DESIGN CHALLENGES OF NARROW ROOFS

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Abstract

Narrow roofs and other façade articulations are often designed and detailed with waterproofing characteristics similar to adjacent vertical wall surfaces, leaving the narrow roof assembly with insufficient waterproofing performance and risk of leakage. Horizontal surfaces in these assemblies experience environmental conditions and exposures that demand the waterproofing materials and detailing of roofs. The presenter will identify narrow roof waterproofing challenges, discuss waterproofing design and detailing considerations, and review case studies from recently completed projects. This paper will inform designers how to approach these conditions and improve building owners’ understanding of the operations and maintenance implications of these features.

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Design Challenges of Narrow Roofs

INTRODUCTION

Modern architectural designs are incorporating narrow roofs, horizontal façade features, and other façade articulations (referred to herein as “setback roofs”) with increasing frequency. While the industry does not define or provide specific criteria for whether such elements should be treated as roofs instead of façade elements, in the authors’ opinion, setback roofs can generally be identified as exterior horizontal surfaces between 16 in. and 4 ft. wide. Anything narrower would generally be considered a “wall articulation,” and anything wider is an obvious roof surface. Setback roofs are often designed and detailed with water-resistant barriers and performance characteristics similar to adjacent vertical wall systems, which can leave these setback roof assemblies with insufficient waterproofing performance or durability with respect to the intended service life, and an elevated risk of water leakage. Even small horizontal surfaces experience environmental conditions and exposures that demand waterproofing materials and detailing typically associated with roofing assemblies, but these tried-and-true roofing design principles often conflict with the desired aesthetic, in particular where the geometry requires multiple transitions within a relatively small area. This paper will identify setback roof drivers, discuss waterproofing design and detailing considerations and challenges associated with setback roofs, and review case studies from recently completed construction projects.

DRIVERS

Setbacks are used on building façades for numerous reasons, including to add visually interesting features to an otherwise uniform wall surface and to optimize the available occupied space within building zoning requirements for building height and horizontal property line clearance. Historically, setbacks were required to limit urban density and increase daylight and air flow to city streets. For example, in 1916, development of the Equitable Building in lower Manhattan prompted New York City to implement the first citywide zoning code in the United States to restrict building massing at certain heights. Over time, many cities and jurisdictions adopted similar zoning requirements to limit building dimensions at certain heights. These zoning requirements often influence design decisions, which in turn create the conditions for variation in the plane of façade components, resulting in narrow roof conditions.

AESTHETICS

Architects often use setbacks in façade designs to add articulation, distinguishing features, and shadow lines to accent otherwise uniform façades. Some examples of well-known buildings that use setbacks in the façade design include The Empire State Building in New York City (Figure 1) and the Bank of America Center in Houston (Figure 2).

Contemporary buildings using modern building materials and construction methods (e.g., cold-formed metal framing with rainscreen claddings) are often designed to imitate the setbacks common to mass masonry designs. Similar to historical architectural language, horizontal surfaces of setback features often incorporate cladding materials rather than exposed roofing membranes based on the desired appearance of the exterior elevation and views experienced by occupants. However, these setback features need to incorporate waterproofing and drainage features behind the cladding to prevent water penetration, similar in concept to rainscreen wall systems, but subject to the demands common to low-sloped roofing assemblies. When the aesthetic expectations for detailing these setbacks are based on the expectations set by historical building examples, our attempts to apply the fundamental waterproofing...
concepts associated with low-sloped roofing best practices will likely produce a conflict between waterproofing performance and aesthetic expectations due to the differences between the functional approaches of mass masonry and drainage wall designs.

Mass masonry buildings rely on the thickness of the masonry for water penetration resistance. In such designs, the masonry surface sheds bulk water, and some water is absorbed into the masonry surface. If the mass masonry assembly is sound, then the mass of the wall has sufficient capacity to absorb water and dry sufficiently between wetting events. Even with the capacity to absorb water, setbacks in mass masonry walls are often covered with metal cap flashing to limit water infiltration.

Modern rainscreen and curtainwall systems are designed to have cladding materials that deflect bulk water, but anticipate some water will bypass the cladding. These systems utilize a combination of a water-resistive barrier on the backup wall and flashings to collect and disperse water from the wall assembly. Rainscreen systems offer redundant water-resistance features, but rely on a combination of an impermeable membrane and fundamental waterproofing design concepts (e.g., slope to drain, base flashing height, watertight penetrations) to provide the desired in-service performance.

