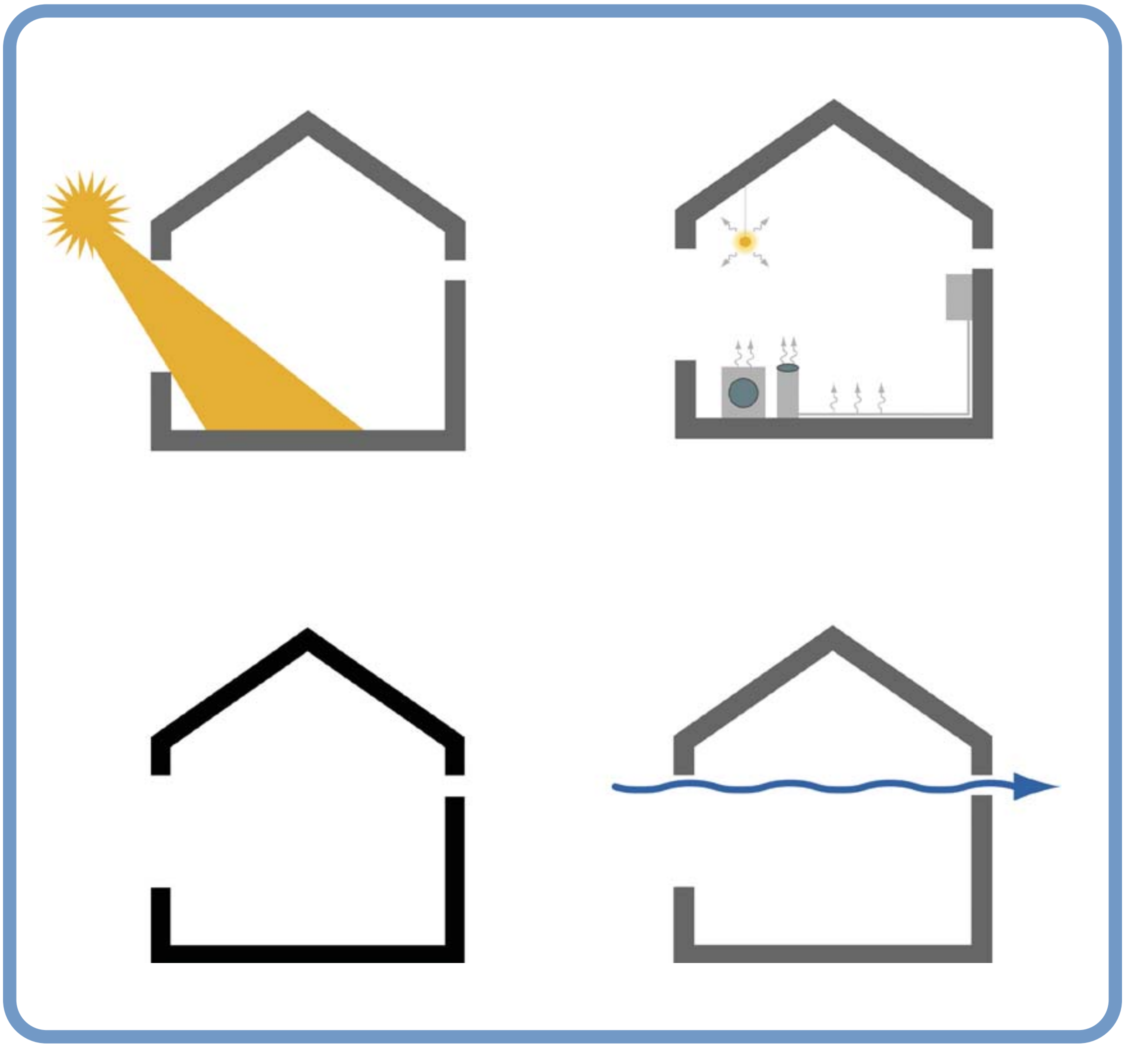
Energy Efficiency Best Practice in Housing

Reducing overheating – a designer's guide



Contents

The risk of overheating

Overheating in a house will not only cause discomfort to the occupier but – if it occurs regularly or over a sustained period – will lead to pressure for the installation of mechanical cooling. In addition to the initial cost and ongoing maintenance requirements of such systems there will be an increase in the overall energy use of the property. This in turn is likely to lead to higher carbon dioxide (CO_2) emissions – at a time when there is a pressing need to reduce them.

The risk of overheating is, paradoxically, a result of efforts over the last few decades to reduce energy demand in UK housing. Improvements have been most marked in new housing. Here the annual heating demand has fallen from around 200 kWh/m^2 for a 1940s property to approximately a quarter of that.[1]

Where overheating was a problem in older dwellings, this was mainly due to heat penetrating into unheated areas of the building (such as hot summer sunshine on the roof heating the bedrooms below). Insulation reduced this problem, but it had other unexpected results.

High insulation levels have reduced the length of the heating season and so internal temperatures can often be maintained by heat 'gains' from sources other than the heating system. However, the increasing level of insulation also means that internal temperatures are more sensitive to changes in energy input. The same amount of heat put into a highly insulated property will cause a much greater change in temperature than in an uninsulated one. If heat gains are significantly greater than the losses then overheating can occur.

[1] Proposed values for Approved Document L1A 2005 in England and Wales

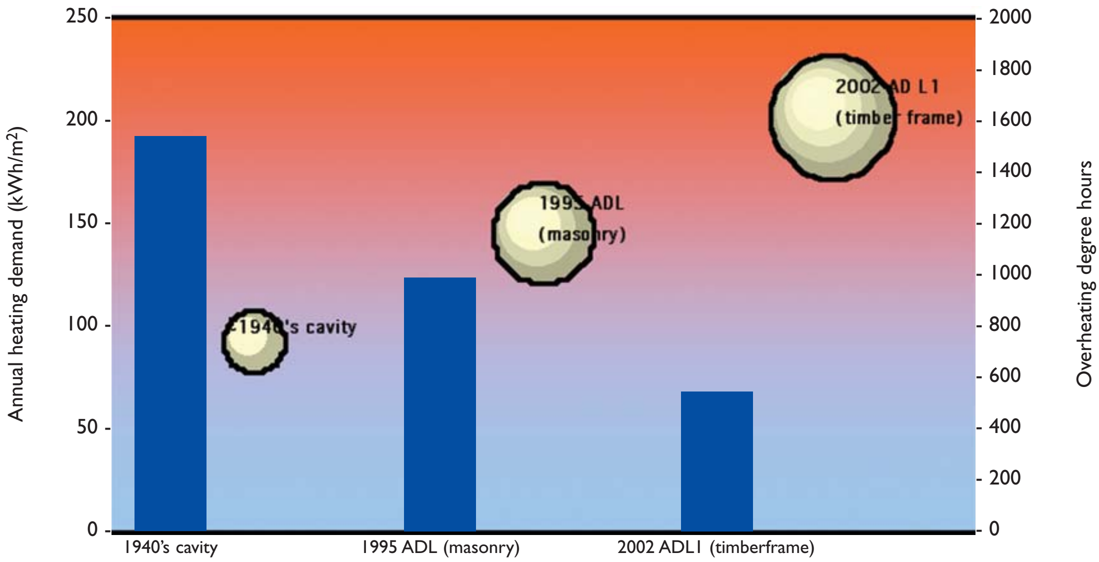


Figure 1: As insulation levels have reduced heat demand, the risk of overheating has increased.

Understanding bubble plots

'Bubble plots' represent the extent of overheating. The centre point of each bubble is the extent of overheating measured in degree hours*. The area of the bubble represents the standard deviation of temperature around the house. Lower and smaller bubbles are therefore preferable.

