CHAPTER 6

THERMAL MASS

The contents of this chapter explain the effect of thermal mass and provide guidelines for its location and extent. Summer and winter effects of thermal mass and the relationship with climate are also outlined.

Understanding thermal mass

Thermal mass is a term used to describe the ability of building materials to store heat (thermal storage capacity). The basic characteristic of materials with thermal mass is their ability to absorb heat, store it, and at a later time release it.

Adding thermal mass within the insulated building envelope helps reduce the extremes in temperature experienced inside the home, making the average internal temperature more moderate year-round and the home more comfortable to live in.

Building materials that are heavyweight store a lot of heat so are said to have high thermal mass (see figure 6.1). Materials that are lightweight do not store much heat and have low thermal mass (see figure 6.2).

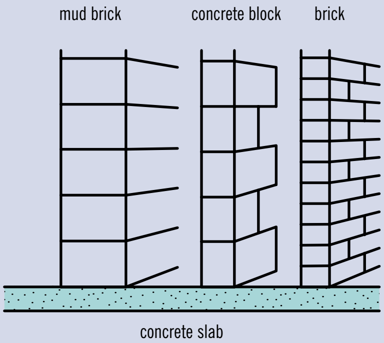


Figure 6.1: Materials with high thermal storage capacity

The use of heavyweight construction materials with high thermal mass (concrete slab on ground and insulated brick cavity walls) can reduce total heating and cooling energy requirements by up to 25% compared to a home built of lightweight construction materials with a low thermal mass (brick veneer with timber floor).

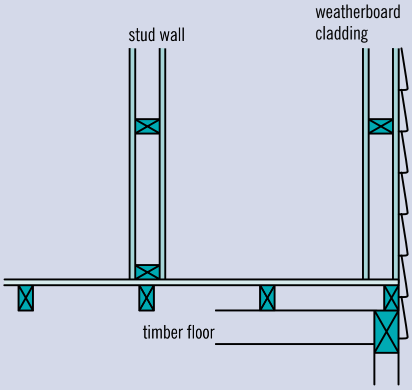


Figure 6.2: Materials with low thermal storage capacity

Thermal mass is particularly important for comfort in climates such as northern Victoria, where summer temperatures are high and there is a large difference between daily average maximum and minimum temperatures. Thermal mass is less important, but still beneficial, in climates with lower summer temperatures. However, in situations where solar access is poor, thermal mass could increase winter heating requirements.

Seasonal effects of thermal mass

SUMMER

In summer, thermal mass absorbs heat that enters the building. In hot weather, thermal mass has a lower initial temperature than the surrounding air and acts as a heat sink. By absorbing heat from the atmosphere the internal air temperature is lowered during the day, with the result that comfort is improved without the need for supplementary cooling (see figure 6.3).

During the night, the heat is slowly released to passing cool breezes (natural ventilation), or extracted by exhaust fans, or is released back into the room itself. Inside temperatures at night time will be slightly higher than if there was low thermal mass, however with the cooling night effects, temperatures are still within the comfort zone (unless a long spell of consistently hot days and nights is experienced).

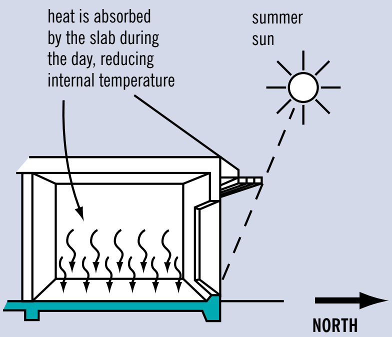
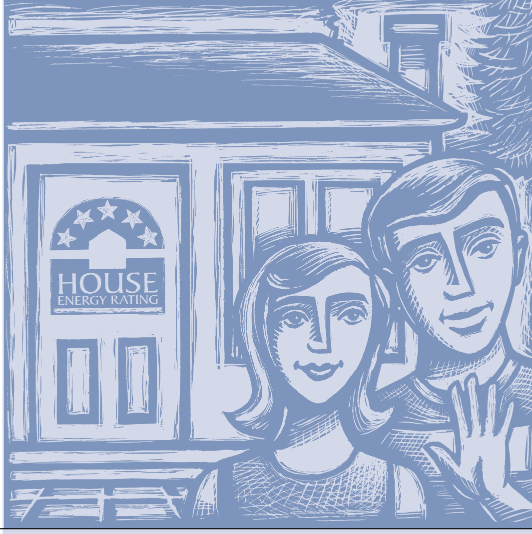


