ENVIRONMENT DESIGN GUIDE

THERMAL MASS AND INSULATION FOR TEMPERATE CLIMATES

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Abstract

Insulation and thermal mass are highly effective ways to reduce energy use and improve comfort in buildings. Insulation reduces the rate or speed of heat transfer through a building façade while thermal mass stores heat and thus creates a lag between internal and external temperatures.

Used correctly, both are instrumental in stabilising internal temperatures, isolating internal temperatures from outside and decreasing heating and cooling requirements.

Used incorrectly, both can at best be ineffective and at worst reduce comfort or pose significant safety risks.

This South Australian passive house benefits from a well insulated and tightly sealed building envelope and strategically placed rock walls for thermal mass. (Image: Judy Celmins)

INTRODUCTION

There is still a lot of confusion in the design professions about the difference between insulation and thermal mass. This paper will give a plain explanation of thermal mass and insulation, including the use of examples to give a practical feel for the difference between the two.

We will give an explanation of different products and their pros, cons and applications; and practical advice on the effective use of materials, including 'don'ts' and common misconceptions. We will also provide installation and specification guidelines, and advice on how to correctly balance thermal mass and insulation with other building features such as glazing and orientation.

This paper focuses on temperate regions of Australia, as these have climates which are characterised by significant annual temperature ranges and diurnal shifts, allowing thermal mass to be deployed effectively.

THERMAL MASS AND INSULATION

Thermal mass and insulation work together to slow the rate of heat transfer in and out of a building. Installed effectively, they keep the building cool in summer and warm in winter, which means less heating and cooling is needed and occupant comfort is improved.

A proper understanding of both thermal mass and insulation is essential if they are to be used effectively. The incorrect use of thermal mass can create unintended comfort problems, while poor installation of insulation, or excessive insulation without due consideration to other building factors such as glazing, will waste money, energy, materials and effort.

Fundamentals of Heat Transfer

Thermal mass and insulation affect heat transfer (e.g. between the inside and outside of a building). To understand how they work, we must first understand the fundamental principles of heat transfer:

- Heat doesn't discriminate – it always wants everything to be at the same temperature. Therefore,
- Heat will always move while there is a temperature difference on either side

The coffee you left on your desk will eventually settle at the same temperature as the air in your office (but the air will warm ever so slightly from the coffee!)

- Heat will always move from the warm side to the cold side

When you put a warm beer into the fridge, the heat moves out from the beer and into the fridge; it's not 'coolth' moving from the fridge into the beer. There is no such things as 'coolth', although the word can be useful for explaining heat movement.

- Heat is lazy and will always take the path of least resistance

If you put your beer into a stubby holder, more heat will escape through the bottle opening, however the overall level of heat transfer is still reduced.

- We can control how fast heat moves but not stop it completely

How They Work

Insulation and thermal mass both slow the rate at which heat enters and leaves a building. They are useful in stabilising internal temperatures, reducing heating and cooling requirements and improving comfort.

Insulation forms a resistive layer which heat can only move through slowly.

A stubby holder provides insulation for the beer inside – you can hold the beer without feeling the cold on your hand and the beer will stay colder for longer. Eventually, though, the beer, the stubby holder and the surrounding air will all equalise at the same temperature.

Insulation's effectiveness is measured by its resistance (R Value): how much resistance it presents to heat transfer (the more resistance, the higher the R Value, the better the insulator). Good insulators include foam, wool and air; poor insulators include glass, metal, earth and concrete.

Thermal mass stores heat. As heat moves from the hot side to the cold side, it gets absorbed and stored into the mass. This causes a lag between internal and external temperatures and thus the internal temperatures are stabilised. As the surrounding air cools down, the heat stored within the mass is released.

On a summer's morning, a brick wall will feel cool. Throughout the day it will absorb heat and then in the evening, if you put your hand up to the brick, you will feel the heat radiating from it as the stored heat is released back into the cooler air.

Thermal mass's effectiveness is measured by its heat capacity (Cp): how much heat energy it takes to change the material's temperature (the more energy, the higher the Cp and the better the thermal mass). The heat used to change its temperature is 'stored' within the material. Thermally massive materials include concrete, mudbrick and water; materials with poor thermal mass properties include wood, air and wool.

Notice that many good insulators have poor thermal mass properties and vice versa.

How They Differ

Both thermal mass and insulation reduce the impact of external temperatures on internal temperatures.

Insulation does this by slowing the rate of heat transfer between the two.

Thermal mass does this by absorbing and storing the heat that would otherwise be transferred between the two.