* See 'Quantifying overheating' on page 8.

Some gains are fairly small or constant whereas others, such as cooking and solar gains, vary significantly during the day. This means that the total gains can be greater than heat losses during some parts of the day and less than the losses during others.

Many of the solutions to this problem concern architectural design and specification – just as they have in the past. Traditionally, designers have used natural 'shelter belts' to reduce exposure to cold winds. They also provided tall windows and light wells to allow the sun to penetrate deep into a building. Today, designers need to be able to keep dwellings cool so that homes remain pleasant places to live in. While it is unlikely that overheating can be avoided altogether, it can be reduced so that simple air movement (from fans and openings rather than cooling systems) will provide the additional comfort needed.

This guide explains why overheating occurs in housing and illustrates how designers can reduce it in a way that is sympathetic to the architecture around us. Some of the measures are simple and have little impact on design; others require more care and need to be adapted to the specific situation.

A guide for planners

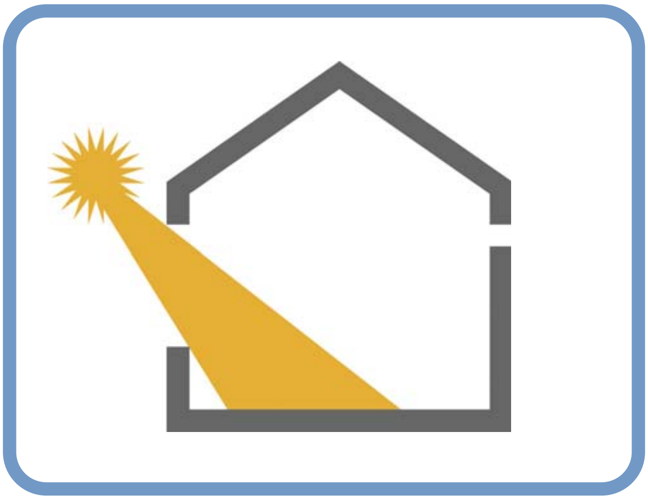
The design choices made to avoid overheating may well affect the external appearance and can therefore impinge on the planning process. So, as well as helping designers, this guide is intended to help planners understand the need for changes to housing design. It also illustrates some of the alternatives available. In the hands of a skilful designer, these can be subtle and complement the surrounding architecture.

Factors affecting overheating

Four main factors can cause a dwelling to overheat and these can be grouped under two headings:

- the control or reduction of summer heat gains (both solar and internal);
- the reduction and subsequent elimination of the impact of thermal gains.

Reducing solar gains



Solar gains are generally welcome. Passive solar design tries to optimise these and offset the need for heat from other sources, such as boilers or storage heaters. However, they need to be controlled.

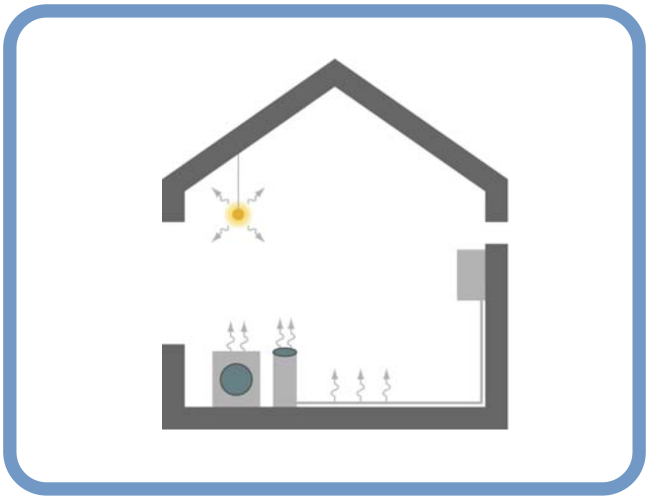
Careful orientation of windows at design stage can give benefits both in summer and winter. Due to the differing angles of incidence of the sun's rays on the glass, rooms with south facing windows are more protected from the high summer sun. Winter sun, however, can penetrate into the home.

In the past, blinds would have absorbed the short-wave solar radiation and re-radiated much of it back out as long-wave radiation. However, low-e glass, which is now standard in most new homes in the UK prevents this long-wave radiation from leaving the building and so diminishes the blinds' effectiveness. Blinds with a reflective surface redirect some of the radiation back through the window still as short-wave (which can pass through the low-e glass). These type of blinds are therefore more effective at controlling gains.

Tinted glazing and heat-reflective glazing systems can reduce solar gains in the summer. However these affect the look of the building and also reduce both daylight levels and beneficial solar gains in winter.

In most situations, external shading is the only viable option. This can take a variety of forms and examples are given later in this guide.

Reducing internal gains



In addition to solar gains there are several other summer heat gains within a dwelling. These 'internal' or 'casual' gains come from:

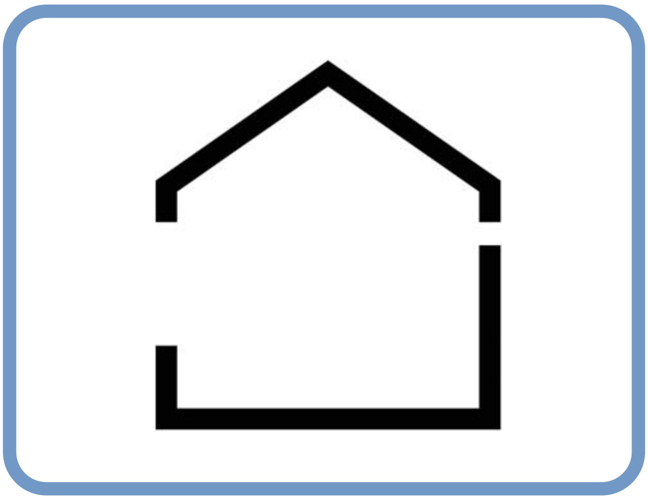
- lighting and appliances;
- hot water production;
- cooking;
- heat given off by occupants (metabolic gains).

With the exception of metabolic gains, these are generally caused by the inefficiency of energy-using appliances. Reducing these gains will save energy as well as reducing overheating.

White goods are much more efficient today and there is little to be saved here. Conventional tungsten lighting is, however, very inefficient and can contribute to the gains. While lighting will not generally be in use when solar radiation is being absorbed by the building, the heat produced by the lighting in the evening will reduce the rate at which a building is able to 'lose' this absorbed energy.

Another summer heat gain comes from the heating of water (in winter this offsets the energy needed for space heating). Modern heating systems with lightweight boilers, good controls and factory insulated cylinders have reduced losses significantly. However, an un-insulated primary circuit can give off over 500 kWh of heat over a year – double that from the cylinder itself!

Thermal mass



Air has very low specific heat capacity so a small energy input will result in a large temperature increase. On the other hand, construction materials have a much higher capacity so the same amount of heat will only have a small effect on temperature. If the surplus heat in the air can be temporarily stored in the structure and then released when air temperatures fall, occupant comfort will be increased. This is how 'thermal mass' is used.

The 'admittance' of a material gives an indication of how quickly a building element can absorb thermal gains and is expressed in W/m^2K (not to be confused with the U-value which has the same units). The greater the thermal mass, the higher the admittance.

However, a large volume of a dense material will not necessarily have a high admittance - the heat may not be able to transfer into it rapidly. For this two other properties are required:

- a large surface area;
- direct contact with the warm air.

Increasing the surface area allows the excess heat to be absorbed more rapidly. Under most normal temperature cycles in a dwelling, only the first 100mm depth of a dense material will absorb heat from the air. And if the dense material is not in direct contact with the air, known as 'coupling', the benefit will also be reduced.

