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FEATURE SECTION

Getting the drop on moisture

When nearly half of our homes have a problem with dampness, managing internal moisture is a major challenge. Investigations into how homes can be both warm and moisture-free are on-going.

In this section

How wet is too wet?

There are many ways to manage internal moisture in new builds or renovations, and it's not all down to the homeowner. Designers and builders have a role to play.

BY TREVOR PRINGLE, ANZIA, BRANZ PRINCIPAL WRITER

Internal moisture has resulted in damage to this window frame.

THE 2010 BRANZ House Condition Survey found that 40% of New Zealand homes had internal moisture problems. Many were cold and damp, with 10% considered very damp. The consequences of this are material deterioration, poor living environments and occupant health issues.

The basics of internal moisture

Homes where internal moisture is managed are likely to be:

- drier, warmer and healthier
- more durable
- much more comfortable to live in.

The amount of moisture in domestic buildings is influenced by:

- how much moisture remains in the building materials and finishes used when a new building is originally occupied
- the design of the building
- how the building is lived in once occupied.

Designer and builder can reduce moisture

While building practices during construction can significantly reduce the amount of moisture contained in materials at handover, it is commonly thought that the designer or builder has little impact on internal moisture levels once the building is finished and occupied.

However, as new homes become increasingly airtight, designers need to design in ventilation with a new build or renovation to reduce the potential impact of elevated internal moisture levels.

By eliminating moisture at the source, a large proportion of the moisture will be removed before issues arise. The balance can then be managed by ventilation, heating and insulation.

Start with the design

Many of the factors that can effectively moderate internal moisture are easy to incorporate into building design, and include:

- maximising insulation to ensure spaces are warmer and reducing the number of thermal bridges within the thermal envelope
- installing double-glazed windows so glass will be warmer, therefore there is less risk of condensation - specifying thermally broken metal joinery also means the frame will be warmer
- using the benefits of the sun by orienting living spaces and bigger glazing areas to the north and providing thermal mass - the easiest way is to expose the concrete floor to the sun

- designing in ventilation, for example incorporate passive ventilators into the windows – while these can be closed off by the occupants, the cost of installing them is small and they retain the security of the building when they are opened
- ensuring that extract systems of sufficient capacity for the situation are specified for spaces where moisture is generated
- isolating spaces where moisture is generated from other areas so that any moisture generated is contained and removed
- using bathroom extractors that are controlled by with a timer attached to the light switch or a humidistat – they will then only operate when needed and remove the risk of switched appliances not being used or left on for too long
- flueing or venting gas appliances that generate moisture to the outside
- making heating appliance selection part of the design rather than leaving it to the owner to sort out afterwards – adding thermostatic control is also recommended
- making the clothes dryer and the vent to the outside part of the building contract
- selecting materials and finishes for wet areas that are suitable for use within that environment
- carefully considering and identifying the consequences to the building owners of design features that can add moisture, such as fish tanks and spas.

Builders also have role

On site, the future risk of condensation will be reduced where:

- materials are allowed to dry fully before the building is occupied, for example, there is 120 litres of water in each cubic metre of concrete that is not required for hydration and that evaporates from the concrete – under good drying conditions, a 100 mm thick concrete slab will take at least 4 months to dry
- insulation is properly installed with no gaps or folds, which create thermal weak spots.

Mould on colder surfaces indicates a problem.

For renovations

Where an existing timber board floor is retained, ensure that moisture is not migrating from the subfloor through the flooring into the spaces above. Options to minimise the risk include increasing subfloor ventilation and adding an impermeable ground cover.

Ensure ventilation, such as extracts or passive vents, are added where existing older air leaky buildings are made more airtight – typically by adding sheet linings to walls and ceiling.

Also insulate all existing external walls, whether being altered or not.

Design tools and education

BRANZ's ALF 3.2 is an online tool that allows both the energy performance and the potential risk of high internal moisture and the consequential mould growth to be calculated at design stage.

Educate owners

Designers or builder can also work with clients to explain the basic principles of moisture management in the home and how they might manage the generation of moisture. The key principles to be explained are based around the need to:

- eliminate the source of the moisture – such as not drying clothes indoors
- manage at source through the use of extract ventilation
- ventilate by opening windows, passive ventilators or mechanical ventilation systems
- heat by incorporating continuous rather than spasmodic heating as an integral part of the design
- insulate by maximising, where possible, to retain heat within the building.

Other key points that owners need to be aware of are:

- to actively use the passive or active ventilation features provided
- how their activities will influence the amount of moisture that needs to be removed
- the warning signs that moisture is not being controlled such as condensation and mould
- the fact that renovated houses are more airtight once work is complete so ventilation should be provided
- that thermal mass such as concrete floors should not be covered by carpet, cork or timber overlay floors, but that tiles, stone and slate finishes are OK
- that a reasonable standard of continuous heating in the 18–24°C range is more effective at controlling indoor moisture than intermittent heating.