Figure 6.3: Thermal mass in summer



The ability of thermal mass to even-out fluctuations in indoor temperatures is illustrated in figure 6.4. The solid line represents the air temperature in summer inside a double-brick house with a concrete slab-on-ground floor. The dashed line represents the air temperature inside a lightweight timber building. Note that the temperature variation in the brick house is much smaller and temperatures are almost always within the comfort zone.

WINTER

In winter, thermal mass in the floor or walls absorbs radiant heat from the sun through north, east and west-facing windows. During the night, the heat is gradually released back into the room as the air temperature drops. This maintains a comfortable temperature for some time, reducing the need for supplementary heating during the early evening (see figure 6.5).

For good winter performance, thermal mass should be exposed to direct sunlight and is best located in areas with unobstructed north-facing windows.

An additional benefit is that some of the heat from lengthy periods of internal space heating can be stored in the thermal mass. Long after the heating is turned off, the slow release of heat from the walls or floor will maintain comfortable internal temperatures.

NEGATIVE WINTER EFFECTS

In some cases thermal mass can actually increase winter energy requirements. Where there is little possibility of solar gain, either because north windows are too small or are overshadowed (poor solar access), the benefits provided by the use of thermal mass will be minimal. Each time supplementary heating is used, the thermal mass needs to be heated before the air temperature rises, increasing the heating energy needed. Increasing the area of north-facing glass can help offset this effect.

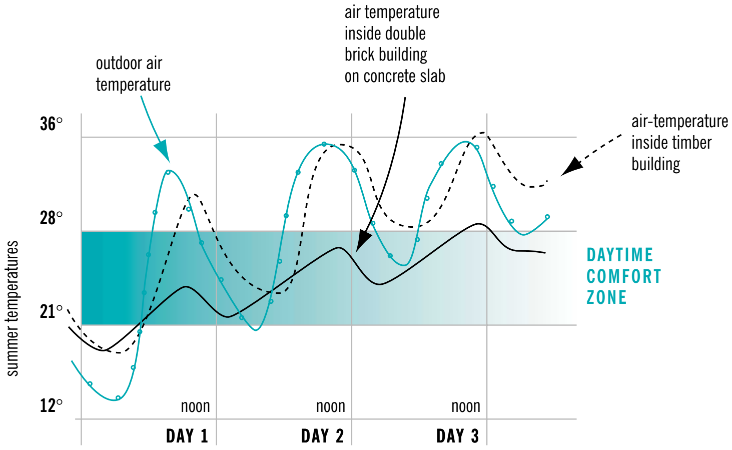


Figure 6.4: Comparing summer temperatures for buildings of different thermal mass

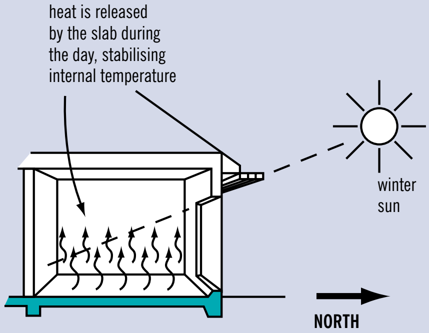


Figure 6.5: Thermal mass in winter

Thermal mass and climate

Thermal mass is particularly effective in places where there is a big difference in the maximum day temperature and minimum night temperature. In general, the greater the daily temperature range, the more thermal mass required.

