Thermal Mass

Thermal mass is the ability of a material to absorb heat energy. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. They are therefore said to have high thermal mass. Lightweight materials such as timber have low thermal mass. Appropriate use of thermal mass throughout your home can make a big difference to comfort and heating and cooling bills. This fact sheet shows you how.

Correct use of thermal mass moderates internal temperatures by averaging day/night (diurnal) extremes. This increases comfort and reduces energy costs.

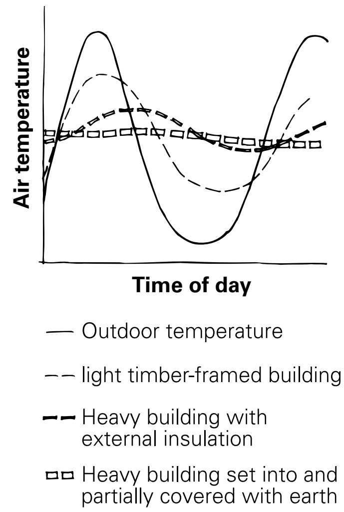
Poor use of thermal mass can exacerbate the worst extremes of the climate and can be a huge energy and comfort liability. It can radiate heat all night during a summer heatwave, or absorb all the heat you produce on a winter night.

To be effective, thermal mass must be integrated with sound passive design techniques. This means having appropriate areas of glazing facing appropriate directions with appropriate levels of shading, insulation and thermal mass. [See: 4.1 Passive Design]

HOW THERMAL MASS WORKS

Thermal mass acts as a thermal battery. During summer it absorbs heat, keeping the house comfortable. In winter the same thermal mass can store the heat from the sun or heaters to release it at night, helping the home stay warm.

Thermal mass is not a substitute for insulation. Thermal mass stores and re-radiates heat. Insulation stops heat flowing into or out of the building. A high thermal mass material is not generally a good thermal insulator.



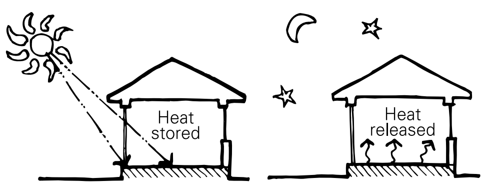
Thermal mass is particularly beneficial where there is a big difference between day and night outdoor temperatures.

Correct use of thermal mass can delay heat flow through the building envelope by as much as 10 to 12 hours producing a warmer house at night in winter and a cooler house during the day in summer.

A high mass building needs to gain or lose a large amount of energy to change its internal temperature, whereas a lightweight building requires only a small energy gain or loss.

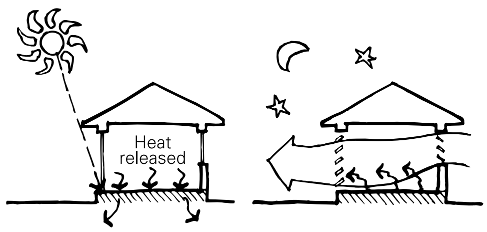
Winter

Allow thermal mass to absorb heat during the day from direct sunlight or from radiant heaters. It will re-radiate this warmth back into the home throughout the night.



Summer

Allow cool night breezes and/or convection currents to pass over the thermal mass, drawing out all the stored energy. During the day protect thermal mass from excess summer sun with shading and insulation if required.



USING THERMAL MASS

Thermal mass is most appropriate in climates with a large diurnal temperature range. As a rule of thumb, diurnal ranges of less than 6ºC are insufficient; 7ºC to 10ºC can be useful depending on climate; where they exceed 10ºC, high mass construction is desirable. Exceptions to the rule occur in more extreme climates.

In cool or cold climates where supplementary heating is often used, houses will benefit from high mass construction regardless of diurnal range. (eg. Hobart 8.5ºC). In tropical climates with diurnal range of 7-8 (eg. Cairns 8.2ºC) high mass construction can cause thermal discomfort unless carefully designed, well shaded and insulated.