Do walls actually breathe?

It is common to hear that walls need to breathe to control moisture and that filling stud cavities with insulation might hinder the passage of air and moisture inside the wall. Is this right?

BY MARK BASSETT, BRANZ PRINCIPAL SCIENTIST

IN THE EARLY DAYS of New Zealand house building, it was common to drill holes through top and bottom plates to allow air movement.

Now the concern is that air flowing through these holes could transport moisture from the subfloor into the roof space and maybe the holes would compromise the thermal insulation performance.

This raises the question: what role does airflow in wall cavities play in the overall moisture balance of the wall and does it affect insulation performance?

Ventilated wall cavities aid drying

The widespread use of ventilated wall cavities in the wake of the leaky building crisis reintroduced ventilation drying behind claddings to deal with water leakage through claddings.

BRANZ helped develop the science behind how cavities work, with field studies in ventilation and drying rates using tracer gas methods. It established an engineering basis for cavity design, and this has incidentally provided the tools to delve deeper into walls.

It is now possible to find out if there are circumstances where moisture from living spaces could accumulate in the insulated spaces. Currently, there is little evidence of this problem in New Zealand, but new insulation and underlay materials are available with a wider range of air and vapour tightness characteristics, and BRANZ considers it prudent to re-evaluate this particular risk.

Airflow paths within walls

The range of possible airflows inside of walls is shown in Figure 1. All but flow path J are small cracks between materials nailed or screwed together and are an incidental consequence of the way in which buildings are put together. Importantly, though, these ventilation paths play a big part in managing water leaks through claddings. Those marked in blue are less well understood but

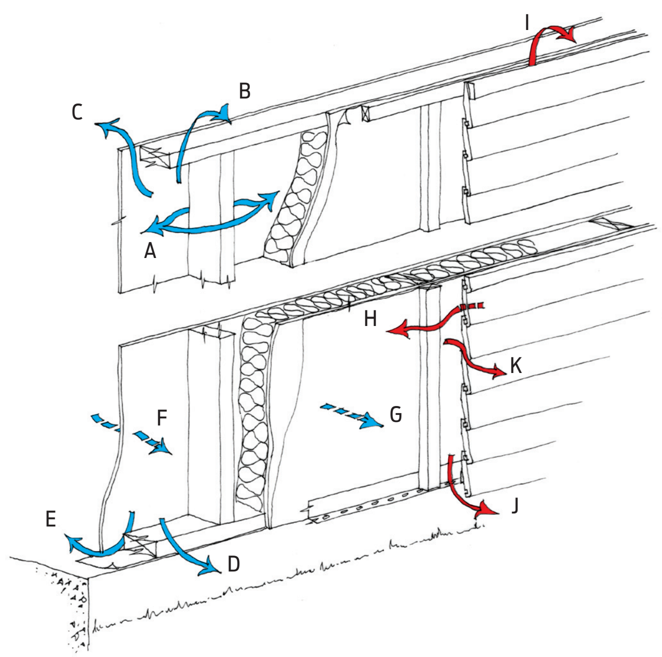

Figure 1: Range of possible airflows inside walls.

are certain to play a part in moisture entering and leaving the insulated cavity.

By measuring the airtightness of the insulated cavities in the BRANZ weathertightness test house, it has been possible to understand the flow paths shown in blue (paths A to G) and estimate the ventilation rate - the total amount of air flowing through the volume - in the insulated space. A series of day-averaged ventilation rates were calculated using the airtightness results and compared with ventilation rates measured directly with tracer gases.

The reasonable agreement between measured and calculated ventilation (see Figure 2) gives us the confidence to see if there are circumstances where indoor moisture might accumulate as condensation in the insulation or elsewhere in the wall.

Cavities greatly improve ventilation

For comparison, ventilation rates measured behind claddings (with and without cavities) are shown in Figure 3 as bars representing several hundred day average measurements in the BRANZ experimental building. These ventilation rates are a result of airflows through paths H, I, J and K, shown in red.

It might be surprising that there is such a large difference - up to 1,000 to 1 - between ventilation rates in cavities with engineered ventilation openings, for example, brick veneer cavities, and in the spaces behind monolithic or large sheet claddings with no engineered provision for ventilation.

