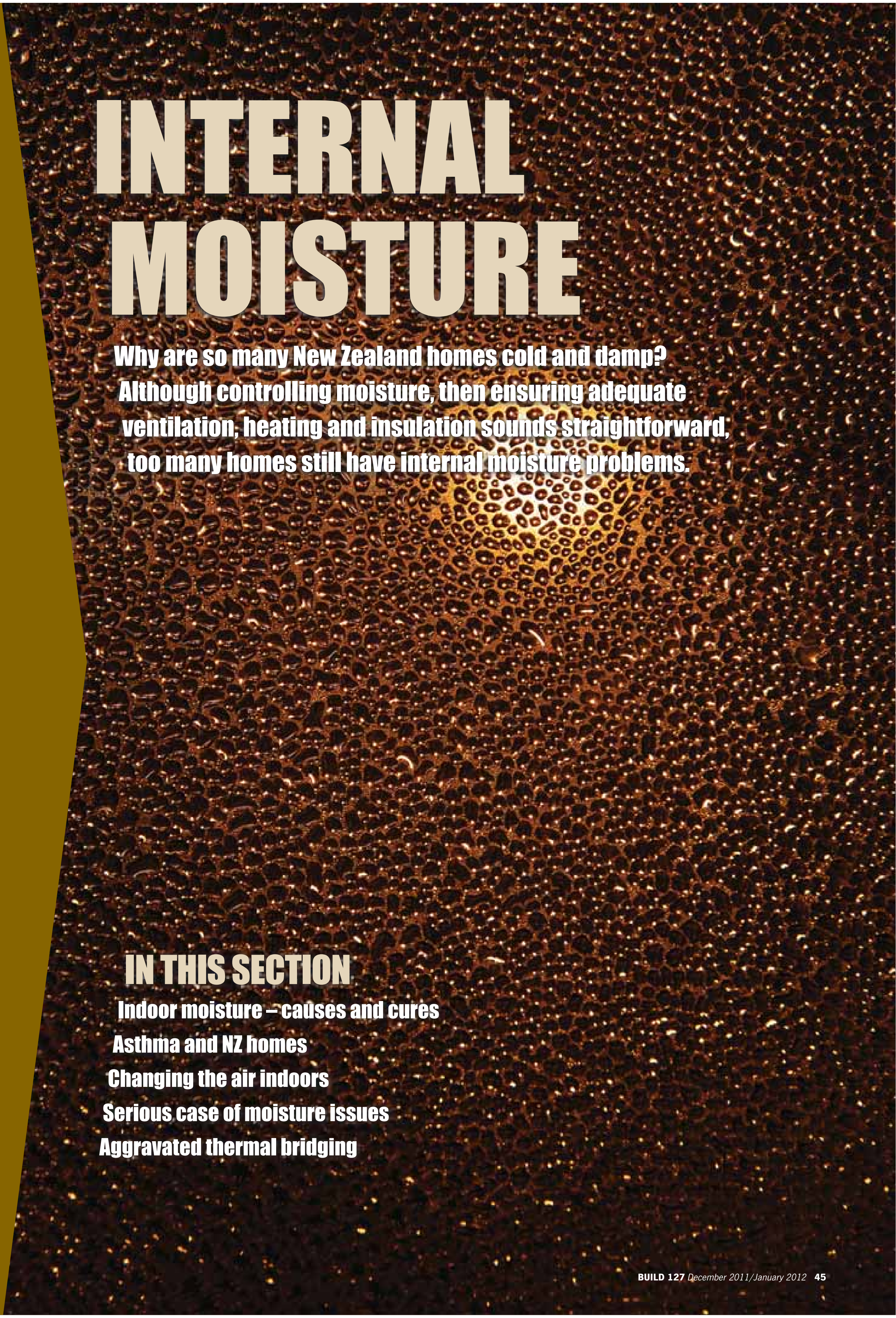


INTERNAL MOISTURE

Why are so many New Zealand homes cold and damp? Although controlling moisture, then ensuring adequate ventilation, heating and insulation sounds straightforward, too many homes still have internal moisture problems.

IN THIS SECTION

Indoor moisture – causes and cures
Asthma and NZ homes
Changing the air indoors
Serious case of moisture issues
Aggravated thermal bridging

INDOOR MOISTURE – CAUSES AND CURES

We're all familiar with New Zealand's cold damp houses, but to understand the causes and fix the problems, it helps to know a bit about how water vapour works.

