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Residential roof drainage design

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- A key component of building design and construction is a roof that efficiently collects and disposes of the rainwater that falls on it.
- Complex roofs often result from a lack of coordination between the floor plan and the design requirements of the roof above.
- This Bulletin outlines good design principles for roof drainage for residential buildings. These principles may be applied across a range of roof styles and types.

1.0 INTRODUCTION

1.0.1 A key component of residential design and construction is a roof that not only keeps the building weathertight, but efficiently collects and drains the rainwater that falls on it.

1.0.2 Water that remains on a roof surface has the potential to leak into the building and increase the rate of deterioration of the roofing system.

1.0.3 This Bulletin covers design principles for roof drainage for residential buildings that can be applied across a range of roof styles and cladding types.

2.0 BUILDING CODE REQUIREMENTS

2.0.1 Roof drainage is required to comply with New Zealand Building Code (the Building Code) clauses:
- E1 *Surface water*
- E2 *External moisture*.

2.0.2 Compliance Documents E1/AS1 and E2/AS1 offer some guidance for the design and construction of roof drainage systems. BRANZ Bulletin 509 *Sizing gutters and downpipes* can be used as an Alternative Solution.

3.0 ROOF DESIGN

3.0.1 When developing the floor plans of a building, consider the design of the roof at the same time to ensure that water is effectively collected and efficiently drained and that the design is logical (Figure 1). Simple roof forms make drainage easier (Figure 2).

Figure 1: A complex series of roofs and junctions.

Figure 2: Simple forms facilitate drainage.

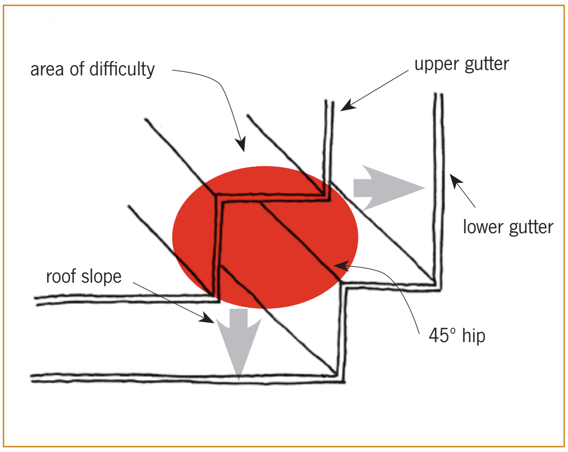

Figure 3: Roof junctions and roof/wall junctions in the area highlighted can be made more difficult through lack of resolution of the roof form during design.

3.0.2 Complex roofs or roofs with poor drainage often result from a lack of coordination between the floor plans and the roof above. Where an upper storey is smaller than the lower, roof forms are often not coordinated with the upper and lower floor wall locations, particularly for designs with hips and valleys. For example, they may land within a wall area (Figure 3) rather than at an internal or external wall corner, which can create very awkward areas to drain and for the builder and roofer to construct.

3.0.3 Modern house designs commonly have a significant area of wall that drains onto the roof below – this can increase the roof catchment area by up to 50% depending on the exposed wall area.

4.0 KEY DESIGN CONSIDERATIONS

4.1 RAINFALL

4.1.1 New Zealand has a relatively moist climate. Design rainfall intensities for different localities (based on measurements in mm per hour for a 10-minute period) range from less than 80 mm per hour to more than 200 mm per hour. Winds are relatively strong. In a number of localities within New Zealand, it is also necessary to factor in snow loading and the likelihood of hail, both of which will affect the roof drainage when they occur.

4.1.2 Territorial Authorities, E1/AS1 or NIWA can provide information on rainfall intensity in particular regions, which must be used for roof drainage design and to select the most suitable roof geometry and material.

4.1.3 It is predicted that global climate change will alter rainfall patterns in the future. The prediction is for increasing rainfall in some areas and more severe weather events, which may result in greater rainfall over a shorter timeframe. This should be considered when roofs and drainage systems are being designed.