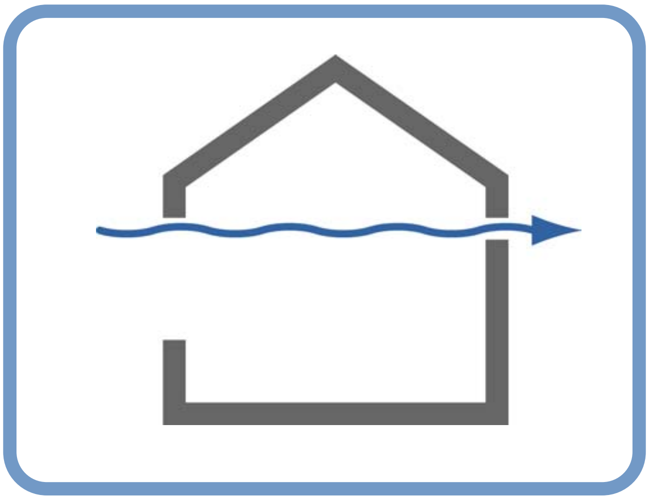
The importance of coupling can be seen by comparing the admittance of two elements of similar physical mass but different finishes:

- 100mm dense concrete block with 13mm wet plaster = $5.1W/m^2K$;
- 100mm dense concrete block with 13mm plasterboard on dabs = $2.7W/m^2K$.

The air space behind the plasterboard has effectively insulated the room air from the blockwork and limited its ability to absorb heat.

If the area and admittance of all the elements are known then a whole house admittance figure can be calculated. As most designers are unlikely to have the resources to do this, a table of admittance values for some common building elements is on page 18. Comparing these values will give designers a 'feel' for thermal mass.

Ventilation



When warm air builds up inside a dwelling, it needs to be removed before comfort is restored. If this is achieved through the use of thermal mass, the heat absorbed by the structure will also need to be removed later to enable the process to be repeated the next day. Since good insulation standards mean that heat cannot escape through the fabric, the only alternative is ventilation.

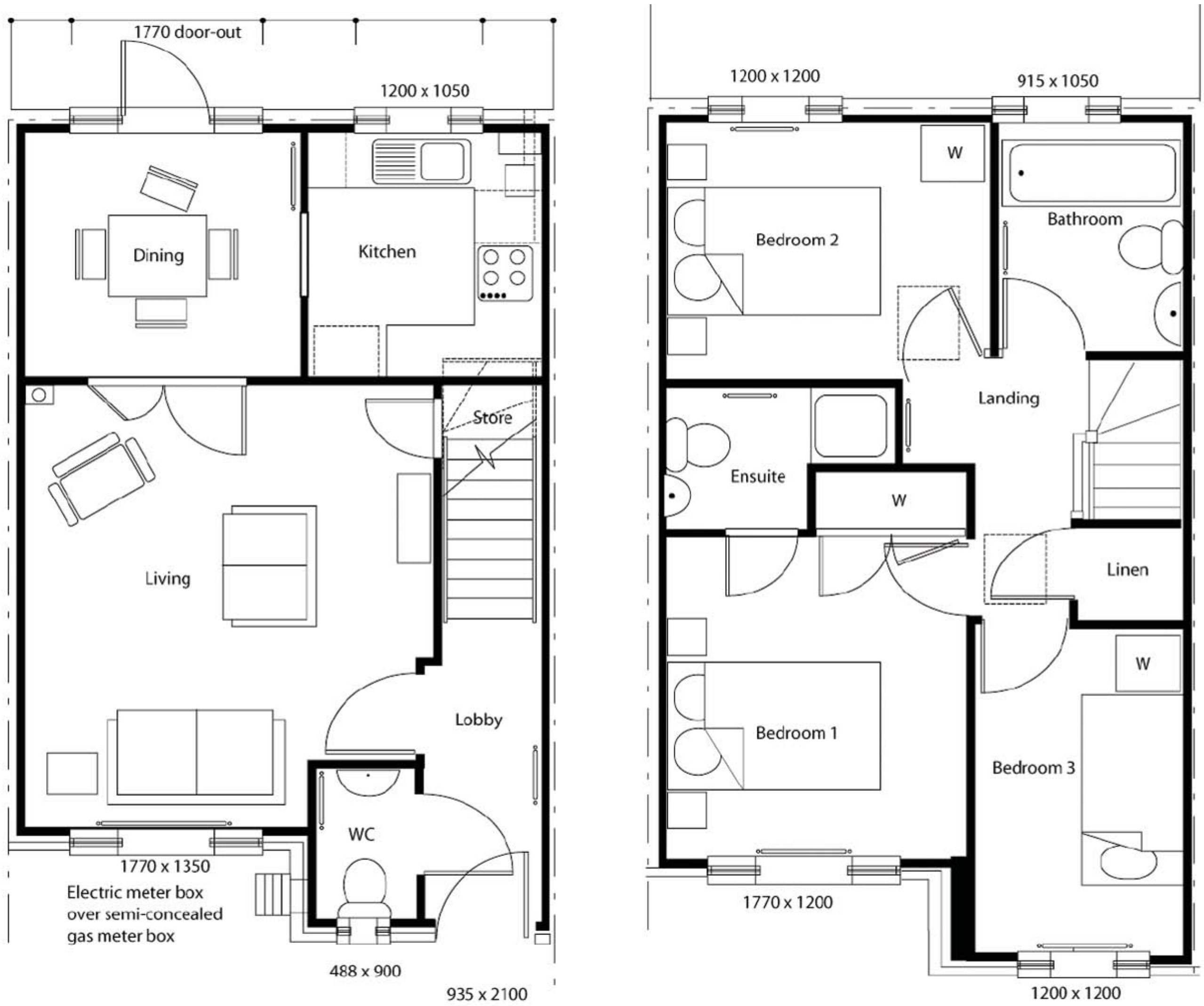
Although air movement from ventilating a building during a hot day will improve the occupants' feeling of comfort, it may also bring in additional gains. Ventilation should therefore be discouraged when the house is not occupied. Gains that do build up and are absorbed by the structure need to be removed at night. The more heat absorbed by the structure, the greater the required ventilation rate.

Identifying the risk

Ideally all the factors that affect overheating should be addressed at design stage but this is not always practical. Designers therefore need to know the difference each factor might make so they can prioritise them. In preparing this guidance, research was undertaken to assess the impact of a range of different measures.

The internal temperatures of a semi-detached property were calculated using APACHE thermal simulation software. Two different construction types were considered initially. These 'base cases' were a lightweight timber frame building and a masonry construction of dense masonry blockwork with plasterboard on dabs. The whole house admittance of masonry construction using lightweight aircrete blocks and plasterboard on dabs is not significantly different to timber frame, which is why the masonry house was modelled using dense blocks. This is not meant to be representative of typical construction but illustrates an 'intermediate admittance' dwelling.

The ground floors were beam-and-block construction with insulation above. Carpet and underlay were assumed.



Once the overheating characteristics of the two constructions were known a number of 'design options' were considered and the impact on overheating assessed. These options were as follows.

- Rotate dwelling 45° to face south-west.
- Rotate dwelling 90° to face west.
- Add external shading using horizontal 'shelves' to shade two-thirds of south facing windows.
- Increase the proportion of south facing glazing from 50 per cent of the total window area to 65 per cent.
- Increase the proportion of south facing glazing from 50 per cent of the total window area to 65 per cent and add external shading using horizontal 'shelves' to shade two-thirds of south facing windows.
- Reduce the proportion of south facing glazing from 50 per cent of the total window area to 30 per cent.
- Reduce internal gains by 25 per cent.
- Add thermal mass by using dense block and plasterboard-on-dabs internal partitions (applied to lightweight house only).
- Provide night cooling ventilation strategy.
- Add thermal mass by using dense block and plasterboard-on-dabs internal partitions and provide night cooling ventilation strategy (applied to lightweight house only).