By Malcom Cunningham, BRANZ Principal Scientist

Cold damp buildings are unhealthy and lead to elevated illness rates, particularly respiratory illnesses such as asthma. It's not just the lower temperatures that cause these ailments, but the proliferation of biocontaminants like moulds, bacteria and dustmites that occur when indoor relative humidity is high. Condensation on windows is also caused by high indoor humidity and may be the first sign of problems.

Solutions can be straightforward and include first controlling the moisture, then ensuring adequate ventilation, heating and insulation. Scientific studies have shown that retrofitting houses with insulation, making them warmer and drier, significantly improves occupant health.

The science behind condensation

To understand the causes of moisture problems in buildings requires some knowledge of the physics of water vapour. Water has three phases: solid (ice), liquid (water) and gas (water vapour). The relative humidity of air is a measure of the quantity of water vapour in that air compared with the maximum the air can hold.

When a body of air is cooled, its relative humidity automatically rises (see Figure 1). When air at 20°C with 40% relative humidity has its temperature lowered to 15°C, its relative humidity rises to 55%. If its temperature is lowered to 6.2°C, its relative humidity rises to 100%, and moisture condenses out of the air.

This temperature is known as the dewpoint. Moisture or condensation will form on any cold surface, such as windows or the linings of external walls, that is below the dewpoint (100% relative humidity).

For mould to grow, the relative humidity at surfaces only needs to be above 80%. Figure 2 shows mould stains on a ceiling. Here the relative humidity near the ceiling under the joists is below 80%, whereas the relative humidity near the ceiling where there is no insulation is above 80%. Mould grows on this part of the ceiling because the surface is colder.

How to make houses warmer and drier

There are several ways to make houses warmer and drier. These improvements should be implemented in the following order:

- Control moisture at source.
- Ventilate.
- Heat.
- Insulate.

CONTROL MOISTURE AT SOURCE

The most effective way of dealing with a moisture source is to remove it. For example, unflued gas heaters produce large quantities of water and should be replaced by heating that doesn't produce moisture. The next best action is to use mechanical ventilation such as rangehoods and bathroom fans to remove moisture at source.

VENTILATE

Openable windows, windows with ventilators or even stack ventilators all provide natural ventilation. Low levels of ventilation result in high indoor humidity (see Figure 3). Houses should be provided with the means to achieve at least 0.5 air changes per hour.

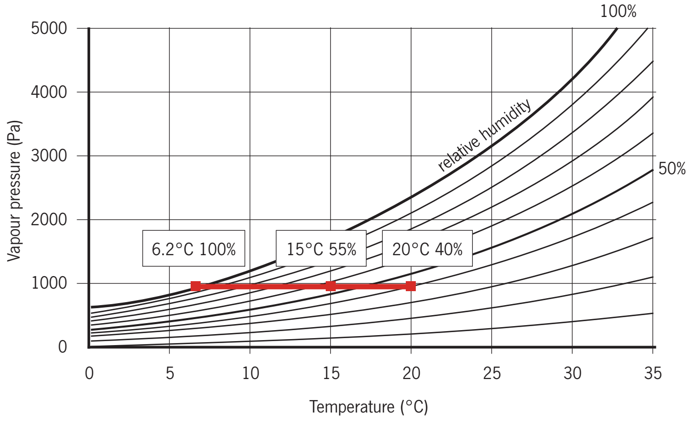


Figure 1: Psychrometric chart showing relative humidity rises as air cools.

Figure 2: Mould growth causes staining on a ceiling.

HEAT

Raising the temperature of the indoor air automatically reduces the relative humidity. Heating particularly reduces the humidity on windows and on the surface of exterior walls, thus avoiding mould growth and condensation.

INSULATE

Insulating a house well makes it easy and cheap to heat. It raises the temperature of windows and the surface of exterior walls, thus lowering the humidity and further avoiding mould growth and condensation.

Beware of construction moisture

Construction moisture is another important source of indoor moisture. Concrete, timber and other building products can be enclosed before they have had time to dry properly. This results in high relative humidity, condensation and mould growth.

New houses are often closed up during the day while owners are at work. The low ventilation levels and newly enclosed building elements loaded with construction moisture can cause serious moisture problems in these new houses.

Concrete slabs are the most important potential source of construction moisture. They contain several thousands of litres of water. The rule of thumb is that concrete takes a month per 25 mm of slab thickness to dry out.