Most thermal mass has low resistance (R Value), hence absorbs heat quickly – and absorbs a lot of it. This means that it takes a long time, and a lot of energy, to change the temperature of a massive structure. In practice, this means that a thermally massive building will maintain a fixed temperature inside. However, if you try to change that temperature from the inside, e.g. by using a heating element in winter, that heat will continue to be absorbed into the mass and, if there is no insulation to slow it from moving through the mass, will be released into the cool air outside. You will end up using a lot of energy to change the temperature of the room. (This is partly why a fire in a cave won't keep you very warm – all the heat will be absorbed into the cave walls).

Thermal mass is not a substitute for insulation, but together they can achieve an energy efficient and comfortable building.

USING THERMAL MASS

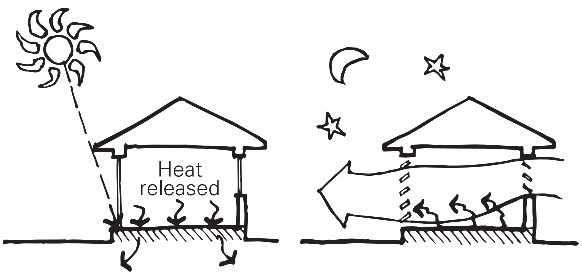
Thermal mass will absorb heat – the key to good building design is to control where that heat comes from.

- Desirable source of heat: the sun! (in winter)
- Less desirable source of heat: the room's heating system

Thermal mass will also release heat. In winter this heat is needed inside; in summer: outside.

In summer, thermal mass will absorb heat from within the room, keeping it cool. Of course, it will also absorb heat from the hot air outside – the external surface must therefore be insulated to prevent this. In the evening, this heat will be re-radiated to the cooler side of the wall – this may often be inside. (You may notice that in a brick house on a summer's day, the internal temperature continues to rise even after the sun has gone down.)

In summer, it is vital to be able to remove the heat being released by the thermal mass overnight. This needs to be done with cool air, which can be a problem if the outside temperature does not drop. This is why



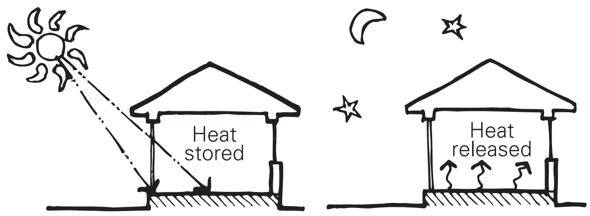
Thermal mass in summer (Image: Your Home Technical Manual, ed. 4, 2008)

thermal mass is not appropriate for tropical climates.

In winter, thermal mass works where it can absorb heat generated by the sun. The sun enters the room through windows and heats the surfaces it falls on, as well as the air in the room. Sunlight is actually solar radiation: when this radiation hits an object, it energises the particles and increases their temperature, sometimes even changing their state (e.g. a griller produces radiation that melts the cheese on your toast). The radiation hitting a concrete floor is absorbed by the particles of concrete and their temperature increases. Once the temperature of the concrete is higher than the air around it, the heat wants to move again and is released as radiation.

Consider a car on a winter's day: even though the air outside is cold, the sun enters a car through the windows and heats the air inside. The dashboard and seats will also become warm as they too absorb the radiation.

The colour of a surface significantly impacts its ability to absorb heat. Dark, matt & textured thermal mass surfaces absorb more heat than light, reflective surfaces. (Note, though, that Mythbusters debunked the "a black car gets hotter than a white car" theory: this is because only a small proportion of the total heat entering the car comes through the body of the car (the body itself is a sealed air cavity so well insulated). Most of the heat in the car comes from the sun entering through the windows. It would be interesting to see the results of testing the same coloured car with a dark interior and a light interior.)



Thermal mass in winter (image: Your Home Technical Manual, ed. 4, 2008)

In winter, it is vital to insulate the exposed external sides of thermal mass to prevent heat from being absorbed inside the building and released outside (remember that mass usually has a low R Value and hence will transfer heat quickly). See the sections on Insulation and on Thermal Bridging, below.

