CONDENSATION IN BUILDINGS

Understanding and avoiding condensation in buildings

This Building Technology Resource explains condensation in buildings, what causes it, and how it can be prevented.

Condensation is a major cause of moisture accumulation in buildings, leading to unsightly (and potentially unhealthy) mould growth and to cosmetic and structural damage. Condensation may be obvious – as the water drops forming on bathroom windows or dripping from factory roofs, for example – or may occur in less visible places within the building fabric, causing decay of materials and threatening the structural integrity of the building.

Building regulations do not target condensation directly, in part because it involves complex interactions between climate and the environment, building design and occupant behaviour. However, Australia's National Construction Code addresses related building requirements that may impact condensation, such as damp and weatherproofing, ventilation, thermal insulation and energy efficiency.

FIGURE 1 Condensation forming on the inside of a window and pooling on the frame. (Amelia Martin/Shutterstock)

WHAT IS CONDENSATION?

Condensation is the water that collects on a cold surface when humid air, or water vapour, is converted into a liquid. The word describes both the process itself and the water droplets that are created.

Condensation arises because warm air can hold more moisture than cold air. For example, a cubic metre of air at 25°C can hold a maximum of 23 grams of water, which corresponds to 100% relative humidity. If this air is cooled to 15°C, then its maximum water content falls to 13 grams per cubic metre, which means that 10 grams of water must condense out of the air.

The air around us is generally not saturated, although it may be warm enough to store a considerable amount of moisture. In this state, its relative humidity is less than 100%. However, if air is cooled below the lowest temperature at which its relative humidity is 100% – known as its dewpoint – then condensation will produce water droplets in the air (as a fog) or on a surface (Figure 1). If the air is relatively moist, then the dewpoint will be not far below the actual air temperature, and condensation will occur readily. If the air is relatively dry, the dewpoint will be much lower than the air temperature, and condensation will occur only if the air comes into contact with colder surfaces.

CAUSES OF CONDENSATION IN BUILDINGS

Condensation within a building requires a source of relatively moist air, surfaces (such as windows and walls) that are relatively cold, and a pathway for the moist air to find its way to the cold surfaces.

Elements of building design and normal building use may create or worsen these conditions.

GROUND MOISTURE

Moisture from the ground can enter a building from various ways. Concrete slabs generally provide a waterproof barrier to ground moisture, but buildings with suspended timber floors (typical of many houses) are susceptible to high indoor humidity arising from moist subfloor spaces, especially if floor vents are blocked. In older buildings with inadequate (or failed) damp courses in masonry walls, moisture may be wicked into the building, causing local damage due to the rising damp and supplying water vapour that may condense elsewhere.

Ground moisture depends on the local microclimate, soil characteristics and watering frequency. Buildings sited in areas that are inherently wet – such as the sides of hills where the water table is close to ground level – are likely to experience problems with condensation. Excessive watering of lawns and garden beds close to buildings, leaky roof gutters and leaking water pipes are other obvious sources of excess ground moisture.

BUILDING OCCUPANCY AND USE

Occupants and some domestic appliances may also contribute to indoor moisture levels. Adults typically produce 0.1 litres of water vapour per hour just by breathing, while hot baths, showers or unvented clothes dryers can produce 1.5–10 litres per hour.

Other domestic and industrial appliances, such as gas-, oil- and kerosene-fired stoves, burners and heaters, produce large quantities of water as a product of combustion. This problem does not arise with flued appliances, because the products of combustion are transferred outdoors.

CLIMATE AND TEMPERATURE

In general, areas with higher humidity are more likely to experience condensation. Regions with cold, wet winter climates tend to have more problems during the heating season, while regions with hot, humid summer climates are likely to experience problems in their cooling season.

During winter (or whenever heating is used), condensation results when insufficiently insulated surfaces inside a building become cold enough to fall below the dewpoint of indoor air. Sheet-metal roofs are particularly susceptible, because they face the cold night sky. Through a phenomenon known as radiation cooling, these roofs can fall to a temperature below the outdoor ambient air temperature, enabling moist air to condense on the cool underside of the sheet metal inside the roof space. In an otherwise well-insulated building, there may be heat bridges that form pathways for heat to escape. Typical examples include water pipes, structural steel or aluminium elements, and window panes and their frames. If the interior surfaces of the building have inadequate vapour resistance, condensation may occur within wall, roof or floor structures.

Condensation can also be a problem in summer, particularly in climates where humidity is high and when mechanical cooling is used. Water vapour may condense on the outside of the building if it is inadequately insulated or if it contains heat bridges and is cooled from inside. As in winter, water vapour may penetrate the building and condense on any cold surfaces between the exterior and interior of the building. The cold parts of inadequately insulated air-conditioning equipment (such as evaporator lines) and the walls next to indoor evaporator units or in their airstream may be subject to condensation.

NEW CONSTRUCTION

In new buildings, moisture stored in the structure itself adds to the moisture generated by the occupants and their activities. It can take up to 12 months for new masonry walls, concrete floors and timber framing to dry out. Although some moisture is transferred outdoors, much of it is released indoors or interstitially, within the building fabric, where it may be the major cause of temporary condensation.

