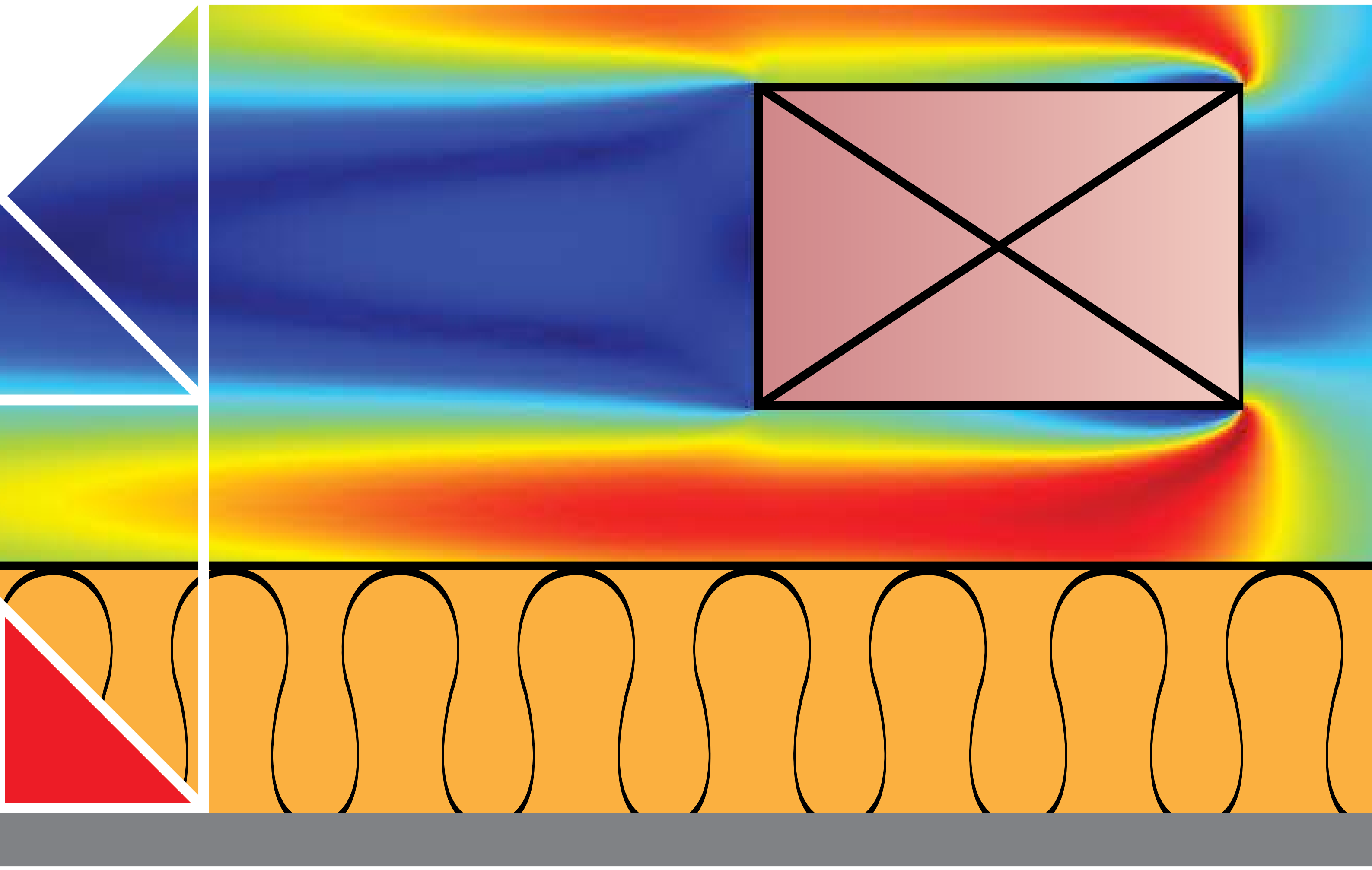
ISSUE**610** BULLETIN



Airflow speed near the purlin in a monopitch skillion roof with ventilating battens.