Climate

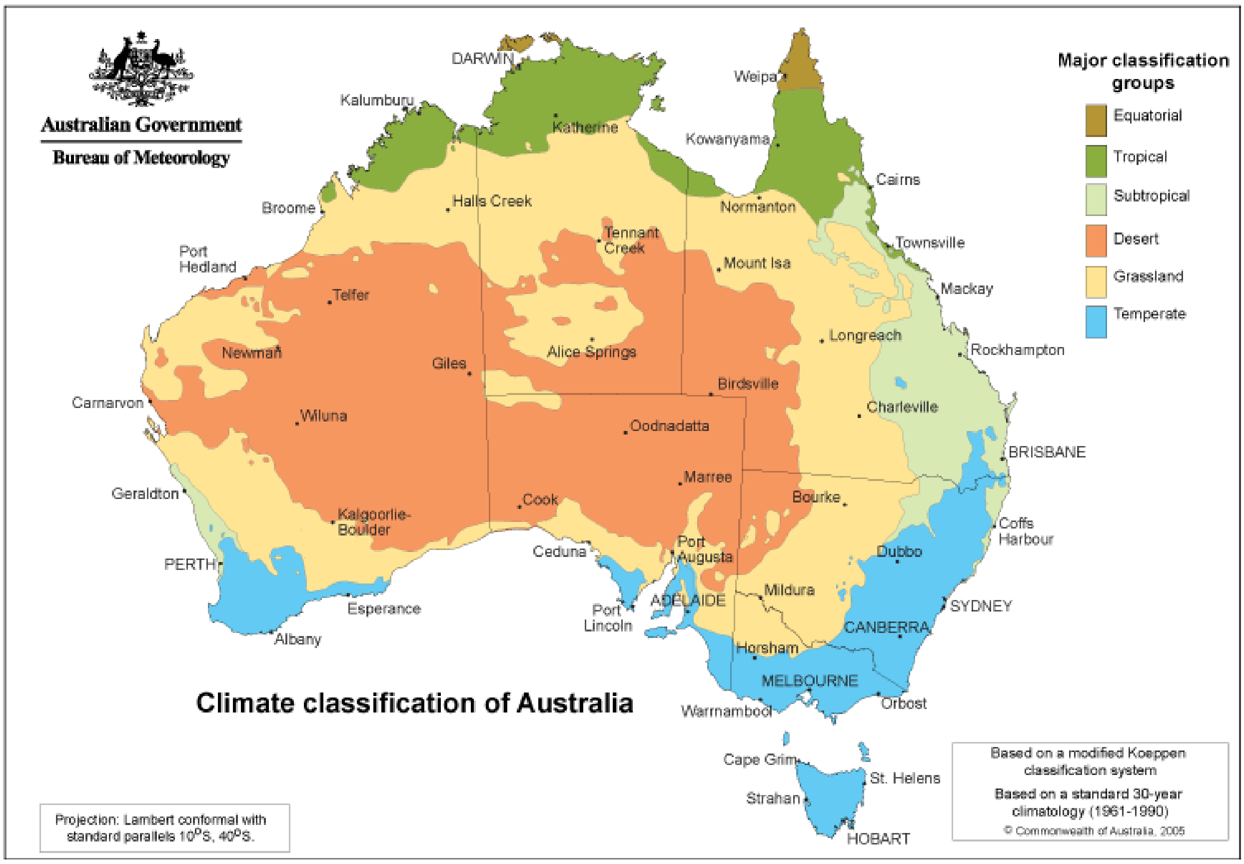
Thermal mass works best where there is a high diurnal range (daytime to nighttime temperature difference). This includes most of southern Australia, alpine areas and dry inland areas. It is not suitable for hot tropical climates.

This paper focuses on temperate climates as shown below:

Comfort

Australia's temperate climate zones experience cool winters and warm to hot summers. Incorrectly placed, thermal mass in these climate zones will create comfort issues for occupants.

One of the main properties of thermal mass and building surfaces is radiant temperature. Radiant temperature is the single biggest factor in determining comfort, the others being air temperature, humidity and air flow.



Australian climate map (Source: Bureau of Meteorology)

Some examples of radiant comfort (or lack of) include:

- Sitting by the window in a restaurant. The cold glass will radiate 'coolth' (i.e. absorb heat from the room and the person), making the person sitting by the window feel cold even though the restaurant is heated.
- Entering an old church on a hot day. Even though the inside air temperature is close to the outside air temperature, it is pleasantly cool inside, as the stone walls and floors are cold. For the same reason, the church will feel cold in winter, even with heaters warming the air.
- Sitting in the sun on a winter's day – even though the air is cold, the sun's radiance makes you feel warm.

Thermal mass will settle at the average room temperature, usually at around 14 to 21°C depending on the season. This is comparatively cool compared to summer air and warm compared to winter air, but cold compared to the human body at 37°C. Also, when in direct contact, the mass will absorb heat from the body and thus be cool to the touch. While this is pleasant in summer, it can be very uncomfortable in winter.

DESIGN CONSIDERATIONS

To avoid uncomfortably cool thermal mass in winter, two key things must be considered:

1. Thermal mass must be placed where it can absorb solar heat during the day. A tiled floor that has been absorbing the sun's rays all day will be warm-ish (though it may still feel cold to a bare foot), while that same floor in a dark bathroom will be unbearably cold.
2. The mass must be insulated externally to reduce heat transfer from/to the outside – uninsulated thermal mass will suck heat from inside and deposit it outside.

Location

Thermal mass must be located where passive solar gains exist. Otherwise it will absorb heat from the room in winter, making it cold.

The best place for thermal mass is in floors and walls that receive direct solar gains in winter. Glass must be north-facing and shading designed so as to protect from summer sun while letting winter sun in.