That, and the difference in drainage capability, explains the different tolerances to rainwater leakage of walls. However, it raises the question of the influence air movement has on the ability of walls to deal with damp air from inside the building. It's early days, but the following is clear from ventilation measurements in the insulated cavities:

- From an energy perspective, the airflow in the insulated cavity represents, at most, a few percent of the heat flow through a wall with R=2 m^2C/W insulation and is therefore not that significant with current minimum insulation requirements.
- From a moisture perspective, moisture carried by ventilation can be at least as significant as moisture diffused through wall linings. This means that moisture carried by the air has to be understood and included in any moisture-related prediction.

What about vapour and air barriers?

Internationally, there is considerable discussion around how, and where, vapour and air barriers should be used to control moisture entering walls in airflow or by vapour diffusion.

One thing is clear, however. There are downsides to the unnecessary application of moisture barriers - they can clamp down on useful drying paths in walls. It will be interesting to see if further research finds an argument to refine recommendations for using vapour control layers in New Zealand house construction.

The current recommendation is to leave them out except in rooms with a high internal moisture load like a spa or swimming pool, or where the building is located in an alpine area.

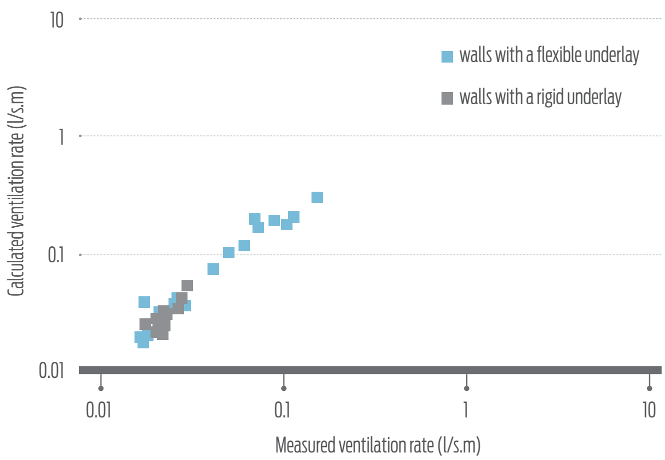

Figure 2: Measured and calculated ventilation rates inside insulated cavities in the BRANZ test building. The units are litres of air/sec/m of wall.

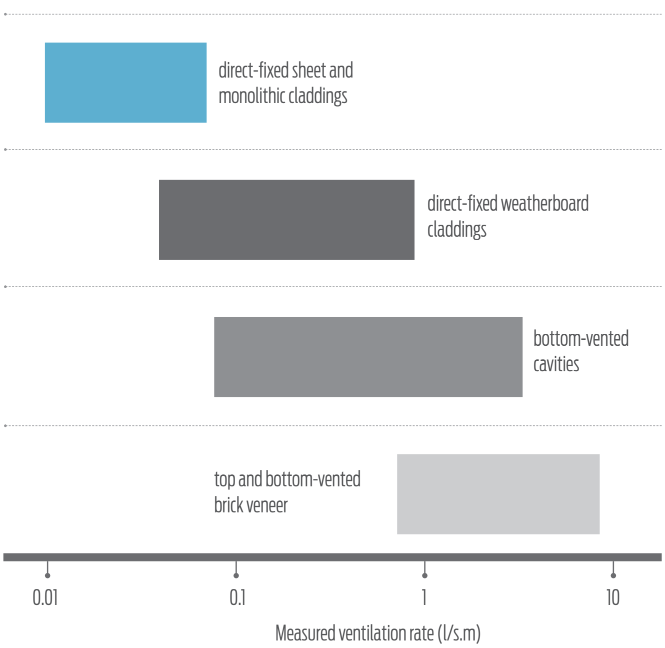

Figure 3: Ventilation rates measured in the space between cladding and wall underlay.

Moisture balance

How much ventilation, heating and insulation is required to avoid condensation and mould? The new moisture tab in BRANZ's online energy calculator, ALF 3.2, has the answers, but how does it work?

BY MALCOLM CUNNINGHAM, BRANZ PRINCIPAL SCIENTIST

THERE IS A LOT OF SCIENCE behind the moisture tab on ALF 3.2, but it is possible to see it in action in the nomogram graphical design tool in Figure 1, one of several used in forming ALF 3.2.

Working through example

As an example, take a room in a house in the North Island, south of Auckland but not in the Volcanic Plateau. The example room has:

- a heating level of 350 W
- an insulation value expressible by a UA value of 58 W/°C (a UA value is calculated from the building dimensions and the R-value of the building envelope)
- the thermal bridges described by an R-value of 0.8 m^3°C/W.

From this, we can calculate the required level of ventilation to avoid condensation and mould growth.

The Figure 1 nomogram has four quadrants. Follow the red line marked OPQRS to see the nomogram in use.

