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THE ROOF-TO-WALL INTERFACE: DESIGNING FOR OPTIMUM PERFORMANCE

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ABSTRACT

The interface between the wall and the roof often poses unique challenges for the designer. Influenced not only by building height, terrain, wind load, climate, construction budget, and the myriad of combinations thereof; the roof to wall intersection must integrate both the performance characteristics of the roof assembly as well as the desired wall components in order to successfully meet all desired performance criteria.

One may arguably consider that the roof and façade share equal importance in a building's protection from the environment. Yet, the façade too often dictates the characteristics of the roof's edge, as most parapet designs are motivated to maintain the building's grade level appearance rather than considering the functional aspects of the building enclosure. In comparison with the building facade, is this roof-to-wall interface composed as artfully, and detailed as technically warranted for this complex and extremely vulnerable component of the building enclosure?

This paper explores this issue through an outline of the various influences that affect the design of a roof and façade. Specific details for controlling moisture, air, and thermal continuity will be examined in the context of various wall systems and roof edge designs. Actual case studies identifying good practice and problematic conditions shall be presented to assist designers in developing durable and technically sound solutions for the roof-to-wall interface.

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The Roof-to-Wall Interface:
Designing for Optimum Performance

Introduction

The roof to wall interface remains a unique often ill conceived component of the building enclosure. It must protect, perform, and prevail in the face of extreme events as well as normally anticipated exposure to the environment. The parapet is subjected to multiple influences from weather, height, terrain, and air pressures from both the interior and exterior of the building. These issues may dictate or substantially impact the overall design. Most importantly these parameters must be factored into any type of roof to wall interface design to ensure it meets the applicable building code, technically performs to resist wind load and other forces, air and water, and water vapor transport, and achieve thermal continuity, all while providing an aesthetically pleasing, sustainable, building component.

The incorporation of plantings at the roof level is rapidly becoming a widespread in the design of roofs as owners and tenants begin to emphasize the importance of energy related performance, reduce load on public storm water systems, and urban heat island effects. In addition, many jurisdictions either require new buildings, or incentivize existing building re-roofing operations to encourage owners to allow the roof to serve as a platform for plantings for use as a the roof top garden. These garden, or green roofs are frequently restricted from use by the public, somewhat diminishing the inherent value of the rooftop garden as a user amenity. When accessible, the roof can be beneficial for increased occupant comfort and maximum worker productivity. At a minimum, roof access must be provided for use by routine maintenance personnel to allow for the inspection and repair of the roof system as necessary. Whether the rooftop is open to the public or restricted for maintenance use only, roof edge designs must afford protection to the user at the roof perimeter edge.

The exterior facade is often the foremost acclaimed design feature of a building. The facade will serve as the primary protective element, ensuring a comfortable indoor environment yet undeniably, every designer also hopes the façade will be appreciated as an aesthetic enhancement to the exterior environment. How the uppermost component of the facade is terminated has long been considered an important design decision. Gothic architecture emphasized verticality and maintained the façade as a primary tool by which the building could inherently appear to extend to the heavens. Contemporary multiple or dual façade systems must factor the uppermost portion of the cavity created between the walls as an important component in the technical performance aspect of the façade. As such, the uppermost portion of the façade as a possible extension of the design language, technical performance, or decoration can motivate designers to reconsider the roof to wall interface as an increasingly important component to the overall appearance and function of the building.

Design Considerations at the Roof-to-Wall Interface

Common to the design of all roofs and facades is the requirement that the roof-to-wall interface transmit to the primary structure all the forces to which they are subjected. In addition, each building is individually responsive to its particular climate and the interaction of such with the building's unique form, materials and use. Given the unique nature of each structure, and subsequently each building's wall to roof interface, the detailing and performance requirements will vary, sometimes slightly yet in some cases quite significantly.