Thermally massive walls in rooms that don't receive winter sun are not desirable as in winter they will draw heat from the room. Walls that are in north facing rooms but that don't receive sun directly can work but should be avoided in deep rooms where the wall is a long way from the window.

In summer, thermal mass must be in rooms that can be well ventilated. Unshaded north or west-facing walls will absorb a lot of heat and if uninsulated may release this heat into the building overnight.

Material	Density (Kg/m³)	Specific heat (kJ/kg.K)	Volumetric heat capacity Cp Thermal mass (kJ/m³.K)
Water	1000	4.186	4186
Concrete	2240	0.920	2060
AAC	500	1.100	550
Brick	1700	0.920	1360
Stone (Sandstone)	2000	0.900	1800
FC Sheet (compressed)	1700	0.900	1530
Earth Wall (Adobe)	1550	0.837	1300
Rammed Earth	2000	0.837	1673
Compressed Earth Blocks	2080	0.837	1740

Density, specific heat and thermal mass of a range of materials (Source: Ecospecifier)

Area

In general, the exposed area of thermal mass should be about six times the area of glass that receives direct sunlight. For example, a north-facing room with a 1m² window should have about 6m² of exposed thermal mass, located where it will be exposed to direct winter sun.

Types of Mass

Brick, concrete, concrete block and rammed earth are all good thermally massive building materials. Water tanks can be effectively used to screen western walls as they will absorb solar radiation in the afternoon.

When considering a material, check its heat capacity Cp: anything over 1300 kJ/m³.K is good.

A number of phase-change materials are appearing on the market. These materials contain the properties of thermal mass without the weight or wall thickness implications. Phase change materials can include screed, plasterboard or paints and usually contain microcapsules of a material (often wax) that absorbs and releases energy by melting and solidifying. Where thermal mass absorbs energy to change the temperature of the mass, phase change materials absorb energy to change the phase of the material (e.g. solid wax to melted wax, water to steam). It takes a lot of energy to change the phase of a material, more than it does to simply raise its temperature. Phase change materials are not yet very common and as such can be quite expensive but many more products are expected to appear in the next few years improving the accessibility and viability.

Thickness of Mass

Thermal mass that is too thick will take too long to absorb heat, while too thin mass won't have the storage capacity. Around 100mm-250mm thick is a good rule of thumb however depends on several factors including the material's thermal capacity and emissivity. Thermal modelling can be used to optimise the best thickness for a given material and room layout.

Embodied Energy

Thermal mass often utilises materials with high embodied energy (the energy used in making a material) such as brick or concrete. Recycled materials should be used wherever possible, including recycled fly-ash in concrete, reused bricks or feature walls made from repurposed floor tiles.

Typical figures for embodied energy of building materials are as follows:

ASSEMBLY	EMBODIED ENERGY MJ/m²
Single Skin AAC Block Wall	440
Single Skin AAC Block Wall gyprock lining	448
Single Skin Stabilised (Rammed) Earth Wall (5% cement)	405
Steel Frame, Compressed Fibre Cement Clad Wall	385
Timber Frame, Reconstituted Timber Weatherboard Wall	377
Timber Frame, Fibre Cement Weatherboard Wall	169
Cavity Clay Brick Wall	860
Cavity Clay Brick Wall with plasterboard internal lining and acrylic paint finish	906
Cavity Concrete Block Wall	465
Strawbale	----

Source: Lawson Buildings, Materials, Energy and the Environment (1996)

These figures can be used to loosely determine the energy payback period of the embodied energy of thermal mass relative to modelled energy savings.

Insulation

Thermal mass must be insulated externally to protect it from outside temperature changes. In very cold climates, or where in-slab heating is installed, the underside of floors must also be insulated.

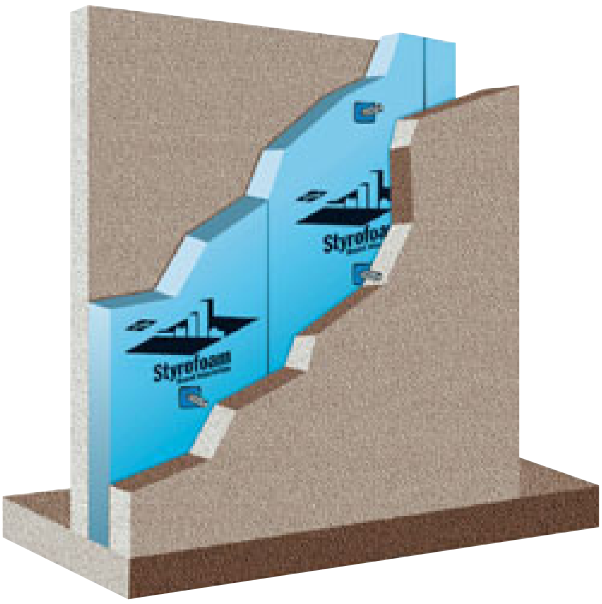
If retrofitting a building with thermally massive walls that do not receive adequate winter sun, insulate them on the inside. If they are receiving a lot of summer sun – i.e. if they are west or east facing – then if possible also insulate them on the outside. If this is not possible, consider shading these walls with trees, bushes or ideally deciduous creepers or plants.