PREVENTING CONDENSATION

Excess moisture supports the growth of mould, which poses a health risk to building occupants (Figure 2). It also promotes the decay of building materials, which can threaten the building's structural integrity.

The risk of condensation and its effects can be minimised by taking the correct steps during the design and construction of the building. Because climate (particularly temperature and humidity) is a key factor in the risk of condensation, it is not possible to set guidelines that are universally appropriate. However, various measures are commonly used to control the accumulation and movement of moisture in buildings (Figure 3).

FIGURE 2 Where condensation forms, mould can grow. (zlikovec/iStock)

VAPOUR BARRIERS

A vapour barrier is a material, typically reflective aluminium foil or a polyethylene sheet, that has high resistance to the flow of water vapour. If moisture poses a particular risk to some part of the building fabric, vapour barriers may be crucial and will be specified by the designer. These barriers are effective only if installed to an adequately high standard, without penetrations or gaps. Vapour barriers are most frequently used under concrete slabs and with blanket insulation under sheet-metal roofs.

Often membranes, such as reflective foil, are specified in buildings for other purposes such as insulation or sarking. When used incorrectly, they may contribute to the formation of condensation by preventing the escape of water vapour from areas where relative humidity levels become excessive. If vapour permeance is required, such membranes may be perforated with small holes or made from a highly permeable material, such as paper or some plastics. In general, vapour barriers should be placed on the warm side of building elements where condensation is likely to form, and membranes that breathe should be placed on the cold side.

Where there is free exchange of air between parts of a building, it is not possible to restrict the flow of water vapour, and moisture generated in one place will rapidly spread to other areas. This can lead to condensation in a cold part of a building due to water vapour that is sourced some distance away.

THERMAL INSULATION

Providing adequate levels of thermal insulation – while avoiding or minimising heat bridges – ensures that surface temperatures remain high enough to prevent condensation. However, high levels of insulation may introduce unforeseen problems where they are incorporated into construction styles that have previously been relatively immune to condensation. This is because insulation not only keeps some surfaces warm, but also keeps other surfaces cold. An example is domestic roof spaces: higher levels of ceiling insulation mean that roof spaces are colder, because less heat is leaking into them from the ceiling below. Condensation tends not to affect tiled roofs because they are well ventilated to outdoors, but it is more likely to occur in pitched roof spaces with sheet-metal roofs and higher levels of ceiling insulation.

GLAZING

Condensation on window glass is generally prevented by the use of double glazing. This is more expensive than single glazing, but its use is increasing in both domestic and commercial construction. In colder rooms, condensation on single-glazed window panes may be unavoidable. It may also occur on the frames if they are poorly designed. Aluminium frames should incorporate thermal barriers between indoor and outdoor sections.

VENTILATION

Ventilation is an effective way of removing moisture generated within a building and keeping the relative humidity low (Figure 4). In bathrooms and laundries, exhaust fans should be used whenever moisture is produced. Electric clothes dryers should be vented to outdoors (either temporarily or permanently) where