PREVENTING MOISTURE PROBLEMS IN TIMBER-FRAMED SKILLION ROOFS

June 2017

- Many low-slope roofs in New Zealand are skillion roofs. The roof cladding and ceiling lining are parallel and usually directly attached to framing.
- Careful design, specification and construction is needed to avoid moisture-related problems in skillion roofs.
- This bulletin explains potential problems and how to reduce the risk of them occurring. It replaces Bulletin 525 of the same name.

1.0 INTRODUCTION

1.0.1 In skillion roofs, the roof cladding and ceiling lining run parallel, typically within 300 mm of each other. Both are usually directly attached to the roof framing. Examples of skillion roofs are:
- chapel or cathedral-style roofs
- roofs with rafters exposed internally
- roofs with ceiling lining attached to the underside of the rafters or battens
- roof decks.

1.0.2 Skillion roofs differ from roofs with an attic or ceiling space because:
- skillion roof spaces or cavities are usually inaccessible
- the air spaces between the ceiling lining and the roof cladding are small
- natural ventilation in the roof space is relatively low
- they are less tolerant of poor design or construction
- faults are difficult to locate and expensive to repair
- space for insulation may be limited – to comply with the New Zealand Building Code (NZBC) and standards, deeper rafters or roof structure may be necessary to accommodate the required levels of insulation
- the cavity volume is small, accelerating potential problems with condensation.

1.0.3 BRANZ has conducted research into moisture in skillion roofs over several years. Findings of that research inform this bulletin.

1.0.4 This bulletin replaces Bulletin 525 of the same name.

2.0 EXTERNAL MOISTURE

2.1 WEATHERTIGHTNESS

2.1.1 Any roof that has insufficient slope for the roof cladding used is more likely to leak when it rains. As the designed roof slope decreases, the number of cladding options reduces.

2.1.2 Minimum acceptable roof pitches for most types of roof cladding are set out in NZBC Acceptable Solution E2/AS1.

2.1.3 For low-slope roofs using a continuous impervious membrane, the minimum slope is 2°.

2.1.4 For other roofing claddings, the manufacturer's recommended lowest pitch must be considered the absolute minimum.

2.2 ROOF DRAINAGE

2.2.1 Many low-slope roofs (less than 10° pitch) and steeper roofs constructed in New Zealand are skillion roofs. They must be designed with positive falls to effectively drain water from the roof.

2.2.2 Minimum slopes for roof cladding options in E2/AS1 are:
- membrane roofing systems over a substrate – 2°
- profiled metal:
  - corrugate – 8°
  - trapezoid with crest height of 27 mm or more – 3°
  - trapezoid with crest height of less than 27 mm – 4°
  - trough – 3°
- clay tiles – from 20° depending on profile and presence of underlay
- concrete tiles – from 15° depending on profile and presence of underlay
- metal tiles – from 12° depending on profile.

2.2.3 For roof claddings not covered by E2/AS1, minimum pitch requirements must be obtained from the supplier. Typical minimums that apply are:
- asphalt shingles – from 9°
- timber shingles – typically 18°.

2.2.4 Although initially constructed to comply, the minimum falls required when using E2/AS1 as a means of compliance for membrane and low-pitch metal roofs can be lost. Ponding can therefore occur as a result of depressions, humps or reverse gradients. These can be caused by:
- structural deflections, particularly when wet timbers are used for long spans (they should be supported until dry)
- thermal movement in the roof structure
- shrinkage of framing timbers
- heavy loads or equipment placed on the roof or from prolonged maintenance traffic
- construction inaccuracies.

2.2.5 Ponding of water on a roof or in a gutter will accelerate the rate of deterioration of the roof and increase the risk of moisture entry because:
- sharp temperature differences occur between areas of ponding and the surrounding roof, which results in stresses developing in membrane roofing material due to differential movement
- mud build-up (from dust) may cause rotting or corrosion and local temperature differences
- moss growth can occur, which accelerates the ponding process and causes deterioration at any faults in the joining system
- there is an increased corrosion hazard for metal roofing due to the prolonged wetting and drying cycles resulting from ponding and the build-up of debris
- deeply ponded water can enter through joints, gaps and nail holes.

2.2.6 Wherever possible, allow for additional fall in the design of low-slope roofs to ensure satisfactory drainage. BRANZ recommends 3° as a minimum for membrane roofing systems.

2.3 TIMBER TREATMENT

2.3.1 Under NZS 3602:2003 *Timber and wood-based products for use in building* (as modified by B2/AS1), timber framing used in skillion roofs with less than 10° pitch must be treated to H1.2.