Always use thermal mass in conjunction with good passive design.

THERMAL MASS PROPERTIES

High density – The more dense the material (ie the less trapped air) the higher its thermal mass. For example, concrete has high thermal mass, AAC block has low thermal mass, and insulation has almost none.

Good thermal conductivity – The material must allow heat to flow through it. For example, rubber is a poor conductor of heat, brick is good, reinforced concrete is better. But if conductivity is too high (eg. steel) energy is absorbed and given off too quickly to create the lag effect required for diurnal moderation.

Low reflectivity – Dark, matt or textured surfaces absorb and re-radiate more energy than light, smooth, reflective surfaces. (If there is considerable thermal mass in the walls, a more reflective floor will distribute heat to the walls).

MATERIAL	THERMAL MASS (volumetric heat capacity, KJ/m^3.k)
WATER	4186
CONCRETE	2060
SANDSTONE	1800
COMPRESSED EARTH BLOCKS	1740
RAMMED EARTH	1673
FC SHEET (COMPRESSED)	1530
BRICK	1360
EARTH WALL (ADOBE)	1300
AAC	550

Source EDG

The above chart compares the thermal mass properties of some common materials. The volume or quantity of these materials in typical application is also important.

Compressed FC sheet flooring has a higher thermal mass value than brick or earth walls but is usually only present in 20mm thick layers which means it can't store a lot of heat. Brick walls are 110 to 230mm thick and earth walls are usually minimum 300mm, giving them the capacity to store large amounts of heat.

The amount of useful thermal mass is calculated by multiplying the above figure by the total accessible volume of the material, that is the volume of material which has its surface exposed to a heat source. Floor coverings such as carpet, which insulate the mass, reduce the accessible volume.

Some thermal mass materials, such as concrete and brick, when used in the quantities required have high embodied energy. Consider the life time energy impact of thermal mass materials.

Will the savings in heating and cooling energy be greater than the embodied energy content over the life of the building? Can lower embodied materials such as water or recycled brick be used? In addition, poor design of thermal mass may result in increased heating and cooling energy use on top of the embodied energy content. [See: 5.2 Embodied Energy]

Phase change materials

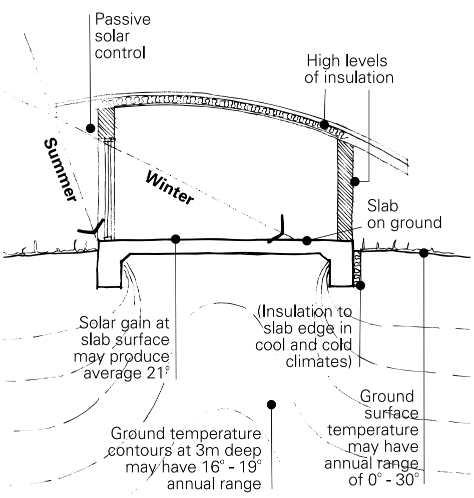
There is growing interest in the use of phase change materials in construction. One development of this technology uses thousands of plastic capsules filled with a wax that absorbs and releases energy by melting and solidifying within the temperature range of human comfort. This increases the effective thermal capacity of the material which contains the capsules and dampens temperature fluctuations, acting like thermal mass.

At least one company manufactures building products that integrate phase-change microcapsules into their structure, including plasterboard and aerated concrete (AAC) blocks. Gypsum plasters, paints and floor screeds have the potential to contain phase change materials and many such applications are likely to appear on the market over the next few years as the technology offers the prospect of lightweight buildings that can behave with characteristics associated with 'traditional' thermal mass – for instance, the thermal capacity of a 13mm thick plaster layer with 30 per cent microcapsule content is claimed to be equivalent to that of a six-inch thick brick wall.

Use of phase change materials can be very helpful on challenging sites where otherwise the provision of thermal mass would be difficult.

TYPICAL APPLICATIONS

In rooms with good winter solar access it is useful to connect the thermal mass to the earth. The most common example is slab on ground construction. A less common example is earth-sheltered housing.