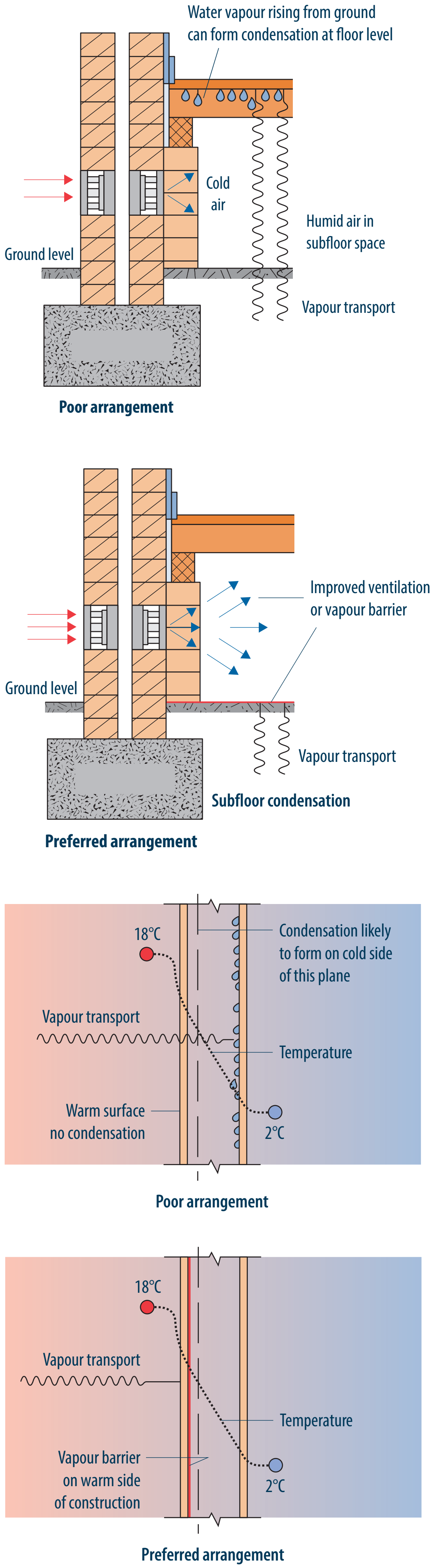
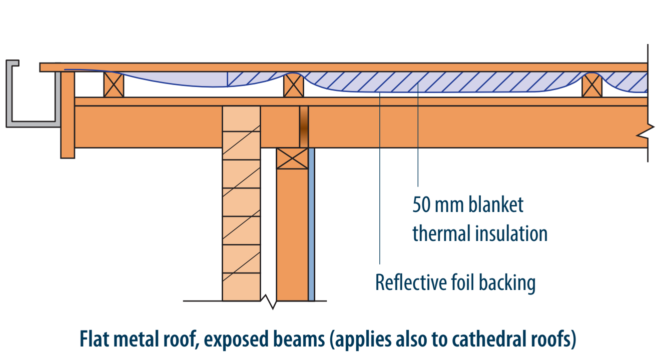
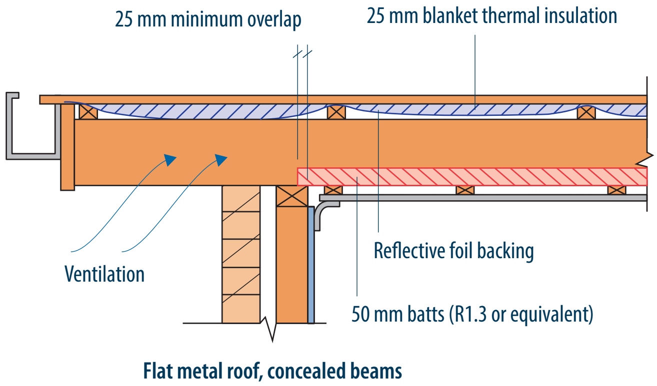


FIGURE 3 Condensation control relies on good design.





possible; otherwise, a nearby window should be opened and the connecting door to the rest of the building should be closed when the drier is in use. In the kitchen, rangehoods should be used, because moisture is generated not just by cooking but also as a combustion product from the gas burners in cooktops and ovens.

Inadequate ventilation may allow condensation to occur in subfloor spaces, which can lead to decay of timber framing and flooring. Subfloor spaces should be adequately ventilated, and floor vents should not be covered. Where serious problems occur, a vapour barrier at ground level may also be required.

In commercial and industrial buildings where significant amounts of water vapour are generated by work activities, increased ventilation to outdoors is likely to help reduce the risk of condensation. It is a common practice in domestic and commercial construction to ventilate bathroom, laundry and kitchen areas into the roof space, where moisture in the air is expected to dissipate. However, in buildings with uninsulated sheet-metal roofs, condensation on the underside of the roof is likely. Metal roofs generally require blanket insulation and a vapour barrier underneath them so that moisture-containing air in the roof space cannot come into contact with the cold sheet-metal surface. It is also desirable to have fixed ventilation at eaves or gable ends for such roofs and to ensure that exhausts into the roof space are ducted direct to outdoors.

Rooms that experience condensation in winter (such as bedrooms) generally benefit from small, continuous amounts of ventilation through partially opened windows. Ventilation in this way comes at some energy cost, as the building will be more expensive to heat.

HEATING

Condensation on internal walls and ceilings in winter may be greatly reduced by using heating to maintain higher internal

FIGURE 4 Air vents attached to the ceiling can remove moisture within a building. (ALPA PROD/Shutterstock)

temperatures. As with ventilation, heating is generally more beneficial if it is continuous, which will necessarily entail higher heating costs.

Unflued gas, oil or kerosene heaters should not be used in spaces that are prone to condensation, as their operation may contribute to the accumulation of moisture.

Where condensation cannot be prevented in some areas of a building, it can often be managed by construction which provides for targeted collection and drainage.

MORE INFORMATION

Additional information can be found in the following resources. Please check your local authorities for specific legislation, codes and guidelines, as they can vary between states and territories.

Australian Building Codes Board (2014) Condensation in buildings. 2nd ed. Canberra: Australian Building Codes Board

Australian Building Codes Board (2016) National construction code. Canberra: Australian Building Codes Board

Australian Standard AS 3999:2015 Bulk thermal insulation – Installation

Australian Standard AS/NZS 4200.1:2017 Pliable building membranes and underlays, Part 1: Materials

Australian Standard AS 4200.2:2017 Pliable building membranes and underlays, Part 2: Installation Requirements

Australian Standard AS/NZS 4859.1:2018 Thermal insulation materials for buildings, Part 1: General criteria and technical provisions

Building Research Association of New Zealand (2012) Building basics: Internal moisture. Porirua: BRANZ Limited

Department of the Environment and Energy (2017) Your home. Canberra: Australian Government. <www.yourhome.gov.au>