Timber can also be a problem and shouldn't be allowed to get wet before or during construction. As well as warping and shrinking as it dries, a significant amount of construction moisture can be released into the inside of the building.

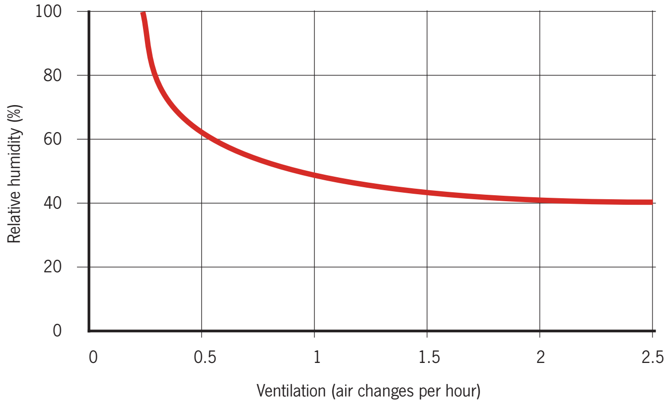


Figure 3: Relative humidity changes, depending on ventilation levels.

ASTHMA AND NZ HOMES

A Finnish study found mould and damp in housing was a cause of childhood asthma. Now, similar research is being carried out here.

By Caroline Shorter, Research Fellow, School of Medicine and Health Sciences, University of Otago, Wellington

Do the conditions of our homes contribute to the onset of asthma in our children? This is the question that researchers at Otago University's Wellington School of Medicine are trying to answer with a study looking at housing factors and their relationship to onset of wheezing in young children.

The HOME study is a Health Research Council-funded collaboration between Otago University and health researchers from Finland, who recently carried out a similar study, which found that dampness, mould and leaks were associated with the onset of asthma in Finnish children.

Housing and asthma onset

New Zealand has very high rates of asthma, and the team at Otago University is keen to know whether the Finnish findings are true for New Zealand homes. The study team at Otago has previously found that housing conditions can worsen symptoms in a child with asthma. The current study will address whether housing conditions are causing the onset of asthma.

Otago University's Wellington Asthma Research Group has teamed up with 54 medical practices in the wider Wellington region who are helping to recruit into the study children who have either recently started wheezing and been medicated for this or, as a comparison group, have no history of wheezing.

Both groups of children will have their homes assessed by a trained building evaluator, who will examine the home for factors that may be important to respiratory health, such as the presence of moisture, leaks, sunshine levels, subfloor water pooling and insulation levels. The evaluator is blinded to the children's wheezing status. In addition, the children and their parents are visited by the health researchers who ask a number of questions about the children's health, and about their home, including the levels of condensation, sunshine, mould levels and ventilation practices, as well as further information on the use of the home.

A total of 450 families will be involved in the study, and by July 2012, researchers hope to have some answers to whether housing conditions contribute to the onset of asthma.

CHANGING THE AIR INDOORS

New houses are becoming increasingly airtight as building technology changes. BRANZ research has been checking whether houses are getting sufficient ventilation to maintain healthy indoor air quality and control moisture.

By Luca Quaglia and **Stephen McNeil**, BRANZ Building Physicists

Ventilation plays a major role in indoor air quality and moisture management in houses, removing and diluting contaminants, including water vapour. Ventilation comes from three sources:

- Infiltration through the building envelope, which depends mainly on the airtightness of the building and exposure to wind.
- The actions of the occupants, such as how often they open windows.
- The operation of mechanical ventilation systems.

Building Code requirements

In New Zealand's temperate climate, opening windows has always been thought to provide most of the ventilation. For this reason, New Zealand Building Code requirements for home ventilation have been for the opening window and door areas in the building envelope to meet or exceed 5% of the floor area.

Figure 1: Blower door system used to measure airtightness.

There have been no requirements for a dwelling to meet an airtightness target as is now common in cold-climate countries wanting to minimise energy losses by ensuring that ventilation systems work efficiently. In these countries, airtightness targets are accompanied by passive or active ventilation requirements so there is enough fresh air for contaminant and moisture control.

BRANZ research checks current ventilation and airtightness

BRANZ has been questioning whether homeowners actually open windows enough for ventilation. It has also been measuring airtightness trends in New Zealand homes for several decades.