NORTH OF THE GREAT DIVIDING RANGE

The climate north of the Great Dividing Range is different to that south of the Divide. Table 3.1 on page 11 shows average day and night temperatures for some Victorian locations. On average, Mildura has a hotter summer, warmer winter and greater day-night temperature range than Melbourne. Thermal mass provides greatest benefits in this situation.

SOUTH OF THE GREAT DIVIDING RANGE

For locations south of the Divide, summer comfort is usually a priority. Thermal mass provides real advantages in comfort terms and energy savings, enough to offset any potential winter disadvantage.

ALPINE AREAS

In alpine areas or cool climates, thermal mass is less important than insulation and correct sizing of glass areas. There is little need for thermal mass to moderate low summer temperatures, although it is not a disadvantage where heating is operating continuously, provided the building envelope is appropriately insulated.

Locating thermal mass

INSIDE THE INSULATED BUILDING ENVELOPE

For maximum effectiveness, thermal mass should be insulated from external temperatures, i.e. it should be located within insulated walls. The benefits of thermal mass are considerably reduced if the external envelope is not insulated (see figure 6.6). For this reason brick veneer walls offer little thermal mass benefit, as the brick is on the outside of the insulated cavity.

CONCRETE SLAB ON GROUND

A concrete floor slab directly on the ground will take advantage of the huge thermal mass of the earth beneath.

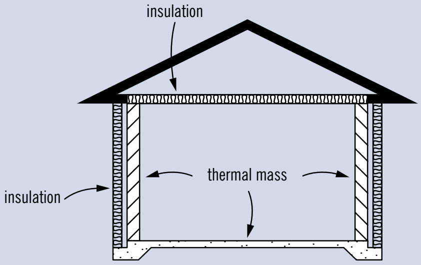


Figure 6.6: Thermal mass within the insulated envelope

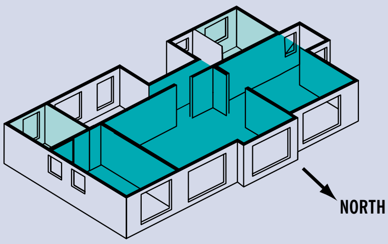


Figure 6.7: Solar radiation directly onto masonry walls and/or slab

INSIDE NORTH-FACING ROOMS

Using thermal mass in north-facing rooms should be a priority, particularly on those walls which receive direct winter sun. As the area of north-facing window increases, the more internal thermal mass is required to maintain a stable temperature (see figure 6.8).

HOT ROOMS DURING SUMMER

Locate thermal mass throughout the dwelling for summer comfort, but particularly in north, east and west-facing rooms (see figure 6.9). Shading of the windows to these rooms is also important.

MASONRY FIREPLACES ON INTERNAL WALLS

Masonry fireplaces are best located on internal rather than external walls so that the chimney can radiate additional heat into the rooms (see figure 6.10).

AMOUNT OF THERMAL MASS

High levels of thermal mass are beneficial throughout Victoria, with the exception of alpine areas and some situations where solar access is poor. While technical studies often recommend certain percentages of thermal mass for different construction types and climate zones, in practice most homes have thermal mass provided in only the following few locations.

- Floor: concrete slab or timber floor.
- External walls: double brick/masonry or brick veneer/weatherboard cladding.
- Internal walls: masonry or stud walls.

Of all the material choices, the wall selection accounts for about 60–70% of the thermal mass of the building, with the floor area accounting for about 30–40%.

Generally, the more thermal mass the better. A double brick or masonry home on a concrete slab offers the highest comfort benefits and energy savings. However, the cost of heavyweight materials can outweigh the value of energy savings. For this reason, use as much thermal mass as you can afford to achieve comfortable indoor conditions.

In most cases, give first priority to provision of a concrete slab (substantially less cost than masonry walls) and supplement this with heavyweight walls where the building budget permits.