ECONOMICS

Building developers understand the market factors that influence the value of a given property type, such as rooftop amenity spaces or floor-to-ceiling heights. Local jurisdictions prescribe the allowable building height and required offset between building walls and the property line. In large cities, developers often desire to maximize site use and occupancy density, and they look to designers to help them optimize these factors while evaluating the construction cost for proposed solutions against the project budget for a given system or component. Maximizing occupancy density and maintaining key economic development factors (e.g., ceiling height), combined with restrictions on building heights, can create building geometries where the setback roof assembly thickness must be minimized to satisfy these other criteria. Minimizing the thickness of setback roof assemblies challenges many fundamentals of good waterproofing design, including the magnitude of slope at the membrane level, drainage, insulation placement and thickness, and base flashing height, which we will discuss further in the sections below.

Project economic factors and building geometry requirements often conflict with performance objectives, and these criteria must be addressed in the early planning stages of any project.

PERFORMANCE

A good setback roof detail must provide the desired performance, including no water leakage and effective insulation of the adjacent interior space. Limiting the risk for water leakage and providing a durable roofing assembly depends on many factors, including membrane selection, slope, drainage, and workmanship. Prioritizing certain aesthetic and economic factors over waterproofing design best practices introduces risk of in-service performance problems and extensive remedial work prior to the end of the expected service life. For example, ample membrane slope and other drainage provisions will limit the risk for water leakage associated with membrane penetrations and minor workmanship deficiencies and extend the service life of the waterproofing.

Model building codes (e.g., the International Building Code [IBC]) require 1/4 in.-per-ft. slope for most types of low-slope roofing systems. However, the minimum slope established by the building code should not become the default roof slope without careful consideration of the conditions specific to a given project. The code requirement for minimum roofing membrane slope is based on the use of an impermeable membrane with reliable seaming details, sufficient slope to prevent water from ponding on the membrane surface, a limited number of penetrations through the roofing membrane with respect to the roof area, and the ability to inspect and maintain the roofing membrane.

Often, designers default to code-required minimums to form the basis of their design, which is prudent when faced with common applications where the risk and durability concerns are well established through our collective experience. But when designers are faced with atypical applications for existing building technologies, they must perform a critical evaluation of the durability and performance implications of following industry standards and manufacturers’ recommendations that have a basis in more common applications.

For example, when faced with a narrow roof area that includes some form of architectural covering, many of the underlying assumptions that form the basis for the minimum slope required by the building code are no longer true, and, depending on the membrane selected for such an application, greater slope may be warranted and beneficial to the long-term performance of the setback roof detail.

In recent years, model building codes have adopted requirements focused on reducing building energy use, including increasing the thickness (R-value) and improving the location (continuous insulation) of insulation within roof and wall assemblies. Often, the required thickness for continuous insulation above the roof deck is greater than the architectural design can accommodate based on aesthetics or height and proper line setback requirements, and the insulation must be placed below the roof deck or between framing members. While allowed by the building code, changing the insulation strategy from continuous above-the-roof deck to an underside insulation solution will require other considerations, including increased insulation thickness, greater risk for condensation, evaluation of vapor retarder placement within the roof assembly, and constructability issues.

The general strategy for dealing with considerations such as roof slope and insulation must be discussed early in the design process so that design features that influence waterproofing and thermal performance of the setback roofs are not overlooked. A well-performing setback roof requires, at minimum, the same design and workmanship attention as other roofing assemblies, despite the relatively small area covered by these roofs.

LOW-SLOPE ROOFING FUNDAMENTALS RELATED TO WALL SETBACKS WITH ARCHITECTURAL COVERINGS

Most of the fundamental considerations for designing low-sloped roofs can be applied to the design of setback roofs, but setback roofs often incorporate common building components in atypical configurations that will challenge the execution of these principles. The following sections focus on applying these design principles in the context of narrow roof areas that must be integrated with the exterior building wall and typically include an architectural covering.
SLOPE AND DRAINAGE

Typically, setback roofs cover long but narrow horizontal surfaces (i.e., small width compared to length). As noted above, designers may choose the code-required minimum slope as a starting point for the design, but need to evaluate the effectiveness of the overall drainage strategy to determine the direction and magnitude of the roof slope. Other relevant factors in the drainage design include drain type, size, and frequency; and design decisions related to the means of collecting water from the roof surface can also be challenged by the same factors that restrict the roofing design.

