As-built Verification

Factsheet and Checklist

Your home built for efficiency and comfort

Sustainability Victoria

VICTORIA State Government

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As-built verification factsheet and checklist

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Sustainability Victoria acknowledges Aboriginal and Torres Strait Islander people as the Traditional Custodians of the land and acknowledges and pays respect to their Elders, past and present.

As-built Verification

Factsheet and Checklist

Contents

As-built verification factsheet

This factsheet and accompanying checklist provide efficient and cost-effective methods for ensuring a new home is air sealed and well insulated.

Introduction

This checklist provides trades, homeowners, and builders with a list of key problem areas for airtightness. It has been developed

to ensure that homes are energy efficient, comfortable, and draught free. Homes that perform well have design specifications that include minimum energy performance levels, airtightness and insulation integrity, installation of high efficiency appliances and lighting.

These types of homes must satisfy three areas:

- 7 or greater star rating under the National House Energy Rating System (NatHERS),
- A Whole of Home design rating, and
- As-built verification.

As-built verification

An As-built verification checks compliance of the constructed home in accordance with its designed energy efficiency requirements:

- As-Built airtightness and insulation integrity testing:
  - Airtightness testing of the home must demonstrate that the building's envelope permeability rate does not exceed an air leakage rate greater than 10 m3·hr-1·m-2 at 50 Pa reference pressure when tested in accordance with AS/NZS ISO 9972 Method 1.
  - Thermal insulation consistency of the building envelope must achieve at least 95 per cent perfect coverage for floors, walls and ceilings. This requirement is met when less than 5 per cent of the intended surface is missing or poorly installed insulation.

Key elements of the construction process that impact airtightness and insulation integrity include:

- Base stage (construction of foundation)
- Frame stage (completion of load-bearing structure)
- Lock up stage (roof, external cladding, windows & doors)
- Fixing stage (plasterboard, services & insulation)
- Practical completion stage (cabinets, services, fittings, fixtures & finishes)

Every step in the construction process requires attention and action for air sealing and insulation consistency.

A simple building envelope

A home must have an effective building envelope for a simple reason: to keep hot, cold, or wet weather outside, and to keep comfortable and healthy air inside. This requirement means insulation must be consistent and full-coverage, and air leakage must be minimized.

A building envelope that functions well is clear and simply defined. Everywhere there is insulation, there should be air sealing. There aren't any surfaces that are "in between", like walls to attached garages. It's either "inside" or "outside" and the insulation and seal should show that.

Protection from the elements

Control water

Protection from the elements is best achieved from the outside in. That is, first focus on sealing the building from rain and wind.

Drainage is crucial to maintaining building durability long-term. This applies to roofs obviously, but flashing and sealing around windows, door frames and all other penetrations is also important to reduce water intrusion.

Building wraps are a common strategy, but no wrap will do its job of water protection and air sealing if it is installed poorly. It must be lapped correctly, pulled taut but not under strain, sealed at all seams, and free of extra folds where water can collect.

Control air

Walls can also get wet from air leakage bringing moisture in. An air barrier helps prevent this. The air barrier in the building envelope is made up of all the materials and components that resist air movement. To work, all the joints between them must be sealed as well. This means all of the following form part of the air barrier:

- Walls and ceiling
- Windows and doors
- Floors (slab, on piers, or suspended)
- Electrical, plumbing, HVAC systems and penetrations

What is an air barrier material? Any of the following can be part of an air barrier, but there are many others as well:

- Membrane products (e.g., "building wraps"),
- Board products with taped joints (e.g. FC sheet, OSB, and plywood)
- Poured or precast concrete
- Board insulation products with taped or sealed joints
- Spray foam

What is not an air barrier?

- Weatherboard, face brick, metal cladding, rendered foam – these are all claddings that protect the air and water control layers behind them, but air is meant to flow past them for ventilation
- Masonry including bricks and blockwork may seem solid, but they often let much air through joints between and through the blocks themselves

Control heat

Insulating material slows the flow of heat into or out of the building. Insulation traps tiny air pockets which resist the flow of conduction. The resistance to heat flow is expressed using R-value, with higher numbers meaning better resistance to heat transfer. Examples include:

- Bulk insulation - glasswool, rock wool, cellulose, polyester.
- Rigid foam insulation – EPS, XPS, PIR, phenolic.

Most bulk insulating products do not stop air flow and must be installed in conjunction with an air barrier. Rigid foam boards will stop air flow, but every joint between boards must be sealed.

To effectively stop both air and heat flow, the insulation and air barrier must be continuous, with gaps and cracks filled and sealed.

Control layers for moisture management

With increased levels of insulation in walls, less heat passes through and less drying occurs. Walls will stay wet longer, so they shouldn't get wet in the first place. But if they do get wet, they should be allowed to dry.

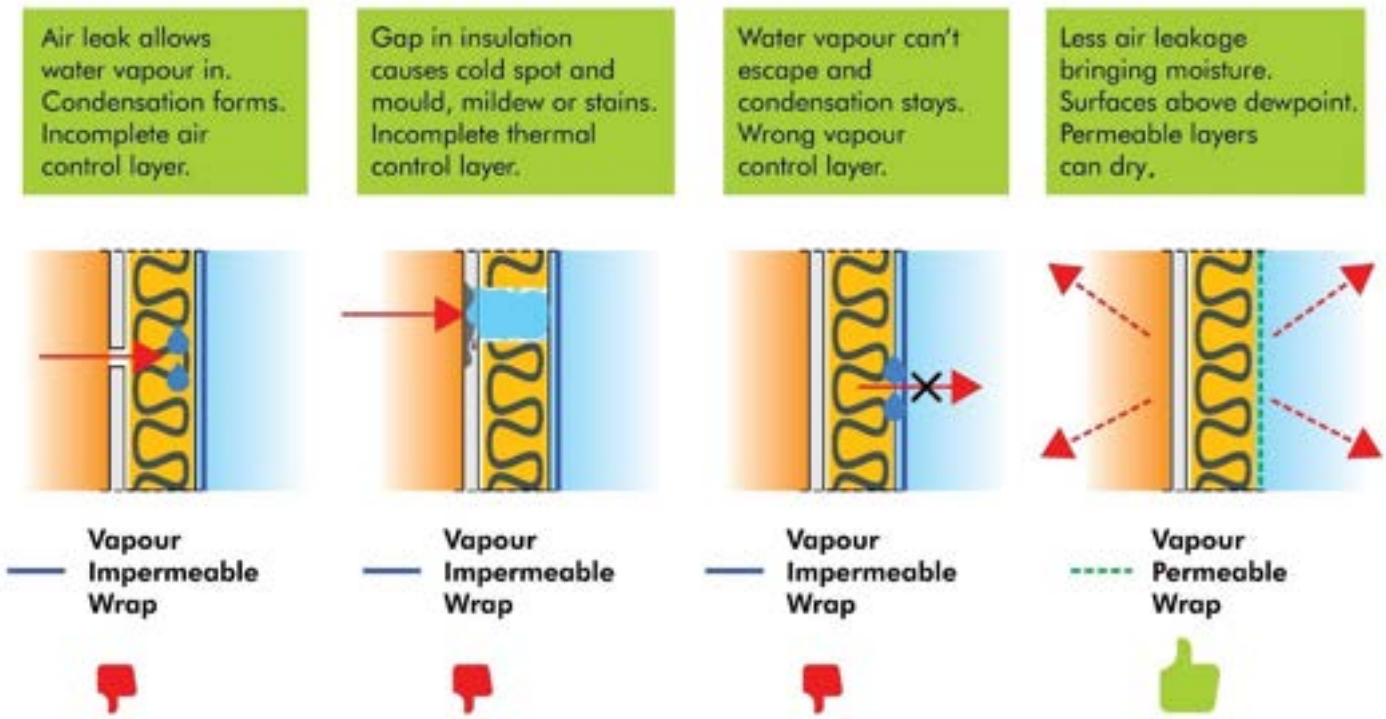
A conditioned envelope must have several *control layers* to minimize flows of liquid water, air, water vapour, and heat. Where one of these control layers is missing or incomplete, problems like rain leakage, mould, condensation, and energy waste can result. These control layers must be in proper alignment and layering across the whole building envelope.

