ROOF CONSTRUCTION DETAILS

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Roof construction details are required where the roofing or waterproofing membrane is terminated, interrupted, or penetrated. Attention to detail is as critical to a roofing system as to an electronic instrument.

Most problems associated with bituminous roofing systems are directly attributable to faulty or incomplete detailing or to damage to flashings and closures. This damage occurs because of improper initial construction or damage caused by integral components used to complete the assembly, and from subsequent roof traffic and environmental conditions. The same kinds of problems will probably occur in elastoplastic, single-ply membrane systems since they are subject to the same lack of attention to detail and the same kind of damage that afflicts bituminous membranes. The performance of any roofing or waterproofing system depends on its detailed design at projections, junctions, and terminations and on the quality of its field application. Each roofing system is as individual as a snowflake and each detail must be conceived and completed to complement each system.

As a structure depends on its footings and foundations for support, so does the roofing or waterproofing system depend on a solid substrate for its base. Fortunately for structures, most materials used in the footings and foundations are relatively stable and foundations are rarely subject to extreme or rapid changes in temperature. Unfortunately for roofing and waterproofing systems, the substrates are not always "stable" and components used in roofing/waterproofing assemblies are subject to extreme or rapid changes in ambient temperature. Because of the extreme changes in ambient conditions to which most roofing systems are exposed, thermal stresses imposed on roofing and waterproofing membranes will always exceed thermal stresses imposed on foundations. As a consequence, roofing membranes and flashings must be installed on a dimensionally stable substrate to minimize the effects of thermally induced stress.

Provision must be made during construction of the roofing assembly to allow for adequate working clearance. Projections located too close to perimeters or elevation walls are difficult to waterproof. Equipment curbs or mounts placed too close together or too close to elevation walls make construction of flashings difficult. When planning new construction, the designer must consider prospective replacement of the roofing system.

Projection mounts or curbs that may provide adequate clearance for new construction may not provide adequate clearance for retrofit. In proper retrofit application, it may be necessary to remove virtually all ducts for housings run from projection curbs for long distances across the roof.

Anyone involved with the roof system after the time of construction should be aware that whatever equipment is added to the roof surface must be added with the thought that, sooner or later, either repairs or replacement will become necessary. No condition is uncorrectable, but corrections during retrofit can be very expensive, sometimes costing 5 to 6 times what they might cost during initial installation to allow for adequate clearance for repairs and/or future replacement.

A detailed discussion of the controversial subject of expansion joints and control joints is beyond the scope of this paper, but the subject merits some discussion, since it logically falls in the scope of detailing. Expansion joint terminal points and junctures must be carefully planned to insure that flashings—both membrane and metal—will continue to provide long term watertight service. Expansion or control joints should be raised or elevated above the roof surface a minimum of 8 in. to preclude moisture entry into the roofing system and/or interior of the structure in the areas of these details. Expansion or control joints mounted flush with the roof surface are subject to damage from roof traffic and/or expansion and contraction of metal flanges. If damage occurs to a closure above the roof surface, water ingress is limited to falling water. But when a flush expansion joint cover is damaged, it allows not only rain water into the structure, but also water that collects on the roof surface or is funnelled over the expansion joint cover by the roof slope. Expansion joints should continue through the entire structure—including elevation or parapet walls to which the roof structural system is joined. If the roof/deck system is totally isolated from the rest of the structure, then coincidence of structural expansion joints in the roof system and the perimeter structural system is less important. Expansion joints must be continued to the edge of the roofing assembly and not terminated short of the roof perimeter. There are a number of details that will allow for the continuation of the expansion joints to the building perimeter.