These changes were applied separately (rather than incrementally) to the base case except where stated.

In each case the degree hours over 27°C (see 'Quantifying overheating', below) were calculated for the period between 1 June and 30 September using a London Design Summer Year. The temperature was calculated for individual rooms and then averaged across the house. The results can be presented as a 'bubble plot' (see page 4).

Summer overheating is likely to be less of an issue in cooler parts of the UK and greater in warmer areas.

The bubble plot below shows the results for all the design options. These are illustrated individually in the next section. The overheating characteristics for a 1940s house are shown for comparison.

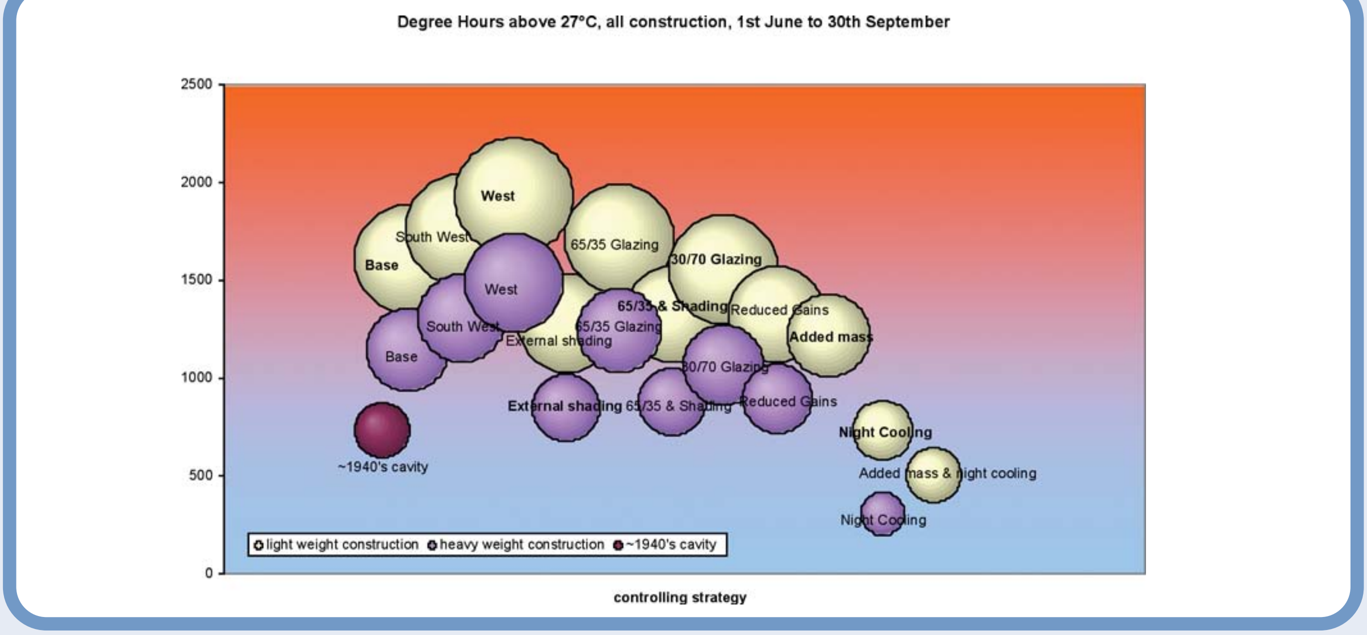


Figure 2: Overheating risk for different design options

Quantifying overheating

Since overheating is related to physical comfort it is partly subjective. However for research purposes a definition is required to allow it to be quantified. There are two main approaches.

CIBSE (The Chartered Institution of Building Service Engineers) guidance suggests using the number of hours for which the internal temperature is above 25°C as a suitable indicator for offices. However, this does not convey the full extent of the impact on occupants as one hour at 26°C is treated the same as one hour at 30°C.

An alternative measure is the number of degree hours above a threshold temperature. If the threshold is set at 27°C then a temperature of 30°C for one hour is 3 degree hours. Lowering the threshold increases the total degree hours, but reduces the difference between the design options, although the relative impact remains almost identical.

The number of degree hours over 27°C (between 1 June and 30 September) was used for the results shown in this publication.

Design guidance

This section gives practical examples of measures to address the risk of overheating where one has been identified. It is not possible to eliminate the risk altogether but applying either individual or combinations of measures will reduce it and provide greater comfort.

Some of the examples are from existing UK housing and can be applied to most other situations. Other techniques are less common or used abroad and may need adapting for the UK.

The impact of each measure on overheating is shown using 'bubble plots' (see page 4). The design options that have been modelled are explained in the previous section (see page 8).

Research findings (reducing solar gain)

Orientating a property away from south (base case) towards the south-west and west increases the amount of overheating. The sun will be directed at the glazing when it is lower in the sky and external temperatures are at their peak. Additional modelling showed a significant reduction in winter gains as the dwelling is rotated westward. This is due to the favourably low angle of the winter sun on south facing windows and the short days reducing incidence on windows facing west.

The addition of shading can significantly reduce overheating (modelling assumed shading 'shelves' protected two-thirds of south facing windows on midsummer day) whilst changing the proportion of glazing facing south and north has a less marked effect.

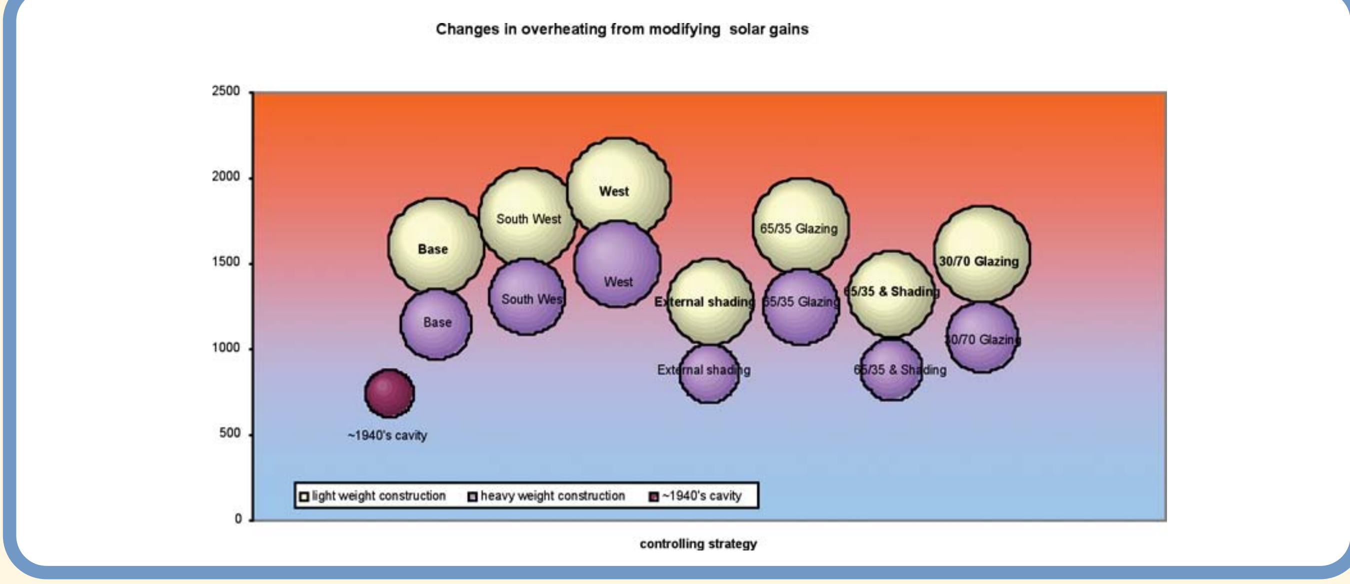


Figure 3: Changes in overheating from modifying solar gains

Reducing solar gain

Key points:

- avoid large west facing openings;
- use natural features;
- use external shading on south facing windows.