In temperate climates, an R Value of R2.0 is preferred for walls and R1 to R2.0 for floors. This should be increased for alpine and cold locations (including Tasmania).

For walls, sandwich panels of precast concrete and foam insulation provide an excellent design solution. With the insulation built in, these panels contain enough thermal mass to maintain internal building temperatures at the average summer and winter condition. This is ideal for applications such as schools, making it possible to avoid air-conditioning or at least reduce HVAC plant size. It also allows quick construction time.

Ventilation

In summer, the heat stored in thermal mass will be released back into the space in the cooler evenings.



Panelmate™ polystyrene foam insulation sandwiched between concrete panels.
(Image: Dow Building Solutions)

Ventilation is needed to remove this heat otherwise it will continue to build up and create an oven effect over several hot days.

Ventilation should be done at night (known as night purge), ideally just before sunrise as this is the coolest part of the day. In offices, where equipment generates heat overnight, it is important that the ventilation period is just before the air-conditioning starts up – if the ventilation closes too soon, the equipment will reheat the air in the room, reducing the potential energy savings.

Air must be able to move effectively through the building. Atria, secure openings and operable windows can all be effective in introducing and exhausting air. Consider though what will happen on still nights which can be common in summer – air will need to be forced through the building. Fans (either through the HVAC system or ceiling fans to promote air circulation) should be considered.

If your building cannot be effectively ventilated at night/early morning, to avoid an oven effect in summer do not use thermal mass. (For natural ventilation strategies, see EDG papers TEC4 and EDG-65-EP.)

Surface Finishes

Dark surfaces absorb and release heat better than light-coloured ones. Dark floor tiles or matt concrete will give the best effect. Don't forget a light-coloured finish for the roof!

Surfaces which receive direct sun must be uncovered, otherwise they will not absorb heat. Carpets should be avoided.

BUILDING TYPE/FORM

Thermal mass can be effectively used in all building types, however each has their pros, cons and individual issues which must be considered.

Schools

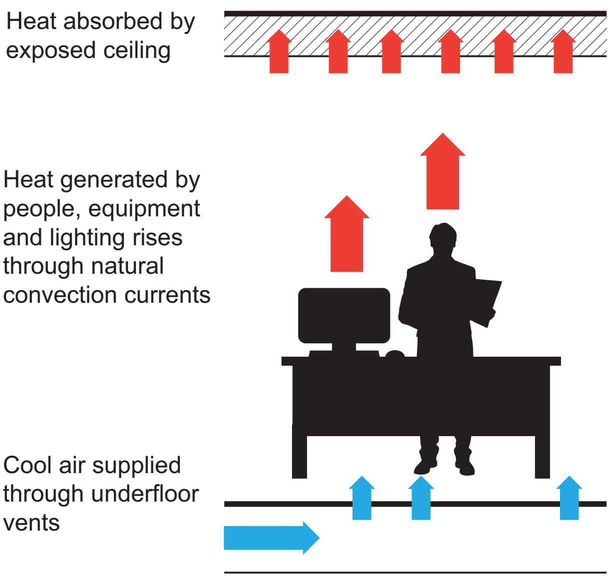
Comfort and security issues need to be carefully considered in schools. In primary schools, large areas of floor space may be available near northern windows. In winter a slab heated by the sun could potentially be quite warm to sit on, but the bare slab may not be physically comfortable. In summer, or on cloudy days, this same area could be uncomfortably cold. However, these floors are also very durable and easy to clean.

Security issues need to be carefully considered with regards to night purge – how can ventilation openings be made secure? Also, who will be in charge of opening and closing them? Potential solutions include automation, which can get expensive.

If designing thermal mass into schools, seriously consider using precast sandwich panels for walls.

Offices

In offices, thermal mass can be effective in absorbing heat generated internally from lighting, occupants and equipment. However, consider that in office areas, furniture and desk layouts are likely to prevent sun from hitting and warming the floor. In this case, an exposed floor will be very cold, resulting in comfort issues. The same applies to exposed wall surfaces – people sitting next to them will feel very cold in winter



Exposed ceiling with underfloor ventilation (Image: Ania Hampton)

(which is also why full-height glazing should be avoided and double-glazed where it can't be).