- *Water control layer* – the ability to prevent rain and groundwater intrusion is a basic requirement of the BCA and is the foremost threat to building health.
- *Air control layer* – an air barrier system reduces passage of conditioned and unconditioned air across the conditioned envelope. Where gaps exist, air can carry water vapour, noise, smells, pests and energy waste with it.
- *Vapour control layer* – water can pass through solid materials by vapour diffusion.
- *Heat control layer* – insulation reduces the flow of heat into or out of the building envelope.

Gaps in one or more control layer can result in problems. Obviously, a gap in the water control layer will result in a wet structure, but other problems can build more gradually. For example:

- A thermal control layer like bulk insulation may not stop air movement, and air carries moisture which condenses on surfaces in the wall. An air barrier would help.
- A wall surface has missing insulation behind it. That surface can become cold and cause condensation and staining. More continuous insulation would help.
- A vapour-impermeable building wrap on the exterior side of the insulation may not efficiently let water vapour out. Condensation builds up. An exterior wrap that is more vapour-permeable would help.

When control layers are properly aligned and continuous, they keep building surfaces above condensation temperature (dewpoint), avoiding condensation. They prevent air leakage from bringing in moisture, and if walls get wet for some reason, they can dry.



Condensation - causes and remedies

Condensation can occur in buildings across all climate zones and is entirely normal. Some moisture for condensation comes from exterior air, which makes it unavoidable, but risks to a building can be minimized. For example, building assemblies that contain a properly drained and ventilated cavity over a vapour-permeable building wrap will keep condensation out and help prevent moisture build-up from within.

Moisture for condensation also comes from the interior, where everyday activities such as showers, cooking, laundry, and even breathing add significant amounts of water vapour to the air. Interior air often contains more moisture than building cavities like walls and roof spaces, making these attractive gathering spots for condensation.

Ironically, in some cases, simply adding more insulation can increase condensation potential. Insulation inhibits heat transfer through building assemblies, which means some surfaces formerly warmed and dried by energy waste will become colder and more susceptible to condensation. Of course, adequate insulation is essential for a comfortable and healthy indoor space, but only if the insulation is protected from interior and exterior sources of moisture by air sealing and use of controlled ventilation.

Basic ways to deal with interior moisture include[1]:

- Mechanically ventilating interior moisture sources such as the kitchen, bathrooms, and laundry to the outside as directly as possible. Passive vents and exhaust fans venting into building cavities are not good enough. Many code requirements for this measure already exist.
- On-demand ventilation is already required by code, but low-level continuous ventilation is becoming more popular and is a good option to reduce a home's potential for condensation. At a minimum, a simple whole-house ventilation system in the form of an energy-efficient exhaust fan running continuously at a low level is an affordable and effective first step.
- On the exterior, use building wraps that are vapour-permeable to allow interior moisture to escape, enabling the home to dry safely. Many code requirements for this measure already exist.
- On the interior, air-seal any gaps, cracks, and penetrations to walls and ceilings to minimize air leaks that can bring moisture to colder surfaces.
- On the interior of walls and ceilings, use a vapour-resistive wrap in some Victorian climates, depending on the design. It is wise to get an analysis of your planned design according to AIRAH DA07, which can help predict whether walls are at risk of moisture problems.

Insulate well, seal against air leakage, and ventilate interior moisture sources.

[1] *Important note: This section relates to Victorian Climate Zones 4 – 6 only. Consult a professional to develop building systems suitable for Climate Zones 7 - 8 (Very Cold) and Climate Zones 1 - 3 (Hot, Humid).*

Key air sealing materials and practices

Sheet products including plywood, cement sheet, plasterboard and rigid foam board can be used as components of the building envelope air barrier. Air will leak at seams, through penetrations and where they join different building materials. A suitable strategy or combination of air sealing materials must be considered.

Adhesive tapes can be used to seal the junction, cracks, and gaps of concealed air barrier systems. The tapes must be carefully selected as part of a trusted air barrier solution. Beware tapes that stick well at first but peel easily after a week. Substrates must be clean and compatible for product adhesion and allow for minor building or material movement.

Expanding foam can be used around windows and doors to fill large cracks or gaps, however if it is cut back and its external skin has been broken it may not be airtight and require a caulking layer. It is not recommended for use near flammable applications such as flue vents. Use only a low-expansion foam around windows and doors to avoid the potential of distorting the frame

Caulking can be used to seal gaps of less than 10mm. Grade selection of the material (interior, exterior, high temperature) is based on the application. If gaps are larger than 10mm, an open-cell or closed-cell backing rod should be used to cost-effectively close the gap and support the sealant over the long term.

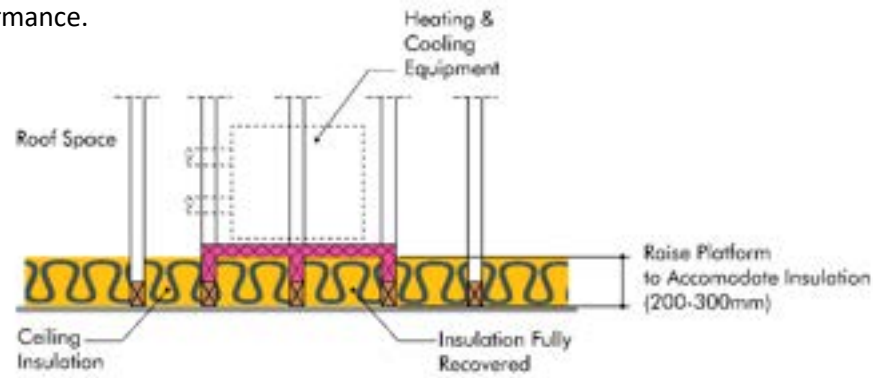
Weather seals (rubber, brush, mechanical seals) are used to seal air- and watertight operable components such as doors and windows. Window and door frames can move over time so the weather seal must be selected to accommodate gaps of varying sizes. Weather seals must be tested during a blower door test to confirm they are working effectively.

Sheet metal is used with high-temperature caulking for sealing around high-temperature components such as flues and framing.

Insulation products include batts, spray foam or rigid foam products and must conform with the National Construction Code. Many products like batts let air pass through, they must be sealed with an air barrier as well.