CONCEPTUALIZING THE DETAIL

Depiction of the detail in a relatively large scale (3" = 1'0") allows the designer to envision the construction of the detail and allows the contractor/mechanic to interpret exactly what is depicted on the detail drawing. Small scale or illegible detail drawings will invariably result in the mechanic's use of imagination in the construction of the detail, and the roofing mechanic's imagination sometimes leans towards the easiest—not necessarily the best—method of construction. Especially important in the detail drawings is how the designer expects the detail to be terminated or joined to an adjacent assembly. The expansion joint provides the best example for this comment since in many cases expansion joints will cross in the open roof area. Expansion joints will also be terminated at roof perimeters, parapet walls or elevation walls. A designer must be explicit as to how the crossover at the intersection is to be handled in the field by the roofing mechanic. Does he want factory-fabricated crossovers or "T's" used on flexible expansion joint covers? How is the sheet metal mechanic to close the crossover or join the top of the "T" section onto the expansion joint cover on a metal closure? Terminal points must be carefully depicted to insure that all assembly components fit properly. Isometric drawings are generally the only way that junctures and terminal points can be depicted by the designer and easily interpreted by the mechanic. Cross sections show the elements and components of the assembly, but seldom show sheet metal joint/junctures or securement methods. An isometric drawing will force the designer to visualize how each component fits into the overall detail and whether the compensation must be made for differing elevations at juncture points. Clear isometric drawings drastically reduce the risk of faulty interpretation by the bidding contractor or by the mechanic in the field.

Roof designers usually omit "joint" details of sheet-metal components even when these details are otherwise carefully drawn. Since sheet metal for roofing applications generally comes in 8 or 10 ft. lengths, a large structure will have numerous joints between metal sections. If, as in the case of a metal counterflashing, the sheet metal merely sheds water over the tops of the membrane base flashings, a "lap" joint is probably sufficient. But an expansion joint cover or a sheet metal coping must provide a watertight closure. The expansion joint cover must be designed to allow for some movement between structural sections and still remain watertight. The sheet metal coping should close off the tops of parapet walls and, it, too, must be watertight. In these two instances, lap joints or butted joints with covers typically will not provide a watertight condition after the first complete thermal cycle since most sealants or caulkings used to seal the laps of the metal harden and break loose with continual thermal cycling. Soldering of the joints is not an appropriate solution, unless the entire length of the closure assembly is less than 40 ft. Any continuous run in excess of 40 ft. must allow expansion and contraction of the closure metal. Standing seams are not only watertight; they also provide for expansion and contraction and stiffen the sheet metal in its span across the area to be closed. Drive type closures can be incorporated into coping covers or expansion joint covers in much the same fashion. Unless the designer shows the required detail, the contractor will probably use the easiest, cheapest detail, regardless of its suitability.

Method of securement for sheet-metal components is another important design factor seldom shown in roof construction details. Are continuous or intermittent cleats required on exterior vertical surfaces? Are screws or nails required to secure metal flanges? Are the specified fasteners compatible with the metal used in the closure? Are expansion type fasteners required or desirable in securing metal sections to masonry walls? Unless the method of securement and the spacing of fasteners is detailed or specified, the desired end may never be achieved during construction. There are a number of sources of guide details to aid the designer in the conceptualization of most roofing-related details: the National Roofing Contractors Association details and the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) comprehensive manual on sheet metal details. There are no guide details covering all possibilities in the countless conditions of each individual project. The principles illustrated in guide details can be adapted to unique project conditions in appropriate individual details, tailored to each specific project. Some manufacturers' brochures are very explicit on methods of application for a particular material, but they cannot cover all the unique conditions encountered on specific projects.

In retrofit applications, especially when the new system joins existing structures, new details must "marry up" to existing details. Existing curb heights must be matched or the existing curbs must be modified to provide the same basic configuration or transition to match the elevation of the new details. If the original detail is bad, then the new detail should be altered to a more appropriate or more acceptable new detail.

Isometric drawings, especially at juncture points, will assist the designer in visualizing construction conditions. There are always some undisclosed conditions, revealed only by removal of the existing roofing system and/or covers, and in any retrofit situation field decisions must be made to alter existing or proposed conditions.