Primary Structural Considerations

In general terms the roof and wall design must be capable of resisting the fundamental forces as outlined by the applicable building code. A building's overall height, location, structural type, use, roof slope, and shape need to be considered in the development of the detailing of the roof-to-wall interface. The Minimum Design Loads for Buildings and Other Structures, ASCE/SEI 7-05 provides a procedure for evaluating anticipated wind pressure at walls and roof edges on commonly shaped buildings. Building location with respect to urban or rural locations as well as proximity to coastal areas plays a major role in ASCE 7 guidelines. Factory Mutual Global (FMG) Engineering Loss Prevention Data recommendations are also widely used by roof system designers to design suitable roof edge details and attachment schemes for all types of structures. When undertaking the design for unusually shaped buildings, or structures in unique environments where wind action may not be easily discernable by ASCE 7, wind tunnel testing is recommended to emulate specific effects on a building. Establishing proper wind loads and stack effect is critical to ensure the long-term performance of the roof and wall assemblies during high-wind events.

Neither the ASCE 7 or FMG guidelines offer the designer any meaningful wind pressure resistance benefit for the roof assembly for parapet edges less than three feet in height. The building will experience the highest roof level wind pressures at the corners, followed by the roof perimeter zone, and finally within what is commonly referred to as the "field" of the roof. The type of façade cladding can also influence the loads applied to the parapet. Barrier wall designs that afford little or zero pressure differential across the cavity of a parapet of at least three feet in height substantially reduce the loads at the roof assembly (membrane and insulation) as well as base flashing considerations. Buildings that are equipped with a suitably supported, continuous perimeter parapet of a three foot minimum height will yield the benefit as a reduction in the design wind uplift pressure resistance along the entire roof edge. The parapet must be suitably designed to resist all combined air movement loads applied from the exterior wall side of the parapet, and may also need to consider the effect of the building's internal HVAC pressure load and stack effect.

Primary Heat, Air and Moisture Factors to Consider

Foremost in determining the performance requirements for the roof-to-wall interface is the widely adopted International Building Code (IBC). These requirements for protecting the quality of the interior environment and building enclosure assemblies from the deleterious effects of air and moisture will likely be unique to each building and location. Although not always a code mandate, there are numerous interdependent additional design decisions which should be considered with respect to the roof and wall's overall resistance to air, moisture and temperature, and durability.

Each building interacts and is responsive to its unique climate, and the micro-climate which it, the surrounding buildings, and local topography create. ASHRAE determines various climate zones with weathering characteristics to assist designers in developing HVAC designs suitable for the region and building type. North America is divided into eight zones as determined by ASHRAE Standard 90.1 - 2004. The zones and weather characteristics are important information for the designer to use in developing the building specific performance requirements of the walls and roof.

In the United States many codes and states do not require a continuous air barrier at the roof to wall transition. However, this is likely changing as the benefits of an air barrier to prevent air leakage for greater energy efficiency, and mitigating the inadvertent effects of moisture laden air transport are being more widely recognized. The design of the parapet must resist moisture penetration, yet must also consider the various forms of moisture; typically rain, ice, snow and vapor. Moisture migration via capillary action and excessive relative humidity in the parapet cavity ultimately resulting in condensation is often overlooked in the parapet design. Water vapor can intrude into the roof-to-wall interface detail in the form of moist air and/or vapor diffusion. The movement of vapor from an area of high pressure to an area of low pressure through materials independent of air flow must also be considered and will be heavily influenced by the roof and/or wall cladding material, geographic orientation/exposure and climate. Inseparable from air and moisture resistance is the importance of a completely continuous thermal insulation plane to provide an energy efficient enclosure, and reduce the deleterious effects of thermal bridging.

Because each building is unique and often requires specialized air handling systems to meet the service expectations of the building, the requirements of the Indoor Air Quality (IAQ) must be considered at the roof-to-wall interface. Increased levels of relative humidity, typically associated with performance-critical facilities should be diligently reviewed in the overall context of the air, moisture, and thermal barrier design.

Parapet-Specific Design Opportunity

In addition to protecting and performing against the aforementioned forces, the roof-to-wall interface provides opportunities to explore the potential offered by this unique location on the building as a possible platform to integrate energy producing systems with the building enclosure. As designers strive to engage the demand for energy efficient high-performance buildings, the roof-to-wall interface might become a popular destination for energy collection devices that will contribute to the overall energy efficiency of the building. To take advantage of the height of a parapet as a location from which natural energy can be harvested, the parapet must not be looked at in isolation from the roof or the wall. Such energy saving features, when established as a goal in the early design phase, can be carefully integrated into the overall whole building design concept. The parapet offers the opportunity to serve as a multi-functional component of the overall building, including passive or active elements.