Insulation Consistency

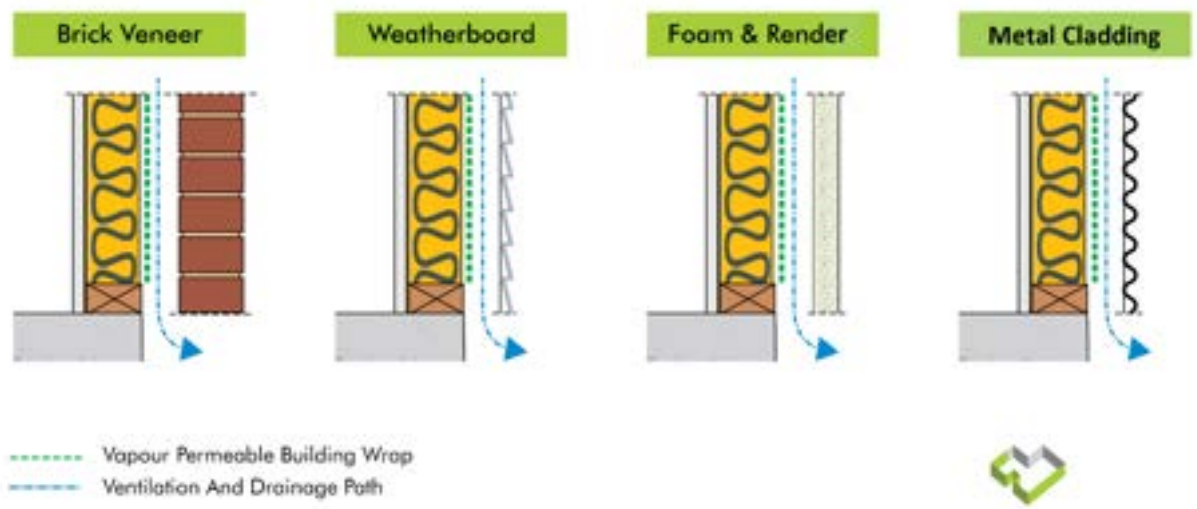
Insulation must be installed consistently and without gaps or compression. Something as simple as moving a batt of insulation and forgetting to replace it can cause a major hit to performance. For example, even if all other insulation in a ceiling is done perfectly, if just 1 out of 15 batts is missing, the heat loss through that ceiling can double. Even very small gaps and areas of compression can cause a significant reduction in performance. Insulation batts must fit the whole cavity they are meant to insulate and must be cut closely to size. Ideally, a wall cavity will be completely filled with insulation to the full depth, because gaps allow for convection and reduces insulation performance.



Mechanical Platforms must be raised to accommodate the full height of the ceiling insulation. To maintain the continuous performance of the ceiling insulation, the plant and equipment platform located in the ceiling/roof cavity must be raised to the depth of the selected insulation. Additional framing will be required, and insulation must be installed prior to plasterboard ceiling installation.

Ventilated cladding

Vapour-permeable building wraps can release interior moisture, but only if there is a ventilated cavity on the exterior to dry into. Any cladding protects the control layers behind it, but it should also give space for drainage and drying. Rather than directly fixing cladding, adding battens to hold the cladding away from the building wrap gives more opportunity for drying.



Roof drainage and ventilation

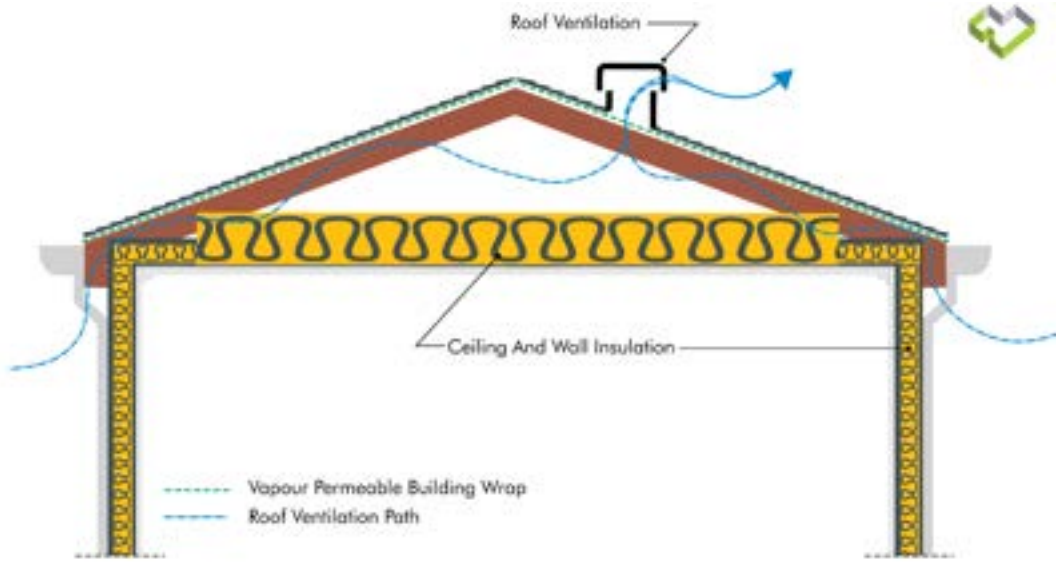
To make sure every roof can drain and dry effectively, there are important steps to take. Draining liquid water is obviously important, but ventilation of the roofing surface is needed to remove condensation that naturally develops on the roofing underside.

Under roof tiles or metal roof cladding, a vapour-permeable Weather-Resistive Barrier (WRB) installed before battens serves multiple purposes. It repels liquid water and allows it to drain safely. Because it is vapour-permeable, it allows internal moisture to migrate out of the roof space and into the battened zone to vent away. Battens installed over the WRB promote better drying. A WRB should be installed with 150mm overlaps and lapped 25mm into gutters. All penetrations and damage must be taped and sealed, to provide a weathertight second layer.

Always ensure there is a clear path for airflow from required venting to the ridge or other roof ventilation. This is important to prevent moisture build-up in the roof space and to promote cooling in warmer weather. Check the current codes for the amount and placement of ventilation required given your roof design.

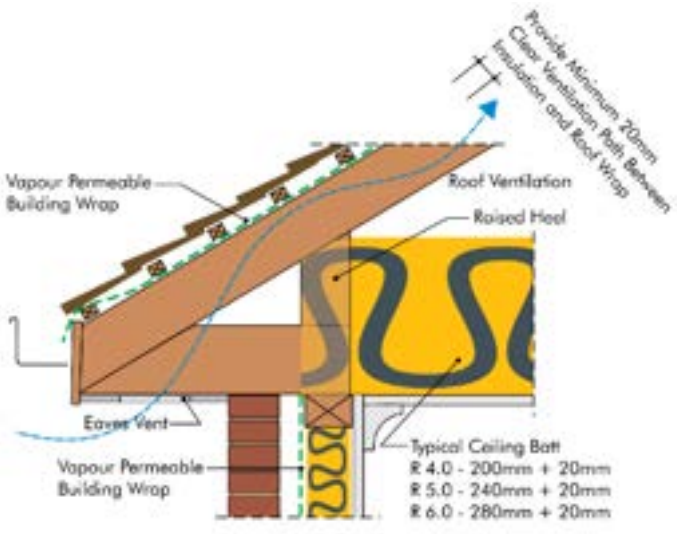
Standard roof pitch – insulating a flat ceiling

In home with a pitched roof, commonly the available space between the top of the external stud wall and underside of the roof system (approx. 90 - 120mm) will be less than the depth of a common insulation batt. Space above the insulation is still required for ventilation of the roof surface. A common solution is to substitute a high-performance quarter-, half-, three-quarter width batt at the ceiling perimeter of the entire home. While not included in the Building Code, the concept of perimeter batts is stated in AS 3999-Thermal Insulation Installation, as a strategy to maintaining a vented roof space.