- Insulation - start with the first quadrant and enter the axis at point O, the UA value, which is 58 W/°C in our case.
- Heating levels - draw the line across to the heating curves in the first quadrant, 350 W in this example, point P.
- Thermal bridging - then draw the line from P up the thermal bridge curves in the second quadrant to Q, 0.8 m^2°C/W for this case.
- Location - draw the line across to the third quadrant, the North Island, south of Auckland and not in the Volcanic Plateau, point R.
- Finally, calculate the ventilation required in the room to avoid condensation and mould growth by drawing the line vertically downwards to the curve in the fourth quadrant, point S, and then across to point T to read the required ventilation, i.e. 14 m^3/hour. If the volume of the room is known, this can be converted to an air change per hour (ach) if required.

Understanding the relationships

The graph can be used to improve intuition on how different factors change the required ventilation to prevent condensation and mould.

For example, as you increase the room R-value, by moving point O upwards and keeping point Q on the correct heating curve, you will need less ventilation. Decreasing the R-value of the thermal bridge by moving point Q down will require more ventilation, and moving to a warmer location by moving point R horizontally will lessen the required ventilation.

ALF 3.2 is based on these nomograms, but also includes the number of occupants in the room, the house shading and other factors.

For more To use ALF 3.2, go to www.branz.co.nz/alf. The moisture tab is in beta testing, so please report any problems.

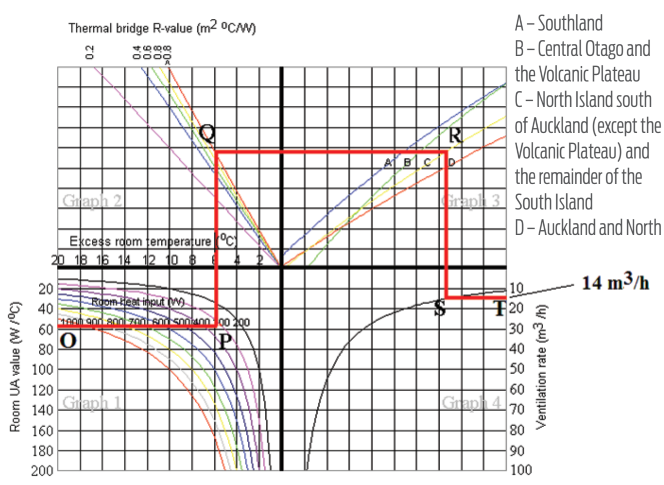

Figure 1: Nomogram for calculating the ventilation levels required to prevent condensation and mould growth (illustrative only).

Retrofitting paperless walls

BRANZ is often asked whether adding insulation to walls built without building paper changes the moisture performance of the wall in any way. A research project is providing some answers.

BY MARK BASSETT, BRANZ PRINCIPAL SCIENTIST

THE BRANZ PROJECT considered whether adding bulk insulation into a stud cavity without building paper changed the passage of a water leak and found that moisture performance does change with the addition of insulation.

No underlay, no drainage path

Six timber-clad walls without building paper were built, and a water leak was introduced high on the wall. The claddings were rusticated radiata pine weatherboards, cedar bevel-back weatherboards and a sheet of exterior plywood. Water was pumped through the leak onto the back of each wall, with a little dye to track its progress.

The insulation was taken out and weighed after each drainage trial, and any water reaching the lining was weighed. Some water was retained in the frame.

The most important observation is that water takes a random path in walls with direct-fixed claddings and no underlay. Unlike a cavity wall where the drainage and ventilation drying paths are engineered and predictable, these walls were not designed to manage water leakage even though they have been used successfully in low-risk applications.

Substitutes for underlay trialled

Another question we asked was: what does it take to keep insulation and framing dry? To find the answer, 60 drainage trials were run in various combinations of cladding type, insulation type and treatment to keep water from the insulation (see below).

Two substitutes for the missing building paper were trialled. One followed the recommendation in NZS 4246:2006 *Energy efficiency - Installing insulation in residential buildings* and fitted a pan of synthetic wall underlay into the stud cavity. The wall underlay was either a traditional smooth synthetic wall wrap or one with a crinkled appearance to promote drainage between the underlay and cladding.

