BRANZ

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ROOF SPACE VENTILATION

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- Roof space ventilation provides air exchange in the spaces above the ceiling insulation and below the roof cladding.
- The purpose of roof space ventilation in New Zealand's climatic environment is primarily moisture management, keeping moisture-sensitive building elements dry to maintain performance and durability.
- This bulletin investigates ventilation options for different ceiling and roof types.

1 INTRODUCTION

1.0.1 Roof space ventilation describes the practice of passively (or sometimes actively) providing air movement through roof spaces above the ceiling thermal insulation and below the roof cladding of a dwelling. Usually, designed openings in the envelope will provide pathways that enable passive air exchanges of the roof space air with fresh outside air.

1.0.2 The purpose of roof space ventilation in New Zealand's climatic environment is primarily moisture management, keeping moisture-sensitive building elements dry to maintain performance and durability. Other benefits can include reducing the summer cooling load and extending the life of roof materials by reducing roof space temperatures.

1.0.3 The hygrothermal condition of a roof space depends on:

- internal building climate within the thermal envelope
- air permeability (leakiness) of the ceiling
- exterior climatic conditions and location of the dwelling
- airtightness of the roof space itself.

1.0.4 Roof space ventilation will add resilience by enabling the removal of excess moisture. However, other factors must be considered as well.

1.0.5 Thermal envelopes in residential buildings are becoming more airtight. There is evidence that this is also true for roof spaces. This can increase the risk of moisture-related problems. BRANZ has investigated a number of newly constructed buildings with significant mould and moisture problems within the roof.

1.0.6 Roof spaces vary significantly in volume. Skillion roofs, where the roof cladding and the ceiling lining are parallel and typically within 300 mm, have a small air space volume. Gable and hip roofs can have tens of cubic metres of volume. Ventilation rates of all roofs are usually measured in air exchanges per hour (ach) of the complete roof space volume.

1.0.7 Skillion roofs and their characteristics are detailed in more depth in Bulletin 610 *Preventing moisture problems in timber-framed skillion roofs*.

1.0.8 This bulletin investigates ventilation options for different ceiling and roof configurations.

2 VENTILATION FOR DIFFERENT ROOF TYPES

2.1 COLD ROOFS

2.1.1 Most roofs in New Zealand are of a cold design (Figure 1). Thermal insulation is placed directly above the ceiling lining, creating a space above that is more or less aligned to the outside climate.

2.1.2 Cold roofs are characterised as roof designs where the condensing surfaces are not controlled. The internal surfaces of the roof space, especially the underside of the roof cladding and underlay, may reach temperatures below the dew point temperature, leading to condensation.

2.1.3 Profiled metal roofs are available in a variety of profiles suitable for different roof pitches. Tray or trough profiles offer less natural ventilation in comparison to corrugated or trapezoidal profiles. Metal roofs don't absorb moisture, are a vapour barrier and exhibit high thermal conductivity. They can cool down quickly to temperatures below ambient, and condensation will be in the form of droplets on the underside of the roofing. Any condensation that is formed during cold, wet conditions will need to be removed by ventilation or absorbed by a vapour-permeable underlay.