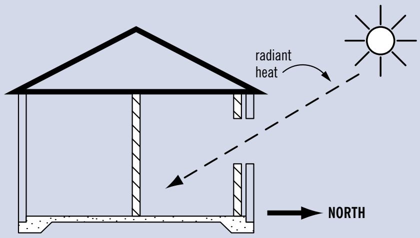


Figure 6.8: Locate thermal mass in north-facing rooms

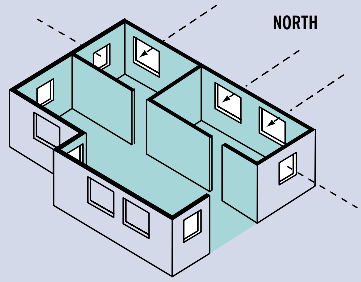


Figure 6.9: Use thermal mass in rooms that may overheat in summer

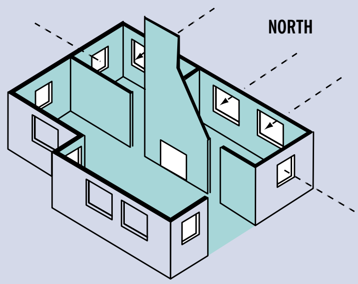


Figure 6.10: Fireplaces on internal walls

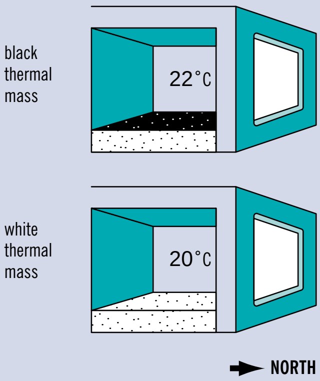


Figure 6.11: Comparison of the effect of colour on room temperature

The effect of floor coverings, colour and texture

Surface colour and texture affect the heat absorption of thermal mass.

SOFT FLOOR FINISHES

Carpets laid over concrete slab floors tend to insulate the thermal mass of the slab from incoming heat. This delays its entry but also slows down its release. The net result is a temperature rise of 1–2°C, which is good in winter, but not so good in summer. This effect partly offsets the winter disadvantage of increased heating energy requirements due to absorption of heat by the thermal mass.

While carpet lowers winter energy consumption, it increases summer energy requirements. Table 6.1 compares the effect on energy use of carpet and ceramic tiles on a concrete slab. Cork tiles are another soft floor finish with a similar insulating effect to carpet.

Table 6.1: Effect of floor coverings on energy consumption (GJ)

	SLAB FLOOR COVERING	
	CARPET	CERAMIC TILES
Heating	28.8	29.3
Cooling	11.3	6.0
Total	40.1	35.3

HARD FLOOR FINISHES

A ceramic tiled finish on a concrete slab floor increases the thermal mass of the floor and the ability to store heat. This can improve cooling in summer (providing the windows are shaded) and works best for rooms with good north solar access. Other hard floor finishes, such as slate and vinyl tiles, have a similar effect on thermal mass performance.

COLOURS

Thermal mass that is coloured black absorbs more heat than white coloured material. Its effect on room temperature could be a 2–3°C year-round temperature rise (see figure 6.11).

TEXTURES

Textured surfaces, such as brick walls, have more exposed surface area and absorb more heat, while shiny or glossy surfaces absorb less heat than dull surfaces.

WALL SURFACES

An exposed brick wall absorbs more heat than a smooth plastered wall. The improved thermal storage of dark, textured walls should be balanced against the negative effect of such walls on internal light levels. Light-coloured reflective surfaces maximise both daylight and artificial light, whereas dark surfaces absorb light.