Active solar devices include the provision for mounting photovoltaic collectors which can be independently mounted or integrated into the design of the parapet. The orientation and angle, in addition to the freedom from obstructions that cause shadows highly influences the efficiency of the solar collecting device. As such, the perimeter parapet can provide an optimal surface area, typically free from interferences that might otherwise be encountered on the roof's surface. The collectors can be mounted at the perimeter of the building, in addition to other areas of the roof or façade. In the northern hemisphere, studies have indicated that collectors facing south, followed by collectors facing south-east and south-west are the best performing devices. (Krippner 2001) Collectors must be properly oriented and at the correct angle depending upon their geographic location for optimum performance. See Figure 1.

Figure 1: Parapet mounted solar collectors at the Mei Yuan 1 Dormitory, Shandong Architectural University Jinan, Shandong Province China

While such collector devices can return energy to the building, they also require additional design consideration to ensure they are properly accommodated; including, ensuring the parapet structure is adequate to address the additional wind loads on the building perimeter and primary structural provisions to withstand all imposed loads. Mounting collector devices on the parapet eliminates roof penetrations through omission of added curbs or posts to support the devices. The raised parapet may also provide a cavity to allow space to conceal pipes or cables where they can be concealed or integrated into the design for access and maintenance, strategically placing them out of harm's way and protected from damage. Without a tall parapet, the freedom from obstruction along with the ability to mount the collector devices without multiple penetrations to the less durable roof membrane may not be feasible.

The roof-to-wall interface may also serve as a horizontal projection effectively forming a passive shading device. For meaningful results the design of the projection must be specific to the buildings location to achieve the desired reduction in anticipated solar heat gain on the façade. Added benefits of shading devices on the façade can include a decrease on the load of the air conditioning systems as well as overall shielding of the uppermost portion of the facade from the often unpredictable effect of wind driven rain.

Viewed in this context, parapet designs are in the infant stage with regard to the opportunity to provide a platform for energy saving related equipment without further complications to general roof system detailing.

Typology of the Roof-to-Wall Interface

The design of the roof-to-wall interface increases in complexity when considered by the variety of codes which address the issues associated with the roof edge design. ASCE 7, IBC, IPCC, IECC, NFPA and ASHRAE all have information which is useful and often times required by reference to be included in the development of roof and exterior wall designs. It is understandable that the input from multiple codes and standards coupled with the unique characteristics of each building design, location, use etc, create a complex web of design tasks to successfully detail the roof-to-wall interface. From experience we can define six rudimentary configurations used to accomplish the task of intersecting the roof to the walls. Below are examinations of these common roof-to-wall interfaces and a brief overview of some of the issues that are associated with their design and function:

Type A: Roof overhang at top of wall.

From the moment that our earliest "builders" realized that leaf laden tree branches could be used as a covering atop stacked rock walls, the most basic of roof-to-wall detail was achieved. Functionality was the key component in the success of this approach, for this type of roof allowed for easy structural support, as well as weather protection of the uppermost wall surface, wherein the extended roof edge effectively completed the wall closure detail. Added benefits included a mechanism to shade building occupants from sun and rain. See Figure 2.

Perhaps the most striking factor when using the basic roof slope overhang configuration design in contemporary structures is the added difficulty in maintaining the integrity of the building's air and thermal barrier requirements. Structural members often create unwanted paths for air transfer and this concern should prompt special attention during the design detailing process to ensure that air barrier and thermal continuity are achieved. Roof drainage provisions must be also accommodated.