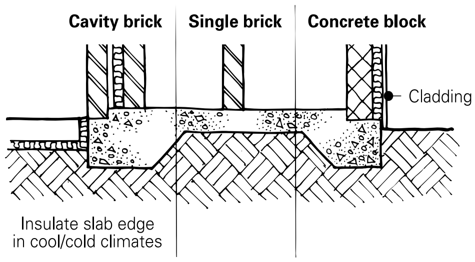


A slab on ground (SOG) is preferable to a suspended slab in most climates because it has greater thermal mass due to direct contact with the ground. The vertical edges of an SOG are required to be insulated in climate zone 8 (cold climate) or when in-slab heating or cooling is installed within the slab. Please refer to Clause 3.12.1.5 (c) and (d) of the BCA Volume Two for more detail.

The whole slab must be insulated from earth contact in cold climates Consider termite proofing when designing slab edge insulation. Care should be taken to ensure that the type of termite management system selected is compatible with the slab edge insulation. Brick or compressed earth floors are also appropriate.

Use surfaces such as quarry tiles or simply polish the concrete slab. Do not cover areas of the slab exposed to winter sun with carpet, cork, wood or other insulating materials. Use rugs instead.

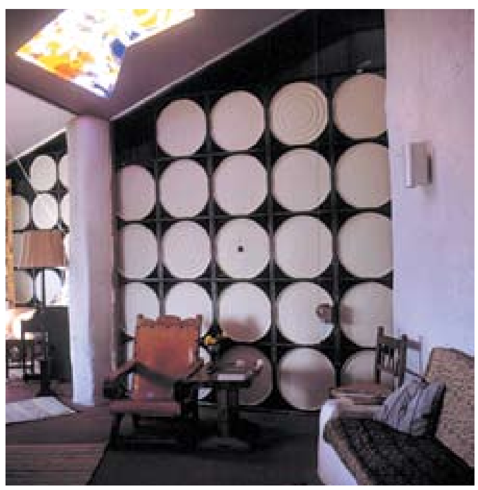
Masonry walls also provide good thermal mass. Recycled materials such as concrete, gravel or re-used bricks can be used.



Examples of high mass construction.

Insulate masonry walls on the outside, for example reverse brick veneer construction. Masonry walls with cavity insulation and rammed earth walls also provide good thermal mass. (Note: rammed earth has a low insulation value and requires external insulation in cool and cold climates).

Introduce thermal mass within lightweight structures by using isolated masonry walls or lightweight steel-framed concrete floors. Always insulate the underside and exposed edges of suspended thermal mass floors.



Water can be used to provide thermal mass. Walls may be built from water-filled containers.

Internal or enclosed water features such as pools can also provide thermal mass but require good ventilation and must be capable of being isolated as evaporation can absorb heat in winter and create condensation problems year round.

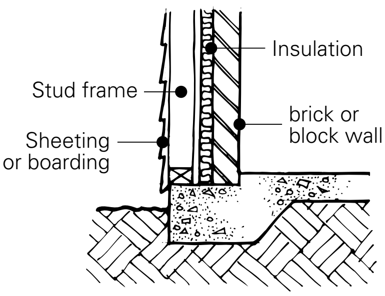
Air enters this building across the pool (thermal mass) via a semi-enclosed courtyard. It is evaporatively cooled before entering the building.

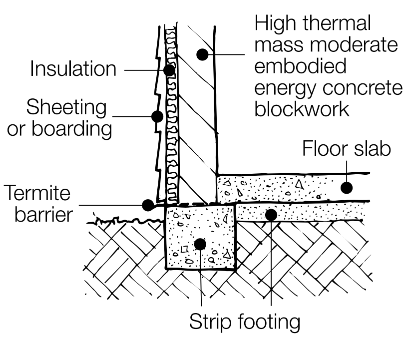
WHERE TO LOCATE THERMAL MASS

The location of thermal mass within the building will have an enormous impact on its year round effectiveness and performance.