Special construction types

MUD BRICK

Mud brick and rammed earth homes generally have thick walls (approximately 300 mm) and high thermal mass. When outside temperatures fluctuate above and below comfort temperatures, the high thermal mass of mud bricks considerably reduces heat transfer, performing particularly well in summer. In winter however, outside temperatures are normally lower than comfort temperatures and the low thermal resistance of mud brick leads to poor winter performance as heat is lost through the walls.

Approximately six times as much heat passes through a mud brick or rammed earth wall compared to an insulated brick veneer wall. To reduce heat losses in winter, it is advisable to install external insulation to mud brick or rammed earth walls (see figure 6.12). Avoid fixing insulation to the internal face as this loses the thermal mass benefits of earth walls.

If uninsulated mud brick or rammed earth is used, limit winter heat losses by keeping non-north windows as small as possible. All north windows should be double glazed and the area of north glazing should be at least 25–30% of the floor area, to help heat the building in winter. Ensure that windows are shaded in summer.

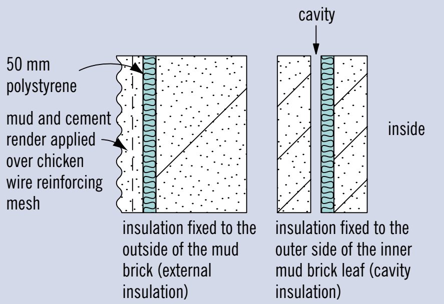


Figure 6.12: Insulating mud brick walls

REVERSE BRICK VENEER

Reverse brick veneer, as the name suggests, puts the brickwork on the inside and timber framing on the outside i.e. the reverse of traditional construction. This form of construction enables a timber-style home to achieve the same level of thermal performance as a double-brick home.

By reversing the traditional construction type, the high thermal mass of brickwork can be used to advantage. Instead of being on the outside of the insulation and hence isolated from the room, the brick skin is within the insulation envelope. Reverse brick veneer can be used in conjunction with either a concrete slab floor (see figure 6.13) or a timber floor (see figure 6.14).

The heating needs for reverse brick veneer are somewhat higher than for traditional brick veneer, although the summer savings outweigh this.

Reverse brick veneer does not have to be used for the entire home—it may be used only for north-facing rooms. The external skin can be any type of lightweight cladding suitable for exterior use.

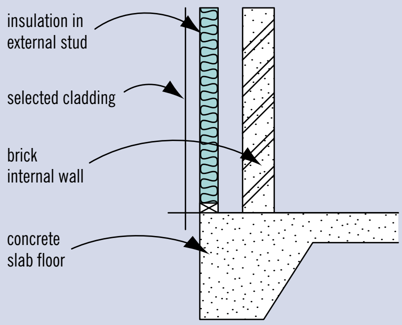


Figure 6.13: Reverse brick veneer on concrete slab

TWO-STOREY DWELLINGS

The upper storeys of homes have the potential to overheat in summer as they are usually of lightweight construction, with either brick veneer or weatherboard walls.

To prevent overheating, upper levels should incorporate as much thermal mass as possible. Thermal mass can be provided by a suspended concrete slab floor, internal brick walls, the continuation of ground-floor double-brick construction, or any other technique that builds concrete or masonry into the structure.

Windows to the east and west should be avoided or minimised because of the tendency to overheat. Limit the upper-storey window area to the north at less than 10% of the upper gross floor area. All windows should be effectively shaded and positioned to allow good cross-ventilation.

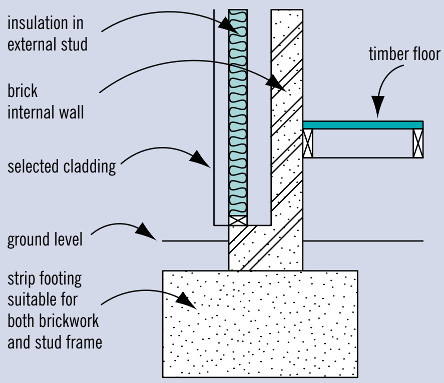


Figure 6.14: Reverse brick veneer with timber floor