In the other approach, a drainage mat was fitted between the insulation and cladding and between horizontal framing and the insulation - covering the top and bottom

Drainage trials materials and methods

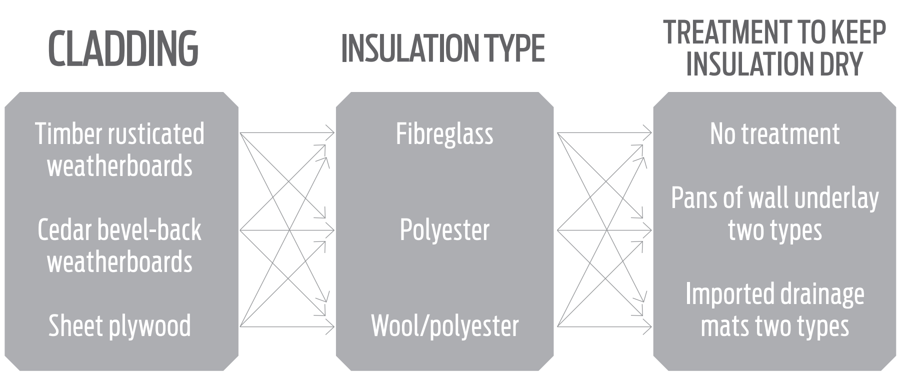

plate and dwangs. These products (see Figure 1) were sourced from the US where they were originally designed to create a drainage path behind stucco plaster and other claddings.

Several conclusions from drainage trials

The cladding has an important influence on where the water goes. While more water was trapped inside the walls when insulation was added, the actual quantity retained in the wall depended markedly on the cladding type.

It has often been noticed in the BRANZ laboratory that weatherboard walls drain water back outside through lap joints or at the bottom plate - particularly bevel-back profiles - while others - cedar cladding in this case - absorb and hold water inside the wall. Both mechanisms reduce the quantity of water reaching the frame and the insulation.

Importantly, pans of wall underlay and drainage mats help keep the insulation dry. Adding insulation on its own trapped water inside the insulation where it would cause problems over time, but fitting pans of underlay or one of the drainage mats kept the insulation reasonably dry. This is the most statistically significant conclusion from the project and one that supports the practice adopted in NZS 4246. Overall, the pans of underlay and drainage mats reduced the quantity of water retained in the insulation from 40% to 4%.

There are differences between the two pans of underlay and drainage mats (see Figure 2), but because the results depend on cladding type, they are not so important.

Pans of underlay or drainage mats?

After finding ways to minimise the water reaching insulation, we are now looking at whether there are any differences between pans of underlay and drainage mats and the rate at which the walls dry out over time.

We mounted the six walls in our experimental building and are now measuring drying rates on the back of the cladding. Although the trials are incomplete, early indications are that the walls with natural ventilation paths between weatherboards dry a little faster than the walls with a sheet cladding. However, it's too early to say whether drainage mats help more than pans of underlay.

North-facing walls dry faster

As expected, the temperature of the cladding has a big influence on drying, with walls on the north drying more quickly than those on the south side. In fact, drying rates on the backs of south-facing claddings - including those on a cavity - slow almost to a stop in winter and start drying again in the spring.

A partial answer

Adding a pan of wall underlay or some other product, such as a drainage mat, helps keep the insulation away from a water leak and lessens the risk of moisture trapped long term in the insulation, but it does not endow the wall with the water management capabilities of a continuous underlay or a cavity.

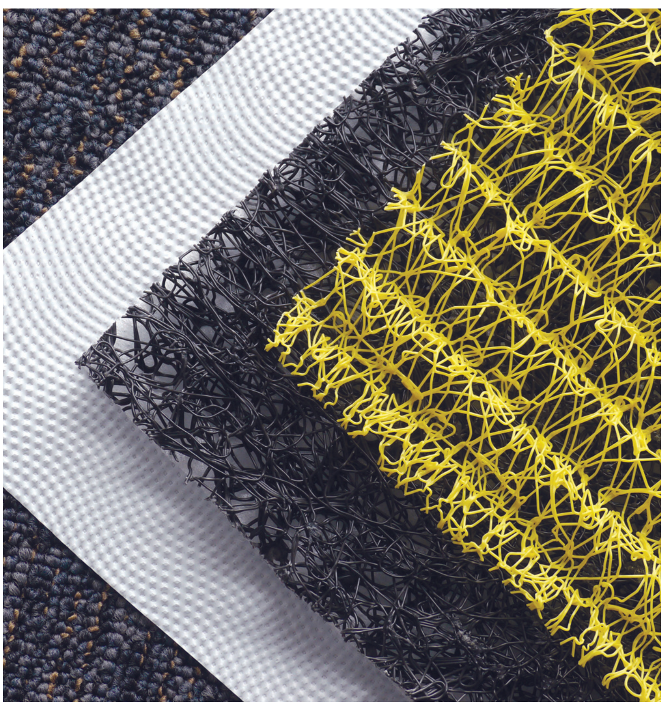

Figure 1: Wall underlay materials and drainage products from the US.