Most low-sloped roofs utilize internal drains as a means to collect water from the surface of the roofing membrane, and the associated roofing design includes 1/4 in.-per-ft. slope at the membrane level to direct water to these drains. When dealing with a narrow roof (less than 24 in. wide), the physical space taken up by the drain body and maintaining sufficient space around the drain to construct a reliable roofing termination often make using such drains impractical. Also, establishing a reasonable spacing for the drains along the length of the roof is difficult, as a large quantity of frequently spaced drains would be required to maintain the roofing assembly thickness, but the cost and available space for the associated plumbing on the interior often cannot be accommodated in the design. Providing drains spaced further apart will either reduce the membrane slope or increase the assembly thickness; the former will negatively impact performance, and the latter often conflicts with the desired aesthetic at the roof edge or alters the elevation of other building features that are intended to align. An internal drainage strategy for a narrow roof increases the risk that water on the roof surface will migrate through the cladding and reach the waterproofing layer below, which may be vulnerable to leakage at drain and cladding attachment penetrations. In addition, internal drains will require in-service maintenance if the drains become clogged with debris. Cladding systems that conceal drains make maintenance work difficult, and accessing the narrow roof often requires special equipment.

Given such architectural restrictions and the practical challenges of locating internal drains within a narrow roof area, designers often choose mono-slope surfaces that drain off the roof edge. While this is effective to shed water from the cladding surface quickly and minimize the assembly thickness by providing slope across the shorter roof dimension, the effects of draining off the roof edge onto the wall surfaces below the setback will increase wetting, staining, and cleaning and maintenance demands for the walls below. In addition, the design of mono-slope roofs must consider the potential for snow and ice accumulation and the risk of falling object hazards below the setback roof edge. Features common to roofs that are designed to drain over the roof edge include projecting the roof edge beyond the façade to protect the walls below and hung gutters to collect water and direct it to grade via downspouts, neither of which are architecturally appropriate for modern commercial buildings.

The plumbing code requires that any roof area with perimeter conditions that may allow water to collect on the surface (e.g., internally drained roofs with parapets) must have overflow drainage. Overflow drainage is often provided by through-wall scuppers or separately piped internal drains with inlets raised above the elevation of the primary drains. It is important that designers consider the flow of water to these overflow drains in the event that the primary drain becomes clogged, and also confirm the potential elevation of water in an overflow situation does not allow water to reach the elevation of door thresholds, windowsills, low-termination flashing heights, and other vulnerable transitions.

INSULATION

The energy use provisions of the model building code include prescriptive insulation requirements for buildings based on occupancy type and location. Similar to code requirements for slope, the energy code prescribes the minimum required thermal resistance value for the roof, which may or may not satisfy the specific energy conservation goals for a given project. Roof insulation can be placed entirely above the roof deck (i.e., continuous) or below the deck/between framing members. The model codes require greater insulating value for insulation placed below the deck that may impact interior finishes (e.g., ceiling height), insulation continuity (e.g., multiple roof-to-wall transitions over a relatively short distance), and create challenging framing geometry, which can make it difficult to construct a continuous air/vapor barrier on the interior side of the roof insulation. These transitions contain inherent inefficiencies in thermal barrier continuity and, combined with the constructability challenges associated with providing a continuous air/vapor barrier on the interior side of the roof insulation, increase the risk of condensation at setback features. Also, where the setback occurs below a windowsill, the framing for the wall above the slab creates a potential uninsulated/unconditioned space that may be vulnerable to condensation due to lack of air changes (Figure 3).