When attempting to reduce overheating due to solar gain through windows, internal blinds are of limited benefit. Tinted or mirror glass have strong visual impacts and reduce desirable winter gains. Some benefit can be gained from careful positioning of a dwelling to make use of deciduous trees but designers rarely have this luxury. This leaves the option of external shading, which can be broken into two main categories – movable and permanent.

Movable shading

The most obvious form of movable shading is the conventional awning which is sometimes retrofitted to dwellings. These can be neatly accommodated into the structure of new buildings when considered early in the design. They have little impact on low-level views when in use and allow continued use of the openings they shade.

Awnings can be highly effective and allow continued access to the building. Lynn Road, Mole Architects. Photo: Reeve Photography

External roller blinds work in a similar way to security shutters but if made out of PVC-coated polyester mesh (or similar) they can be accommodated discreetly within the window soffit. Vertical tracks, which again can be 'designed in', prevent the blinds from blowing around when in use. They provide a good level of shading whilst allowing some light to penetrate (depending on the mesh size). External roller blinds, when in use, do not allow access through doors but some ventilation can be maintained if used in conjunction with inward opening (or sliding) windows and doors. This type of blind is, however, rarely used in the UK.

External roller blinds can be discretely accommodated in the dwelling structure. Lynn Road, Mole Architects. Photo: Reeve Photography

Where external blinds and awnings are part of the structure, the impact on planning requirements is minimal so long as sight lines are not infringed. However, this should be checked with the local authority first, especially in conservation areas.

The traditional form of movable shading is the window shutter. This cannot be used with outward opening windows but is widely used abroad as it provides excellent shading. Unlike awnings and external blinds, shutters have a permanent influence on the building design but may be appropriate in some styles of housing.

Traditional shutters, or persiane, are common abroad and provide shading and ventilation. Photo: ATLL, www.atll.it

One drawback of movable shading is that it needs to be controlled. If left retracted during an unexpectedly hot afternoon, gains may build up. Where blinds and awnings are electrically operated, automatic temperature and wind sensors controls can be added at little extra cost.

Permanent shading

Here, the shade for the openings is designed into the form of the building and its effectiveness is heavily dependent on the style of the property as well as the local architecture. In urban environments, especially with flats, modern designs can draw from commercial buildings and use projecting louvres as at Greenwich Millennium Village.

Permanent shading such as louvres work particularly well in urban settings. Greenwich Millennium Village Phase 2a, Proctor and Matthew. Photo: David Churchill

In some situations the same technique can be applied to rural environments as at the award winning Black House near Ely, Cambridgeshire.

Louvres protecting openings in a rural setting. Black House, near Ely. Mole Architects. Photo: John Donat

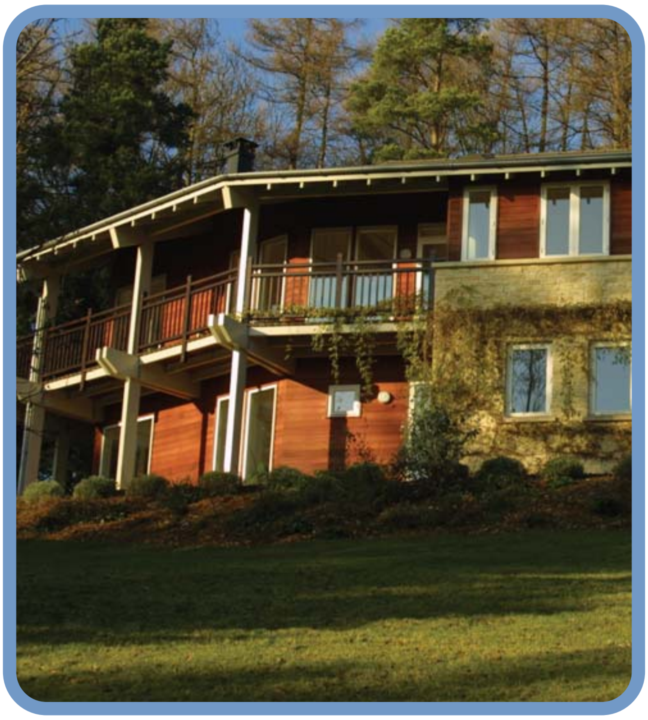
Even garden structures can be used to provide the same effect – although loss of light will occur if not adequately maintained.

Vegetation needs to be maintained if it is to be used for shading! Photo: John Willoughby

Overhanging eaves have often featured in UK housing, although this has traditionally been to throw water away from rendered cob walls. The same technique can be adapted to reduce solar gains. Different degrees of shading can be achieved by varying the setback of sections of the external wall.

Setting back the façade allows different degrees of shading to be provided. Low energy bungalow, Cheltenham, Buchanan Partnership. Photo: Bruce Buchanan

Overhangs work well with low pitch roofs; these extend further without obscuring views or the entry of winter sun. Balconies can be used to provide shading for lower storeys, whether continuously along a façade, or just over highly glazed openings to downstairs rooms.



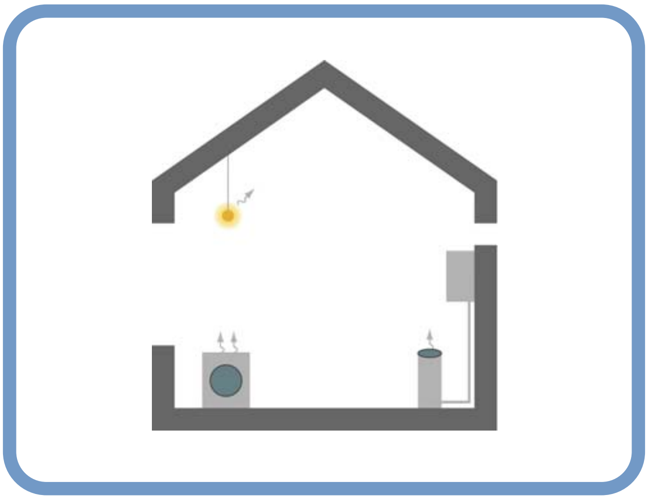
Balconies can be used to shade lower storeys. Energy efficient house near Painswick, Buchanan Partnership. Photo: Bruce Buchanan

An interesting variation of these two options is the use of a rising overhang together with horizontal louvres. A rising overhang will not shade as much of the window as a horizontal one but the louvres protect the rest of the opening, whilst allowing daylight and winter gains to penetrate the room.

Rising overhang and horizontal louvres combine to shade summer sun. House extension, Reid Architecture. Photo: Andrew Lee Photography

Most shading devices lose some of their effectiveness as window orientation is moved away from south. They are then less able to protect against lower sun angles while at the same time allowing light to enter the building and maintaining views out.

Minimising internal gains



Key points:

- use efficient electrical appliances;
- use low energy lighting;
- insulate cylinders and primary pipe work;
- keep boiler and hot water cylinder close together.

Research findings (minimising internal gains)

The modelling results show that decreasing internal gains by 25 per cent (hot water, lights and appliances) can have an appreciable impact on overheating.