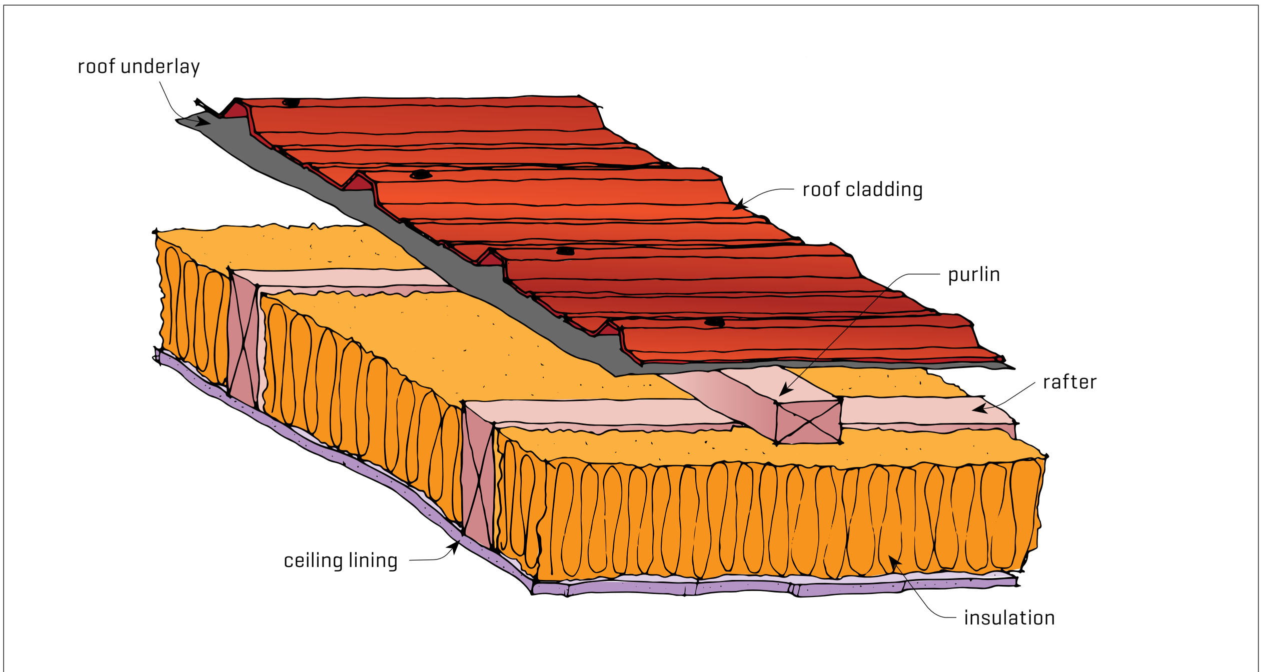

Figure 1. Example of a cold roof.

2.1.4 Asphalt/timber shingle roofs typically require ventilation. Obtain and follow the specific recommendations from the manufacturer.

2.1.5 Concrete or clay tile roofs, especially those without a roof underlay, exhibit a high degree of natural ventilation. It is good practice to install roof underlay under all concrete and clay tiles.

2.1.6 A minimum 25 mm gap must be maintained between the insulation and the roof cladding to provide a ventilation path and prevent condensation wicking into the insulation.

2.1.7 Membrane roofs with a minimum gap of 25 mm between the underside of the membrane/support structure and any insulation can be considered cold roofs. Manufacturers of membrane roofing generally recommend ventilation of the roof space. Obtain and follow their specific recommendations.

2.2 WARM ROOFS

2.2.1 Warm roofs are designed in such a way that the condensing surfaces are controlled. This is usually achieved by keeping the innermost surface warm enough not to reach the dew point temperature and will not allow indoor moisture (either by convective or diffusion transport mechanisms) to reach the outer cold surface. Figure 2 shows one of many ways to create a warm roof. Other examples include:

- membrane/insulation board/vapour barrier/substrate or roof framing
- membrane/loadbearing roof board/insulation board/vapour barrier/substrate or roof framing.

2.2.2 Bulk insulation pushed hard against the roof cladding does not constitute a warm roof design, since moist air can move easily through the insulation to reach the cold roof cladding and condense.

2.2.3 Warm roofs are not permanently ventilated as any space below is within the thermal envelope of the building. Care is required in the design and construction of a warm roof to avoid air and water vapour leakage paths through to the cold surfaces. Sealing between junctions is critical. Good ventilation practice for the living spaces below still applies.

3 CONDENSATION AND TRANSPORT OF MOISTURE

3.1 CONDENSATION AND HUMIDITY

3.1.1 Condensation will occur when the temperature of a surface drops to the dew point temperature of the surrounding air.

3.1.2 Cold air can hold less moisture in its gaseous state than warm air. The moisture content of air is described in one of two ways:

- Relative humidity (RH) – 100% RH indicates saturated air with condensation starting to form.
- Absolute moisture – indicates the mass of water contained in a volume or mass of dry air (grams of water per kilogram of dry air).

3.1.3 Relative humidity is dependent on temperature while absolute moisture is not.

3.2 TRANSPORT AND DRIVING MECHANISMS

3.2.1 There are several ways moisture is transported into the roof spaces from the living spaces underneath:

- Airflow through cracks, light fittings, access hatches and other openings at the ceiling level. This mechanism can be effectively reduced by an airtight ceiling that is also serving as an air barrier.
- Diffusion of moisture through the building materials. In comparison to a flow of moist air. This is a very slow process and is of limited concern.