As a rule of thumb the best place for thermal mass is inside the insulated building envelope. Insulation levels required will depend on the climate. A better insulated envelope will mean more effective thermal mass. [See: 4.7 Insulation]

Thermal mass should be left exposed internally to allow it to interact with the house interior. It should not be covered with thermally insulating materials such as carpet.

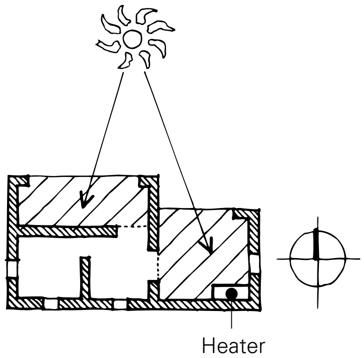




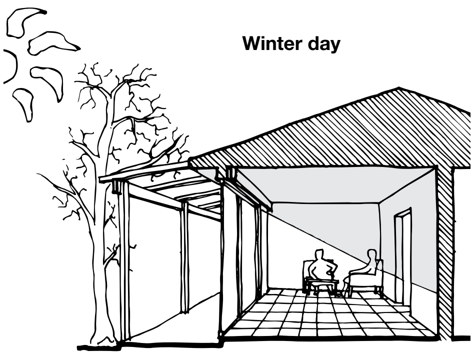
To determine the best location for thermal mass you need to know if your greatest energy consumption is the result of summer cooling or winter heating.

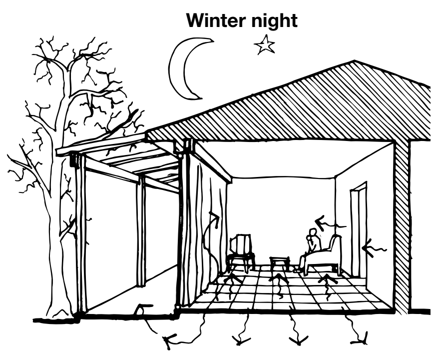
Heating: Locate thermal mass in areas that receive direct sunlight or radiant heat from heaters.

Heating and cooling: Locate thermal mass inside the building on the ground floor for ideal summer and winter efficiency. The floor is usually the most economical place to locate heavy materials and earth coupling can provide additional thermal stabilisation.



Locate thermal mass in north facing rooms which have: good solar access; exposure to cooling night breezes in summer and additional sources of heating or cooling (heaters or evaporative coolers).



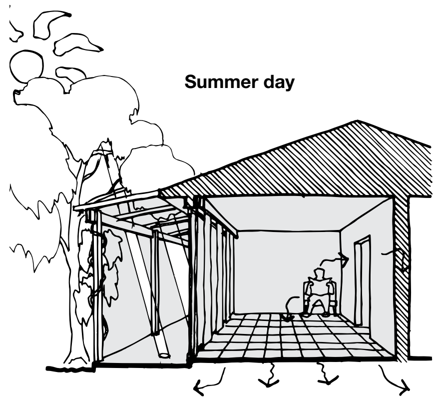


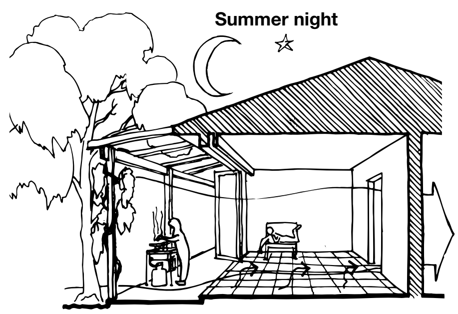
Insulate slab edges in cold climates or when in-slab heating or cooling is installed within the slab.

Locate additional thermal mass near the centre of the building, particularly if a heater or cooler is positioned there. Feature brick walls, slabs, large earth or water filled pots and water features can provide this.

Cooling: Protect thermal mass from summer sun with shading and insulation if required. Allow cool night breezes and air currents to pass over the thermal mass, drawing out all the stored energy.