2.4 SOLAR-DRIVEN MOISTURE TRANSFER

2.4.1 Moisture penetration can occur if roof claddings that absorb water, such as timber shingles, are not installed with an interleaved impervious membrane (such as reinforced polyethylene sheet) between each roofing course.

2.4.2 As the roof cladding dries in the sun, some of the absorbed moisture is forced downwards through the material, and if the interlayer is not inserted, the moisture may enter the skillion roof cavities.

2.5 RAIN DURING CONSTRUCTION

2.5.1 Take precautions during construction to prevent moisture from rain or dew increasing the moisture content of materials:

- being stored for use
- already installed in a partly completed structure.

2.5.2 Once skillion roof cladding is installed, the installation of the ceiling should not start until the framing is dry enough (see 5.0.1). If closed in too early, wetted framing can take a long time to dry sufficiently because of the limited exchange of roof cavity air with the outside air.

3.0 THERMAL MOVEMENT

3.0.1 Roofing materials expand and contract with rises and falls in temperature. The thermal movement of the structure, the roof cladding and roofing accessories such as flashings must be allowed for at the design stage. Allowing for movement helps to prevent:

- damage to the roof cladding and roofing accessories, particularly with metal roofing and on roofs that use metal flashings and ridges
- premature failure of the roof cladding caused by buckling and possible tearing of the roofing at fixing points
- subsequent damage to the roof structure and internal finishes.

3.0.2 Timber-framed structures and light roof claddings respond quickly to temperature changes. Roof temperatures can fluctuate widely over a short period of time. For example, the surface temperature of a dark-coloured steel roof may vary by up to 70°C over a 24-hour period.

3.0.3 The stress created in a roof cladding by temperature changes is directly related to the rate of change. The more stress a cladding is subjected to, the greater the risk of failure. Selecting light-coloured roof cladding will reduce the thermal stressing.

4.0 INTERNAL MOISTURE

4.0.1 Air contains moisture in the form of water vapour – the warmer the air temperature, the more water vapour it can hold. On contact with a sufficiently cold surface, the water vapour will condense and form water.

4.0.2 In an occupied building, the air inside is usually warmer and more moist than the air outside because human activities such as breathing, heating and cooking generate moisture and heat. The warmer internal air holds more moisture in the form of water vapour than the colder external air. This is particularly so in winter (see 6.0.2).

4.1 MOISTURE MOVEMENT

4.1.1 Moisture can move into and through skillion roof cavities from the spaces below.

4.1.2 Natural air leakage is usually the dominant cause of moisture movement from inside the building into the roof cavity. Room air is driven by air pressure differences (generated by wind or because the room air is warmer) into the roof cavity through gaps and cracks in the ceiling lining. For example, wherever an electrical wire penetrates the ceiling, air can move through the gaps around the wire. Recessed downlights are another potential pathway for air.

4.1.3 Water vapour can also slowly diffuse through bulk material such as ceiling linings. Water vapour pressure is generally greater inside a building, causing the water vapour to migrate towards the lower pressure areas outside the room.

4.1.4 Ensure that moisture from damp underfloor areas of the building cannot move to the roof via the wall cavities. All possible routes to the roof space via gaps, penetrations and brick cavities must be sealed. Drained cavities must not vent into the ceiling space.

5.0 TRAPPED MOISTURE

5.0.1 Timber-framed skillion roofs are usually closed in relatively early during construction, and it can happen that internal linings are fixed before the timber has dried to an average moisture content of 20% or less.

5.0.2 If timber has been enclosed while wet, moisture evaporates from it as it dries. This moisture can take a long time to leave the roof cavity – if the natural air movement is low, drying is slow. This may result in:

- condensation forming within the roof space if surfaces become cold enough
- lifting or rupturing of membrane roofing due to water vapour pressures – vapour pressures increase as a roof is warmed but outward movement of the vapour is halted by a roofing membrane, and the pressures generated can cause the membrane to bubble
- water being formed when water vapour condenses, leaking through the ceiling and causing damage.

5.0.3 Trapped moisture, particularly construction moisture, must be allowed to escape through the ceiling lining if no ventilation channel is provided. This will be prevented if a vapour barrier such as reflective foil or polythene sheet is present – trapped moisture may pond, causing local damage, or may run down a sloping ceiling and cause damage elsewhere.