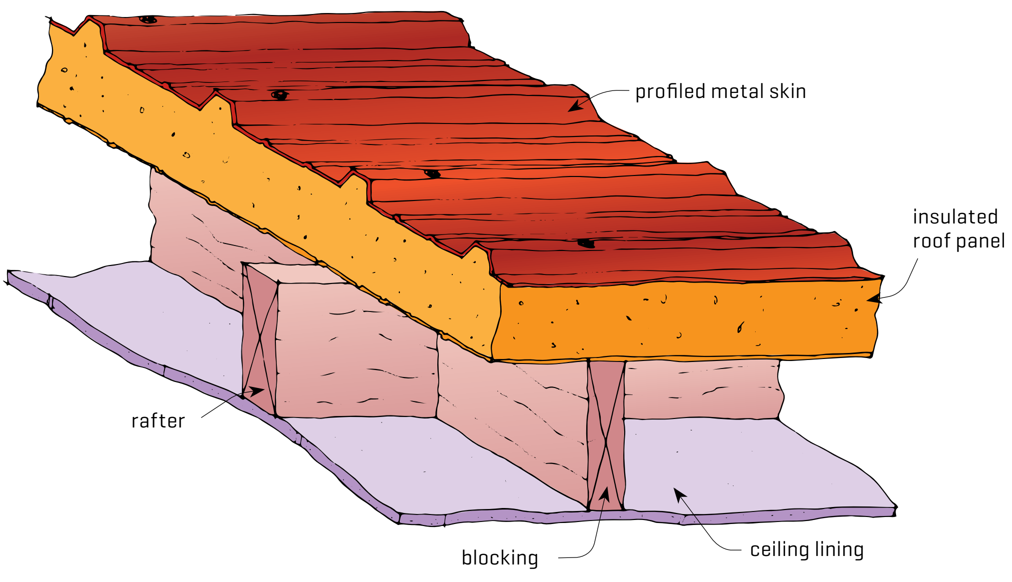

Figure 2. One example of a warm roof: metal-insulation-metal assembly, where the innermost surface is kept warm.

- Other airflows can include unintended paths though wall cavities or holes for ducting and services, creating continuous paths from the subfloor to the roof space.

3.2.2 Any actively driven home ventilation systems will significantly change the pressure and airflow patterns.

3.2.3 Physical conditions are generally such that air and moisture move upwards from the living spaces into the roof space and not vice versa. Two key factors drive this process passively:

- Warm, moist air is less dense than cold air. The air mass of a heated inside living space with its moisture sources will generally be less dense than the colder air outside and roof space air.
- Wind action across the building envelope creates a pressure gradient across the ceiling leading to inside air moving upwards into the roof space.

3.2.4 Measurements over some weeks have indicated the pressure difference across the ceiling of a single-storey residential dwelling is mostly 1–4 Pa acting to pull air upwards into the roof space.

4 SOURCES OF ROOF MOISTURE

4.1 INTERNAL MOISTURE

4.1.1 The climate of the living quarters plays an important role for the condition of the roof space. In an occupied building, the air inside is usually warmer and moister than the air outside because of human activities. Breathing, showering, drying clothes, using unvented gas heaters and cooking generate moisture that must be removed from the living spaces by adequate ventilation practices. Opening windows and doors completely for 10–15 minutes will lead to an air exchange and removal of moisture without significantly cooling down the indoor surfaces of a building.

4.1.2 The ceiling design and finish is an important factor in preventing moisture-related problems in the roof space. An airtight ceiling reduces the amount of moist indoor air that can move up into the roof space, so the following should be considered:

- Downlights, especially old designs with gaps, offer an easy conduit into the roof space. Replace existing open downlights with tight-sealing CA-rated LED design styles or specify these for new construction.
- A tight-stopped plasterboard ceiling is an effective air barrier. Fixing scotias and trims with adhesive can reduce the air leakiness. Alternatively, tool sealant into wall/ceiling junctions before fixing scotias.
- Tongue and groove timber ceilings are not airtight due to the numerous joints and require the installation of an air barrier behind the timber.
- Acoustic tile ceilings are often used in schools and offices. They offer little resistance to air movement. Designers should keep this in mind from a moisture flow point of view. Depending on the design, an air barrier (often in the form of a sealed plywood ceiling) can be added above the acoustic tiles and any existing services.
- Specify sealed roof access hatches with integrated thermal insulation.