4.2 WIND AND WIND PRESSURE

4.2.1 Wind forces acting on a roof can have considerable impact on roof drainage – at worst, being strong enough to stop the water draining from the roof or blowing water back up under flashings or into laps. The potential effect increases as roof slope reduces because the gravity forces acting on the water becomes less than the wind pressure, and drainage stops.

4.2.2 Specifying a fascia gutter with a front edge that projects above the roofing profile will mitigate this effect by deflecting the wind over the bottom of the roofing and allowing the water to drain.

4.2.3 The top ends of profiled metal roofing always have a stop-end formed to the trough of the profile to stop water blowing over the end of the roofing.

4.3 ROOF GEOMETRY

4.3.1 Roof shape affects roof drainage as well as the ease with which the roof can be constructed. Simple gable roofs with a roof surface running from a ridge to an eaves gutter will drain more effectively than a hip and valley roof where the flow of water is collected or diverted before reaching the eaves. As complexity of roof design increases, so does the risk of water entry.

4.3.2 Intersecting the flow of water on a roof surface increases complexity of roof construction, roof cladding installation, flashing and valley installation (especially junctions) and drainage.

4.3.3 Roof designs need to be planned to avoid concentrating water flows (Figures 4 and 5) because this can lead to overloading of valleys and gutters and an increased risk of water entry.

Figure 4: There will be a major concentration of water flow from a valley and a gutter into a constricted area because of the (poor) design of the roof. Note also the difficulty in installing some of the roof and gutter components and that there appears to be no overflow provision in the fascia gutter system and the area of roofing under the eaves that will not be washed by the rain.

Figure 5: This roof concentrates flow but also creates a roof plane area that makes the installation of tiles more difficult.

4.3.4 In 2-storey buildings, consider how the water is discharged onto the lower roof from the upper roof and the effect of wall surfaces draining onto a lower roof.

4.3.5 Roofs with valleys or dropper downpipes from a higher level roof concentrate the water flow, which may increase loads at specific points in the roof drainage system. Droppers discharging onto a lower clay/concrete tile roof trigger specific installation requirements under E2/AS1, and it is common to see a dropper located where it discharges (usually without a spreader) a concentrated amount of water at a weak point in the roof design such as the head of a valley (Figure 6). Ideally, upper roofs should be designed to drain directly to the stormwater systems and via a lower roof.

4.3.6 Complex shapes are also more likely to facilitate the accumulation of airborne leaf debris, which (if not regularly removed) leads to blockages of valleys, gutters and sumps and allows water entry.

4.4 ROOF SLOPE

4.4.1 Roof slope, or pitch, is a critical component of roof design to ensure effective drainage from the roof surface. Different roofing materials and roofing profiles have differing drainage capacities and require specific minimum slopes. Roofing manufacturers and E2/AS1 specify minimum slopes.

4.4.2 The slope of the roof affects the rate of drainage – the greater the slope, the faster water will drain. However, roofs are also affected by wind speed and direction, and this may slow the drainage from the surface.

4.4.3 Low slope roofs (less than 10°) will be more susceptible to the effects of wind slowing down roof drainage, as the speed of water disposal will already be slow and be more readily affected by wind.

4.4.4 Very low slope roofs (from 5° down to 1.5°), which generally incorporate membrane roof claddings, are also more

Figure 6: Concentrating water flow from a dropper (even with a spreader) where the flashings are the hardest to detail and install is not recommended. Spreaders should be constructed with a partially closed end (to prevent a concentrated flow) and holes along the horizontal leg to allow a number of small streams of water, which has not been done here.

susceptible to construction inaccuracies that may create a variation below the minimum slope and affect drainage.

4.4.5 Roof slope may need to be increased for longer roof runs – as the length of roof runs increase, so does the amount of water to be managed. The increase in roof slope is to maintain drainage. E2/AS1 requires that the minimum slope of metal and tile roofs be increased once the length exceeds a specific distance – 18 m for profiled metal, 12 m for pressed metal tiles and 4.5 m for masonry tiles.

