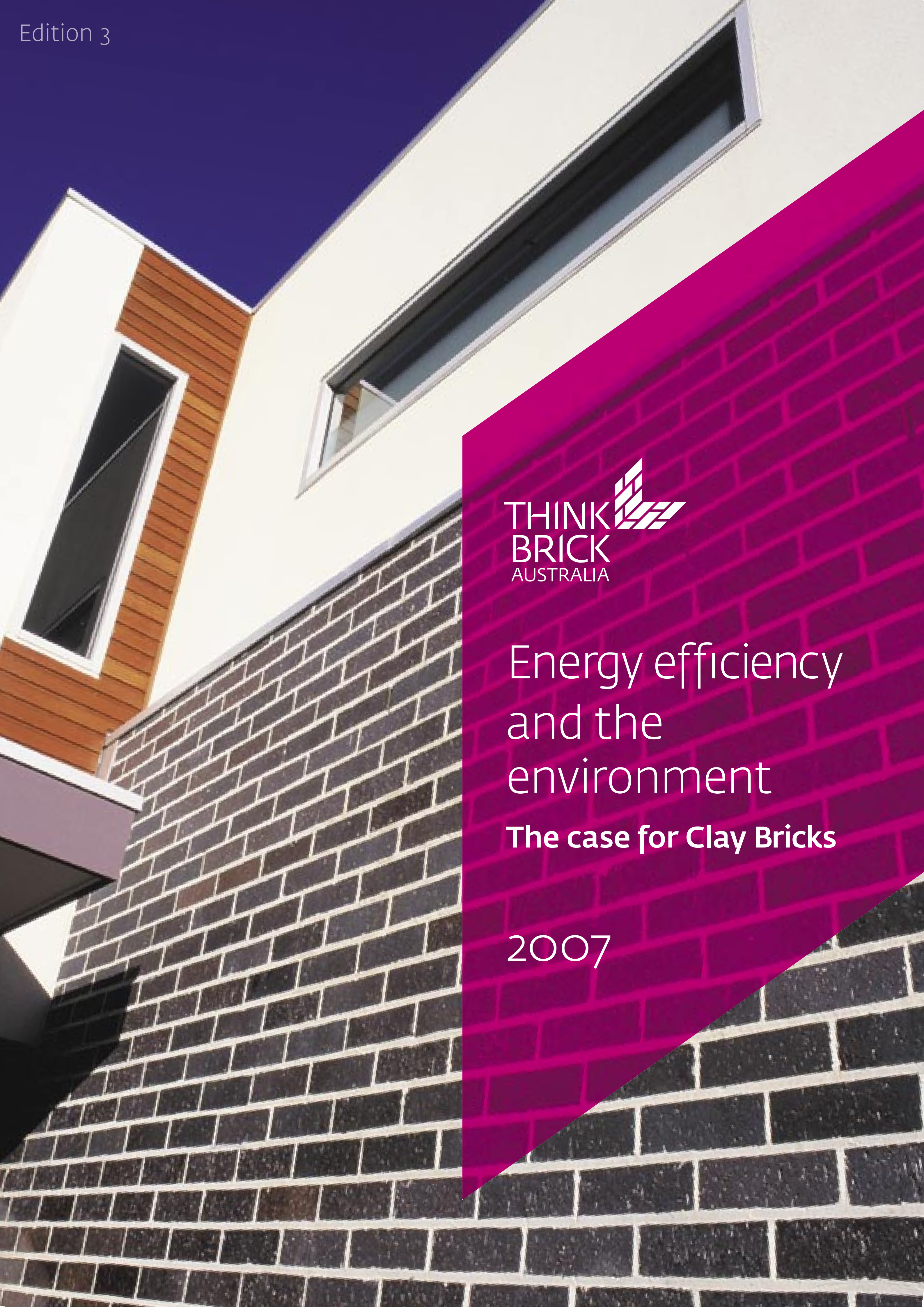
Edition 3



THINK BRICK AUSTRALIA

Energy efficiency and the environment

The case for Clay Bricks

2007

We represent the clay brick and paver manufacturers of Australia.

Our purpose is to make sure clay brick is recognised as the pre-eminent building material by leading architects, developers, builders and property owners.

We're here to promote great home and commercial design using clay brick and pavers.

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The case for research

In recent years there has been growing world-wide concern for energy conservation, the reduction of greenhouse gases and sustainability.

In Australia, it is estimated that 39% of the end energy usage in domestic buildings is used for space heating and cooling (AGO 1999).

Designing and constructing an energy efficient house has the potential to substantially reduce the amount of energy consumed.

In 2002 Think Brick Australia (formerly The Clay Brick & Paver Institute) embarked on an eight year thermal research program, in collaboration with The University of Newcastle's Faculty of Engineering and Built Environment, to understand the role of clay masonry in achieving sustainable design. To date, the research has proven clay brick is a superior building material in producing thermally comfortable, energy efficient environments for people to live, work and play.

This document sets out to describe the research methodology and some of the early outputs. Further updates will be made available to industry as new data comes to hand.

Research conducted by Think Brick Australia in conjunction with the Faculty of Engineering and the Built Environment, at the University of Newcastle.

What is energy efficiency and how do we achieve it?

An energy efficient home is a building which provides a high level of thermal comfort without an over reliance on artificial heating and cooling.