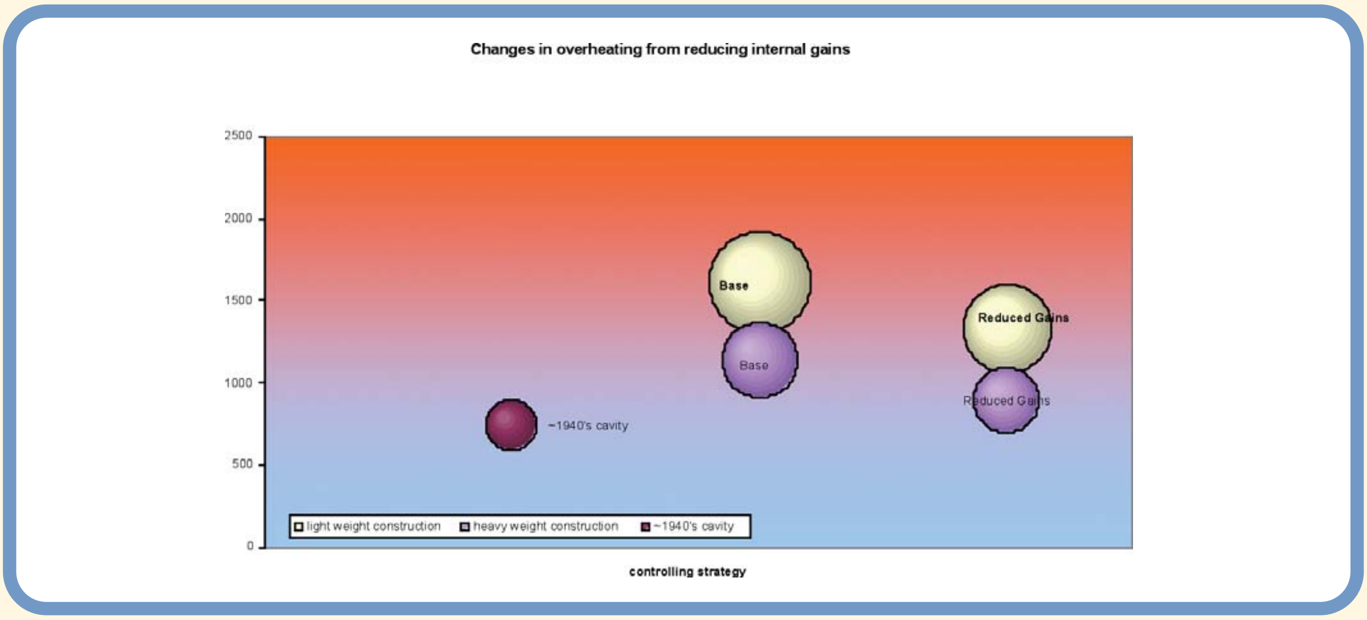


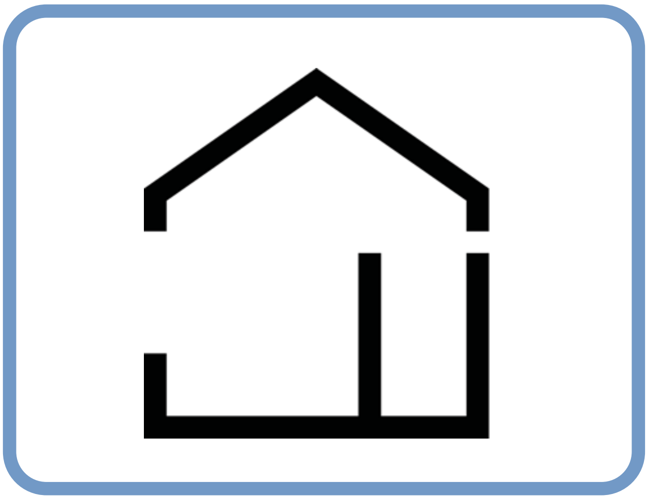
Figure 4: Changes in overheating from reducing internal gains

In new-build properties where kitchen appliances are supplied, highly efficient models will help to keep gains to a minimum. Correct positioning and installation are also important. The backs of cold appliances should be adequately ventilated and they should not be placed next to ovens (which will only increase their energy consumption and result in additional gains). Placing freezers outside the insulated envelope (e.g. in a garage) will remove gains completely and also increase their efficiency in winter.

All the energy used by lighting eventually turns into heat and so low energy lighting can significantly reduce internal gains. Designing low energy lighting fixtures into buildings helps prevent lamps being replaced with tungsten lamps at a later stage. *Low energy lighting – looking good for less* (CE81) gives more ideas on how this can be achieved.

Locate the boiler as close as possible to the hot water cylinder to reduce the primary pipework and therefore the gains from it. It is equally important to check that the specified pipe insulation is actually installed on site. Specifying high performance cylinders which have thicker insulation will also help.

Increasing thermal mass



Key points:

- use large areas of 'thermal mass';
- keep the thermal mass exposed.

Research findings (increasing thermal mass)

Increasing the mass of the lightweight construction will reduce overheating. For modelling purposes, all internal stud partitions were replaced with dense blockwork and plasterboard (although the practicalities of this approach are limited). It should be noted that the 'heavyweight construction' used dense blockwork throughout the modelling and is different from most modern masonry housing which makes extensive use of lightweight aircrete blocks (see page 7 for more information on the base cases).

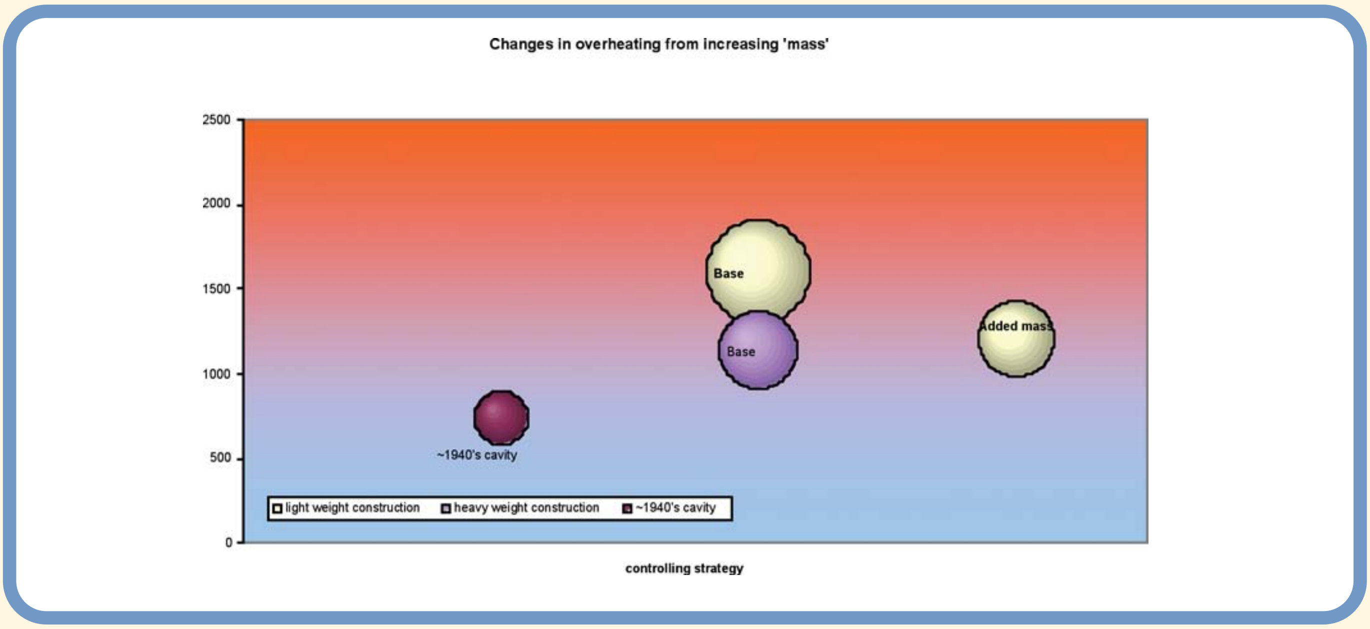


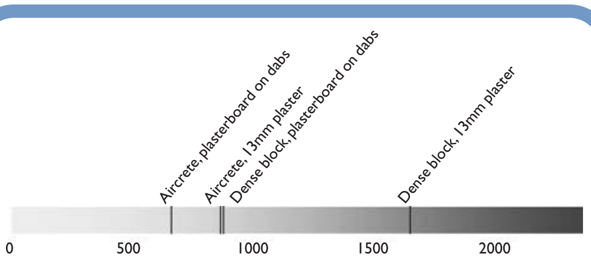
Figure 5: Changes in overheating from increasing thermal mass