4.4.6 Roof profiles outside the scope of E2/AS1 may offer greater drainage capacity allowing the use of longer runs at a lesser slope – obtain product-specific information form the manufacturer.

4.4.7 Increasing the slope also increases the catchment area of the roof, and this will also add to the water volume.

4.4.8 On steeper roofs, the water draining off will be moving faster, and this must be considered when designing valleys to prevent water being driven by the momentum under the roofing or over the front edge of an external gutter.

4.4.9 Curved roofs, which are outside the scope of E2/AS1, incorporate a range of slopes, with the slope at the apex of the curve being less than the remainder of the roof (and usually below the minimum slope recommended for the profile) – this should be considered when the profile height is being chosen.

4.4.10 Curved roofs that butt into a vertical wall surface at their apex can create problems because the roof is effectively horizontal at the intersection with the wall. This means that, even when cover-flashed, water can easily be driven under the flashing unless a full profile height stop-end can be folded in the trough or pan at the top end of the roofing.

4.4.11 Manufacturers require the sealing of laps where the slope falls below the minimum – the slope at the eaves must not be less than the minimum for the profile.

4.5 STRUCTURAL MOVEMENT

4.5.1 Creep or deflection in the building or roof structure (purlins, rafters) may affect the roof slope and ultimately roof drainage, particularly for lower slopes, as the tolerance available to accommodate any deflection while still maintaining good drainage is less than with a steeply sloped roof.

4.5.2 A low slope roof is more likely to have foot traffic over the roof during its life and therefore has an increased risk of drainage being compromised by these loadings on the roof. It is also more likely that equipment such as a retrofitted heat pump exterior unit (with its penetrations through the roof) will be installed on a roof that has a lower slope.

4.6 ROOF MATERIAL SPAN

4.6.1 For profiled long run metal, manufacturers give maximum spans for roofing profile and for metal strength to ensure that any sagging between supports should not affect the drainage from the roof. The effect on drainage is greater where medium strength (G300) steel roofing is installed at the lowest slope permitted and the span between purlins is taken to the maximum. High strength G450 steel roofing will generally only be affected when foot traffic causes a creasing of the rib – a design consideration must be the expected amount of foot traffic on the roof.

4.7 MAINTENANCE

4.7.1 Roof design must take consideration of access for roof maintenance. Steeply sloped and complex roofs are often difficult to access, and this restricts the ability to carry out maintenance on both the roof material and drainage mechanisms.

4.7.2 Roof design should also consider the need for metal roofing products to be kept clean by not creating unwashed areas, which will deteriorate more quickly (see Figure 3).

4.7.3 Maintaining the roof material in good condition and keeping drainage mechanisms clear of debris are fundamental to ensuring adequate drainage performance.

4.8 OTHER DESIGN FACTORS

4.8.1 While this Bulletin concentrates on designing the roof to facilitate drainage of water, designers must also consider:

- the durability of the specified roofing in the environment it is to be used in
- for metal roofing, the creation of areas of roof that are not readily rain-washed, as this may affect durability
- thermal movement
- fixing (type and frequency) of the roofing and flashings
- material compatibility
- purlin spacing and fixings, particularly around roof edges
- the installation of aerials and satellite dishes on the roof (often done after the roofer has completed work)
- increasing the gauge of the metal roofing used on lower sloped roofs to reduce the risk of damage.

5.0 DRAINAGE MECHANISMS – WATER COLLECTION

5.0.1 Key references for roof detailing and construction include the following:

- BRANZ *Good Practice Guide Profiled Metal Roofing*, 2003
- BRANZ Weathertight Solutions *Volume 5 Roofing*, 2007 and *Volume 6 Membrane Roofing,* 2008.
- New Zealand Metal Roofing Manufacturers' Code of Practice.
- Torch-on Membrane Code of Practice.
- Manufacturers' product-specific literature.
- E2/AS1 Third Edition.