Interior drain assemblies cause problems for roofing contractors because they usually do not provide the drains. The specifier should be aware that there are several interior drain configurations. One common mistake made by specifiers is to call for a drain type designed for the wrong deck—for example, a drain designed for a lightweight concrete fill installed on a steel deck. This usually occurs when alternates are taken for the deck type. Some drains can be made to work with a roofing system over any given deck, but other drains cannot be appropriately modified for a given installation. Roof insulation should be recessed around interior drains to insure rapid roof drainage. The recess fabricated around the drain should be large enough so that flashings—including lead and stripping plies—will fit inside the recess, rather than being built up around the perimeter of the recess, damming water that would otherwise run into the sump. Some types of roof insulation can be tapered or fabricated to provide a recess around the drain area. Other types of insulation are more difficult to form or shape in the field, and in these cases it is usually easier to use a tapered cant strip to form the recess prior to insulation application. The wood-fiber cant material can be easily fabricated into solid substrate for the roofing membrane and flashing in the recessed area. Use of tapered insulation around the interior drains results in less insulating efficiency in these areas, a benefit since it promotes melting of ice and snow. This usually eliminates "ice dams" that obstruct surface water from running to the drains. "Filler" insulation can be used underneath tapered strips when thicker insulations are installed. If condensation on cold drain sumps/leaders is anticipated, drain sumps and leaders should be insulated and the insulation covered or "closed" with a vapor retarder material applied over the insulation.

On steel-deck roof assemblies recesses formed by tapering the roof insulation are preferable to metal sump pans built into the deck. Metal sump pans seldom allow for a uniform transition to the drain sump thus requiring "manipulation" of available roofing materials. While attempting to make non-comformable materials conform to odd configurations, the roofing mechanic may leave voids in the substrate for the roofing membrane at a critical point. Some sump pans do not allow enough room between the deck and drain sump to effectively install any common roofing materials to form a transition. As a result, the mechanic may be unable to install the drain-clamping ring without damaging the roofing membrane and/or lead flashing. Drain lead sheet dimensions should not exceed the recess dimensions. Lead extending 12 in. maximum from each edge of the roof drain sump is generally adequate to provide the seal necessary between the roofing membrane and the drain sump itself.

On roofing systems with perimeter drainage, the two-piece gutter design is usually preferable except in northern areas where ice is likely to build up in the gutter. Accumulated ice will dislodge the separate gravel stop, damaging the roofing membrane and allowing water to run into the roofing system or behind the gutter and down walls. One-piece gutter design should incorporate expansion joints in the metal gutter every 30 to 40 ft. depending on the type of material used. Aluminum generally makes poor one-piece gutters, since sealing of the joints is almost impossible under field conditions. One-piece gutter designs best incorporate metals that can be soldered and sealed with tight joints under field conditions.

Provision for expansion and contraction will minimize rupturing or breaking of the metal joints at the critical roof/metal juncture.

If there is one key to roof construction detailing, it is to isolate the roof/deck assembly from perimeter walls, fire walls, or elevation walls and from roof-penetrating components. If the roof-deck assembly can move independently of any adjacent structural components and if any projection through the roofing membrane can move independently without causing undue stress or strain on the roof-system components, then the chances for satisfactory roofing system performance are greatly increased. Projections through the roof should be completely closed or flashed. Tubular mounts may be extended through the roofing assembly from structural components beneath the roofing system. Tubular mount/projection configurations allow easy installation of weather caps, to cover pitch pans or lead flashings. These weather caps eliminate the major maintenance problems of constantly restoring bituminous materials in the pitch pans and minimize the possibility of water entry around these projections. If the designer can eliminate mechanical ties between the roofing system and projections or structural components, he can be reasonably sure that damage to the roofing system from external mechanical stresses will be minimized.

MATERIALS

There are countless combinations of materials that can be used to flash a roofing assembly. Again, it is necessary to differentiate between membrane base flashings and metal flashings.

After the detail has been visualized and its full purpose determined, appropriate materials should be selected to fit the application. By limiting the materials to be incorporated into the roofing system to those manufactured by one material supplier, the specifier is usually eliminating the use of some specialty materials that can be used very effectively to solve special problems encountered in roof system application. He must then weigh the advantages of "single source responsibility" against the advantages of providing a wider variety of problem solving materials. There is not one single material manufacturer which offers a "complete" line of materials which can be used under most conditions. The physical properties and limitations of all available material must be evaluated to determine which will probably perform best in a given situation.

Membrane flashing materials must, above all, be flexible and durable enough to stand the rigors of foot traffic and the deterioration produced by direct sunlight. Inorganic reinforced materials generally offer much better weathering properties than organic based materials. There are special reinforced, bituminous flashing surfacing plies that offer very good durability and weather resistance. Some surfacing plies incorporate light colored mineral granules to provide reflectivity for the flashing surface. Others rely on heavily filled asbestos-base materials for the weathering surface.