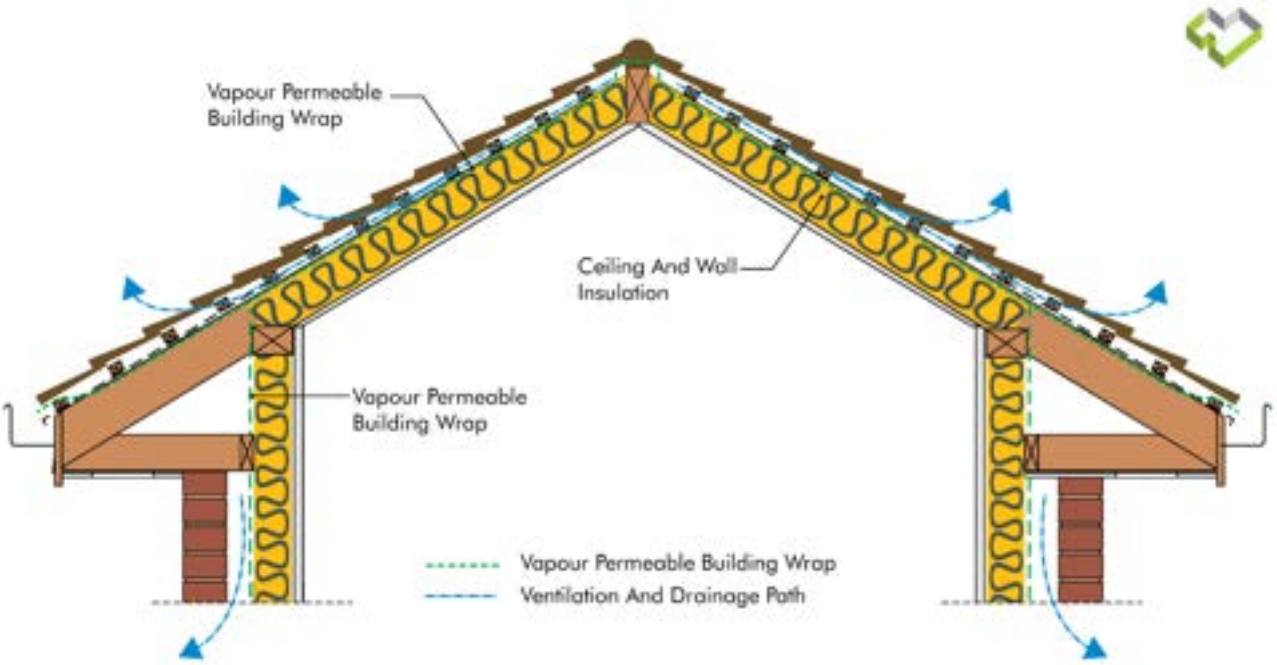
Where a high-performance batt is not used or is poorly installed, several negative outcomes result. First, it results in a major hit to overall ceiling thermal performance because a significant portion of the ceiling is insulated to a lower level. Second, in some weather the surface under less-insulated spaces can become colder, leading to small amounts of moisture gathering. This can promote collection of dust, called “ghosting”. The surface can even become damp enough to cause mould or mildew to develop.

A better practice is to maintain the full height and full thermal performance of a selected ceiling insulation over the entire ceiling area, including the perimeter. To accommodate this greater height, use a roof frame assembly that allows for full depth of insulation to extend fully over the wall top plate below. The introduction of a vertical heel (aka “raised heel”) as part of the roof truss design, will create height to accommodate the insulation as well as the required minimum 20mm ventilation space above. Building height and external wall height will increase because of the revised truss design.



Standard roof pitch – insulated roof slope

When insulation is installed directly under a roof slope, it should be protected by a vapour-permeable building wrap on the outside. Clear drainage and ventilation above the wrap also promote drying. Battens are always necessary for fixing the roofing but adding *counter-battens* parallel with the rafters will lift the battens off the building wrap, adding further drying and helping remove condensation or liquid water. In addition, the extra space helps keep the roof cooler in hot weather.

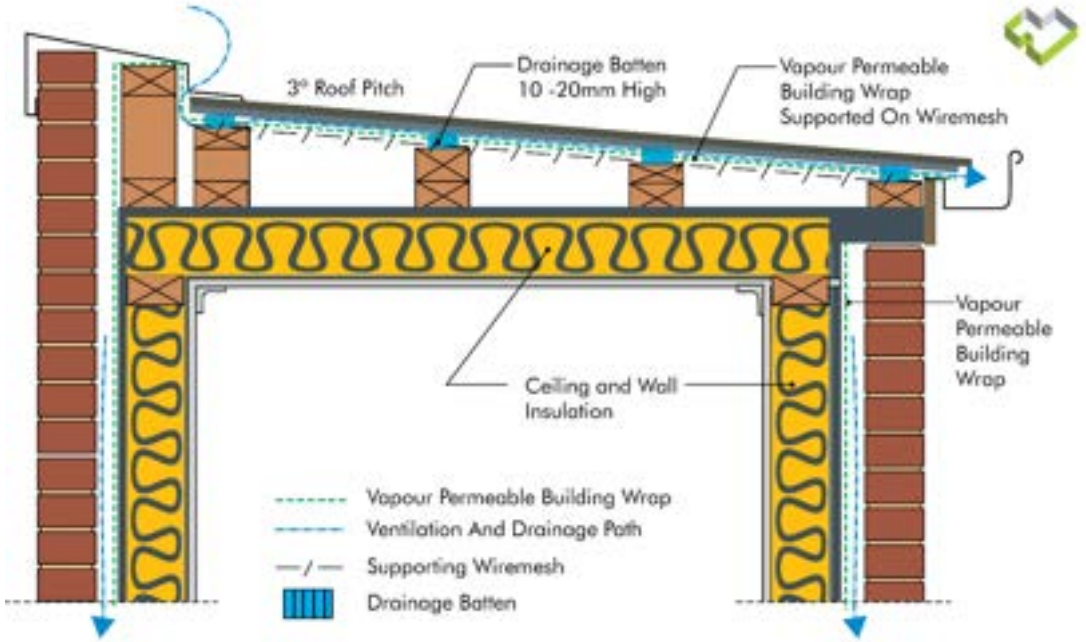


When used on an insulated roof slope, a building wrap must be installed under the roof tiles or metal roof cladding and under or over the roof battens, as a Weather-Resistive Barrier (WRB). It must be vapour-permeable to allow internal moisture to migrate out of the roof space and into the sub-roof zone, to vent away safely. A WRB installed under roof battens with no rigid substrate may drape sufficiently (10-20mm) between roof beams/rafters to allow a drainage and ventilation. If a rigid substrate like OSB or plywood is used, counter-battens should be added or drainage battens should be used. In any case, a WRB must be installed with 150mm overlaps, lapped 25mm into gutters, and any penetrations and or damage taped and sealed to provide a weathertight second layer.