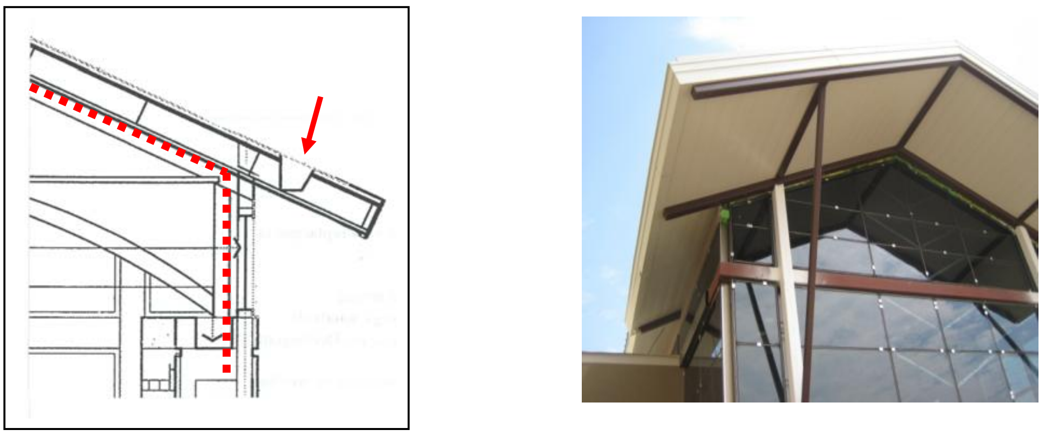

Figure 2: The Type A sloped roof overhang at top of wall poses difficulty (red highlights) in maintaining air and thermal barrier provisions. Roof drainage must also be suitably designed along the roof edge.

Type B: Zero roof edge (90 degree box)

Absent of both parapet as well as roof overhang provisions, the obvious end result was the formation of the basic building "box." Economics above all other factors served as the catalyst for this most common and basic roof-to-wall interface. The evolution of roofing and wall panel coverings into commodity materials served as the springboard for a construction where the demand was, and continues to be quite high. Low cost roof covering materials further support this seemingly endless program of simply crafted box structures which reflect the roof slope as a component of the facade.

Wind action upon this simplest of roof-to-wall intersections plays a significant role in the final selection of roof covering materials. Low-rise, unprotected roof edges place significant demands upon the integrity of roof edge detailing to withstand high wind forces. With this in mind it is easy to realize that the primary design decisions for this type of structure and roof edge will hinge upon roof system design choices, as the bulk of the building enclosure area takes its shape as a horizontal plane. Often ballasted systems will require the installation of integrated pavers to withstand uplift, yet the “walk-way” paver at the zero roof edge affords no fall protection for the user. See Figure 3.

The roof to wall interface that does not extend above the roof plane will allow for water runoff in the event that storm water rates are at peak levels, roof drains are obstructed or additional water resulting from firefighting efforts occur. The elementary ninety degree “box” building can readily become victim of thermal and air barrier discontinuity issues, in addition to how the roof to wall detail is supported. Roof-to-wall detailing must account for the control of rain water collected on the roof such that the water is not allowed to simply drain down the face of the wall. Gutters, scupper boxes, downspouts and their attachments back to the structure must be properly detailed to ensure these fastening methods do not create additional problems at the penetrations into the wall.

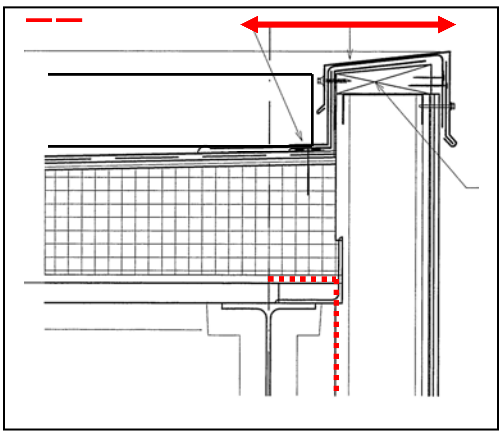

Figure 3: The Type B Zero height roof edge affords little protection with respect to wind forces. Air and thermal barrier continuity must be maintained. Rooftop users are placed at maximum personal risk along the roof edge.

Type C: Low Parapet (less than 36 inches)

Roof edge height definitions are most easy defined in technical terms wherein entities such as FMG establish anticipated wind resistance performance in terms of perimeter roof edge provisions. Although defined in these technical terms, perhaps it was building wall design decisions that served to transform the simple “box” building structure into a more aesthetically pleasing facility by adding the perception of height to the façade: the parapet. With even minor height increases in wall, the building’s appearance could be enhanced. Shadow lines could be introduced, articulated, and manipulated with greater ease. A greater variety of materials could be incorporated into the final wall design. The parapet also gave the designer the opportunity to create a level appearance of the roof. The changes in roof elevation to accommodate slope were evened out, however along with this visual enhancement of the facade, came the problem of ponding water at the roof-to-wall interface if slope was not properly designed and installed at the base flashing interface.