Whole house admittance values (page 7) can be used to compare different construction options. Doing this for the semi-detached house shows no great difference between that achievable with the use of aircrete blockwork and plasterboard, and that of timber frame. Given that most modern masonry construction also makes extensive use of studwork with plasterboard this difference is likely to be even smaller in practice. However, both can be improved, although to differing extents.

Increasing mass does not generally affect the aesthetics but may have other secondary effects, some positive and some negative.

Masonry construction

It is relatively straightforward to increase thermal mass in masonry housing. Moving from aircrete blocks and plasterboard (on dabs) to either dense block or wet plaster will have a similar effect, but when both are used together an even higher whole house admittance can be achieved (see Figure 6). It can be increased still further (not shown) if other measures are used, such as placing the floor insulation below the concrete slab and also below intermediate concrete floors.



All walls – as per description
Ground floors – beam-and-block (aircrete block construction) or in-situ concrete (dense block construction), insulation, chipboard, underlay and carpet
Intermediate floor – timber, underlay and carpet

Figure 6: Whole house admittance (W/K) for different masonry constructions

If the thermal mass is to be increased, it is preferable to replace any studwork partitions (their presence is not assumed in Figure 6) with dense blockwork. Using dense blocks instead of aircrete on external walls will affect the U-value and so additional insulation will be needed.

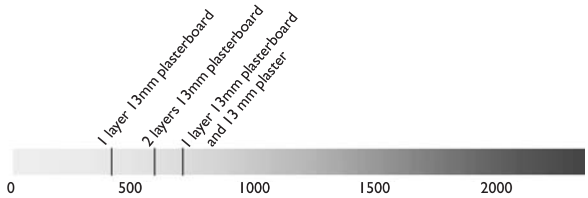
Although wet plaster is normally slower to apply than plasterboard, the introduction of sprayed or 'projection' plaster has changed this. This is very fast to apply, and better than plasterboard at sealing walls, improving both air tightness and sound insulation (although allowance has to be made for drying out time).

Keeping the mass exposed to the air ('coupled') is also important. Specifying tiling for floors will reduce the likelihood of 'decoupling' with carpets, laminate floors etc. This is particularly important if the potential benefit of concrete intermediate floors is to be realised.

Thermal mass should not be increased without the introduction of night ventilation. This is needed in order to 'recharge' the mass by removing the heat absorbed during the day. Failure to do so may result in a greater risk of overheating during long periods of hot weather.

Framed housing

It is more difficult to introduce mass into lightweight constructions such as timber and steel frame. However, improvements can still be made (see Figure 7). One way is to use two layers of plasterboard (party walls and ceilings normally have this for fire protection anyway). This will increase the mass slightly. Using denser material (such as a full coat of wet plaster) in lieu of a second layer of plasterboard will be of greater benefit. The fact that it is difficult to increase mass makes the control of solar and internal gains even more important.



All walls – timber studwork plus finish as described
Ground floor – beam and block, insulation, chipboard, underlay and carpet
Intermediate floor – timber, underlay and carpet

Figure 7: Whole house admittance (W/K) for different timber frame constructions

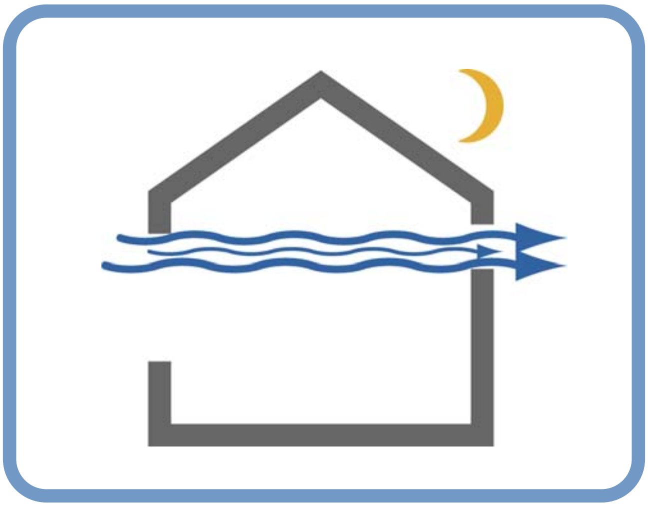
Although the use of dense blockwork for all internal partitions may not be practical, it is possible to provide hard coverings to floors and to build some high-admittance internal walls on ground floors. Large masonry chimneys will only have a small impact if the surface area is small compared to the volume of the masonry, though.

A stone wall and slate floor providing mass in a timber frame house - Dragon house, Herefordshire, Constructive Individuals. Photo: Philip Bier

There is increased pressure towards modern methods of construction, most (but not all) of which are 'lightweight'. Designers and system suppliers could find it useful to develop other ways of incorporating mass whilst not detracting from the advantages of their systems.

It should be noted that although the term 'lightweight' is generally used to describe framed construction, dense blockwork external walls with internal insulation or insulated formwork are also lightweight, if mass is not introduced elsewhere.

Ventilation



Key points:
- reduce daytime ventilation rates;
- design for high night time ventilation rates;
- provide secure openings.

Research findings (ventilation)

The base case assumes some opening of windows during the daytime and evening only (5-15 per cent of total window area) but the night cooling ventilation strategy assumes five air changes per hour during the night - the equivalent of 25 per cent of total window area. This has the most significant effect of any measure in both heavyweight and lightweight constructions. In lightweight structures its effectiveness can be increased when thermal mass is introduced.