With a number of elasto-plastic membranes now available for roofing applications, membrane flashings are usually comprised of a sheet membrane of similar composition to that of the roofing membrane. It should be noted that some of the elasto-plastic membranes have reasonably good weathering capabilities, whereas others do not. In general, most elasto-plastic membrane flashings should be well protected with surfacing aggregate or special accessory metal to retard deterioration of the membrane and/or adhesive used to join laps at the membrane joints. Some elasto-plastic membrane materials will have similar durability to built-up bituminous membrane flashings, whereas others will be more easily damaged. An evaluation should be made of each material to be incorporated into details used with elasto-plastic waterproofing membrane.

In general, flashing material should be similar to the membrane material: i.e. bituminous built-up base flashings with bituminous roofing membranes and a compatible elasto-plastic flashing membrane with elasto-plastic membranes. Most elasto-plastic membranes are incompatible with bituminous materials and therefore should not be considered as a component of bituminous roofing systems. Elasto-plastic materials have sometimes been used to solve the "lateral wrinkling" problems associated with either creeping roofs of differential structural movement, however, in most instances after only a few seasons, plasticizers are leached from the elasto-plastic membrane by the bituminous materials and separation occurs between the roofing membrane and the flashing ply. Metal base flashings have proven to be unsatisfactory in most roofing and waterproofing applications.

Membrane base flashings are essentially vertical extensions of the waterproofing membrane. They should be constructed with uniform applications of waterproofing adhesive material and an appropriate number of reinforcing plies. In flashing construction, the two most commonly used waterproofing materials are Type III (Steep) asphalt and a plasticized, filled asphaltic material usually referred to as flashing cement. There are advantages and disadvantages to the construction of membrane base flashings using either of the materials, but uniformity of application of the waterproofing medium is as critical to flashing performances as it is to roofing membrane performance.

There are now available a number of prefabricated, single-ply membranes incorporating a reinforcing material, a surfacing of some type and a placticized asphalt as the waterproofing medium. They vary in durability and in mode of application, but they generally provide considerable flexibility for handling special flashing problems.

The accessory metals commonly used with roofing systems, both bituminous and elasto-plastic are galvanized metal, aluminum, copper, (sometimes lead-coated) and stainless steel. Choice of accessory metal depends upon the roof's environment. For extremely corrosive conditions, stainless steel offers the best resistance to long-term weathering. As a general utility metal, galvanized metal offers economy and easy fabrication. Copper offers some distinct weathering advantages and easy installation. Aluminum makes a good utility metal, but is difficult to seal at joints usually requiring a sealant compound and mechanical securement. Moreover, aluminum must be protected from the effects of alkali in masonry construction when used for thru-wall flashings.

Accessory metal should generally shed rainwater onto the roof surface. If a metal closure must be watertight, it requires an appropriate method for fabricating the joints. Wherever metal is incorporated into a roofing system, a wood nailer is normally provided to anchor the horizontal flange of the closure metal. Any wood incorporated into the roofing system should be treated, with a water-based preservative. Preservative fumes from creosote or other solvent-reduced preservatives reduce bituminous materials or cause plasticizer damage to elasto-plastic membranes.

Fabrication techniques for accessory metal vary considerably from fabricator to fabricator. Flat configurations of accessory sheet metal, even the heavier gauges or thicknesses, are generally less rigid and more vulnerable to wind damage or damage from roof top traffic than are metal configurations incorporating one or more intermediate breaks in the vertical surface. Much the same as the auto manufacturers have discovered that a slight break in the metal stiffens the outer skin of the car, roofing accessory sheet metal should be designed and specified in a similar manner. If rigidity of the watershed material is required (surface mounted counterflashings, metal counterflashings and receivers on masonry walls, etc.), one additional intermediate break on the horizontal surface will provide exceptional rigidity to the accessory metal. This additional horizontal break also provides some "spring action" in that the base of the counterflashing is held more tightly against the surface of the membrane base flashing. Since only a narrow edge of metal is in contact with the membrane flashing, there is little probability of capillary action between metal and the flashing membrane.