Technically, a raised roof edge will provide a minor yet unremarkable increase in protection against wind uplift forces; however, it is important to note that even a minor height increase along the roof-to-wall interface immediately force a series of design decisions that include safety, air barrier integrity, thermal resistance continuity, roof slope/saddle design and constructability considerations. Even minimal parapet wall heights result in Code mandated snow drift load considerations to ensure collapse of the roof deck does not occur. Above all these considerations, the taller parapet is often necessary by code to prevent the migration of flame from one building to another. To help in preventing the ignition of a combustible roof, the NFPA standards recommend a parapet height of at least three feet. It is commonly held opinion that the taller the parapet, the greater protection it will offer from adjacent fire. (Clark 1991) See Figure 4.

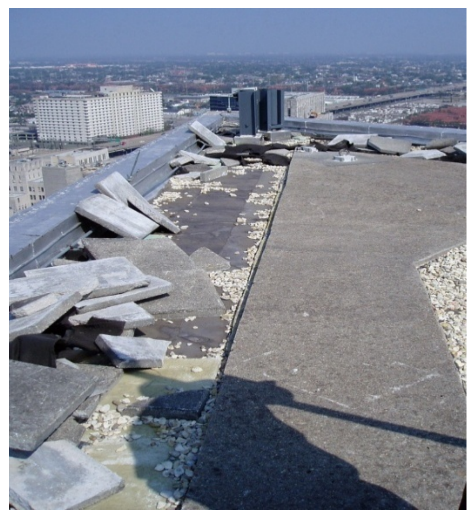

Figure 4: Type C low parapet (less than 36 inches in height) often creates a false sense of protection along the roof edge.

With the design of the wall to roof interface extending above the roof, a secondary form of drainage is typically required by code. Overflow drains may be included in the design by the plumbing engineer. However, often the requirement to provide a secondary set of drainage lines tied to the storm water system is cost prohibitive and scuppers are added to the wall to roof interface. The governing code discusses the type, location and size of scuppers relative to the roof, yet the complex issue of detailing remains the responsibility of the designer. The scupper penetrates the roof and the wall assembly, and as such, the unique conditions of each must be factored into the design, in addition to the risk of development of condensation, air barrier continuity and material choices.

For a more durable design, the parapet should be capped with weather tight non-combustible construction that is as wide as the wall is thick, and complete watertight underlayment. The coping is typically constructed of a light gage sheet metal, either aluminum or painted steel. Traditional copper copings tend not to be used due to cost and resulting staining of the wall and ground materials below due to water run-off from the copper. The coping introduces yet another set of complexities to the detailing of the roof to wall interface as air barrier continuity, underlayment membranes and sheet metal detailing must be handled to prevent premature deterioration of the coping or underlying parapet construction.

In the design process, the differentiation between “roof” and “wall” components can often become easily confused. The structural wall components must properly interact with the roof, with due care given to possible differential movement issues between the roof deck and the wall assembly, with special attention paid to the type of anchorage of the wall at the roof slab/structure. The wall construction will critically impact the development of this detail as the gap between the wall and roof must be bridged when walls are comprised of a type of curtain wall, and typically may need to include a fire stop assembly. Roofing membranes will require continuous support at this transition, including sufficient anchoring of the base flashing and possible accommodation for movement. First and foremost, with respect to general building user safety there is little doubt that a low roof edge parapet (less than 42 inches in height) can readily create a false sense of personal security when performing even the most basic of tasks that demand roof access near the perimeter edge.

Confusion can easily result from unclear or incomplete depictions of the desired location of air barrier materials. Thermal short circuits often manifest themselves within the small cavity created by the framing along the low roof parapet edge, and the roof side of the parapet must be protected from the effects of air, moisture and temperature similarly to the roof or wall.

