-mounted rail system for the reasons described above. It is better, although not ideal, to utilize the system to operate over a concrete runway.

Figure 6

CARRIAGES ON CONCRETE RUNWAYS

Description

Self-propelled carriages traveling on concrete runways are more predominant than track-mounted units for buildings with minimum setbacks. Runways are constructed of a reinforced concrete slab, approximately 3-m (10-ft) wide, that follows the parapet around the building perimeter (*Figure 6*). The outboard side terminates within a few centimeters (inches) of the inboard face of the parapet. The inboard side of the runway is provided with a 100- to 150-mm- (4- to 6-in) high curb to prevent the carriage from straying off the runway (*Figure 7*). Rings or prefabricated, flush-mounted tie-downs are installed on or near the curb to help counterbalance the scaffold. The curb is equipped with scuppers or drains at regular intervals.

Figure 7

Until a few decades ago, the membrane below the runway was constructed as a multi-ply bitumen-and-felt built-up roof (BUR) installed over insulation (or directly on the concrete deck, if insulation was not required). A variation of this system is a PMR configuration in which the membrane is installed on the roof deck, covered with loose-laid, extruded polystyrene insulation,

Figure 8

and ballasted with aggregate or pavers. Contemporary membranes run the gamut of liquid-applied membranes, BURs with polymer-modified bitumen plies, and loose-laid thermoplastic and thermoset, single-ply sheets. In the absence of a PMR system, window-washer runway slabs were cast over cap sheets or preformed asphalt/felt protection boards laid dry or mopped to the membrane.

OSHA/ANSI- and ASME-approved, self-propelled, wheeled carriages or trolleys support outriggers with their hoists and platforms. They run on cast-in-place concrete runways divided with control joints.

Problems

Most slabs are cast in 3-m (10-ft) lengths with 25-mm (1-in) joints. These joints are filled with a preformed expansion joint filler and caulked. The caulking may extrude in the summer where it is often damaged by the carriage's wheels. The joints are intended to absorb thermally induced movement, and are thus dynamic. Since the slab is floating, its movement can impart shear stresses to the membrane and abrade or tear the base flashing. More serious problems develop when the slab is cast around tie-down anchors that are secured to the deck structure through the roofing system, and therefore limit the slab's movement. Runways also deteriorate from freeze/thaw cycles as well as the wheels, where the turning radius of the carriages or trolleys is short (*Figure 8*).

Cast-in-place concrete paving proved to be a satisfactory wearing surface for window-washer carriages, providing it was properly reinforced and of good quality concrete (which is not always the case). From a roof maintenance and replacement standpoint, it was another story.

Most high-rise buildings are designed to last from 50 to 75 years, and some, for as long as a century. On the other hand, it is generally agreed that roofs are considered to perform successfully if they can be maintained leak-free for 20 years. Thus, an average roof on an average high-rise building will require replacement at least once, and more than likely, twice before the building has outlived its useful life. When this occurs, the concrete runway becomes a white elephant; it is too big and too expensive to remove and incapable of being made watertight for a reasonable time when the roof below it leaks.

If roof replacement is not required, roof maintenance creates another problem. The slab inhibits access to the parapet base flashing for repairs because it is cast against, or in close proximity to the parapet base flashing. And repairs are required more frequently because the slab movement often damages metal flashing end joints or abrades composition flashing as discussed above.

Figure 9

In an effort to avoid the financial and logistical headaches of removing some or all of the runway to effectuate repairs, attempts have been made to seal the runway and thus stop water infiltration into the concealed penetrations (i.e., tiebacks, anchorage, etc.) and flashing below it. This is rarely successful. Where a coating was applied to the runway surfaces, we observed premature failure of the coating (*Figure 9*). Although the field of the runway can be "waterproofed," the expansion joints, the joint between the runway and the parapet flashing, and the joint between the runway curb and roofing remain dynamic and well beyond the elastic capabilities of liquid coatings. Elastomeric sheet materials are equally ineffective because they are vulnerable to damage from the carriage's wheels when they run against the parapet or twist over the expansion joints.

Figure 10

Figure 11

Recommendations

Although a cast-in-place concrete runway is the most common substrate for a window-washing carriage to circumnavigate the perimeter of the roof, its durability is shortened by the need to remove it in part or whole to repair or replace the roof or waterproofing membrane below. The effects of freeze/thaw cycles will also cause the runway to deteriorate.