Roof-mounted solar pool heating is relatively inexpensive and can be used in conjunction with hydronic heating systems or water storage containers to heat thermal mass in winter or (in reverse) to provide radiant cooling to night skies in summer. This method can resolve situations where direct solar access for passive heating is unachievable or where conventional thermal mass is inappropriate (eg. Pole homes). [See: 6.2 Heating and Cooling]





WHERE NOT TO LOCATE THERMAL MASS

In brick veneer houses with tiled roofs the thermal mass materials are on the outside and the insulative materials are on the inside. The value of thermal mass is minimal in this form of construction.

Avoid use in rooms and buildings with poor insulation from external temperature extremes and rooms with minimal exposure to winter sun or cooling summer breezes.

Careful design is required if locating thermal mass wall on the upper levels of multi-storey housing in all but cold climates, especially if these are bedroom areas.

Natural convection creates higher upstairs room temperatures and upper level thermal mass absorbs this energy. On hot nights upper level thermal mass can be slow to cool, causing discomfort. The reverse is true in winter.

SPECIFIC CLIMATE RESPONSES

Climatic consideration is critical in the effective use of thermal mass. It is possible to design a high thermal mass building for almost any climate but the more extreme climates require very careful design.

Adaptation

Think about the impact of predicted changes in climate due to global warming. Will the current use of thermal mass still be appropriate in 20 or 30 years time if temperatures rise and diurnal ranges are reduced? This is a particularly important issue in tropical climates where temperatures are already close to the upper comfort level.

For the main features of these climates see 4.1 Passive Design.

It is important to insulate ground slab edges in cold climates.

High humid (tropical) climates

Use of high mass construction is generally not recommended in high humid climates due to their limited diurnal range. Passive cooling in this climate is generally more effective in low mass buildings.

Thermal comfort during sleeping hours is a primary design consideration in tropical climates. Lightweight construction responds quickly to cooling breezes. High mass can completely negate these benefits by slowly re-releasing heat absorbed during the day.

Whilst low mass is generally the best option, recent research has shown that innovative, well insulated and shaded thermal mass designs have been able to lower night time temperatures by 3 to 4°C in high humid areas with modest diurnal ranges.

Warm humid and warm/mild temperate climates

Maintaining thermal comfort in these benign climates is relatively easy. Well designed houses should require no supplementary heating or cooling.

The predominant requirement for cooling in these climates is often suited to lightweight, low mass construction. High mass construction is also appropriate but requires sound passive design to avoid overheating in summer.

In multi level/story design, high mass construction should ideally be used on lower levels to stabilise temperatures. Low mass on the upper levels will ensure that, as hot air rises (in convective ventilation), it is not stored in upper level mass as it leaves the building.

Cool temperate and alpine climates

Winter heating predominates in these climates although some summer cooling is usually necessary.

High mass construction combined with sound passive solar design and high level insulation is an ideal solution.

Good solar access is required in winter to heat the thermal mass.

Insulate slab edges and the underside of suspended slabs in colder climates. It is advisable to insulate the underside of a slab on ground in extremely cold climates. [See: 4.8 Insulation Installation]

Buildings that receive little or no passive solar gains can still benefit from high mass construction if they are well insulated. However, they respond slowly to heating input and are best suited to homes with high occupation rates.

Auxiliary heating of thermal mass is ideally achieved with efficient or renewable energy sources such as solar, gas or geothermal powered hydronic systems. In-slab electric resistance systems cause higher greenhouse gas emissions. [See: 6.2 Heating and Cooling]

Use a solar conservatory in association with thermal mass to increase heat gains. A solar conservatory is a glazed north-facing room that can be closed off from the dwelling at night. Shade the conservatory in summer and provide high level ventilation to minimise overheating. Reflective internal blinds also reduce winter heat loss.

Hot dry climates

Both winter heating and summer cooling are very important in these climates. High mass construction combined with sound passive heating and cooling principles is the most effective and economical means of maintaining thermal comfort.