5.0.4 The risk of damage from trapped moisture is greater when membrane roofing is used. Excess

moisture is unable to escape through the membrane as it is both an air and vapour barrier. The only escape routes available are:
- downwards through the ceiling
- via the limited (if any) air leakage from or air movement through the roof cavity.

6.0 CONDENSATION RISKS

6.0.1 Moist air that is not removed by air leakage or evaporated and driven out by solar radiation remains within the skillion roof structure. On contact with a cold part of the structure, such as the underside of the roof cladding, the moisture can condense to form water, which can wet insulation and damage materials and finishes.

6.0.2 In winter or in buildings at higher altitudes such as ski lodges, the condensation risks increase because the roof cladding and structure are usually substantially colder than the interior of the building and the rate of evaporative drying during the day is lower. Clear night skies can cause the temperature of metal claddings to be lower than the external air temperature.

6.0.3 Where conditions are severe enough to generate condensation, such as on still frosty nights, any condensation that occurs on cold surfaces is not removed by wind-induced natural ventilation.

6.0.4 For a pitched skillion roof over 10°, this water can:
- run down the underside of the roof cladding under the force of gravity until it escapes at laps or eaves
- be trapped at a purlin and be absorbed by the roof underlay – in time, it will be evaporated by a rise in temperature
- be absorbed by a membrane roof substrate such as plywood
- be reabsorbed by the roof space air as it warms and be removed by natural air leakage.

6.0.5 For a low-slope skillion roof under 10°, this water will:
- cling to the underside of the roof cladding or membrane substrate until it evaporates
- be forced through cracks and openings into the spaces below by increased vapour pressures due to the sun heating the roof
- drip from the underside of the roofing or sarking/membrane substrate and be absorbed by the structure, insulation and/or linings.

7.0 DESIGN OPTIONS

7.0.1 Once a roof cladding system has been selected, the main design decisions relate to controlling moisture levels within the skillion roof.

7.1 ROOF UNDERLAY

7.1.1 In skillion roofs (other than membrane roofs and roofs with asphalt shingles), roof underlay should always be installed under the roof cladding (profiled metal, clay/concrete tiles, metal tiles). It provides an important storage place for the intermittent condensation that may occur in frosty or cold conditions. Also, much of any condensation appears under the underlay rather than under the roof. E2/AS1 requires the roof underlay to be installed at right angles to the roof slopes for pitches below 10°. This is good practice for all roof slopes.

7.1.2 Under E2/AS1, underlay is not required for type 1 concrete tiles installed at a pitch of 20° or greater or type 1 clay tiles installed at a pitch of 25° or greater. BRANZ recommends that underlay is used under all clay and concrete tile roofs. (Roof underlay is a requirement for all concrete or clay tile roofs receiving discharge from a spreader and all roofs in very high or extra high wind zones.)

7.1.3 An air gap of at least 25 mm between the flexible roof underlay or sarking/membrane substrate and the insulation must be maintained. This prevents the insulation from becoming damp or saturated by absorbing moisture held in the underlay. If the insulation becomes wet, it loses its effectiveness, causing an increase in condensation, and may have an impact on timber durability.

7.1.4 If a synthetic roof underlay is used, it must comply with the requirements in NZS 2295:2006 *Pliable, permeable building underlays* and be acceptable to the roof cladding supplier. This standard is currently under revision.

7.2 MINIMAL AIRFLOW

7.2.1 There are two mechanisms for moisture transport into the roof cavity from the living space underneath:
- Moisture transported together with an airflow through cracks, light fittings and other openings. This mechanism can be effectively reduced by an airtight ceiling serving as an air barrier.
- Diffusion of moisture through the building materials themselves. In comparison to a moist airflow, this is a very slow process and is of secondary concern (see 7.3).

7.2.2 Ceiling linings must resist the flow of air to avoid transporting airborne water vapour into the skillion roof cavity. Ceiling linings that allow the free flow of air through joints such as those in tongue and groove boarding must be sealed by an air barrier. A layer of breather-type (vapour open) underlay must be used as an air barrier behind such materials (Figures 1–3). A flexible wall underlay meeting the air barrier requirements of Table 23 of E2/AS1 is a suitable air barrier provided joints are taped.