4.1.3 BRANZ has a test facility to characterise ceiling types and ceiling penetrations for their airtightness. Results are being published progressively in BRANZ Facts: Roof Space Ventilation #3 *The air permeability of common New Zealand ceilings and ceiling penetrations*.

4.1.4 For dwellings with suspended floors and timber board flooring, the subfloor can be a significant moisture source. Water evaporates from the ground and can move upwards through gaps in the floorboards. Cavities behind brick veneer cladding that are open at the base of the subfloor can also act as a conduit for moisture to move up into the roof space. (This was common in older houses, but the base of veneer cavities should be closed off from the subfloor in houses built from the 1970s.) Moisture levels in the subfloor can be reduced by covering the ground with a vapour barrier and closing off the base of veneer cavities from the subfloor space.

4.1.5 Incomplete or badly installed extractor fans and ducting continues to be a major concern. After the electrical installation of a rangehood or bathroom extractor fan, checks are needed to ensure that the ducting is discharging air to the outside. This oversight has been the cause of many roof moisture problems.

4.2 TRAPPED MOISTURE

4.2.1 If timber in the roof space has been enclosed while wet (particularly with timber-framed skillion roofs), moisture evaporates from it as it dries. This moisture can take a long time to be removed from an airtight roof construction and/or the drivers for ventilation (i.e. wind action) are not sufficient.

4.2.2 High levels of construction moisture in the roof space timber must be allowed to escape either through the ceiling level or through ventilation openings to the roof space before the ceiling linings are installed. The moisture content of framing timbers must not be more than 20% and preferably in the 16–18% range (see Table 1 of NZS 3602:2003 *Timber and wood-based products for use in building*). When internal linings are fixed and the roof space is airtight (with no vent elements, trough profile or membrane roofing), the moisture content should be as low as possible, preferably below 18%.

4.3 EXTERNAL MOISTURE SOURCES

4.3.1 The air inside the roof space will be a mix of air coming up from the conditioned spaces and air infiltrating from the outside through any existing openings. Ventilation openings in the roof envelope will lead to an increased air exchange of the roof space, shifting the balance to a higher content of outside air.

4.3.2 Under certain climatic conditions, the moisture content of the air outside can be higher than the air in the roof space. Ventilation openings might then lead to a faster influx of moisture into the roof space. Modelling for selected New Zealand locations and indoor conditions suggests that, over long periods of time, the benefits outweigh the drawbacks.

4.3.3 BRANZ is currently investigating actively driven roof vent systems that operate only during the daytime when the air is generally warmer and drier.

4.4 WEATHERTIGHTNESS OF VENT ELEMENTS

4.4.1 Passive roof ventilation elements necessarily need to provide an air channel into the roof space. Usually, these elements are installed at the eaves and the ridge of a roof construction. The design of these elements needs to ensure that no weathertightness issues can cause detrimental issues.

4.4.2 BRANZ has developed a test rig where different vent elements can be installed and tested for water ingress under different roof angles and rain conditions.

5 WHEN TO VENTILATE

5.0.1 Most New Zealand houses do not have severe roof moisture problems. However, with the trend towards buildings that are more airtight, there have been examples where recently built dwellings have developed problems, resulting in costly remediation work.

5.0.2 Ventilation adds to the resilience of a roof space and can prevent moisture-related damage in high-risk situations. Incorporating passive ventilation elements should be considered when the roof design is such that condensation can occur on internal surfaces (cold roof design) and in any of these situations:

- The indoor moisture level is too high or is likely to be high in the future. Occupant behaviour plays an important role. The number of inhabitants and behaviours around moisture management such as showers, unvented clothes dryers, cooking and ventilation practices have a large impact on the internal moisture levels.
- There are no strong mechanisms for driving air exchange by infiltration (i.e. low wind speed areas).
- The ceiling cannot be considered an effective air barrier due to the lining material itself or the number and type of ceiling penetrations.
- The roof space is likely to be airtight. This can be due to the specified metal profile or detailing of roof underlay.
- Low-pitch roofs and roof claddings are severely shaded.