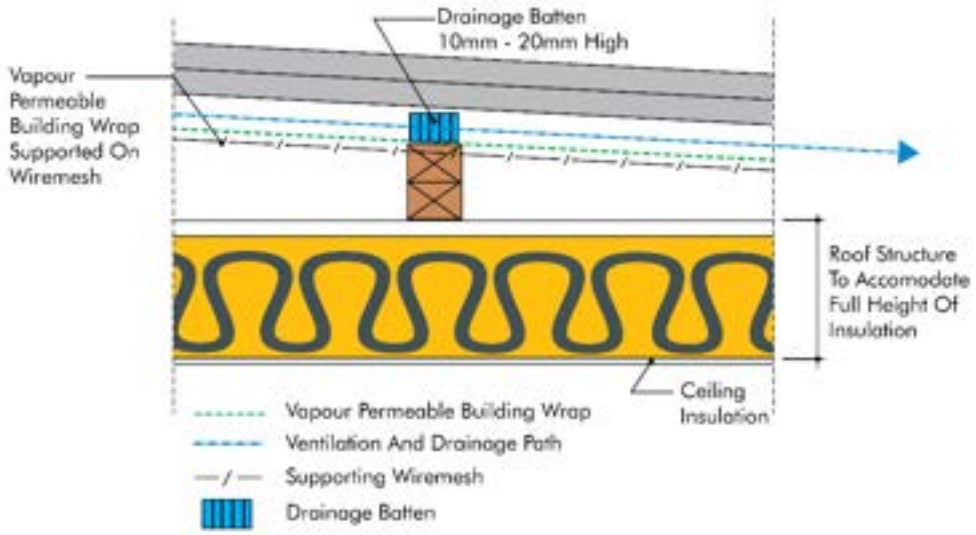
Low Roof Pitch

Low roof pitch has the potential for rainwater gathering in pockets. To help prevent this, a vapour-permeable building wrap (called a Weather-Resistive Barrier or WRB) should be installed, fully supported from underneath with a rigid material like OSB or plywood. If rigid sheathing is not an option, even wire mesh provides some support. Any building wraps must be installed with 150mm taped overlaps and lapped 25mm into gutters. Any penetrations or damage must be taped and sealed to provide a weathertight second layer.

A building wrap should be installed under metal roof cladding and under or over the roof battens. It must be a vapour-permeable WRB to allow internal moisture to migrate out of the roof space and into the sub-roof zone. Sub-roof drainage should be provided by installing a 10-20mm drainage batten, to allow moisture to vent or drain safely away via the gutter system. Alternatively, cross-battens along the same slope of the roof may be added underneath the battens and over the WRB to provide a totally drained and ventilated space.

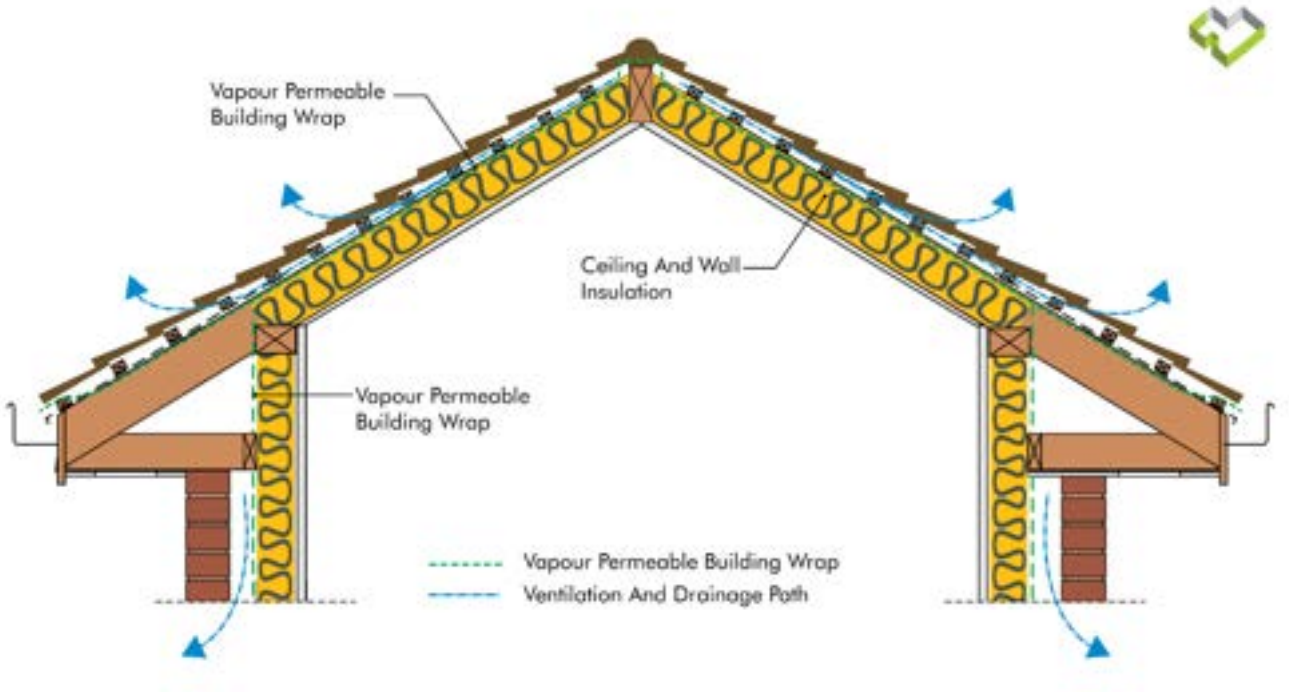


To further promote ventilation of the roof surface, drainage battens that allow air to pass through along the slope of the roof may be used. The air flow promotes drying and cooling. A batten 10 – 20mm high located between the roof building wrap and roof deck, will help provide a clear ventilation and drainage path.



Standard roof pitch – insulated roof slope

When insulation is installed directly under a roof slope, it should be protected by a vapour-permeable building wrap on the outside. Clear drainage and ventilation above the wrap also promote drying. Battens are always necessary for fixing the roofing but adding *counter-battens* parallel with the rafters will lift the battens off the building wrap, adding further drying and helping remove condensation or liquid water. In addition, the extra space helps keep the roof cooler in hot weather.