7.2.3 Avoid penetrations that will allow air movement through the lining of the skillion roof. Recessed downlights should be CA or ICF rated and be fully enclosed in a lined recess or be sealed at ceiling level.

7.2.4 If the roof design requires the use of an air barrier to restrict airflow between the ceiling and the roof cavity, its continuity must be guaranteed at all times. No post-installation penetration must take place unless professionally sealed.

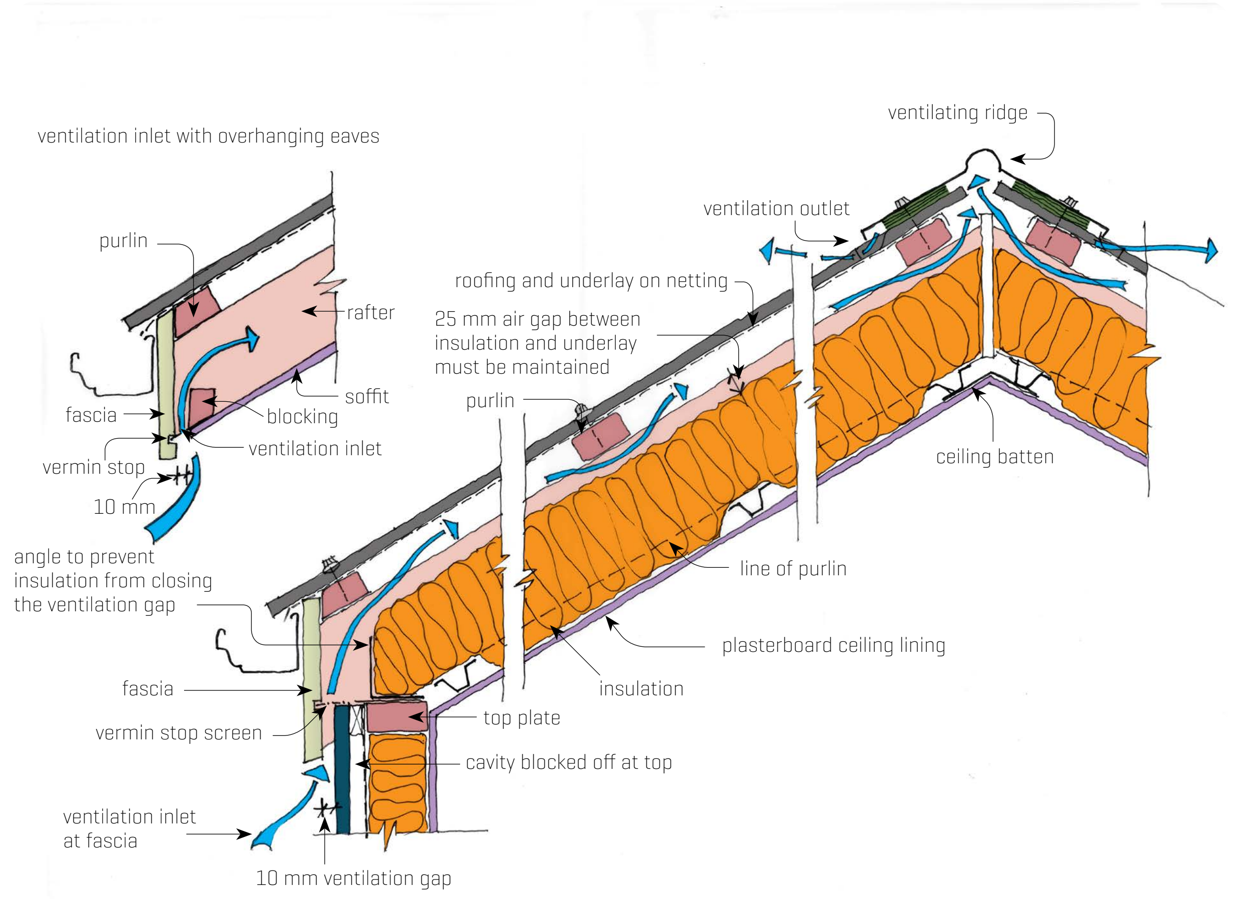


Figure 1. Construction of a skillion roof to allow air movement

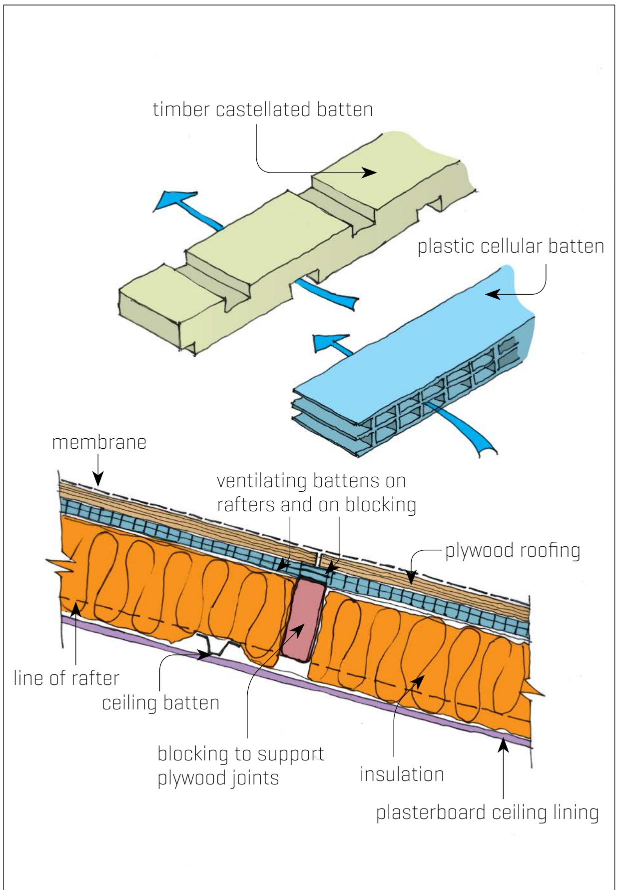


Figure 2. Construction of a skillion roof with plywood and membrane finish to allow air movement between rafters.