Diurnal ranges are generally quite significant and can be extreme. High mass construction with high insulation levels is ideal in these conditions. [See: 4.7 Insulation]

Where supplementary heating or cooling is required, locate thermal mass in a position of exposure to radiation from heaters or cool air streams from evaporative coolers. The mass will moderate temperature variations between high/low or on/off and will lower the level and duration of auxiliary requirements whilst increasing thermal comfort.

Underground or earth covered houses give protection from solar radiation and provide additional thermal mass through earth coupling to stabilise internal air temperatures.

RENOVATIONS AND ADDITIONS

Where to locate extra thermal mass

For heating, thermal mass should be added where winter solar access is already available (or made available by 'turning the house around' to place living areas to the north). Thermal mass can also be located near a heater.

For cooling, thermal mass must be protected from summer sun and exposed to cooling night breezes.

Use of thermal mass is generally not recommended in high humid climates, but it has useful applications in all other climates.

Some quick tips

Thermal mass must be used in conjunction with good passive design in order for it to work effectively. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Add shading to protect thermal mass from summer sun. Its ability to absorb and re-radiate heat over many hours means that in summer or hot climates it can be a source of unwelcome heat long after the sun has set. [See: 4.4 Shading]

Remove carpet or insulative covering from concrete slabs that have exposure to winter sun. The slab surface can be tiled or cut and polished to give a unique and practical finish. [See: 5.12 Concrete Slab Floors]

There are easy opportunities to add useful thermal mass when renovating, such as using new slab on ground or suspended concrete floors, or using reverse brick veneer construction.

If the floor of the existing building is suspended timber it is often practical to retro-fit a suspended concrete slab, which replaces the timber floor completely in rooms with winter solar access. The slab can be supported on the original piers or stumps, using steel lintels or beams as bearers.

New slabs can be tiled, polished or burnished (highly steel trowelled when poured, with a post-applied finish such as acid reactive staining). These surfaces let the thermal mass of the slab interact with the room to moderate indoor temperatures.

An internal skin of brickwork can be added to timber-framed structures to increase thermal mass. This construction technique is known as Reverse Brick Veneer.

Most houses are conventional Brick Veneer, with a timber wall frame clad in an external non-load bearing brick skin, or veneer. The thermal mass of the bricks is not utilised because they are located on the outside. They are really only doing the same job as weatherboards. For this reason brick veneer is low mass construction (not to be confused with full brick construction, which is high mass).

Reverse Brick Veneer (RBV) is a construction technique which places thermal mass (the brick skin) on the inside of the wall frame. The highly insulated wall frame protects the thermal mass from external temperature extremes. The thermal mass is in contact with the room and helps to regulate indoor temperatures, for the benefit of the occupants.

It is important to note that any high mass material can be used in place of the bricks. Examples include rammed earth, core filled concrete blocks and mud bricks.

RBV is best used in north facing living areas with solar access, especially in climates with a high diurnal temperature range.

If the existing building is slab on ground, the new RBV can be built directly on the concrete slab, after engineering checks are carried out. If the existing building has a raised timber floor it is often practical to combine RBV with a retro-fitted suspended concrete slab.

Roof-mounted solar pool heating is relatively inexpensive and can be used in conjunction with hydronic heating systems or water storage containers to heat thermal mass in winter or (in reverse), to provide cooling to night skies in summer. This method can resolve situations where direct solar access for passive heating is unachievable or where conventional thermal mass is inappropriate (eg. Pole homes). [See: 6.2 Heating and Cooling]

ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/environ/design/design.shtml

BEDP *Environment Design Guide*
DES 4 Thermal Mass in Building Design.

Commonwealth of Australia, *Australian Model Code for Residential Development* (AMCORD) (1995), AGPS Canberra.

Hollo, N. (1997), *Warm House Cool House: Inspirational designs for low-energy housing*, Choice Books, Australia.

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