5.1 VALLEY GUTTERS

5.1.1 Valley gutters are installed within the roof area and to the slope of the roof, but below the roof surface, and as such, they can create challenges – failure generally results in water entering the roof structure. Valleys that terminate at an external gutter line, usually at an internal corner, are reasonably easy to design and construct as they drain into the gutter (provided it is installed to be below the outlet of the valley) and can be made deeper to accommodate larger flows or snow loadings.

5.1.2 Where possible, a drainage outlet or downpipe should be installed in close proximity to the exit location of the valley to take the concentrated flow.

5.1.3 Valleys that terminate within a roof area like those adjacent to a gable dormer window are more complex to detail and to construct (Figure 7). The bottom end of the valley needs to be shaped or lifted to allow it to discharge the water onto the roof below. Such junctions are generally easier to construct when tile roofing rather than long run roofing is specified, and for long run, the profile height is lower (for example, it is considered easier to construct with a corrugated profile rather than a trapezoid profile).

5.1.4 Detailing difficulty also occurs where the roof design has a valley gutter that has the low end terminating against a vertical surface. In these situations, an internal gutter – which increases the risk of water entry – must be constructed to drain the water from the valley. The design of the gutter must allow for the area of roof being drained and for future maintenance such as cleaning. Rainheads can also be used to avoid splashback at valley/gutter intersections.

5.1.5 Valley gutters must be designed to ensure that:
- water is drained from the gutter into an external gutter or out and down over a suitable adjacent roof surface
- they are wide enough and deep enough to have sufficient capacity to manage the relative rainfall intensity for the roof area being collected
- they are wide enough to be easily cleaned and maintained – a minimum width of 50 mm between the edges of the roofing is recommended (100 mm allows the valley to be readily cleaned during maintenance)
- they are designed with sufficient upstand at the sides to ensure water does not discharge into the roof structure
- the material forming the valley is fully supported by a valley board or solid blocking
- valleys with unequal catchment areas or slope on each side of the valley are designed to accommodate the heaviest load.

5.1.6 E2/AS1 gives specific requirements for the maximum roof catchment area, sizing and construction of valley gutters in Sections 8.1.6.1 and 8.1.6.2.

5.1.7 The design and sizing of internal and external eaves gutters is covered in E1/AS1 and BRANZ Bulletin 509.

Figure 7: Valleys need to be detailed and installed to discharge water over the roofing below. Note the gutter outlet installed without a spreader.

5.2 FLASHINGS

5.2.1 All roof flashings act as drainage devices as they deflect water away from critical junctions in the roof surface and allow water to drain over them.

5.2.2 Minimum cover dimensions for flashings are given in Table 7 of E2/AS1 for buildings within the scope of the Acceptable Solution. Manufacturers may also provide minimum cover requirements for their roof cladding.

5.2.3 Specify that flashings are lapped away from prevailing winds and to ensure gravity drainage across the roof surface occurs over the lap, and they should be manufactured from a material that suits the roofing material and profile.

5.2.4 Hip and ridge flashings are reasonably easy to design and construct, although care is needed at the junctions of ridge to hip flashings, at end terminations and also where the flashings terminate at vertical wall surfaces, where they must be under-flashed by the apron flashings.

5.2.5 Barge flashings are required to provide cover to the roof cladding (a minimum of two crests for profiled metal) with a downturn of 50 mm minimum (70 mm in very high wind zones) to the barge board or fascia. This means that the flashing will generally need to be site measured to suit the roofing crests.

5.2.6 Size apron flashings to ensure that they provide sufficient cover (Table 7 E2/AS1) as an over-flashing to the roof surface and sufficient upstand (Table 7 E2/AS1) behind the adjacent wall cladding.

5.2.7 Apron flashings that follow the fall of the roof surface and terminate in the face of the wall cladding must provide cover to the roof cladding (a minimum of two crests for profiled metal) and incorporate a stop-end or diverter that directs water onto the roof surface at the end of the flashing.