Reinforced precast concrete panels provide a structurally sound substrate for the window washing unit to travel and transverse the roof perimeter. The panelized runway provides the following advantages:

- They create runways that are independent of the roofing/waterproofing and flashing systems
- They can be removed and reinstalled as required for roof maintenance and replacement
- They can be designed to incorporate tie-down anchors that do not penetrate the roof/waterproofing system
- If and when panels are damaged or deteriorate, individual units can be easily replaced

Based on experience from previous attempts to repair membranes and flashings under cast-in-place runways, constructing the same runway from precast units can improve the durability of roofing system (*Figures 10* and *11*).

TIEBACKS AND HOLD-DOWNS

Description

Window-washing systems require tiebacks for personal fall protection systems. Tiebacks and hold-downs are also required to counteract the overturning forces of carriages that support outriggers, boatswains' chairs, and davits. These are usually anchored to the structural framing supporting the deck. Anchors are usually in the form of a ring mounted on a pedestal, although some are U-shaped and countersunk flush with the roof or with the concrete runway (*Figures 12* and *13*).

Problems

Tie-backs and hold-downs are usually specified by the façade maintenance consultant and indicated on both his drawings and the drawings produced by the structural engineer. These are items manufactured to conform to codes and are not often indicated on the architect's roof plan. As discussed under davits, the pedestal heights are frequently specified by the engineer or façade maintenance consultant who may not be aware that tapered insulation systems can create varying heights above the structural deck. Consequently, the industry standard for flashing membrane penetrations is often violated.

Tie-backs on standing seam roofs create another problem with coordination between the façade maintenance consultant and the architect who lays out the spacing of the standing seams. Again, the tie-back locations are not always indicated on the architectural drawing. This can result in interrupting the standing seam (*Figure 14*) and creating stress concentrations.

Recessed U-bolts and rings also create problems where the enclosure is below the membrane or runway surface. Tie-downs that are cast into the runway are particularly difficult to flash to the membrane and almost impossible to waterproof at the slab surface.

Note that tie-backs in the plane of the roof are located and their height determined and detailed by the structural engineer or façade maintenance engineer without input from the architect who selects the insulation and slopes.

Recommendations

Flush or countersunk tie-backs or hold-downs should be avoided. Their use creates flashing issues, whether installed in the roof area or a concrete runway. Since tie-backs or hold-downs are required by code or OSHA for personal fall protection or to counter the overturning forces of the carriage, it is important that their design, heights, and locations be coordinated with the architect, engineer, and façade maintenance consultants.

As with davits, tie-backs and hold-downs should be designed to provide heights above the roof membrane that will eliminate flashing problems and avoid violating industry standards.

Consideration should also be given to future reroofing and the potential requirements for even greater thermal resistance.

Figure 13

Figure 12

CONCLUSIONS

Each type of façade and window washing maintenance system can generate its own unique problems. However, the one common problem that they all share is the potential for abuse and subsequent premature failure of the roof system.

Understanding the common design requirements and the ancillary elements of the window-washing system can reduce or eliminate these problems.

Coordinating the design of the window-washing system with the roof design from the beginning of the project can save countless hours during the construction phase redesigning the flashing systems or correcting problems after the project is completed.

Platforms for these systems are electrically powered. Outlets that are mounted on concrete runways have conduits that penetrate the waterproofing membrane located under the runway. Movement of the runway, by either thermal or braking loads, can cause failure of the flashing at the conduit. Additionally, during placement of the concrete, the flashings can be damaged. It is better to locate and mount the outlets on the interior face of the parapets. Conduits should be located to avoid penetrating the roof or waterproofing membrane.

Figure 14

Rooftop traffic to operate and maintain the window-washer system often results in abuse of the roof membrane. Providing walkways to the equipment and a suitable protection layer under the equipment will help reduce or eliminate damage to the roof membrane. Consideration should be given to using pavers or walkway pads beyond the equipment area to afford better protection of the roof, including locating them around tiebacks or anchorage units.

If the window-washing system is designed to travel on a concrete runway, the engineer should consider designing the tie-backs into the runway curbs. This would eliminate a penetration through the roof or runway and the subsequent difficulty of flashing the tie-back or anchorage unit.

If the window-washing system design requires a concrete runway, consider using precast segmented concrete units. The units create runways independent of the roofing and flashing and can be removed and replaced for maintenance.

KEYWORDS

Window-washing systems, davits, tie-backs, runways, carriages, high-rise buildings, glass curtain walls

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