Type D: Classic 42 inch high parapet

It can be argued that the resurgence of the classic height 42 inch parapet is a direct result of the green roof design movement. Just as the roof parapet historically served to provide building occupants with a safe barrier against external attack, the railing height roof-to-wall intersection for garden roof returns it to its primarily protective role. Wind uplift resistance parameters at last achieve meaningful values with a suitably elevated protective height parapet. See Figure 5.

Figure 5: Type D full 42 inch high parapet offering the best protection against wind forces as well as user safety.

Clearly, the resurgence of raised parapet roof edges impacts overall cost, particularly in areas where total building height plays a pivotal role in the final shape and height of a structure. The ease in which green roof designs can be accommodated is noteworthy, and as more test proven standards are developed for green roof concepts it is conceivable that the benefit of the full height parapet will be further realized. The protection offered by the taller parapet from wind scour of growing media and plantings, also affords the user greater visual privacy. Roof deck areas become a private landscape amongst the growing number of publicly accessible roof tops, and screening of mechanical equipment may be possible.

Increasing the height of the roof-to-wall interface now presents the designer with a new set of detailing development decisions. The “walls” along the building perimeter are now two-sided. As was the case for low height parapet edges, structural issues with respect to differential movement between the wall and roof deck must be accommodated. In addition, overall parapet strength must accommodate all anticipated loads inclusive of the high winds generated by abnormal storm incidents such as hurricanes and tornadoes.

Type E: Screen wall / open top roof

Elevated height parapets, essentially taller than typical height roof “screens” introduce an enhanced set of roof-to-wall interface issues. Screen walls can be located at the roof’s edge to visually hide roof mounted mechanical equipment, and are on occasion required by code for this purpose. Literally all of the previously identified protective advantages to building users are easily realized; however, the protective nature of the perimeter roof screen introduces considerable structural issue in terms of wind action against such elevated wall surfaces and access. Access panels within screen walls should be provided, unless the ability exists to access the wall from over the top of the screen device.

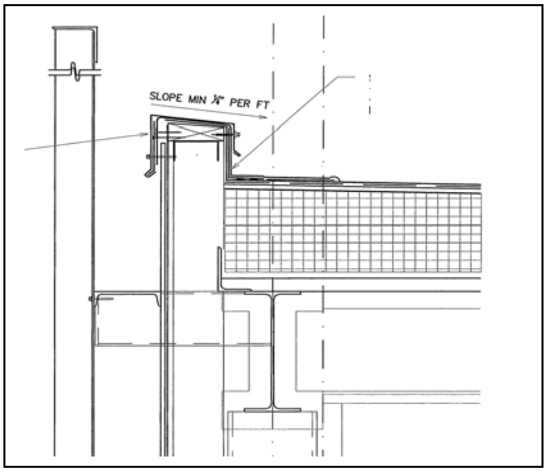

Figure 6: Type E elevated screen parapets yield excellent protection against wind uplift forces, but must be structurally capable of resisting additional loads.

Such perimeter parapet screen designs simplify roof design issues, for the roofing installation is shielded against damage caused by external forces. Air barrier integrity and thermal barrier integrity concern remain constant, unless the perimeter screen is designed independent of both the wall and roof system. See Figure 6.

Type F: Parapet appendages

Roof-to-wall interface design concerns increase exponentially when the building design includes perimeter mounted roof edge appendages. The appearance of the parapet often is enhanced by screens, sunshade devices, decorative fins, and dramatically placed signage.

Although possibly graceful in terms of visual appearance, structural support for perimeter appendage mounts can be extensive and often pose issues with respect to roof and wall system construction. In that regard, structural support details in concert with consideration for future exterior staging access must be dutifully considered and clearly detailed. It is not uncommon to encounter significant air barrier discontinuity issues when larger roof appendage designs are employed. See Figure 7.

With respect to roof performance, the primary issue of wind uplift resistance can easily be skewed by unusually shaped roof appendages. With respect to thermal resistance, the waterproof flashing provisions can become complex when a high number of unusual roof flashings must be accommodated. These details are beyond the scope of typical manufacturer’s guidelines.