5.0.3 These risk factors can change over a building's lifetime. Different occupants have different habits leading to possibly very different indoor humidities. For example, an intact air barrier is easily disrupted by alterations.

5.0.4 BRANZ recommends ventilation be provided in all skillion roofs. It should be considered for trussed roofs if the risk factors in 5.0.2 are met.

5.0.5 Manufacturers of membrane roofing and other roofing systems such as asphalt shingles recommend ventilation of the roof space. Obtain and follow their specific requirements.

6 VENTILATION DESIGN CONSIDERATIONS

6.1 DEFINING VENTILATION OPENING SIZES

6.1.1 Ventilation elements are often characterised by the manufacturer in terms of a net-free opening area per unit length of installed product.

6.1.2 The total ventilation opening area for the roof space is usually normalised to the insulated ceiling area and expressed as a ratio. This allows comparison of different sized dwellings. Insulated ceiling area is used because it is representative of the size of the living quarters and proportional to the volume from which moist air can be drawn to move into the roof space. For instance, the Canadian Building Code specifies a 1:300 ratio, meaning 1 unit of roof ventilation area is required for every 300 units of insulated ceiling area.

6.1.3 While the net-free opening is a useful, simple way of describing opening sizes, the actual ventilation characteristics of elements with the same opening area can be quite different. For a detailed understanding of the element, the airflow through the vent as a function of the pressure difference across it (leakage function) is required. Vent manufacturers should provide this information.

6.2 HOW MUCH VENTILATION IS NEEDED?

6.2.1 At present, the New Zealand Building Code does not specify a minimum ventilation opening for roof cavities. The required amount of passive ventilation, above what is provided by natural infiltration, depends on a number of factors. These include occupant behaviour (indoor humidity), geographic location and local topography as well as the building design and detailing.

6.2.2 BRANZ has introduced a relatively simple procedure to estimate ventilation opening sizes. This calculation takes into account indoor and outdoor climatic conditions and the air permeability of the ceiling – see *Build* 157, Roof ventilation (pages 57–58).

6.3 VENT INSTALLATION

6.3.1 The primary purpose of ventilating the roof space is the removal of excess moisture. The location of vent elements must enable an efficient and homogeneous exchange of the roof space air (Figure 3).

6.3.2 All areas of the roof space need to be reached by a cross-ventilation flow between the eaves and the apex of the roof space. The internal structure must be designed so free airflow is achieved over the entire roof space. Vented battens can prevent separated and closed-off cavities, especially in skillion-type roofs.

6.3.3 The performance of vent elements can be impeded by the subsequent installation of ceiling insulation potentially blocking the airflow. Proprietary products are available to prevent this (Figure 4).

6.3.4 There are specific requirements for skillion roofs (Figures 5 and 6) – see Bulletin 610 for more information.

6.3.5 Some designs propose the installation of ventilation battens between the roof cladding and the roofing underlay. This means the underlay will not be in direct contact with the cladding and may maintain a higher temperature as compared to the cladding. This is especially so on clear nights when the cladding can drop to below ambient temperatures due to radiative cooling. This ventilation option can remove condensation from the underside of