Previous surveys of New Zealand homes identified a trend towards more airtight construction, despite a lack of Building Code requirements to drive this. Recent measurements as part of the Weathertightness Air quality and Ventilation Engineering (WAVE) programme have shown that this trend has continued in the last two decades.

The latest BRANZ survey measured the airtightness of 60 houses around the country – Auckland, Palmerston North, Wellington and Dunedin – over the last two winters. So far, results for winter 2010 have been analysed, and 2011 results will be available later.

The airtightness of a dwelling is measured with a blower door (see Figure 1). The main component of this is a fan mounted on the frame of an external door that pressurises the house. The resulting airflow through the building envelope at 50 Pa pressure is a measure of the airtightness of the building, often expressed in air changes per hour at 50 Pa (ach@50 Pa). The airtightness expresses how many times the total volume of air contained in the house would go through the fan in 1 hour at a test pressure of 50 Pa. This test pressure is chosen because it is far higher than the normal pressure differences naturally generated by wind and temperature, so the influence on the measurement of these background pressures is reduced. The value of 50 Pa is also that prescribed by international standards (ASTM E779).

From the airtightness measurement, an estimate of the average infiltration rate can be worked out using the air infiltration calculator in ALF (www.branz.co.nz/alf). Infiltration is driven by pressure differences across the envelope generated by wind and temperature differences, which are typically of the order of a few Pa.

Increasing airtightness could impact air quality

There was a marked increase in the airtightness of New Zealand homes from the 1950s to the 1970s, corresponding to a decrease in the number of air changes per hour at 50 Pa (see Figure 2). This was due to the use of aluminium joinery and particleboard floors replacing strip flooring.

The trend continued, although at a slower rate, in the 1980s and early 1990s. The last bar on Figure 2 represents the value obtained in the recent survey for Wellington and Palmerston North houses, indicating the trend is continuing. An airtightness result of 5 ach@50 Pa translates to an estimated average infiltration rate of around 0.25 ach. This means that, in a modern house, about a quarter of the entire volume of air in the dwelling is replaced by fresh air every hour due to air leaking through gaps and cracks.

International guidelines on indoor air quality recommend that the ventilation rate should ideally be 0.35–0.5 ach. Ventilation should be enough to effectively remove contaminants but not so high as to compromise energy efficiency.

The survey results show that New Zealand homes are becoming sufficiently airtight that infiltration alone will not generally provide adequate ventilation. This could impact indoor air quality and moisture control.

Most houses have sufficient ventilation

However, the infiltration rate is only one component of the ventilation rate in a dwelling. In 15 of the 20 houses monitored, the average ventilation rate was also monitored using a passive tracer gas system. The system comprises small and unobtrusive metal tubes installed in each room of the house and left for a period of 3 or 4 weeks. Dosing tubes continuously release tiny amounts of a safe tracer gas, and sampling tubes absorb the tracer gas. Since ventilation dilutes the tracer gas and we know the release rate from the dosing tubes, the amount of ventilation occurring can be calculated from the amount of tracer absorbed in the samplers.

From the average ventilation rate and average infiltration rate estimated for the 15 houses monitored in 2010, it can be seen that the ventilation rate is usually higher than the infiltration rate by an amount provided either by window opening or mechanical ventilation (see Figure 3).

The data so far shows that ventilation rates around 0.5 ach are achieved, putting most of those houses within the internationally recommended levels of ventilation. Some houses (m, n and o) exhibited higher levels of ventilation due to mechanical ventilation systems.

Some below healthy levels

However, the ventilation in some houses (i and j) was little more than the estimated infiltration rate and below the minimum healthy level.

While analysis of the data collected during winter 2011 is ongoing, a preliminary assessment suggests those measurements will lead to similar conclusions.

This research is part of the WAVE programme and is funded by the Building Research Levy and Ministry of Science and Innovation.