In some cases, setback roofs will have the opportunity to provide the insulation above the roof deck, in which case the designer will need to balance the considerations for providing insulation using either a conventional or protected membrane assembly. In conventional membrane applications (where the roofing membrane is placed over the insulation), the insulation type is often polyisocyanurate and can be tapered to provide slope-to-drain. Conventional membrane applications provide the opportunity to use insulation with a greater thermal resistance (R-value) per unit thickness, but use of tapered insulation to generate
slope will increase the insulation thickness at perimeter curb heights. For protected membrane applications (where the roofing membrane is placed directly on the structural deck and insulation is placed outboard of the membrane), the deck is sloped to drain, and the membrane is covered with a moisture-tolerant insulation, such as extruded polystyrene. In general, protected membrane systems will require a greater insulation thickness in the field of the roof, but the greater impact to the overall thickness of a protected membrane assembly is the need to secure the insulation against wind uplift. On setback roofs, the cladding attachment can be used to secure the insulation against wind uplift; however, if no cladding is provided, stones or pavers will be required as ballast for the insulation, which, in turn, will require a greater parapet height to satisfy the wind uplift requirements on the ballast.

AIR BARRIER AND VAPOR RETARDER

Air flow and vapor transport in a setback roof assembly must be evaluated in the same manner as roofing assemblies to limit energy loss and the risk of condensation and related thermal and moisture issues. The setback roof air barrier and vapor retarder must be continuous with the adjacent wall air barrier and vapor retarder. The model energy conservation code requires a continuous air barrier, but the code requirements for vapor retarders vary by climate zone. Ultimately, the vapor retarder placement must be coordinated with the insulation strategy to limit the risk for moisture accumulation due to heat and moisture transport mechanisms.

WIND UPLIFT RESISTANCE

The setback roof assembly, similar to other roof assemblies, must be designed to accommodate the anticipated wind uplift pressures at the subject roof area. Wind uplift pressures can be calculated using prescriptive methods described in the building code. Building codes may require that setback roof surfaces be designed to resist uplift pressures for “edge” or “corner” zones, depending on building geometry. Complex building geometries may require wind tunnel testing to determine accurate building wind pressures. Nonballasted assemblies must be designed to resist component and cladding wind loads according to Chapter 16 of the IBC and, by reference, ASCE 7, Minimum Design Loads for Buildings and Other Structures. In addition, uplift resistance of nonballasted assemblies must be verified through testing according to FM 4474, Standard for Evaluation of Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures; UL 580, Standard for Tests for Uplift Resistance of Roof Assemblies; or UL 1897, Standard for Uplift Tests for Roof Covering Systems. The behavior of nonballasted roof assemblies is complex and can only accurately be determined through testing. In addition to evaluating the choice of the primary roofing assembly at a setback, the roofing membrane edge securement must be designed in accordance with Chapter 16 of the IBC and tested according to ANSI/SPRI ES-1, Test Standard for Edge Systems Used with Low-Slope Roofing Systems.

The IBC requires ballasted roof assemblies to be designed according to ANSI/SPRI RP-4, Wind Design Standard for Ballasted Single-Ply Roofing Systems. Forms of ballast include concrete and stone pavers, stone ballast, and soil media. Aggregate surfacing is not allowed by the building code on roofs in hurricane-prone regions and roofs of certain heights above ground level based on exposure category, and while larger stones can be designed to function as ballast, this often requires either increased parapet heights or zones of pavers at the perimeter of the roof, so stone ballast will rarely be a consideration for setback roofs.

Vegetative overburden shares the limitations associated with stone ballast, but is more likely to be considered at setback roofs due to its finished appearance and requirements for stormwater retention. In addition to the basic wind uplift requirements, the designer must consider that until the plantings in a vegetative overburden assembly have established root systems, the soil media is vulnerable to wind scour, and displaced soil media will reduce the chances for successful plant growth. Finally, these plantings will require regular maintenance, and the design must consider how these setbacks will be accessed for maintenance of the overburden and the roofing membrane.

PERIMETER TERMINATIONS AND PENETRATIONS

Roofing terminations should be located such that the membrane stops above the elevation of expected water level, including overflow drainage and drifting snow/slush, if necessary. The roofing industry has long established an 8-in. base flashing height as the recommended minimum. An 8-in. base flashing height on setback roofs is often lowered in favor of other architectural objectives such as increased glazing area or other cladding alignment issues. Such choices should be accompanied by corresponding design decisions to provide increased roof slope or other drainage features to limit the potential for water leakage due to low base flashing heights.