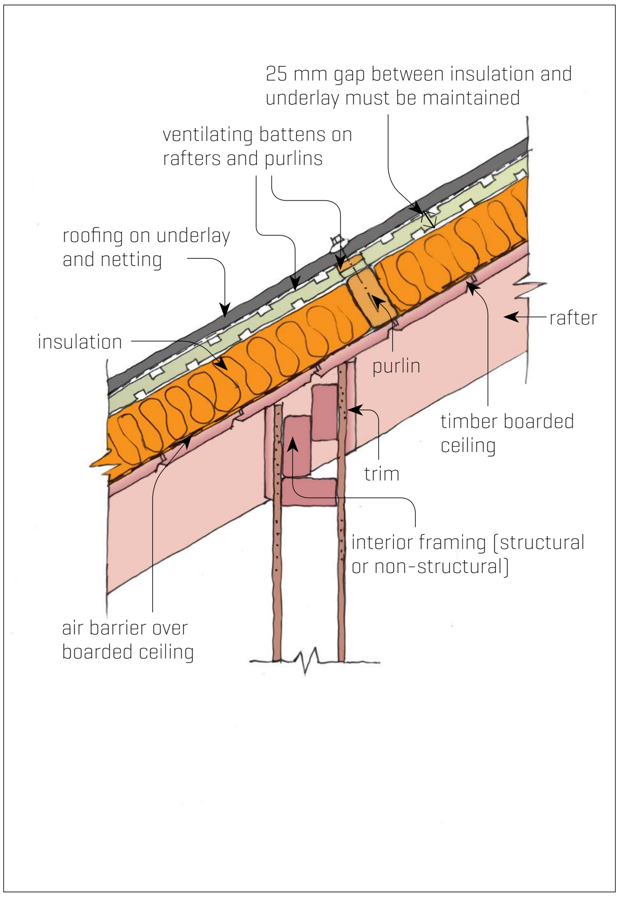


Figure 3. Construction of a skillion roof with exposed boarded ceiling to allow air movement between rafters.

7.3 VAPOUR-RESISTANT LININGS

7.3.1 BRANZ does not recommend the installation of a vapour barrier for domestic skillion roofs except in extremely damp conditions. Special situations where advice from a suitably qualified professional should be sought include:

- indoor swimming pools and spa pool rooms
- air-conditioned rooms
- cold stores (where the vapour barrier will be on the outside)
- spaces in which wet industrial processes take place.
- skillion roofs in buildings located in very cold environments, such as ski lodges.