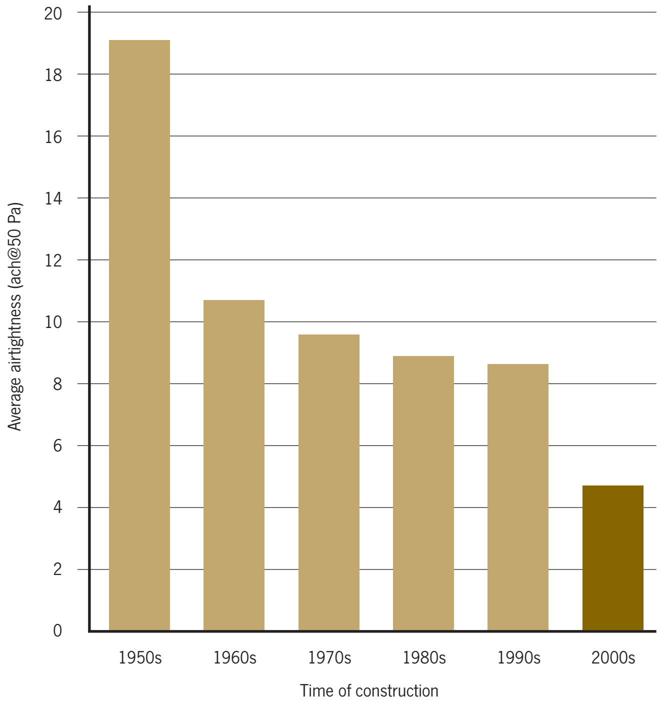


Figure 2: Average airtightness at 50 Pa of New Zealand homes built from the 1950s to the 2000s.

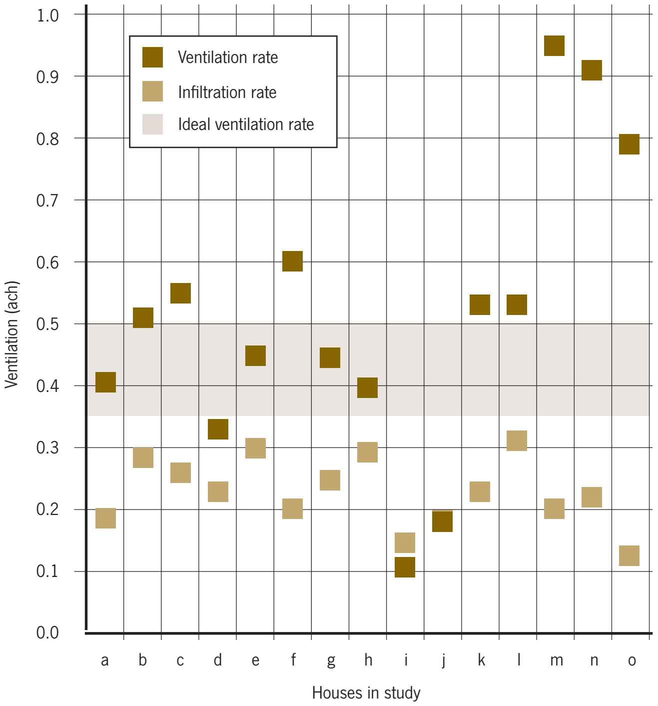


Figure 3: Average ventilation and infiltration rates measured in 15 houses during winter 2010.

SERIOUS CASE OF MOISTURE

Taking the presumed warmer, drier air from the roof space in an older era house certainly didn't have the expected effect for one family. Serious internal moisture problems resulted... and they aren't alone with this problem.

By Richard Popenhagen, Eco Building Design Adviser, Nelson City Council

An investigation followed earlier this year when an early 1900s house in Nelson, built from native timbers, went from being comfortably cosy in winter to a space that was damp and costly to heat following some work on the property. The house has a timber floor built relatively low to the ground and poor subfloor ventilation.

The problem

The owner of the 3-bedroom family home had noticed a serious moisture problem in the roof space. Large amounts of moisture were accumulating on the underside of the roofing underlay, turning to ice on cold winter nights and dripping onto the ceiling insulation when thawing the next day. Timber roof members were wet, and mould was growing on the purlins.

Additionally, the bedrooms seemed colder than usual, the house was harder to heat and the normal winter power bill of around $200 a month in previous winters had skyrocketed to over $400.

As the house had been reroofed earlier in the year with long-run coil-coated corrugated steel roof sheets over a bituminous self-supporting roofing underlay, the owners were concerned that either there was a serious roof leak or that the roofing underlay was somehow causing the problem.

The investigation

A site visit confirmed the problem. As well as the excessive moisture in the roof space, the windows were covered in condensation, mould was growing on curtains and the house felt cold and damp. The young son's bedroom on the southwest corner of the house was particularly bad.

The house is heated by a modern inverter heat pump that was installed 3 years ago and had proved effective up until last winter. Electric panel heaters in the bedrooms provide additional heat.

The temperature of the bedrooms was around 12°C and the living area around 16°C – lower than the recommended World Health Organisation minimum of 16°C and 18°C respectively.