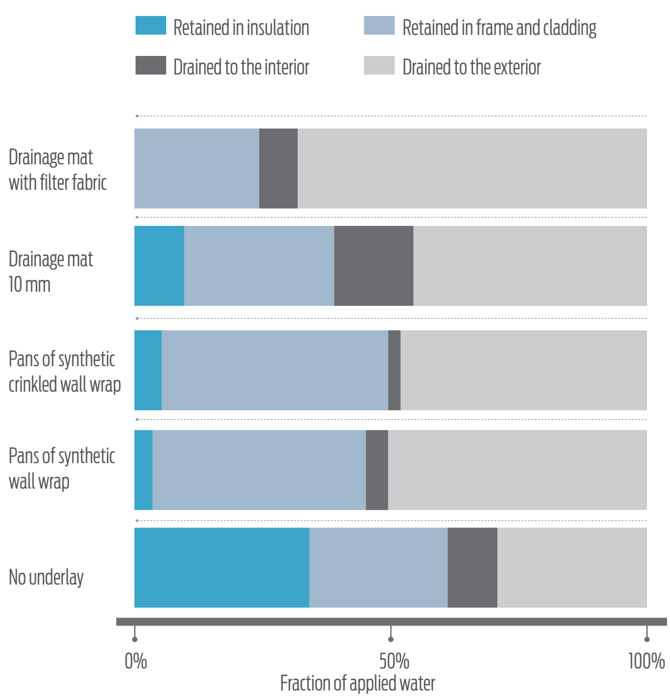

Figure 2: Results of drainage trials averaged over three cladding types.

Indoor pool challenge

There have been some spectacular failures from indoor heated swimming pools with condensation in the walls and roof, mould growth, saturated decaying timber and severe corrosion of steel. Quite different construction is needed to avoid this.

BY STEVE ALEXANDER, DIRECTOR, ALEXANDER & CO, AUCKLAND

INDOOR HEATED SWIMMING POOLS provide unique challenges. Usually, the main challenge of the building enclosure is to keep the water out. However, with indoor heated swimming pools, it's necessary to keep both exterior water out and interior water in.

Incorrect design can result in severe damage. Water vapour inside the building may migrate through the wall assembly until it finds a cold surface. These problems can be addressed by building wall and roof assemblies with methods that are unfamiliar to many in New Zealand.

Vapour barrier and insulation needed

The key to success is having an appropriate vapour barrier and sufficient insulation located in the correct position within both the roof and wall assembly.

Interior air temperature needs to be controlled and maintained at a higher temperature to the pool water to conserve energy, avoid condensation on internal surfaces and excessive humidity, which will be uncomfortable for non-swimming building occupants.

Opening windows are undesirable - random opening of windows will prevent accurate temperature control - so a mechanical ventilation system is required. This also provides a net positive pressure on the inside, preventing the migration of cold external air into the building.

However, the consequence of a net positive internal air pressure is that very humid warm air will migrate into the wall and roof assembly if there is not an effective and continuous vapour barrier present. If the warm, humid air does escape into the wall and roof assembly, it will find a cold surface where condensation will occur, and this can cause saturation of all materials in the wall or roof.

The right balance is crucial

When designing an indoor heated swimming pool, identify the interior conditions and user experience required. This includes the desired water and air temperatures and the on-going budget for maintaining those temperatures. This must be compared with the outside air temperatures throughout an entire year.

Getting the balance wrong can have unintended consequences, such as high water loss from the pool due to excessive evaporation. This will increase water consumption and heating costs.

Temperature ranges for pools vary according to the use, but air temperatures should always be slightly higher. For leisure pools, 27°C is a common pool temperature, with interior air in the 28-30°C range.

Wall and roof details

Appropriate wall and roof assemblies are shown in Figures 1 and 2. In a hot and humid environment with forced mechanical ventilation, the vapour barrier must be continuous across the entire enclosure and should not be penetrated by services. Unavoidable penetrations should be planned and thoroughly sealed to prevent air escaping.

The continuity of the vapour barrier between the roof and the wall is particularly important. This is a challenging location where designers and builders are most likely to fail.

The most reliable location for a continuous vapour barrier is usually on the outside of a rigid air barrier located on the outside of the framing. This location receives the least number of penetrations for building services and allows the easiest continuity at the wall to roof intersection.

The vapour barrier must be located on the warm side of the wall assembly, meaning that the insulation needs to be on the outside of the framing, not between the framing as is traditional. If the insulation is outside of the vapour barrier, there will be no rapid transition from outside cold to inside warm to attract condensation, and the inside of the vapour barrier will not be cold enough to cause condensation of internal vapour.

This method requires a wide rainscreen carrier to provide space for insulation and a drainage gap behind the cladding. Fixing points for the carrier system need to be minimised to reduce the number of thermal bridges that penetrate the insulating layer. It is also helpful for fixings to be on an insulated pad to minimise thermal bridging.