Exposed ceilings can be very effective in absorbing heat with minimal comfort issues. They must, however, be designed with the aid of an acoustic consultant to avoid noise issues. Exposed ceilings work well with underfloor ventilation, which supplies tempered air at the occupied floor level and forces hot air up to the ceiling (although this is just one option). Modern office HVAC systems can also be easily configured to flush the building with cool outside air for an hour or two prior to the HVAC system starting up. Please note that energy modelling is needed to confirm that this is indeed an energy saving – with today's efficient chillers and pumps, the additional fan energy used can often outweigh plant energy savings and it may be more efficient to have a higher load on the system for the first hour.

Aged care and Hospitals

Aged care facilities and hospitals are used and occupied all day every day. Stabilising diurnal temperatures can significantly reduce energy consumption and improve comfort. However, radiant temperatures must be controlled – elderly and infirm people are particularly sensitive to cold, especially when they are inactive.

In these types of buildings, thermal mass in the ceiling and floor can be effective, particularly in north-facing rooms. Cool floors will not significantly affect bed-ridden patients and will provide relief for active staff (balancing these two extreme comfort requirements is a major issue in hospital design).

Homes

Thermal mass can be very effective for heating homes as most heating is done in the evening. Again, north-facing aspects for winter solar gains are vital, as are exposed floors. Natural ventilation needs to be carefully considered for summer, particularly with regards noise and security at night.

INSULATION TYPES

There are many different insulation products on the market, each with their suited applications:

Batts

The most common type of insulation in Australia, batts work by trapping air. The material on its own actually has very little insulative properties, and for this reason batts must be installed uncompressed – squashing a 150mm batt into a 100mm cavity significantly reduces its effectiveness.

Batts can be made from many materials including glasswool, wool, polyester and even recycled plastic bags. Polyester batts have improved longevity, don't compress over time as much as glasswool batts and are less attractive for rodents and pests (reasons unknown).

Batts come in a range of thicknesses and R Values – it is important to carefully check each product as thickness on its own doesn't determine R Value.

Reflective Foil

Reflective foil, on its own, has no insulation value whatsoever (metal is an excellent conductor of heat, after all). Reflective foils work by reflecting heat away and also by emitting only a small amount of radiant heat, thus reducing heat flows across an air cavity.

Reflective foil must face a sealed air cavity as per manufacturer's instructions in order to be effective. Without the air cavity, it is a pointless piece of metal. It must also face into a closed, unventilated cavity – if air can move, the foil's effectiveness is significantly reduced. This means air gaps must be completely sealed.

Consideration should also be given to the location of the foil – the shiny side needs to remain shiny in order to be effective. This makes it unsuitable for very dusty areas and is why the shiny side should face down where possible.

Foil comes in many different forms. Concertina-shaped products are available, however the author's experience shows that these are often poorly installed and lose their shape in time, reducing their effectiveness. They can also collect dust and moisture.

Moisture movement also needs to be considered – perforated foil does not allow enough moisture movement to remove condensation. Where condensation is an issue, foils or foilboard products with specific moisture-control properties must be used.

Extruded Foam

Extruded foam insulation (a.k.a. Styrofoam insulation board) is a rigid board product that has a high R Value compared to its thickness. This makes it particularly useful for underfloor insulation (as it requires less support) or in narrow wall cavities. It is relatively easy to install but more expensive than batts.

Blow-In / Loose-Fill

Cellulose insulation is made from treated paper or mineral fibres. It was very commonly used through the 70s and 80s in housing. The loose fill is blown into the wall or ceiling cavity and the air trapped within it creates the insulative barrier.

Blow-in insulation
(Image: iStockphoto © Don Nichols 2009)

Loose fill insulation tends to settle quickly (thus reducing its R Value) and getting an even coverage can be difficult, particularly around studs and wire. They are also extremely sensitive to moisture. It is not a preferred option.

Insulative Paint

Insulative paint is a relatively new product and was developed by NASA's Ames Research Center. The ceramic-based paint creates a tight, thin vacuum layer that reduces heat transfer. How effective these paints are is difficult to ascertain, as R Value measurements require a 1" thick material. However, NASA's own tests suggest heat transfer is reduced by around 40 per cent.

Insulating paint is often the only option for insulating existing walls without removing internal or external linings. It is however around double the price of batts (per area) with significantly less R Value.

Combined Products

Various products exist which combine two or more forms of insulation. Most commonly, these involve the addition of a reflective foil layer to a bulk product such as a batt or foam board. These products perform well and are convenient to install but manufacturer's installation instructions must be followed carefully.

Where condensation is an issue, foils or foilboard products with specific moisture-control properties must be used.

R VALUES

The R Value of a product refers to how much resistance that product provides to heat transfer. The higher the R Value, the better the insulator. R Values are used for solid, non-opaque elements.

The U Value is the inverse of the R Value. It is used for glazing and, in Europe, other materials. The lower the U Value, the better the insulator.