Roof space ventilation system

A roof space ventilation system (also called a positive pressure ventilation system) had been installed 3 months previously. These systems take air from the roof space and pump it into rooms of the house via a series of ducts. They work on the premise that air inside the roof space is drier (with lower humidity and warmer when the roof receives sunshine) than air inside the house.

The system in the Nelson house delivers roof space air into the living room and the bedrooms. The installation includes a recirculating function that takes some of the air from the living room, mixes it with the air extracted from the roof space and distributes the mixed air throughout the house. This function is promoted as assisting with moisture control and heating, but in this case, it was suspected that the system was part of the problem.

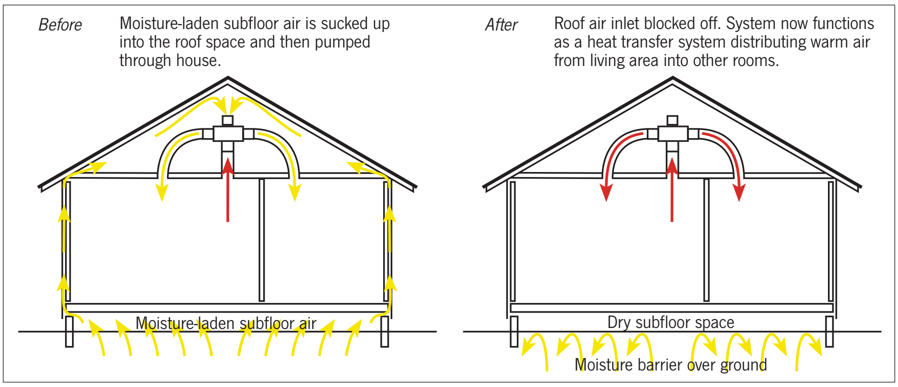
Air may continue to trickle into the house even when the roof space temperature is colder than the air inside the house, overloading the heating systems. In this home, the air delivered into the bedrooms was a chilly 6°C when measured mid-morning.

The new roof installation appeared to be a good tradesman-like job with no identifiable issues. The roofing underlay also appeared to have been installed correctly and, apart from being saturated in moisture, was in good condition.

Moisture from damp subfloor

Identifying the source of the moisture was the key to solving the problem. Although the homeowner initially thought that the new roof must be the cause, the main moisture source was coming from the damp subfloor space.

Figure 1: Moisture is clearly visible on the roofing underlay.



Before Moisture-laden subfloor air is sucked up into the roof space and then pumped through house.

After Roof air inlet blocked off. System now functions as a heat transfer system distributing warm air from living area into other rooms.

Figure 2: The problem and solution for the 1900s Nelson house.

Houses of this era were typically constructed from green (wet) native timbers. Standard practice was to drill holes in the bottom plates, top plates and any dwangs to allow air movement to dry out the timber framing once the house was closed in.

The roof space ventilation system was creating a negative pressure in the roof space. These systems can move large quantities of air, and in the Nelson house, some of the air drawn into the roof space to replace the air being pumped into the house was moisture-laden subfloor air, drawn up through the wall cavities.

Another likely contributor to the problem was that the roof access hatch is situated in the bathroom, allowing bathroom moisture to be drawn around the edges of the hatch cover into the roof space by the negative roof space pressures. This moisture-laden air was condensing on the cold surfaces of the roofing underlay and roof timbers (see Figure 1).

The quantity of moisture generated was overloading the capacity of the roofing underlay to absorb and hold the moisture as it is designed to do, so ice was forming on cold nights. The roof space ventilation system was also pumping the moisture-laden air into the house, increasing the moisture levels in the house and resulting in condensation and mould.

Several solutions identified

As a result of the findings, the owner was advised to:

- trial turning the roof space ventilation system off
- install a ground moisture barrier over the ground under the house
- consider installing a bathroom extractor fan ducted to the outside to remove bathroom moisture from inside the house
- treat and remove all mould from any interior surfaces.

When the roof space ventilation system was turned off, the moisture issues lessened and the ability to heat the house improved. The system installer suggested modifying the system to draw fresh air from outside the building envelope to stop the moisture issue. However this would not have helped with the problem of heating the house.

Ultimately, the homeowner had the system modified, blocking off the inlet from the roof space, and now runs it purely as a recirculation device that takes warm air from the living area and transfers it to cooler parts of the house (see Figure 2).