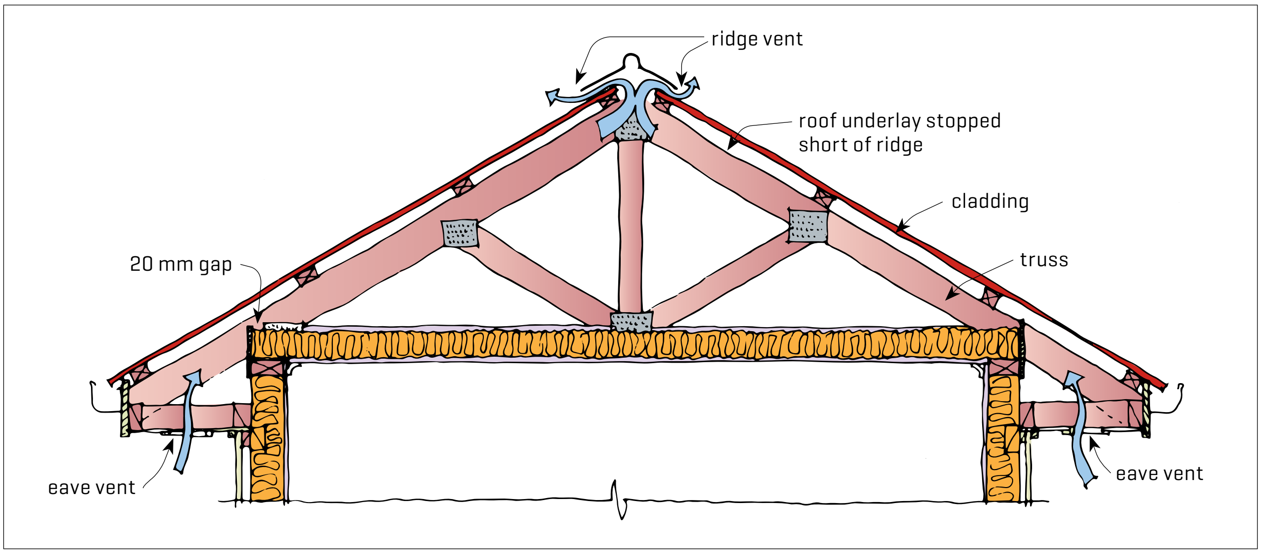

Figure 3. Eave and ridge vents.

the cladding. However, its effectiveness in ventilating the main roof space where moisture from the living quarters can build up is reduced due to the underlay acting as an air barrier. Also, this method needs to consider how any moisture that drips from the cladding can be drained out as the underlay needs to be raised at the fascia line.

6.3.6 Passive ventilation elements can act as inlets for fresh outside air or outlets for roof space air. Wind conditions will often determine which element acts as an inlet or outlet. Elements installed at the ridge will usually act as an outlet, while fresh air will be drawn into the building around the eaves.

6.3.7 Air that is removed from the roof space through an outlet should be replaced by as much fresh outside air as possible. The airflow upwards from the living quarters should be minimised by an airtight ceiling.

6.3.8 As a rule, designated inlets should be dimensioned slightly larger than the outlet vents to avoid an increased driver for air from downstairs to move up into the roof space.

6.3.9 For gable-type roofs with a ridge vent, the roofing underlay needs to be cut to enable an effective airflow.

6.3.10 Installation of a ridge vent only, without soffit vents, will lead to an increased driver to move air from the living quarters into the roof space. This must be avoided (Figure 7).

6.3.11 Roof vent elements should not be installled in close proximity to extractor fan outlets to avoid moist air from bathrooms or kitchens being channelled back into the roof space.