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As-built verification checklist

Project details:

Owner:

Builder:

Building location:

Construction Type: Residential homes, Class 1A

Checklist

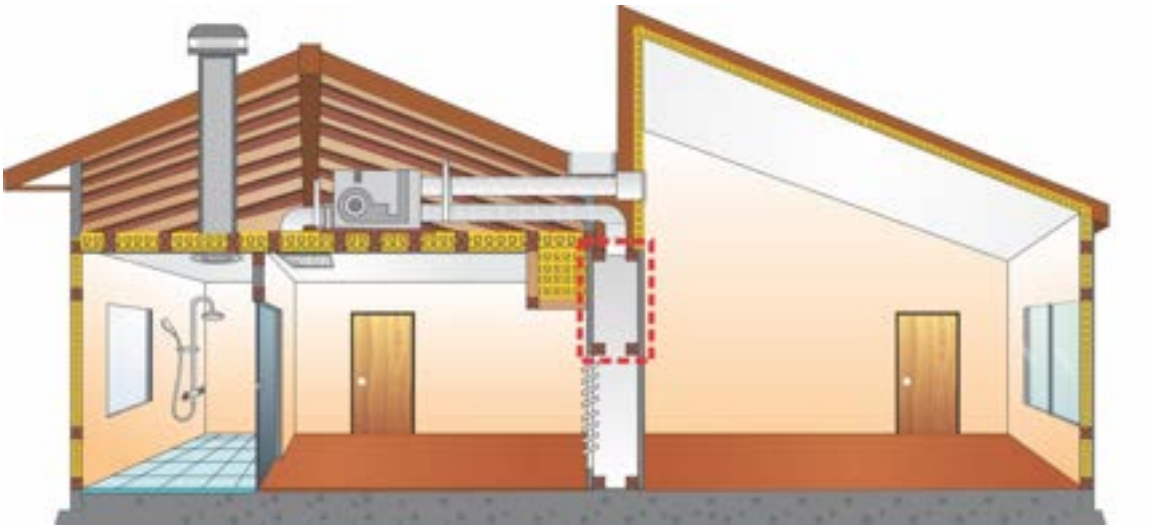
The following section provides a checklist of actions to ensure homes are able to pass an as-built verification.

Base stage

☐Slab: Services that penetrate the slab must be sealed at entrance and exit points.

☐Slab: Junctions at split or stepped slabs must be sealed.

☐Timber floors: Seal all joints in floor sheeting and around plumbing and service penetrations.



Frame stage

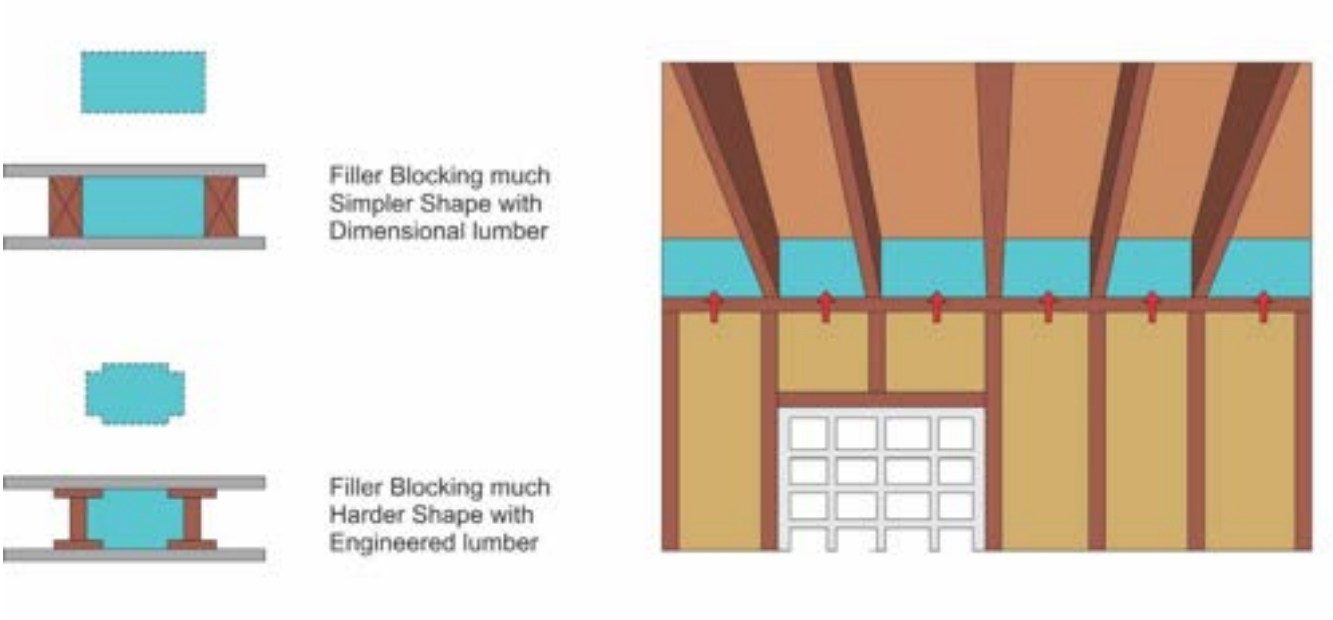
☐Heating returns work best when fully ducted. When a plenum is used, it must be made completely airtight. It must be fitted with a spigot at ceiling level, and all plasterboard junctions and corners at the floor level must be caulked. Alternatively, the carpenter can install plywood caulked and sealed airtight to line the inside of the plenum before the plaster is installed.

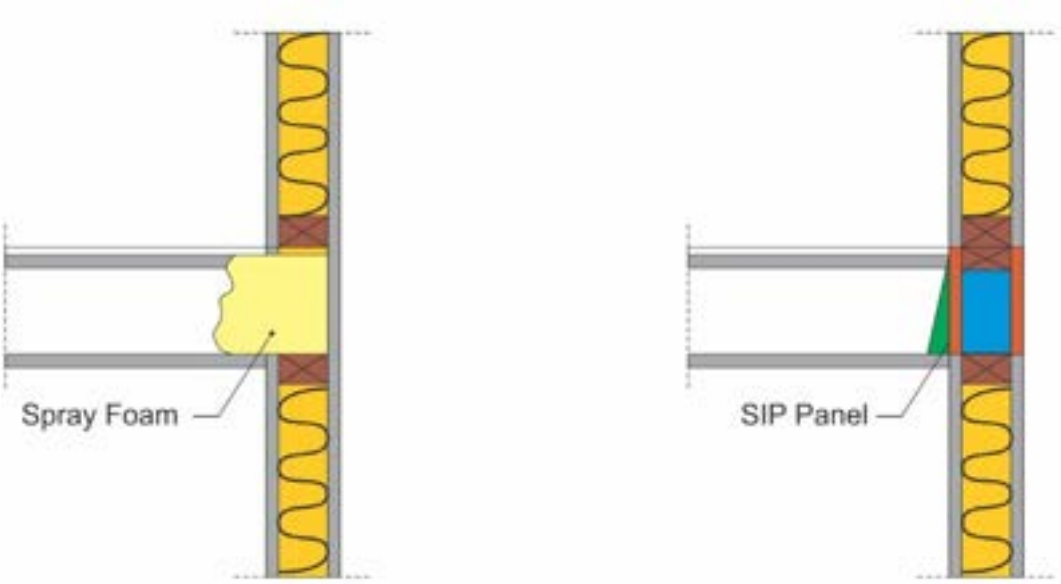
☐Internal cavity sliders must be encased with a continuous wooden frame. Any joins and penetrations through this frame, for example for services, must be caulked. Additional detail is specified in future stages to reduce internal cavity slider air leakage.

☐Internal voids within the floor plan, for example plenums, columns, nib walls are required to be sealed for air tightness and insulation consistency at the ceiling level. Air from the roof area should not be able to freely move into these cavities on the floor plan.