A ground moisture barrier has been installed under the living room with plans to extend it to under all areas of the home by next winter, and the underside of the floor has been insulated.

Since making these changes, the moisture problems have disappeared, the house is easier to heat and power bills have reverted back to around the level they previously were.

Not an isolated problem

Unfortunately, this is not an isolated case. Another house visited about the same time had similar problems. So much condensation was building up inside the house that water was running down the walls, double-glazed windows were covered in condensation, and objects stored in the roof space were dripping wet with condensation, even though the temperature in the roof space was 25°C at 3 pm on a sunny winter's day.

AGGRAVATED THERMAL BRIDGING

Recently, several cases of an insidious new form of thermal bridging have been seen. Aggravating factors have been identified that contributed to the problem, so there are now lessons to be learnt to avoid this on other buildings.

By Malcolm Cunningham, BRANZ Principal Scientist

Classical thermal bridging occurs when the building envelope is bridged by a high thermal conductivity rafter (see Figure 1). Figure 2 shows an infrared thermograph of a ceiling with thermal bridges at the joists identified as areas of lower surface temperatures.

Aggravated thermal bridging is more subtle than classical bridging because the bridging element is only in touch with the roof – it doesn't touch the ceiling as well (see Figure 3).

Several aggravating factors

The roof design of the institutional buildings in which aggravated thermal bridging has been identified is reasonably common. Condensation problems have not always been seen. However, condensation, sometimes quite heavy, has been observed on the steel element in the roof – in some cases, this has led to serious levels of corrosion. Several aggravating factors have been identified as contributing to the problem:

- Steel in direct contact with a low-temperature thermally conductive metal roof (usually with an intervening underlay that has no thermal benefit).
- High R-value (0.3–0.5 m^2°C/W) ceiling tiles – these thermally isolate the steel element from the warm interior, allowing the steel to approach the temperature of the cold roof cladding.
- Steel elements thermally isolated from a warm room – below the steel element and above the ceiling is an air gap or sometimes a timber packing that has sufficient R-value to further thermally isolate the steel from the warm occupied space.
- High internal moisture loads from 20–30 people in a relatively small space.
- Air-permeable ceiling allowing moist air to easily move into the roof cavity.
- Airtight metal roof cladding meaning there is little air movement through the roof.
- No purpose-designed ventilation with no ceiling, roof or ridge ventilators.

Individually, each of these factors will increase the chance of condensation; together, it is unsurprising that many of these roofs have significant condensation problems.

High vapour-resistant insulating layer needed

The usual way of dealing with thermal bridging is to provide a thermal break in the form of insulating material (timber, polystyrene and so on) placed on the top of the steel member (see an example on page 19). However, in many of these aggravated thermal bridging cases, this does not raise the temperature of the steel member sufficiently to avoid moisture condensing upon it.

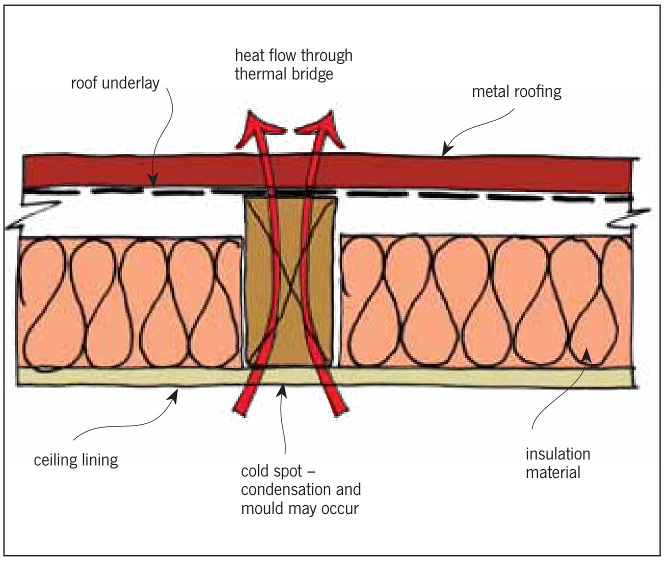


Figure 1: 'Classical' thermal bridging – a highly heat-conductive path is provided by a bridging element connecting the ceiling and roof.