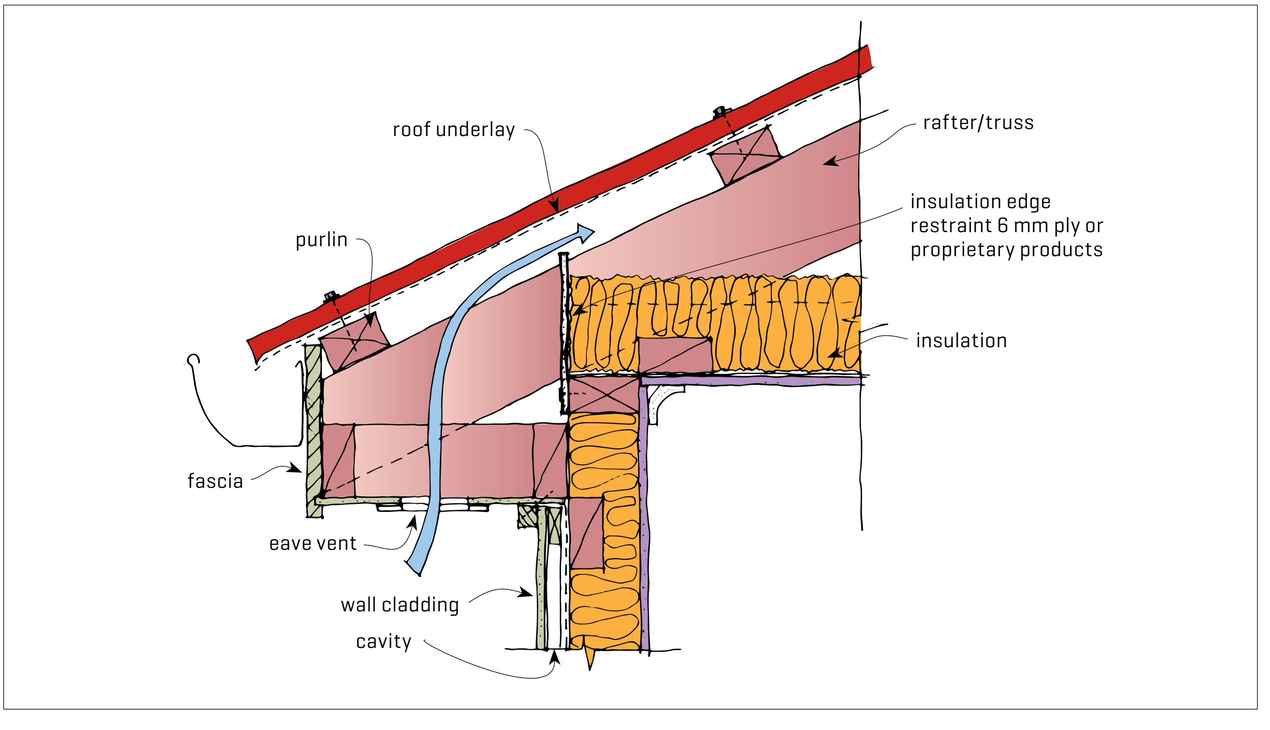

Figure 4. Eave ventilation with insulation barrier enabling natural airflow throughout the roof cavity.

6.4 DETRIMENTAL EFFECTS OF ROOF VENTS

6.4.1 During the heating season, depending on the level of insulation, the roof space will gain some energy from internal heating losses. An increased air exchange of the roof space air will contribute to some energy losses.

6.4.2 Corrosion of some low-grade metal fixtures can occur in marine or geothermal environments. There is the possibility that increased air exchanges, especially in marine environments with higher salt levels in the air, can lead to higher corrosion rates on metal fixtures with limited corrosion protection inside the roof space. Sand may also get into roof spaces, which can accumulate over time and hold moisture or prevent drainage. While a study is undertaken to look into this, higher-grade metal fixtures are recommended around the ventilation openings.

7. FURTHER INFORMATION

Build 157. Roof ventilation. (pages 57–58)

Build 164. Cold roofs? Warm roofs? (pages 78–79)

BRANZ Bulletin 610 *Preventing moisture problems in timber-framed skillion roofs*