MAINTENANCE REQUIREMENTS

Setback roofs require routine inspection and maintenance of the roofing membrane and associated flashing details to extend performance and useful service life just like other roof assemblies. Setback roofs are narrow and can be difficult to access safely for inspections and other maintenance activities. In many cases, a component or area that cannot be easily accessed becomes an afterthought and is neglected by operations staff, so design of these roof systems should consider maintenance accessibility. The setback roof designer needs to understand how the adjacent façades will be accessed and maintained safely, including OSHA-approved methods for roof edge protection, and provide a setback roof assembly that is durable to withstand maintenance loads such as foot traffic and façade access equipment.

SETBACK CHALLENGES AND DESIGN CONSIDERATIONS

Carefully planned and constructed setback roofs can perform and last just as long as any other roofing assembly if the fundamentals of roofing design discussed above are implemented and setback-specific issues are carefully dealt with. While this sounds simple, the design of setback features inherently contains competing objectives, and designers must make decisions about which roofing fundamentals will be compromised in favor of other design objectives. Designers should analyze the available options and choose the roofing concept that gives the setback roof the best chance of success. Although all the roofing fundamentals discussed in the previous section are important, providing the most slope possible, in combination with the best membrane possible, typically provides the greatest benefits in terms of waterproofing durability.
MEMBRANE SELECTION AND DETAILING

The waterproofing membrane used on setback roofs should be intended for low-sloped roof surfaces. Roofing membranes to consider for setback roofs include single-ply membranes, modified bitumen, and fluid-applied asphalt or polymer membranes. Metal roofing is another option, but water-tight (as opposed to water-shedding) metal roofing systems require careful design, workmanship, and vigilant quality control to execute a reliable roof, and are generally more expensive than other roofing options.

Often, setback roofs are covered with cladding to conceal the waterproofing membrane to coordinate with the appearance of the building façade. Cladding at setback roofs is only for appearance and should be designed using a concealed waterproofing membrane that is detailed and drained to function as a roofing assembly. The cladding attachment concept will be an important factor in the membrane selection (see the following section for discussion related to cladding attachment).

It is common practice for architects to illustrate waterproofing systems as a single dashed line on architectural drawings and refer to the project specifications for the system components, details, and performance requirements. Often, designers use the same line type for setback roofing as the adjacent wall air and water-resistant barrier, which may lead the contractor to believe that these are the same materials and products. If the setback roof waterproofing assembly is not identified as a different system, the contractor may assume that the designer intends for the wall air and water-resistant barrier to be used on the roofing surface. In general, wall air and water-resistant barriers are not intended for or warrantable as roofing membranes, do not have a proven track record of waterproofing performance in low-sloped applications, and should not be expected to perform well in this application. Setback roofs demand a dedicated roofing membrane appropriate for the membrane slope to have the best chance of successful performance.

CLADDING SYSTEM ATTACHMENT

Cladding or other coverings should be designed as a rainscreen system with an underlying waterproofing membrane and membrane-level drainage. The cladding attachment to the structure must be designed to support the required loads on the cladding and be coordinated with the waterproofing membrane flashing and drainage concepts. Narrow setbacks may only require attachments at the roof edge and rising wall, avoiding penetrations through the roofing membrane. Deeper setbacks, heavy cladding, or cladding designed for loads associated with maintenance activities may require anchors in the field of the setback roof. The anchor size will depend on the ability of the cladding to span between supports, but regardless of the underlying framing requirements, it is best for spanning members to be elevated above the membrane surface to reduce the number of penetrations, provide a base that can be flashed reliably, and limit obstructions to membrane-level drainage.

Roofing membranes are not well suited to many small-diameter penetrations (e.g., fasteners). Such penetrations are difficult to seal and obtain reliable waterproofing performance using manufacturers’ standard details. In addition, roofing membranes covered with architectural cladding cannot be inspected or maintained, which may void manufacturer warranty requirements. For these reasons, some designers will choose to use exterior wall membranes or roofing underlayment that have some ability to “self-seal” around nails as a means to limit the overall assembly thickness. While these membranes have established performance in steep-slope roofing and above-grade exterior wall applications, performance as a primary waterproofing membrane in low-slope applications can be risky, and the membrane use in these applications may not be warranted by the manufacturer. In such instances, the design must consider additional measures to limit the risk of water leakage to offset the increased demand on these membranes, or select a cladding attachment concept that is compatible with a roofing membrane intended for low-slope applications.