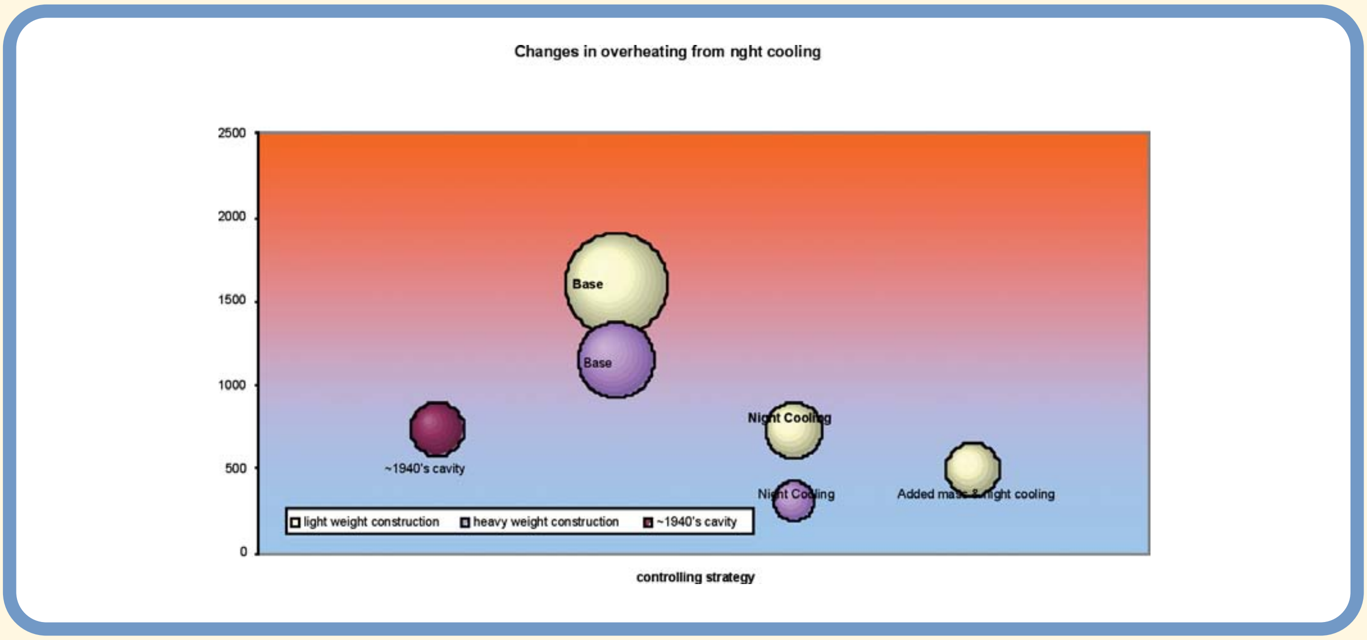


Figure 8: Changes in overheating from the use of night cooling

Ventilation control is critical if unwanted gains are to be reduced during the day and removed at night. Whilst control is down to the occupants, it is the designers' role to provide the means.

During the daytime, ventilation should be discouraged once the external temperature is higher than the internal one, as this will introduce additional gains. Any heat exchangers in the ventilation system should be by-passed in summer months. Areas which are prone to overheating (such as south-facing conservatories and sunspaces) should have secure cross-ventilation, including vents at high level such as opening rooflights. These can operate automatically if security is not an issue. External quality doors should be provided between these spaces and the main living area to prevent heat flowing into the main dwelling.

At night, a high ventilation rate, far above that provided by standard ventilation systems, is needed to remove the gains absorbed during the day. The most obvious solution is to leave windows open. However this may not be desirable, especially on ground floors or in urban areas. Choosing windows which provide secure ventilation, such as bottom hung, inward opening casements, is one option.

Inward opening windows provide secure ventilation

Another solution is to use an opening rooflight above a double height space. This can be used to create a stack effect, drawing air through the house at night. If the rooflight is motor-operated, it can be positioned directly over a stairwell.

Rooflights are a useful way of providing night ventilation.
Dragon house, Constructive Individuals. Photo: Philip Bier

Purpose-made vents can also be used. Airbricks are the simplest form but a large number would be needed to provide the required area. The vents also need to be designed to prevent high heat loss in winter. Larger purpose-made openings consisting of louvred vents can provide secure ventilation. These are fitted internally with a hinged insulated panel to prevent heat loss when ventilation is not required.

Side vents to windows can provide secure night ventilation.
Log cabin, Finland. Photo: John Willoughby

Night ventilation can be extremely effective in reducing overheating. However, its effectiveness depends both on a sufficient area of secure openings and on correct user behaviour. It is therefore particularly important that this measure is used in combination with others.

Appendix A – Admittance values for building constructions

This table shows admittance values for different building constructions. It includes some non-standard methods in order to assist designers in adapting construction techniques in the future.

These are illustrative only and are provided to highlight the relative differences between different options.

	Construction	Admittance (Y) W/m^{2}K
External Walls	Dense block, 13mm wet plaster	5.89
	Aircrete block, 13mm wet plaster	2.86
	Dense block, 13mm plasterboard on dabs	2.60
	13mm plasterboard + 13mm wet plaster on timber frame wall	1.90
	Aircrete block, 13mm plasterboard on dabs	1.85
	Two layers 13mm plasterboard on timber frame wall	1.45
	Single layer 13mm plasterboard on timber frame wall	0.85
Party Walls	Dense block, 13mm wet plaster	5.66
	Dense block, 13mm plasterboard on dabs	2.61
	Aircrete block, 13mm wet plaster	2.58
	Aircrete block, 13mm plasterboard no dabs.	2.11
	13mm plasterboard plus 13mm wet plaster on timber frame wall	2.08
	Aircrete block, 13mm plasterboard on dabs	1.73
Internal Partition	Two layers 13mm plasterboard on timber frame wall	1.62
	Dense block, 13mm wet plaster	5.06
	Dense block, 13mm plasterboard on dabs	2.67
	Aircrete block, 13mm wet plaster	2.53
	Aircrete block, 13mm plasterboard no dabs	2.05
	13mm plasterboard plus 13mm wet plaster timber frame wall	2.01
	Aircrete block, 13mm plasterboard on dabs	1.81
	Two layers 13mm plasterboard on timber frame wall	1.55
Ground Floor	Fair-faced aircrete block	1.54
	Single layer 13mm plasterboard on timber frame wall	0.86
	Insulation, concrete slab, wood blocks	3.37
	Concrete slab, insulation, chipboard, wood blocks	2.68
	Beam and medium density block floor, insulation chipboard, wood blocks	2.67
	Beam and aircrete block floor, insulation, chipboard, wood blocks	2.67
	Insulation, concrete slab, screed, wood blocks	2.63
	Insulation, concrete slab, underlay and carpet	1.81
	Beam and aircrete block floor, insulation, chipboard, underlay, laminate flooring	1.65
Ground Floor Ceiling	Concrete slab, insulation, chipboard, underlay and carpet	1.59
	Beam and medium-density block floor, insulation, chipboard, underlay and carpet	1.59
First Floor (floor)	Beam and aircrete block floor, insulation, chipboard, underlay and carpet	1.58
	20cm timber-joist internal ceiling; 22mm wood blocks	0.80
	20cm timber-joist internal ceiling; laminate flooring and underlay	0.81
	20cm timber-joist internal ceiling, carpet and underlay	0.81
	20cm timber-joist internal ceiling; 22mm wood blocks	0.90
	20cm timber-joist internal ceiling; laminate flooring and underlay	0.88
	20cm timber-joist internal ceiling, carpet and underlay	0.88

Further reading

Energy Efficiency Best Practice in Housing publications

These publications can be obtained free of charge by telephoning the Helpline on **0845 120 7799** or by visiting the website at: **www.est.org.uk/bestpractice.**

Advanced insulation in housing refurbishment (CE97)
Central Heating System Specifications – CHeSS (CE51)
Energy efficiency in new housing: Summary of specification for England Wales and Scotland (CE12)
Energy efficiency in new housing: Summary of specification for Northern Ireland (CE23)
Low energy domestic lighting – looking good for less (CE81)

Other publications

CIBSE Guide A, Chartered Institute of Building Services Engineers, 1999.
Control of Overheating in Well-Insulated Housing (Report of Partners in Innovation research project). Can be found at:
www.fabermaunsell.com/research/overheating
Solar shading of buildings, PJ Littlefair, BRE Report BR364, 1999
Summertime solar performance of window with shading devices, PJ Littlefair, BRE Trust Report FB9, 2005

Useful organisations

British Blind and Shutter Association. Website: www.bbsa.org.uk.

Energy Efficiency Best Practice in Housing

CE129

Reducing overheating – a designer's guide

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