For example:

A batt with R2.5:

U = 1/R, so R2.5 = 1/2.5 = U Value 0.04 W/m^2.K

Glass with U = 6 W/m^2.K

R= 1/U = 1/6 = R0.17

Calculating the overall R Value of a construction can be quite complicated, particularly when there are reflective air spaces involved. For example, the R Value of the air space depends on the emissivity of the foil, the orientation and size of the air gap, air movement and the direction of heat flow. The BCA contains good guidelines for calculating overall construction R Value, however an accredited thermal assessor should be consulted to be sure.

When considering the R Value of a product, beware that in the United States R Values are measured in imperial units ft^2.°F•h/Btu where Australia uses metric SI units K.m^2/W). It is easy to confuse the two as both are usually stated without their units. US R values are approximately six times Australian R Values so if the R Value seems impossibly high, check the units.

Understanding the Manufacturer's Claims

The R Value of insulation is tested under strict laboratory conditions and allows one product to be rated against another.

However, most manufacturers specify the R Value of their product as it performs within a building construction. This means that the construction overall achieves the specified R Value (including air films, reflective air cavities, building materials etc.), not the product alone.

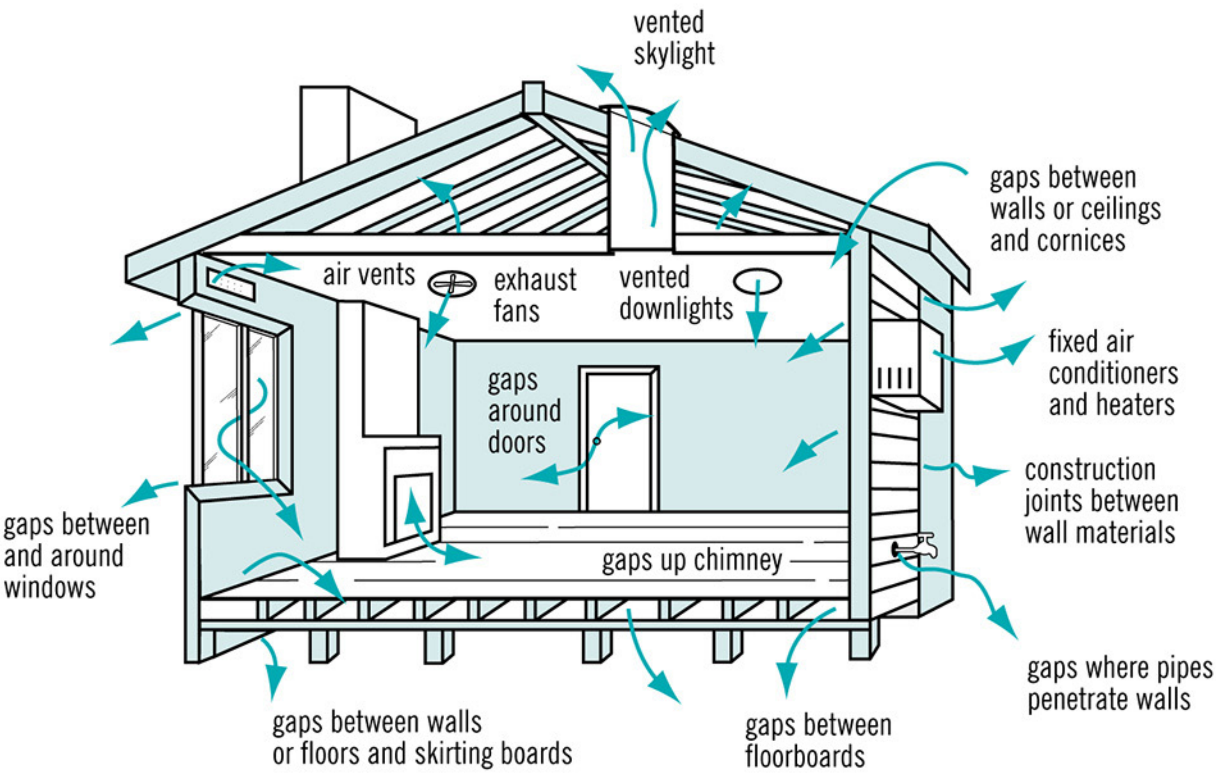
It is imperative that you understand what the R Value is referring to. Putting the same product into a different construction (e.g. metal deck vs. tiled roof, flat vs. attic roof) will not achieve the same overall fabric R Value.

This is especially important when specifying insulation to meet BCA requirements. If in any doubt, seek the opinion of an accredited thermal assessor.

THERMAL BRIDGING

Heat will always take the path of least resistance. Thermal bridging occurs when two surfaces are connected by a conductive element. A good example is metal purlins connecting a plasterboard ceiling to a metal deck roof. Even though there may be insulation between the purlins, the resistance across the purlin is much less, so the heat will flow that way. Thermal bridging can reduce the effect of insulation by up to 20 per cent.