FAÇADE STAINING

Limited slope on setback roof surfaces will allow some water to accumulate on the roof surface. Surfaces that remain wet for extended periods will collect dirt left behind when the water evaporates and will appear more heavily stained than other well-drained areas. Runoff from setback roofs will concentrate water on the façade below these roof areas that can stain wall surfaces in the same manner (Figure 4).

This can be noticeable for porous cladding materials such as masonry and glazing systems. Staining issues on the setback roof can be mitigated by providing sufficient slope on the cladding surfaces to remove the water from the roof. Staining on adjacent façades can be mitigated by collecting water runoff through internal drains or gutters. In our experience, gutters are rarely a desirable architectural feature on a setback roof edge, though they may be worth considering in some cases.

SNOW AND ICE ACCUMULATION

Snow and ice can accumulate on horizontal surfaces only a few inches wide. Falling ice can become a falling-object hazard to pedestrians and property located below these roofs. Often, snow on roofing
membranes will melt before becoming a falling hazard to pedestrians below, but cladding such as metal panels will be significantly less likely to retain snow. Each setback roof condition should be analyzed to assess the risk for snow and ice accumulation and associated hazards to people and property. Some cladding surfaces may require snow guards to retain snow and ice on the roof surface until it melts.

**ACCESSIBILITY AND CONSTRUCTABILITY**

Access to the setback roof area should be considered by designers—from both the standpoint of constructability and for maintenance. For example, hot-applied roofing membranes may be inconvenient to transport and difficult to install safely from a suspended scaffold, and the designer should expect the contractor to propose other membranes for constructability purposes. Cold, fluid-applied membranes with a limited pot life may have similar workability issues if the installer is working from a scaffold. Sheet-applied membranes are well-suited for many setback roofs. Compatibility with adjacent wall air and water-resistive barriers must be considered and coordinated by the designer and contractor. The designer can circumvent coordination issues and contractor requests for information by considering the likely construction sequence of the transition details and the subcontractors likely to install the various components of the assembly. Creating a design with clear intent and well-thought-through materials and transition details will make the contractor’s job easier and reduce conflicts within the project team.

**ADJACENT WALL ASSEMBLIES**

Transition details with adjacent enclosure systems should be carefully planned and detailed by the designer. Illustrating each waterproofing system with different line types and line weights conveys to the contractor important information about the design intent. If this information is not clearly shown on the design drawings, then important transition details will be left to the contractor or subcontractor to figure out in the shop drawings or in the field during installation. The setback roofing membrane should be lapped with adjacent wall air and water-resistant barriers to shed water. Transitions to adjacent glazing systems can be complex and need to be coordinated with the basis-of-design glazing system and must consider material adhesion and compatibility. Often, additional flashings and separators are required to accommodate material incompatibility.

**FAÇADE MAINTENANCE**

Access to all areas of the building for façade maintenance should be discussed during the design phase with building owners and developers to ensure that the design creates a building that can be effectively maintained. Setback roof areas create offsets to the vertical wall planes that can make maintenance access difficult and costly. Special equipment may be required for façade maintenance, which can make a building costly to operate over time and may cause some areas to be neglected. For example, the cladding material for the setback roof cladding may be subject to traffic from maintenance workers and equipment. Designers can reduce maintenance challenges and increase the service life of these setbacks by having discussions regarding façade maintenance during the design phase and planning for maintenance access.

**CASE STUDIES**

The following case studies provide examples that illustrate the importance of integrating low-sloped roofing design fundamentals into setback roof conditions.

**Wood-Framed Apartment Project**

A recently completed suburban apartment complex included several four-story wood-framed buildings. The exterior walls were load-bearing wood stud walls with oriented-strand board (OSB) exterior sheathing, mechanically attached building wrap (intended to function as the air- and water-resistive barriers in the wall assembly), a combination of brick veneer and fiber cement lap siding/panel rainscreen wall cladding, and aluminum-framed windows and doors in punched wall openings.