5.2.8 Detail support to parapet or cap flashings over 150 mm wide to prevent damage to or deflection of the top surface. Detail a cross-fall of at least 5° to the flashing.

5.2.9 For buildings outside the scope of E2/AS1, flashings will need to be specifically designed as an Alternative Solution to show the building consent authority (BCA) that the level of risk has been allowed for in their design. One example is how the designer has approached the design of the flashings to accommodate a specific design wind speed and therefore higher weathertightness risk on an exposed site – more cover, bigger upstands, thicker flashing material to resist uplift and so on.

5.3 CHANGES OF SLOPE

5.3.1 Many roof designs incorporate changes of slope within one plane of the roof. Details for change of slope need to provide sufficient flashing cover, with the roof underlay installed to allow drainage of any condensation or a leak to the outside at the change in slope.

5.4 PENETRATIONS

5.4.1 Roofs often incorporate a number of large and small penetrations. These can interrupt the flow of water down a roof surface and represent high potential for water ponding and entry into the roof structure (Figure 8). The location of the penetration within the roof area also affects the volume and velocity of the water it has to deal with – those located higher up on the roof area will be subject to less water than those by the eaves. Water velocity increases as it travels down the roof slope.

Figure 8: The location of this chimney interrupts the flow of water down the gable end.

5.4.2 Large penetrations (greater than 200 mm wide) such as chimneys or roof lights can interrupt a large volume of water draining down a roof surface – they should therefore incorporate flashings that effectively under-flash the roof surface (up the slope) and incorporate a diverter or cricket (details are given in the New Zealand Metal Roofing Manufacturers' Code of Practice) to channel the water around the obstruction. The sides and front of the penetration must then be flashed to the roof to maintain water flow paths around it. Where possible, it is recommended that an over-flashing that runs above the penetration to the nearest ridge or roof over-flashing is used, to avoid having to install an under-flashing, which can often prove difficult.

5.4.3 Flashings above large penetrations also need to ensure that the water draining down the roof slope is diverted around the penetration upstand to avoid ponding. This can be done with the use of crickets or raised diverter flashings that ensure water flows to either side of the penetration and does not pond behind the penetration, causing loss of durability and increased risk of water entry.

5.4.4 Small penetrations (less than 200 mm wide, such as vent pipes) interrupt much smaller volumes of roof water and can generally be flashed with formed flashings or with proprietary boot-type flashings that seal to the upstand of the penetration and over-flash the roof surface. Roof water will divert naturally around small penetrations. These penetrations need to be positioned so that they do not block the drainage of water – that means ensuring the penetration is centred on a crest or rib (Figure 9).

Figure 9: Inappropriate location and installation of a boot-flashed penetration.

5.4.5 E2/AS1 places limits on the roof catchment area above a penetration. See Table 9 for roofing generally and Table 17 for profiled metal specifically.

6.0 MAINTENANCE

6.0.1 Regular maintenance is fundamentally important for the ongoing performance of roof drainage systems. The roofing material and associated components need to be maintained to ensure effective drainage off the surface and long-term weathertightness (Figure 10).

Figure 10: A number of modern roof designs are not easy to effectively maintain.

6.0.2 Roof geometry needs to take into consideration access for roof maintenance – steeply sloped and complex roofs are often difficult to access, and this restricts the ability to carry out maintenance on both the roof material and drainage mechanisms. It may be prudent for the designer to consider the installation of suitable anchor points, particularly on steeply sloped roofs, for future maintenance work.

6.0.3 Gutters and valleys need to be cleared of any debris to ensure that collection capacity and drainage are unimpeded – this is particularly important with internal and valley gutters where any blockage has the potential to create water leakage into the roof structure.

6.0.4 Downpipes and drainage outlets need to incorporate protection devices, which require regular cleaning, to restrict the entry of debris and foreign objects that may cause blockages that restrict capacity.

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