To prevent thermal bridging, a thermal spacer should be installed between bridging elements (such as purlins



Common sources of thermal leakage (image: Sustainability Victoria)

or wall studs) and the external fabric. Thermal spacers are typically constructed from solid elements such as polystyrene or extruded foam board (or other closed cell foam structures) or from specialist gels.

Compressing bulk insulation between purlins or studs and the external fabric does not create an effective thermal break.

INTERACTIONS WITH OTHER BUILDING ELEMENTS

As discussed, heat always takes the path of least resistance. This means that continually increasing insulation in one area will not correspondingly improve the thermal performance of the whole building, as the heat will simply find other, easier parts to move through.

There is no point putting R5 into the roof when the walls are only at R1, the floor is uninsulated and the windows are single glazed.

Current good design practice suggest the following for temperate climates:

- Roof: R4 added thermal insulation
- Walls: R2 added thermal insulation
- Timber floors (everywhere) and slabs in cold climates (e.g. Alpine, Tasmania): R1 to R1.5
- Windows: double glazed or single glazed with low-e coating

Minimum R Values stated in the BCA are just that – a minimum.

Lighting Elements

Insulation around lighting elements also needs to be carefully considered. Downlights can become very hot (particularly halogen downlights) and hence need a gap around them to prevent insulation catching fire. This obviously significantly reduces the level and effectiveness of insulation. Potential solutions include avoiding recessed downlights altogether, using LED lights, which burn much cooler, and installing roof insulation directly underneath the roof material rather than on top of the ceiling.

Building Sealing

Insulation works by isolating the internal temperature from the external. Consider then that the average older Victorian home changes its air three times per hour. This means that all the inside air is replaced with outside air every 20 minutes! Draughts account for up to 15 to 25 per cent of heat loss in winter . Sealing gaps is imperative in effective performance of insulation.

The following strategies help reduce air leakage:

- Use airtight construction detailing, particularly at wall/ceiling and wall/floor junctions.
- Choose well made windows and doors with airtight seals (must comply with AS2047).
- Use draught-proofing strips between the door and frame, at the door base and between the openable sash of the window and the frame.
- Seal gaps between the window/door frame and the wall prior to fitting architraves.

- Avoid using downlights that penetrate ceiling insulation.
- Duct exhaust fans and install non-return baffles.
- Avoid open fires and fit dampers to chimneys and flues.
- Do not use permanently ventilated skylights.
- Use tight fitting floor boards and insulate the underside of timber floors in cooler climates.
- Enclose the perimeter of underfloor areas.
- In existing homes, seal off air vents and use windows and doors for ventilation as required. (Note that this may not be advisable for homes with unflued gas heaters that require a level of fixed ventilation.)

INSTALLATION

The installation of insulation is fundamental to its effective performance – a 5 per cent reduction in insulation area due to poor edging can reduce the performance of the insulation by up to 50 per cent .

Insulation must be installed as follows:

Uncompressed –

- bulk insulation must rest at its full expanded height
- Ensure loose insulation or insulation batts cannot become wet

Effectively –

- Ensure reflective surfaces face a minimum 25mm air gap
- Face reflective surfaces down or vertically to reduce dust collection
- Support bulk insulation in wall cavities

Without gaps –

- Ensure batts are fitted snugly and abut each other
- Fit insulation closely against joists, door and window frames, purlins etc
- Overlap ceiling and wall insulation at the wall/ ceiling boundary
- Overlap edges of foil or membrane by at least 50mm and tape carefully
- Ensure there are no folds or tucks
- Use cut-offs to fill any small gaps

Safely –

- Avoid downlights and other fittings which protrude into the ceiling cavity
- Follow manufacturer's instructions for clearances around light fittings, chimneys and flues, extractor fans and electrical fittings
- Avoid stapling near electrical cables
- Use respiratory equipment where recommended and protect exposed skin, particularly with glass and fibre batts (or don't use these types of products)

Dry –

- Ensure the cavity is dry prior to installation and remove any damp insulation.

Use vapour barriers to protect from condensation where:

- o There is a high temperature difference between inside and outside (e.g. alpine areas)
- o In low-ventilated ceilings such as cathedral and raked
- o High amounts of vapour are generated and not exhausted
- o On the underside of metal roofs

The BCA instructions for the installation of insulation must be followed exactly and should be supplemented with the manufacturer's installation instructions (the BCA takes precedence where there is a conflict).

CONCLUSION

Insulation and thermal mass are highly effective ways to reduce energy use and improve comfort in buildings. Both are instrumental in stabilising internal temperatures, isolating internal temperatures from outside and decrease heating and cooling requirements. Used or installed incorrectly, however, they can at best be ineffective, and at worst reduce comfort or cause safety issues. Used correctly, they offer cost effective methods for delivering comfort in buildings.

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