BRANZ Facts: Roof Space Ventilation

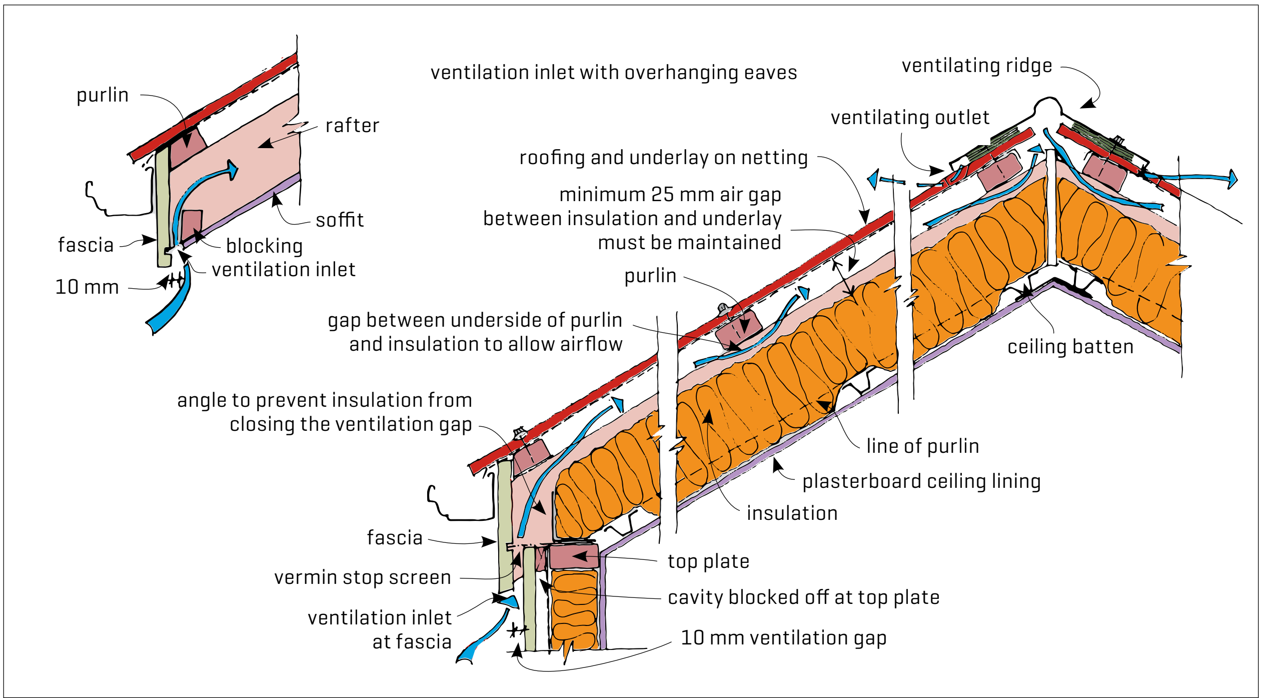

Figure 5. Construction of a skillion roof to allow ventilation.

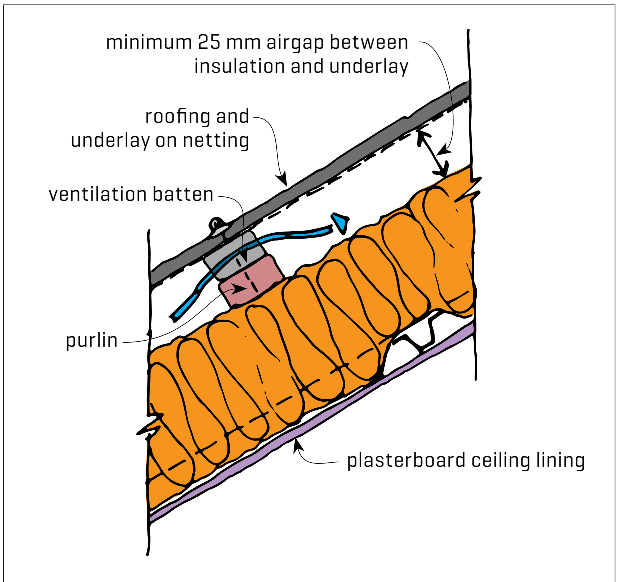

Figure 6. Alternative construction for skillion roof: when insulation abuts purlins, ventilation batten must be added above purlin to allow airflow.

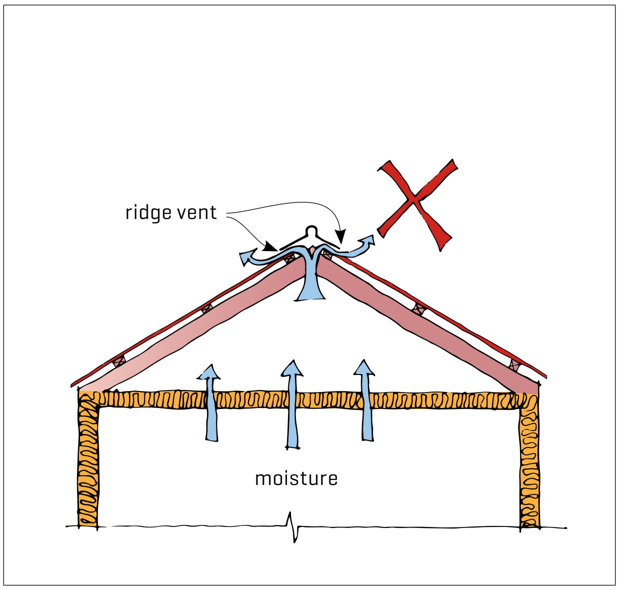

Figure 7. Installing only a ridge vent with no eaves vents increases the potential for moisture to be drawn into the roof space.

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