The architectural design included a transition from brick veneer to fiber cement panel cladding near the mid-height of the fourth level, with the inside face of the fiber cement panel generally in plane with the inside face of the brick veneer below—an architectural accent common to buildings of this construction type. The cladding transition was independent of the framing/building wrap configuration, and required no special detailing or flashing. As the design developed, the design team endeavored to accentuate the change in plane between the cladding materials by offsetting the exterior wall framing by a stud width, creating a setback in the plane of the exterior wall sheathing at this cladding transition. To offset the cladding materials, the designer used side-by-side wall studs, with the inner studs extending floor to floor and the outer studs fastened to the inner studs and extending from the floor to mid-height of the inner framing. The brick veneer terminated with a rowlock course at the framing transition, and the design included a metal coping to close the gap between the fiber cement cladding and the rowlock brick. However, the design did not illustrate any special waterproofing details or flashing integrated with the building wrap at this condition; the wall sections only showed the continuation of the typical wall assembly with a single dashed line representing the building wrap extending over the step in the backup wall covered with metal trim (Figure 5).

After the cladding and most of the interior finishes were installed, the contractor
observed staining and water intrusion below this cladding transition following rain events. The contractor removed cladding components near the areas of water leakage and, combined with observations at other similar conditions that had not yet been concealed on other buildings at the complex, the project team identified several deficiencies in the building wrap where it covered the horizontal surface created by the framing transition (Figure 6). First, building wrap is not intended to perform as flashing on low-sloped surfaces. Next, the contractor terminated the building wrap at the inside corner created by the framing transition, which, combined with the lack of slope and the volume of mortar filling the top of the brick veneer cavity, allowed for water to accumulate against a poorly configured water-resistive barrier transition and to leak to the interior (Figure 7).

The setback design did not indicate a roofing or flashing assembly at the setback, and the contractor assumed the design intent was to build the setback similar to the typical wall assembly, without consideration for the application of these components. The designer likely assumed that because the setback was not very wide, it did not require a special detail or alternative waterproofing materials. Building wrap has a long track record of acceptable performance as a wall air and water-resistive barrier; however, it is not appropriate to use as a horizontal roofing membrane or flashing, regardless of the width of the horizontal surface.

Many different solutions could have been implemented to improve the performance of this setback condition, including using sloped wood blocking on top of the outer line of wall framing to provide slope to drain, removing the mortar blocking the top of the brick veneer cavity, and covering the sloped blocking with self-adhesive membrane covering both the inside and the outside corners with shingled laps between the water-resistive barrier and self-adhesive membrane. Fortunately, the shortcomings of the original construction method were addressed before the building was occupied.

**West End DC Public Library**

The West End Public Library in Washington, DC, was dated and functionally obsolete. The city entered into a partnership agreement with a developer to build a new public library with a combination of apartments and condominiums above the library. The design included an “all-glass” façade on the street-facing elevations with numerous setback roof areas as the primary exterior design feature (Figure 8). The architectural design created numerous technical challenges for the design and construction teams in terms of providing water, air, and thermal barrier continuity while meeting the intended design aesthetic.

The architectural design included continuous aluminum-framed window walls at each floor with extruded aluminum channel slab edge covers wrapping the primary street-facing and courtyard elevations.
The interior design provides the residential occupants with nearly floor-to-ceiling glass at exterior walls for unimpeded views of the surrounding neighborhood.

The configuration of the setback roof areas varied with the building footprint, but most were approximately 4 ft. wide by 45 ft. long in plan. The design intended for these setback roof assemblies to be as shallow as possible to maximize the glass height and associated views from the interior. The design team carefully analyzed the roofing design options and made compromises as necessary to balance the roofing performance criteria with other design requirements. The following sections highlight some of these tradeoffs and the underlying thought process.

**Setback Roof Design Considerations**

The original design concept was for each of these setback roof areas to be covered with vegetative overburden. Given the depth of soil media required to provide a suitable environment for the plantings, parapet height requirements to limit soil scour and provide sufficient wind uplift resistance, potential for reflected solar energy to damage plantings, and requirements for regular maintenance access to care for the plantings, the design team decided to use a synthetic turf system supported on discrete steel posts to mimic the appearance of vegetative roofing instead.

In combination with the design decisions regarding the vegetative overburden, the team analyzed various roofing system options. The fundamentals of setback roofing design discussed above were considered by the design team, and two primary roofing options emerged as viable candidates: a protected roofing membrane assembly (PRMA) with a hot-applied rubberized asphalt (HRA) membrane (Figure 9) and a conventional roofing assembly with a single-ply PVC membrane (Figure 10). Key issues considered by the design team included slope, drainage, base flashing height, insulation, and wind uplift resistance.