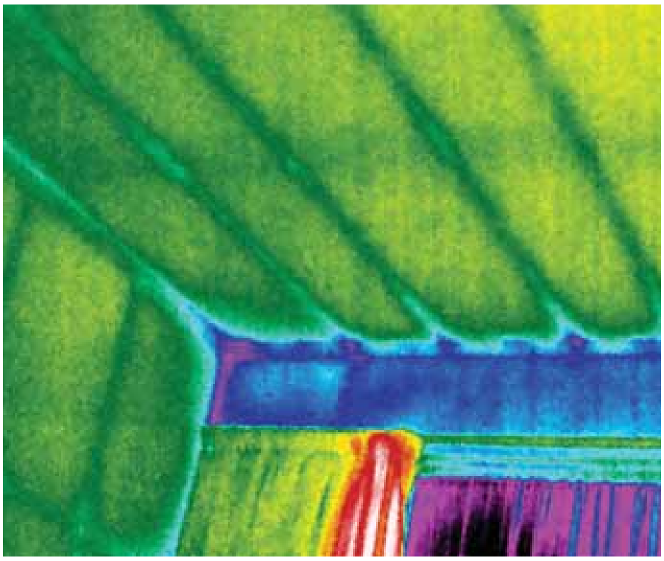


Figure 2: Thermograph of a ceiling showing cold bridges at the ceiling joists.

A solution is to use a high R-value, high-vapour resistant insulating layer, for example, polystyrene or phenolic insulating boards (see Figure 4 schematic). This provides a much higher level of overall roof R-value, resulting in significantly higher steel temperatures. The high vapour resistance is required, otherwise there will be very high levels of condensation in the underlay and under the now very cold metal roof, particularly because ventilation immediately under the roof is very low. ◀

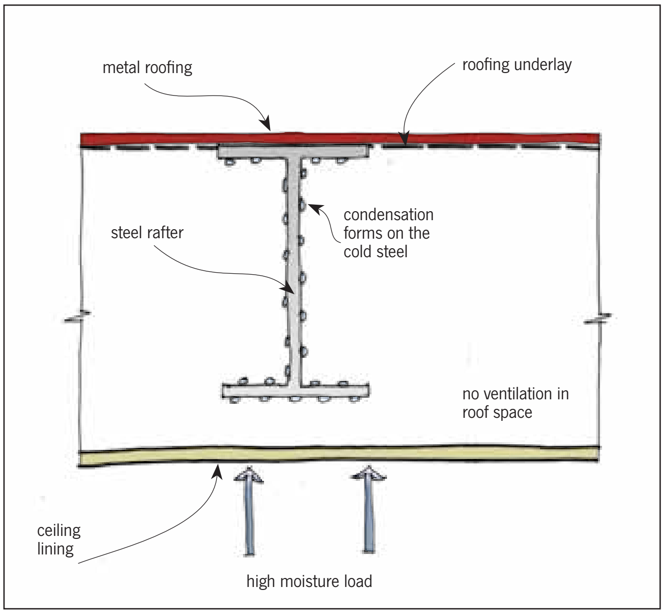


Figure 3: 'Aggravated' thermal bridging – the bridging element is in touch with the roof only.

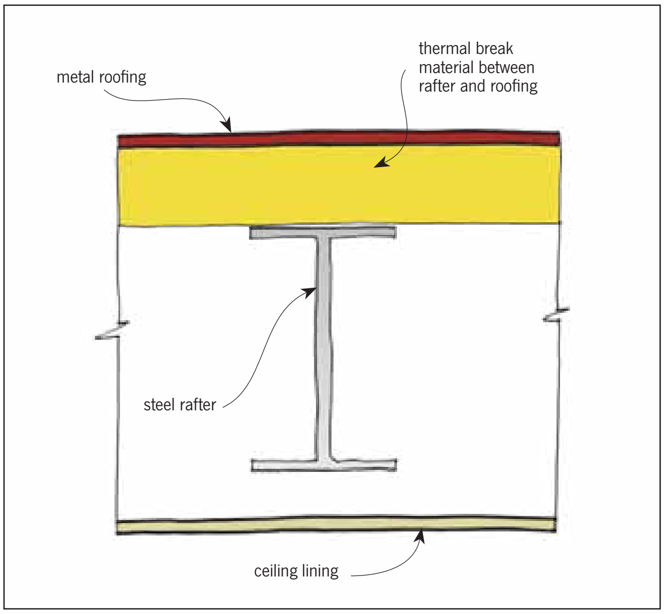


Figure 4: Avoiding aggravated thermal bridging (schematic only – structural, fire and acoustic issues must also be considered).