Where securement of membrane base flashings is difficult—for example, to metal curb projections—continuous sheet metal cleats can be run at the top of the membrane base flashing and secured with sheet metal screws through the membrane flashing to the metal base. This insures that the top of the membrane base flashing will stay tight and that weight of the flashing will not pull the material from place and cause a void in the watershed surface. Surface-mounted counterflashings can be used in much the same way, and when incorporting a caulking receiver, will provide a relatively maintenance-free watershed condition. The pre-manufactured, modified bituminous membranes bond well to metal surfaces and can be effectively used to seal the roofing system around penetrations, or the tops of membrane base flashings at projections.

Some guidelines for the installation of accessory metal are as follows:

1. Always install the horizontal metal flange on top of the complete roofing membrane and the roof membrane envelope (if installed).
2. All horizontal metal flanges used in conjunction with bituminous built-up roofing membrane should be set in a solid bed of flashing cement to provide a watertight seal between the metal and the roofing membrane. Note that the type of accessory metal specified too close the perimeters of elasto-plastic membrane assemblies will vary, and the respective manufacturer's application recommendations should be followed in each case.
3. All horizontal metal flanges or metal closures used with either bituminous or elasto-plastic membrane should be secured to a salt-treated wood nailer by staggering the fasteners front to rear on the horizontal flange 3" to 4" on center.
4. All horizontal flanges to be sealed into the roofing membrane must be primed with a primer compatible with the hot bitumen being used. After priming the horizontal flanges with asphalt primer, strip the metal flange onto the roofing membrane using stripping plies of basically the same material as the roofing membrane. With bituminous roofing membranes, two plies of inorganic roofing felt—one 6-in. wide and one 9-in. wide—should be feathered onto the biuminous membrane. Installation of the first stripping ply in flashing cement and the second stripping ply in hot bitumen, or both in hot bitumen, are preferred methods of installation. On elasto-plastic membranes, special adhesives and/or sealants are specified by each respective manufacturer for the stripping of accessory metal to elasto-plastic membranes.

The same principle generally applies to the installation of accessory metal as applies to detailing of the roofing system. If practicable, accessory metal should never be adhered directly to the roofing membrane, but should be isolated from the roofing system by placing it over an elevated perimeter curb or using it as a "watershed" over perimeter curb type flashing.

GUIDELINES FOR DETAILS

1. Isolate the roofing system from the rest of the structure penetrations and accessory metal whenever practicable. By allowing the roof/deck system to move independently of other structural and

accessory components, external mechanical stresses on the roofing system are minimized and mechanical damage is less likely. A building expansion joint should be continued through the entire roofing system to insure that the expansion joint on the roof has two independent supports not connected by any mechanical means.