For double story buildings

☐Seal up floor joists zone around the perimeter of the second floor using high density foam board (with appropriate fire ratings). Caulk or apply spray foam to the top and bottom plate of walls leading into the attic spaces and garages. See diagram below.



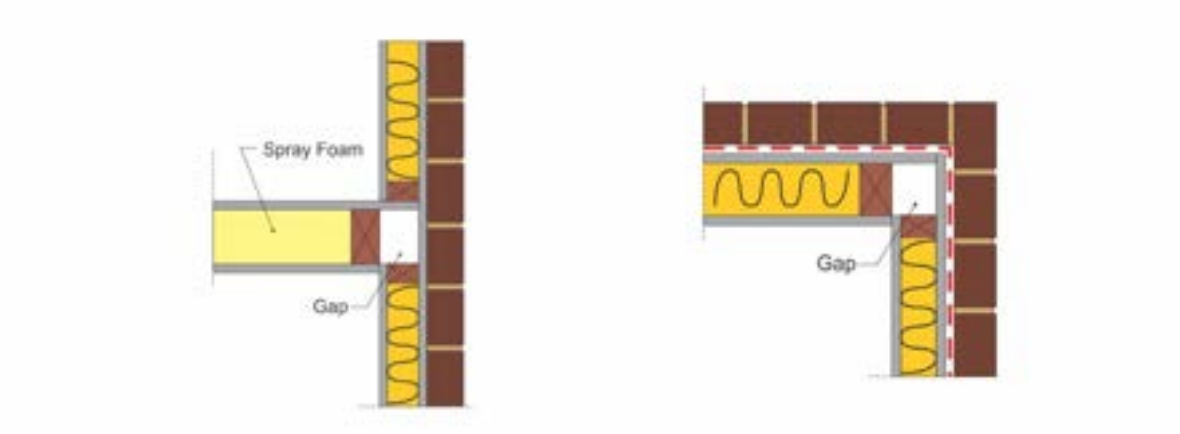


Lock-up stage

☐Install exhaust outlets for bathrooms, kitchens, and toilets directly to the outside via a roof or an eave vent. Exhaust air shall not be exhausted into roof, ceiling, or floor cavity.

☐ Areas with insufficient headroom, i.e. close to the edge of the ceiling, must be fitted with insulation prior to plastering.

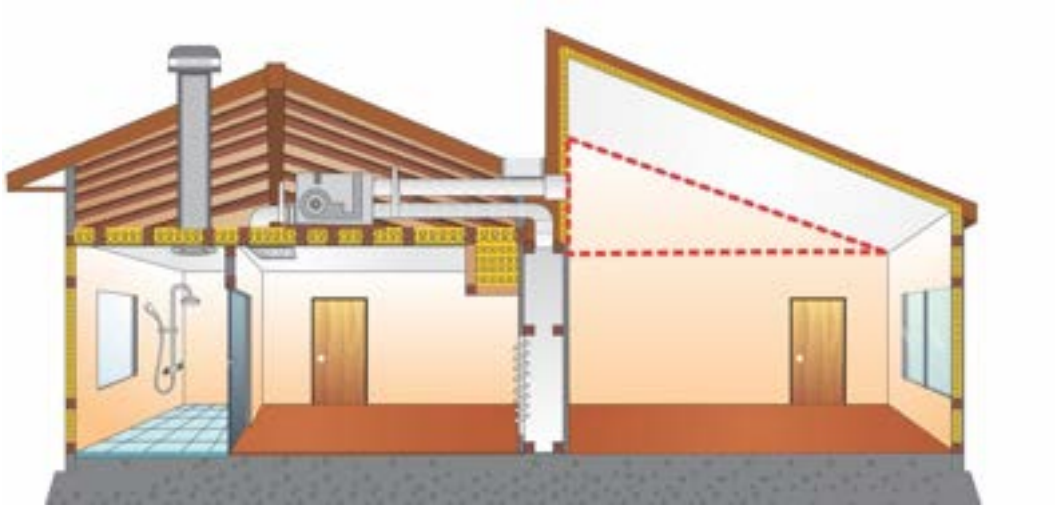
☐Insulate internal wall junctions abutting external walls before building wrap is installed. Use conventional batts or expanding foam. All gaps in these junctions between studs must be fully insulated, including small gaps of 25mm.



☐Insulate closed corner external wall junctions before installing building wrap installation with conventional bats or fire retardant expanding foam.

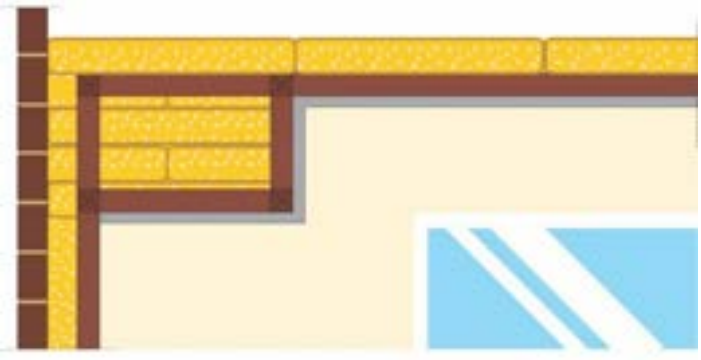
Fix stage (insulation)

☐ Ensure that stud frame walls that join with any cathedral ceilings have been insulated.



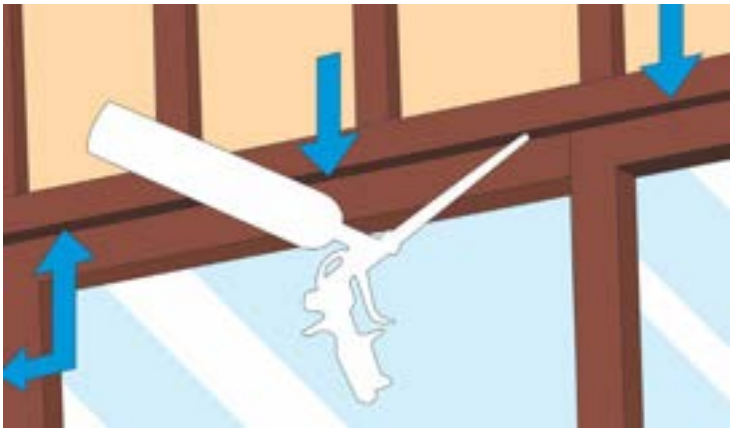
☐ Mechanical HVAC platform should be erected to accommodate the full depth of insulation, and insulation installed before ceiling plaster installation.

☐ Bulkheads or lower ceilings need to be filled with insulation to the same height as the ceiling insulation. The plaster is the air barrier. For vertical and horizontal plaster surfaces, insulation must directly abut the plaster.



☐ For bathtubs on the outside walls, insulate the exterior wall and air-seal behind the bathtub with cement sheet or blue board (plywood, plaster, rigid foam insulation) before the tub is put into place. After the drain is installed, seal the tub drain penetration with caulk or spray foam.

☐ Any gaps of less than 30mm between lintels must be sprayed with foam to ensure insulation consistency. Any larger gaps should be insulated with thinly cut strips of insulation.