The roof detail in Figure 1 has purlins supported on specially made brackets. If purlins are fixed directly to the rafter below, they will provide a large thermal bridge for heat loss. There is also a high risk of creating unsealed holes in the barrier from skew nailing purlins though the vapour barrier. The bracket allows better continuity of insulation, a smaller area of thermal bridge and specific, disciplined fixing placement.

Consider the windows

Windows also need careful consideration. Single glazing is unsuitable as it would allow extensive energy loss and a high level of condensation, resulting in mould or algae growth on the inside.

The vapour barrier must be sealed to every window so there is no air escape at the wall to window connection (see Figure 2).

Using thermally broken aluminium window frames reduces the risk of condensation forming on the window frame within the wall assembly where it will remain undetected and, if the window frame is not wrapped thoroughly, the adjacent framing will become wet.

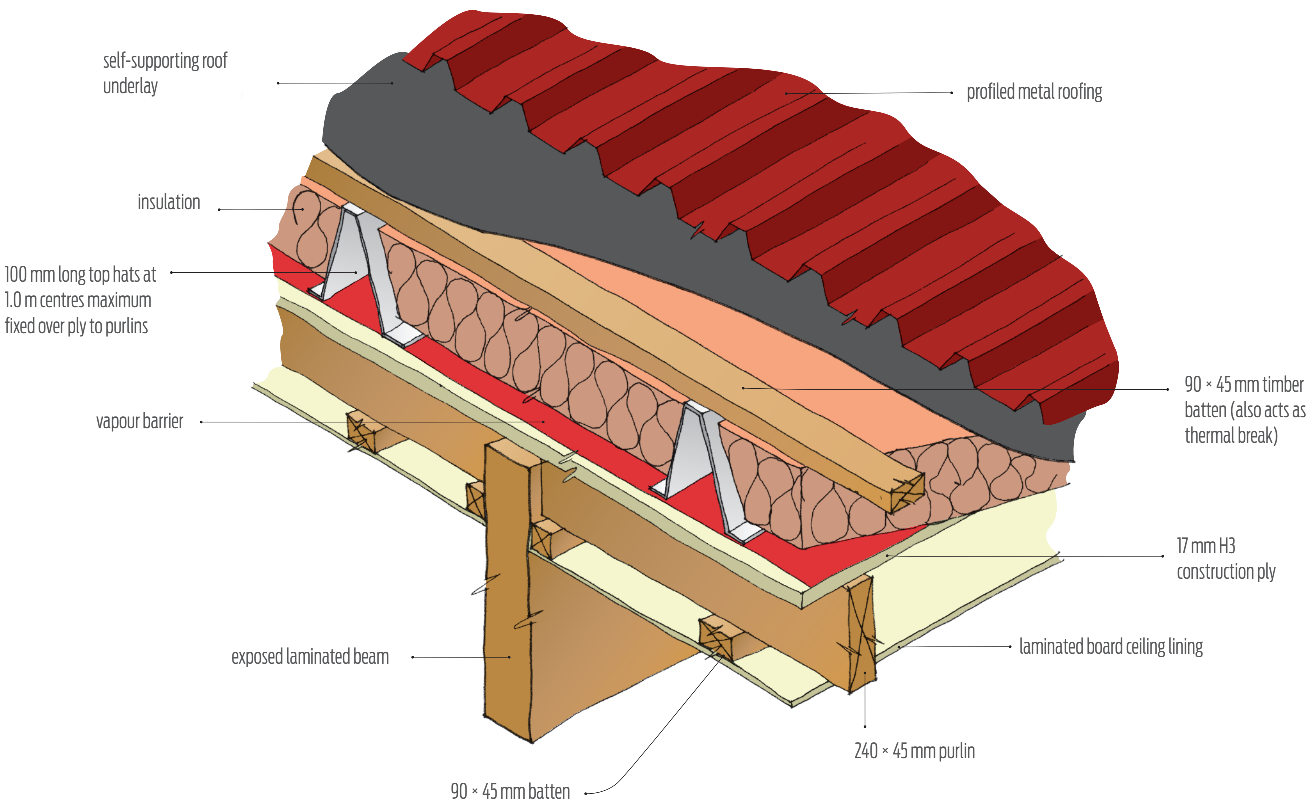

Figure 1: Roof detail.

Interior walls

The temperature and humidity in the pool room and facilities opening into it may be higher than the adjacent habitable spaces. Specific calculations will need to be carried out to determine the temperature and vapour pressure differences and whether a vapour barrier is needed.

However, when designing interior walls, note that the demands on them equate to exterior conditions - water splash creates wet conditions, and cleaning is often performed with a hose and broom.