7.3.2 A gloss or semi-gloss paint system, at least one coat of which is oil-based, will provide a high enough vapour resistance to limit the water vapour diffusing upwards through the lining into the framing space of a skillion roof. Any openings in the ceiling lining will render this diffusion resistance largely irrelevant as moisture transport with air is the dominating effect.

7.4 VENTILATION OF THE ROOF SPACE

7.4.1 For most skillion roofs (including those not deliberately ventilated), research shows that even limited air movement in the roof cavity is sufficient to remove small amounts of vapour. However, natural ventilation is limited for claddings that are practically airtight when installed, such as:

- long-run trough or tray section profiled metal roofing
- continuous membrane roofing
- asphalt shingles.

7.4.2 Adding purpose-built ventilation channels to a skillion roof has been shown to decrease the risk of condensation events. If such channels are desired as a precautionary measure or where there is a higher risk of moisture entering the roof cavity, care needs to be taken to avoid blockage of these paths by insulation or purlins.

7.4.3 Vent openings situated directly underneath the eaves are in general more effective than venting strips

Skillion roof with roof cavity openings.

of the same total cross-section located above the fascia board.

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

7.4.5 By ensuring that natural air leakage from the roof cavity is possible in roofs that use a continuous membrane for weathertightness, normal levels of moisture can be satisfactorily maintained. Flat roofs should have ventilation pathways provided through the roof structure.

7.5 AVOIDING TRAPPED MOISTURE

7.5.1 Kiln-dried timber, typically H1.2 treated in accordance with NZS 3602:2003 (modified by B2/AS1), should be used for skillion roof framing.
7.5.2 If larger sizes of timber are not available in kiln-dried timber, consider designing the roof using proprietary engineered timber members.

7.5.3 The moisture content of framing timbers must not be more than 20% (see NZS 3602:2003 Table 1) and preferably lower (particularly with membrane roofing) when internal linings are fixed. Some manufacturers may require a lower figure for their products. In the unlikely event of framing being wet, it must be ordered as early as possible and, once delivered, fillet stacked to allow it to dry before being installed to reduce the risk of problems caused by trapped moisture.

7.5.4 Until the structure is weatherproof, ensure there is protection to prevent rain and dew increasing the moisture content of materials being stored and those already installed but open to the weather.

7.5.5 Avoid designs that have cold water services running through the roof cavity. If needed, they should be insulated or lagged to prevent condensation forming.

7.5.6 Quality control is essential during construction to ensure that poor-quality work will not lead to the entry of water, either from condensation or leakage.

7.5.7 Manufacturers' recommendations should be followed for all materials used.

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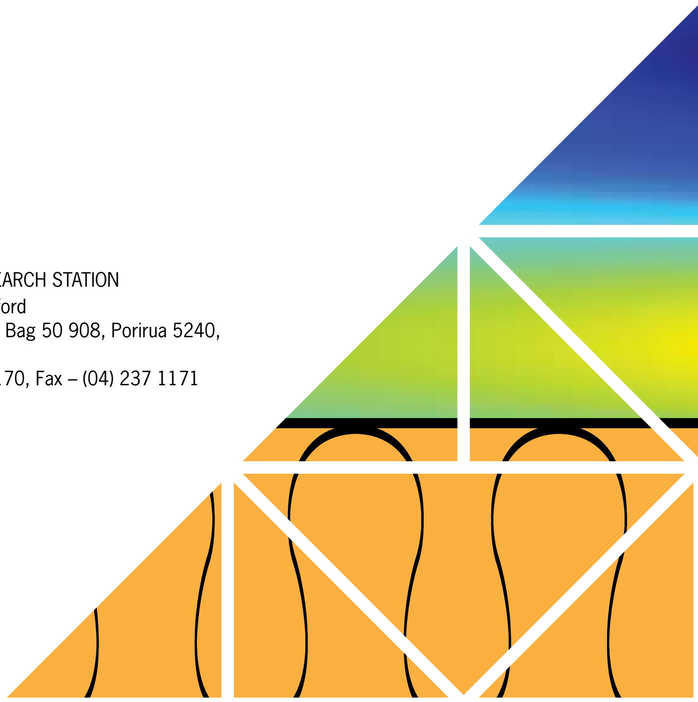

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