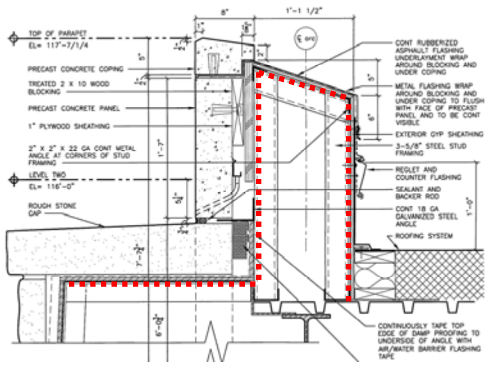

Figure 7: Air and thermal barrier continuity demands scrutiny when roof appendages and wall edge extensions are incorporated into the design.

Material Selection at the Roof-to-Wall Interface

The materials comprising the parapet greatly influence the performance of the exterior wall, the roof termination and base flashing detailing. Failing components on building facades are all too often a result of parapets. The parapet is exposed to weather from both sides, increasing its vulnerability to decay and deterioration. Numerous cities with older and taller buildings are requiring façade inspections to ensure the streets are safe for pedestrians from falling objects located at parapets.

All too often, masonry parapets pose the greatest concern due to their inherent properties to retain moisture. Numerous causes of this problem result in a general premature failure of the masonry components at either the wall or roof side of the parapet. Often, through wall flashings are not coordinated with the upper most roof system termination details such that masonry flashings weep behind roof flashings. The stability and protection of the interior side of the parapet is essential, however must also allow the porous masonry material to breathe to ensure a durable roof-to-wall interface.

Discussion

The exterior wall often determines the construction of the parapet, and detailing of the roof follows. The parapet is the all important extension of the façade, yet arguable of equal importance for performance, is the termination of the roof. To benefit from the façade extending to form the parapet, as outlined above, there are additional considerations which must be accommodated in the design and installation. The design detailing of a separate parapet construction, one which allows the roof and wall to be completely integrated with respect to continuity of the air, heat, and moisture barriers is the optimum solution.

To assure a successful interface, the wall and roof must maintain a continuous air, moisture and thermal barrier, yet also account for the various structural and movement aspects of the two components. Critical to the success of any exterior wall that extends above the roof level as a parapet is to ensure that all interior air is completely isolated from accessing the parapet cavity such that condensation does not develop. In consideration for the development of a common best practice, the wall type was assumed to be comprised of a common curtain wall. (However each building interface assembly must be considered unique and the principles adjusted to accommodate for the various individual characteristics of each wall assembly and its integration with the roof.)

Ideally, it is recommended that the wall-to-roof interface is handled as two structurally separate components. The wall is vertically independent of the roof and attached for lateral bracing at the roof edge of slab, and vertical roof component is structurally tied to the roof slab. By allowing the two to be separate, the roof membrane can be extended up the parapet and protects the vertical wall part of the roof while also minimizing potential for blow-off as uplift resistance is improved. Flashings can be easily accommodated, and the horizontal to vertical base flashing detail is not unduly stressed due to differential movement.

At the top of the parapet, the interface with the exterior wall can be handled with only slight variation on a primary detail. The continuity of the air and moisture barrier can be accomplished at the top of the facade that is level with the top of the parapet, or can align with the roof slab if the curtain wall is not required to extend above due to possible different cladding materials at the cornice/parapet. At either location, details to address differential movement between the walls or the roof parapet structure is recommended. Thermal isolation and a non-permeable air barrier at the path between interior air and the parapet cavity between the two walls are essential. Concrete cast-in-place slabs offer the greatest ease of installation of this isolation detail, while metal pan decks may require greater forethought by the designer to achieve this separation due to the direction and cavities created by the flutes.

The structural parapet facilitates protection of the user and safe access at the roofs edge. The vertical surface of the parapet provides a plane upon which piping, lightning protection cables and miscellaneous attachments can be made without penetrating the more vulnerable horizontal membrane surface of the roof.

Conclusion

The exterior enclosure’s primary function is to provide protection for the building occupant. The parapet in height equivalent to guard rails offers protection not only for occupants at the roof level, but also provides protection for the roof detailing and the top of the facade. If the designer fails to consider the various influences acting independently and collectively, or the contractor fails to install vital components at this critical interface, the exterior wall and roof assembly are prone to premature failure.

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