Common overseas in colder climates

While this type of wall assembly is not common in New Zealand, it is common all around the world in colder climates. By placing a hot pool inside a building in the colder areas of New Zealand, we are effectively inducing the conditions that exist in climates much colder than New Zealand.

Existing pools can be checked

The performance of existing pool structures can be assessed by installing dataloggers in the wall and roof assemblies and measuring weather conditions outside to provide actual data about the difference between internal and external conditions in all seasons.

Why things go wrong

The design of these buildings requires a multi-disciplinary approach with cooperation between numerous parties and a willingness of clients and territorial authorities to embrace methods of construction that are not common in New Zealand.

Failures can arise from:

- insufficient understanding of the requirements for vapour barriers
- inadequacy of insulation
- conflict of priorities in a multi-disciplinary team.

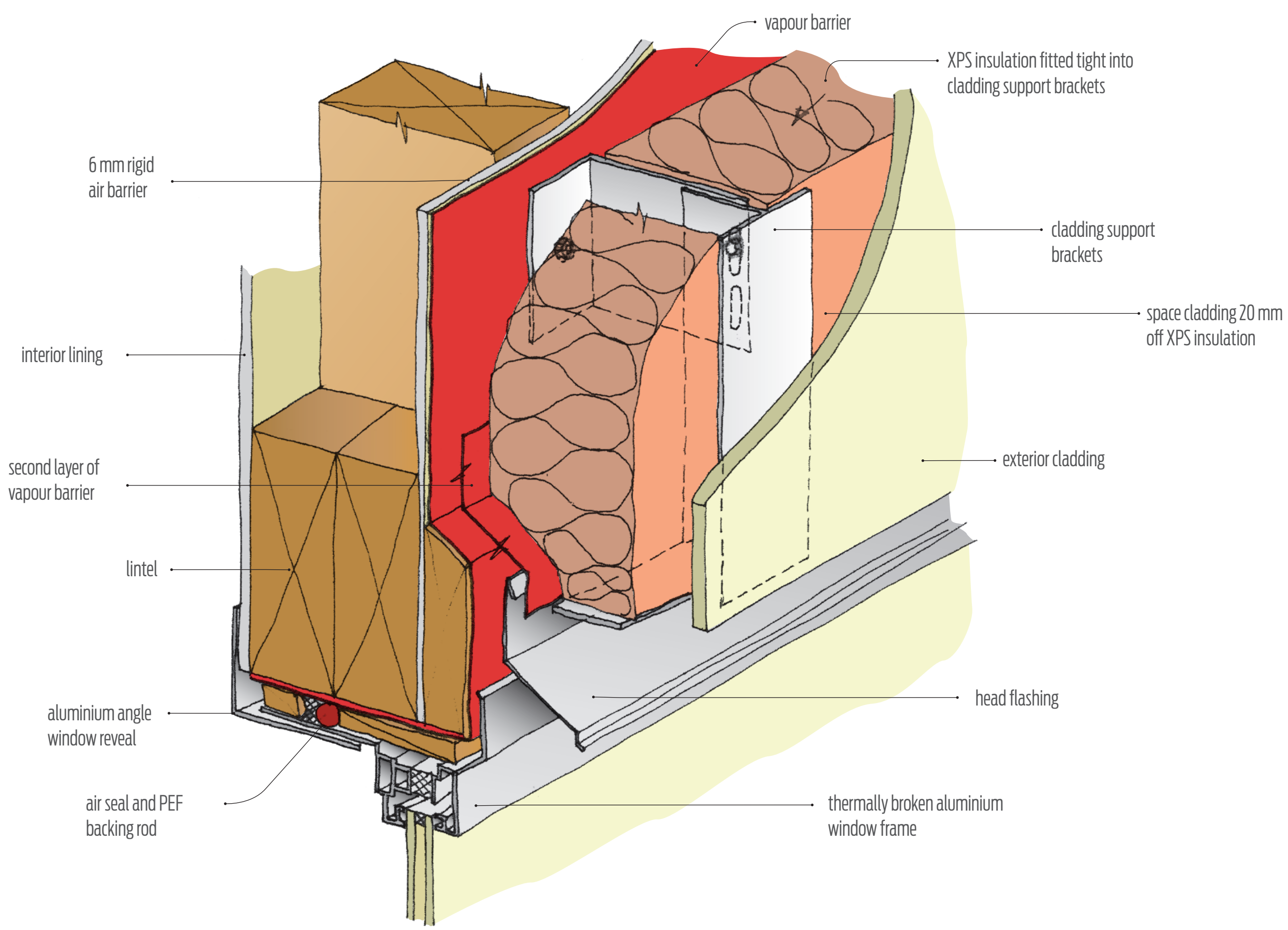

Figure 2: Window head detail.