**Slope and Drainage**

The PRMA option could be constructed with HRA applied to the flat concrete slab. While local building code amendments include exceptions that allow for the membrane in these types of assemblies to not be sloped, this was still considered a significant liability to the water penetration resistance and long-term durability of the waterproofing. However, given the project goals for minimizing the assembly thickness, placing the waterproofing membrane on the flat deck provided a potentially desirable benefit that warranted further consideration.

The conventional roofing assembly option would require tapered insulation boards to create the code-required slope to drains, and the accumulated thickness of the tapered insulation would use most of the curb height available below window-sills and parapets, resulting in low base flashing heights. Designing a functional tapered insulation plan for such roof areas was challenging. Due to the long, narrow shape of the setback roof areas and interior conditions that limited each setback roof to a single internal drain, the roof was sloped to a central valley running the length of the roof so that water could reach the drain before accumulating against the perimeter flashings, with an expectation that some water would pond at the valleys for a limited time following rain events.

Both membrane options use internal drains for primary roof drainage. Dedicated internal overflow drains were not a viable option with the plumbing system design, and overflow scuppers disturbed the continuous horizontal slab edge cover design and were not the preferred aesthetic option. Although not the most desirable drainage option, a viable option was to configure the setback roof parapet edge to be lower than the adjacent windowsill so that in an overflow situation, water would freely flow over the parapet edge before standing against the windowsill perimeter seals.

**Base Flashing Height**

The PRMA assembly option provided a greater membrane base flashing height relative to the membrane surface than the conventional assembly because the membrane was applied to the concrete slab and insulation was placed above the membrane. While the best practice for waterproofing design is to measure base flashing height from the top of the overburden, given the restrictions on the overall assembly thickness, the flashing height above the membrane...
surface would be a functional advantage over the conventional roofing assembly.

The tapered insulation required in the conventional roofing assembly consumed most of the available perimeter base flashing height, and the posts used to support the synthetic turf frame were located at various locations across the roof area, while the base flashing height at these penetrations varied. Roofing manufacturers provided valuable insight to the design team during this analysis by providing detailing and constructability requirements for their system warranty coverage at the many low base flashing conditions.

**Insulation**

The PRMA assembly required moisture-tolerant insulation. Extruded polystyrene is often used in PRMA assemblies because it maintains most of its insulating value, remains durable when wet, and is available in high-density formulations that are often required for heavy overburden. However, extruded polystyrene provides a lower thermal resistance per inch compared to other insulation types, which is a disadvantage on this project that has tight thickness constraints.

The conventional roofing assembly would use polyisocyanurate insulation, which provides a relatively high thermal resistance per inch compared to other insulation types. The higher insulating value of polyisocyanurate used in a conventional roofing assembly would help to limit the thickness of the insulation at setback roof areas and provide valuable additional base flashing height.

**Wind Uplift Resistance**

The PRMA assembly required ballast or other means to secure the loose-laid insulation to resist wind uplift pressures. The ballast thickness and required minimum parapet height required raising the parapet, which in turn required raising the windowsill to maintain the overflow drainage concept for these roofs.

The conventional roofing assembly could be fully adhered or mechanically fastened to the concrete deck, which eliminates the need for ballast and the associated modifications to the parapet construction.

**Design Analysis**

Ultimately, the combination of improved drainage, insulation thickness, and wind uplift considerations associated with the conventional roofing assembly provided the right balance of performance features in the context of the project objectives (Figure 11). While not without risks and limitations (e.g., base flashing height lower than industry standard recommendations), the careful evaluation of the roofing performance features produced a well-conceived design.

**CONCLUSION**

Setback roofs often do not receive the design detailing attention they need to provide reliable waterproofing performance. Designers often do not account for the space required to implement fundamental roofing design concepts, including detailing setback roofs with water-resistant barriers and flashing components intended for above-grade exterior walls, limited slope to drain, no means to collect water from the roof surface, and limited insulation thickness due to the architectural demands for alignment between façade features. Setback roofs experience similar environmental demands as other roof surfaces and should be designed with the best practices for roofing design where long-term, durable waterproofing performance is required; however, architectural design constraints can put designers in the position of compromising between competing advantages of multiple waterproofing and insulation strategies. In these instances, it is essential to understand the performance expectations and limitations of the individual system components, and have an effective method for evaluating their relative contribution to a successful outcome.