2. Elevate closures above roof level. Curbed expansion joints are preferable.
3. Locate flashings at high points, so water will immediately drain away from these vulnerable joints. Membrane base flashings exposed to standing water will weather more rapidly at a very critical juncture. Construct crickets or saddles on top of the insulation to divert water away from membrane flashings at perimeter or interior elevation walls or curbs. Metal flanges adhered to the roofing system will ultimately separate from the stripping plies and possibly rupture the roofing membrane allowing any water standing in the area to be admitted to the structure.
4. For reasons mentioned in paragraph No. 3, avoid metal adhered to the roofing membrane whenever practicable. Design details that allow free movement of the metal on top of the roofing system. This will generally necessitate a raised curb which sheds water away from the critical roof/metal juncture almost immediately.
5. The width of metal flanges to be adhered to the roofing membrane should never exceed the width of the treated wood nailer. The horizontal flange should be secured with fasteners staggered front-to-rear on the flange spaced 3 or 4 in. to restrain movement of the accessory metal. Gravel stops are the most common application of this type, and gravel stop details should incorporate external joint closure plates to isolate the roofing membrane and stripping ply from direct movement of metal at joints. Treated wood nailers should be a minimum 2 × 6 in. to insure that the back side of the horizontal metal flange can be mechanically secured to prevent "scalloping" of the metal during thermal contraction and expansion, and that there is adequate thickness of wood to hold nails or fasteners. This "scalloping" of curling of the metal at the back side will damage the stripping plies and break the seal between the metal and the roofing membrane.
6. Minimum height for any base flashing should be 8 in. This dimension will minimize the possibility of wind-driven water entering over the top of the membrane base flashings. In areas where snow drifting is a problem, capillary action of water between two closely adjacent surfaces may allow the ingress of some moisture at perimeters. Configuration of the water-shedding accessory metal should place the metal tight against the base flashing at the drip flange and bent away from the membrane flashing as it leaves its contact surface.
7. Maximum height of membrane base flashing should be approximately 12 in. Membrane base flashings over 12 in. high are prone to sagging and distortion from differential movement of the substrate. If the inside of parapet walls or fire walls must be waterproofed, construct the membrane base flashings approximately 12 in. high, and install a waterproofing membrane on the wall to act as a watershed over the tops of the membrane base flashings. Waterproofing membranes will generally be of a lighter weight material and can be more easily secured and bonded in place than a heavy base flashing weathering ply.
8. Use solid, treated wood cant strip when it must be mechanically anchored or when the solid wood cant is necessary to stabilize a vertical wood nailer at expansion joint curbs and perimeter curb details. If the cant is not required for structural stabilization then the wood fiber cants make acceptable transitions between the horizontal and vertical planes at the roof/curb junctures.
9. Recess all interior drains to insure rapid runoff from the roof surface. Insure that all flashing plies can be contained inside the recess area to prevent a damming build up of bituminous or stripping materials on the roof surface.
10. Expansion or control joint covers should be elevated above the roof surface along the same guidelines as elevations for membrane flashing. Expansion joint curbs should be approximately 8 in. above roof level to raise membrane base flashings well above the roof water level. The use of expansion or control joints flush with the roof surface runs the risk that ponded water will leak into the building through any damaged spot in the closure. Damage to closures on elevated details will admit limited quantities of water and can be more easily repaired.
11. Perimeter wood nailers should be anchored to the structural deck to isolate the roof/deck system from adjacent structural components. When wood nailers are attached to perimeter walls, differential structural movement may cause damage to the roofing system at the critical wall/deck juncture. Even when the structural members are tied into bearing walls, masonry thermal contraction and expansion can damage the waterproofing membrane.
12. Two-piece, through-wall flashings should be installed at all masonry walls. Through-wall metal reduces the possibility of water entering the roofing system or building interior through vertical wall cavities. By including the counterflashing receiver with the through-wall metal, continuity of the "watershed" is assured and counterflashing metal may be easily removed and reused at the time repairs are necessary to base flashings or at the time of reroofing. Weep holes should be provided on top of the through-wall metal to allow escape of any water entering the wall above the metal.
13. Continuous metal cleats should be used to secure the face side of metal coping, gravel stop and/or fascia metal. The cleat allows for lateral expansion/contraction of the exposed fascia metal while insuring positive securement against wind uplift. Cleats should be of heavier gauge metal than the coping, gravel stop/fascia of perimeter curb metal.
14. Gravel stop metal should be fabricated from light-

gauge metal to allow more positive anchorage of horizontal flanges and minimize expansion/contraction forces.

15. Extend metal cap or counterflashings a minimum 3 in. down over the tops of membrane base flashings to insure positive water shedding.
16. Specify watertight mechanical joints for coping and expansion joint cover sections. Sections should be maximum 60" long to control expansion. Keep corner "legs" to a maximum 18" long.

Do not attempt to use guide details for all occasions. Even attempting to make the entire structure conform to guidline roofing details will be a frustrating and unrewarding experience. Instead, apply the guidelines and basic principles to individual project details that fit actual or anticipated conditions. Visualize these conditions and depict them in isometric drawings to show how everything fits together. Show clearly the type of metal joint to be constructed and name fasteners by trade name for easy identification by the contractor. Indicate fastener spacing. Draw details in large enough scale to clearly show all components and their relative positions in the construction. Such planning will make the job go more smoothly, allows for good, competitive bidding and minimizes surprises.

Despite all the precautions, attention to detail and professional installation, flashings and roofing accessories are subject to damage from roof-top traffic or severe weather conditions. A continual audit schedule and regular routine maintenance are the only ways to insure good performance and long service life for any type of roofing/waterproofing system.