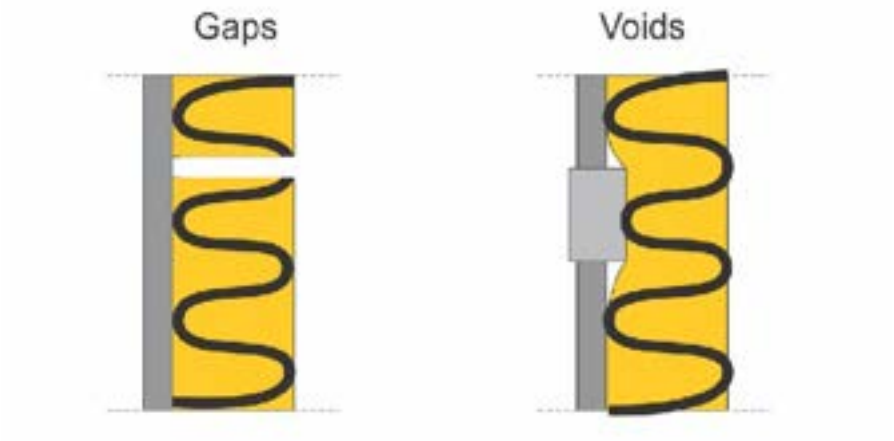


☐ Insulation must be installed on both sides of structural beams or wall metal bracing to reduce thermal bridging effects. The insulation must be installed on inside and outside facing sides.

☐ Seal window frames and exterior door frames with caulk or expandable foam to the stud frame. Be cautious when using spray foam as it can expand and pinch jambs and may void some window warranties. Use a low expanding spray foam, designed for this purpose.

☐ Insulate skylight shaft walls using straps on all sides so that the insulation is not relying on plaster to stay in place.

☐ Ensure that insulation is consistent and not compressed around electrical and plumbing services.



☐ Insulation must be installed with no gaps or voids on all surface areas of the building envelope including walls and ceilings to outside and junction points where the ceiling roof and walls are close together.

For double story buildings

☐ Conditioned spaces above garages must have insulation strapped directly to the wooden flooring above and not abutted to the plaster ceiling in the garage.

Plaster installation (air barrier)

☐ Seal the bottom of the plaster wall around the entire building (external, internal, garage walls) before the skirting boards are installed. If this step has been omitted, caulk the top and bottom of skirting boards.

☐ Internal cavity sliders that have been plastered on one side should then be caulked internally. The final piece must be installed with a foam gasket to form a continuous seal around the stud encasement frame.

☐ Behind all joinery the plasterboard must be caulked to the concrete slab before joinery is installed

- THIS MUST BE DONE BEFORE CABINETRY IS INSTALLED.

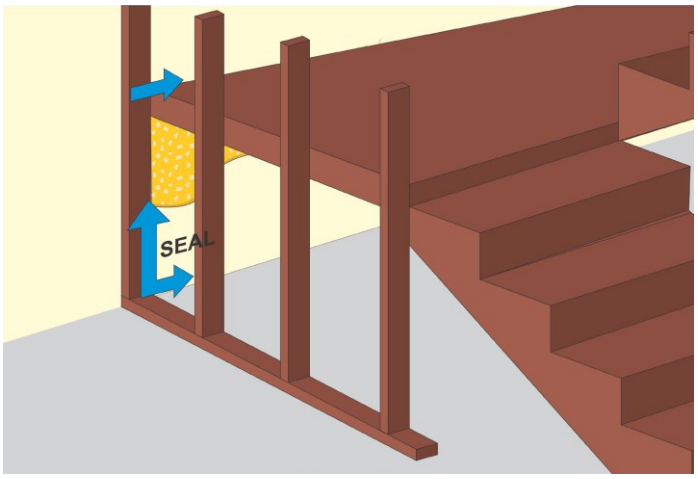
☐ Using a low expanding foam, seal all plumbing penetrations in bathrooms, kitchens and toilets

- THIS MUST BE DONE BEFORE CABINETRY IS INSTALLED.

For double story buildings

☐ Insulate the area under the stairwell if it is an external or garage connected wall.

The area will then require plastering. Proceed to caulk all the joins (including to the floor) to ensure the internal and external wall does not leak under the stair storage area.

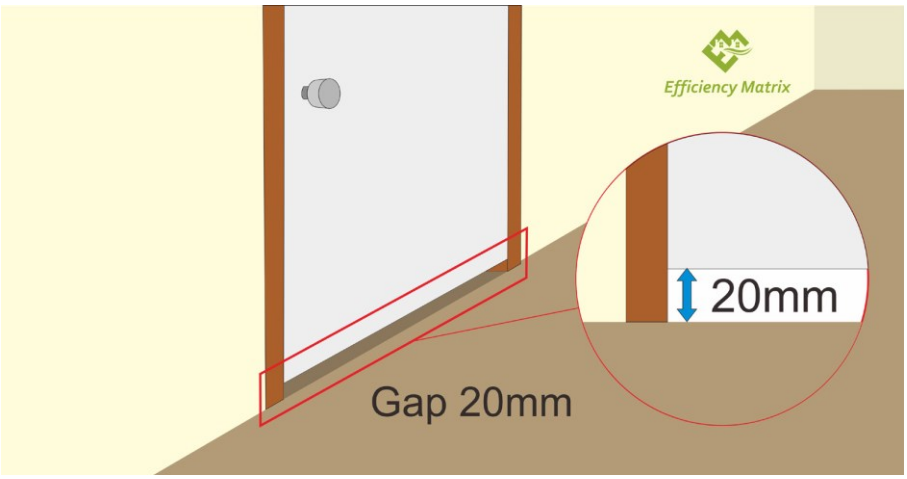


Practical completion stage

☐ Use expanding foam on any penetrations caused by the installation of split system heating and cooling units. It is best to do this when installing the head units.

☐ CO sensors must be installed in kitchens with gas cooktops.

☐ Ensure there is a gap of at least 20mm at the bottom of bathroom and toilet doors, measured from the floor finish.



☐ Bathroom exhaust fans must be installed with a humidity sensor and a good quality draught stopper that is fixed and sealed to the top side of the plasterboard.

☐ Rigid foam board of R-Value 3.0 needs to be cut to the shape of the manhole lid and adhered with adhesive spray foam so that a loose insulation batt is NOT relied upon to insulate the manhole surface area.

☐ Before the grills are installed for the ducted air conditioning systems, seal all ducted heating boots to the floor or ceiling plaster with an acrylic caulk.

☐ Install downlight covers that are tested to provide an R-value performance of at least 0.5 over ceiling installed recessed downlights luminaires. This ensures insulation consistency across the ceiling. All luminaires must be LED and IC4 rated and control gears must be located away from insulation and not submerged under or within insulation.

☐ Caulk all architraves around windows and doors before painting (and pay special attention above and below window and sliding door frames because these gaps can be large and contribute significantly to airleakage).

☐ Caulk all skirting boards to the floor (before carpet installation). Caulk all skirting boards to the plaster before painting.

☐ Caulk around the architrave of manholes before painting.

☐ Install weather stripping between the manhole (attic access) frame and manhole lid.

☐ Install door and window seals and ensure they are aligned to provide an airtight weather seal.

☐ Install door draft stoppers at the bottom of doors (external and internal door that connects to a garage)