Passive design features make the difference

Passive design is energy efficient design which makes the most of local conditions to make your home more comfortable while reducing your bills.Passive design costs no more when included at the planning stage. Good passive design uses natural heat from the sun and natural night-time cooling to keep your home at a comfortable temperature year round. It can significantly reduce the need for expensive mechanical heating and cooling.

The interaction of passive design features is illustrated in Figure 1 and the key considerations are:

- Orientation and solar access
- North-facing shaded glass
- Sealing and ventilation
- Insulation
- Thermal mass

It is important to tailor the passive design features to each climate. For example, in southern parts of Australia, prominent north-facing shaded windows with eaves that overhang permit the entry of winter sun and restrict summer sun.

On the other hand, in northern Australia, large eaves around a building and well designed ventilation will help keep the building cool.

Well designed properly sealed doors and windows allow cross-ventilation in summer and restrict air and heat leakage in winter.

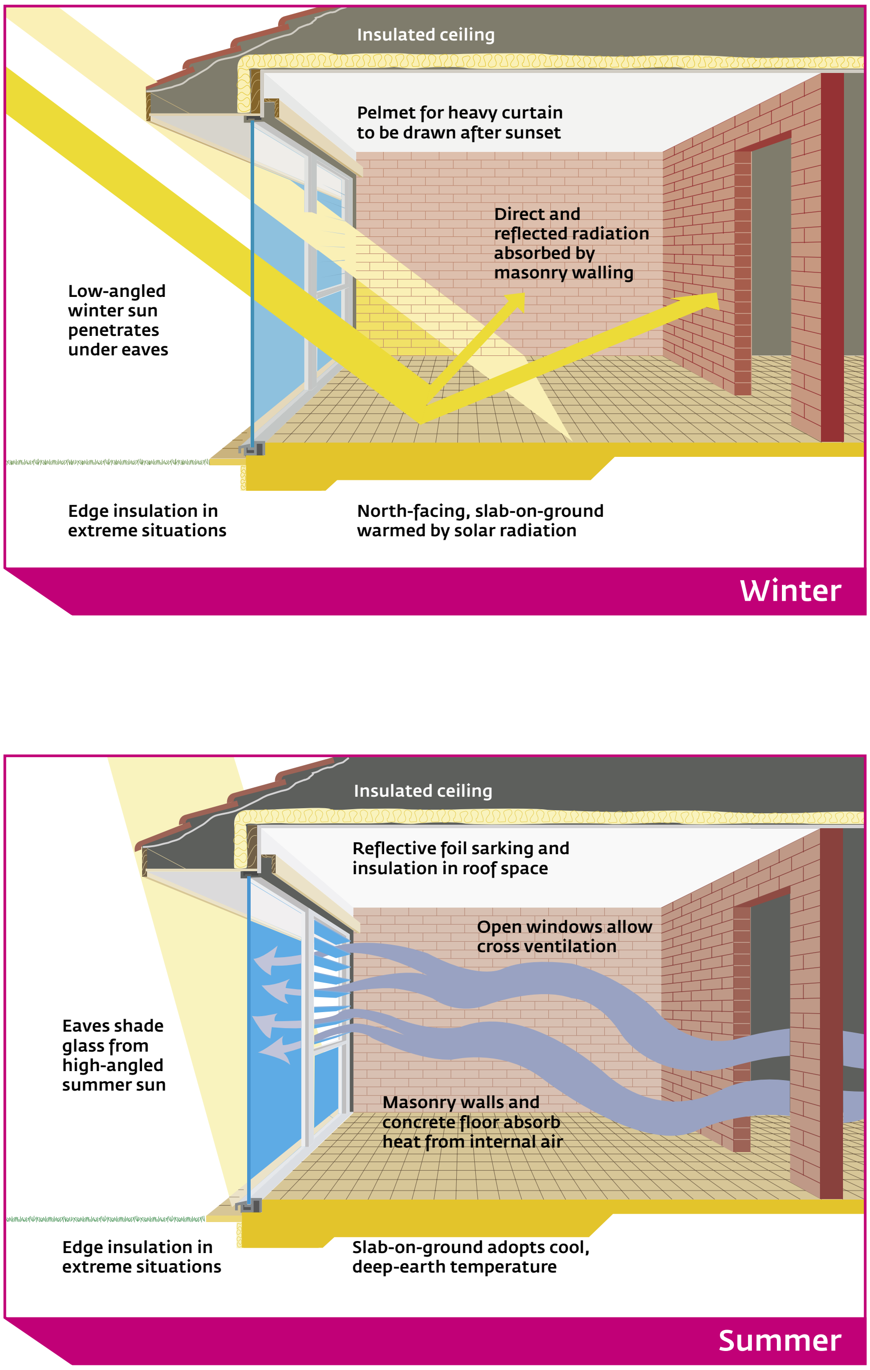


Figure 1 Principals of passive solar design.

Important terminology

Heat is a form of energy and can be sourced directly from electricity, combustion of fuels or the sun. Heat flows from hot to cold surfaces via the processes of conduction, convection and/or radiation.

The following list provides an example of how heat moves through the building envelope.

Conduction — **Is the transfer of heat through solid materials. Conduction occurs through opaque (bricks) and transparent (glass) materials.**

Convection — **Involves the transfer of heat through the movement of a fluid. In buildings this fluid is air. In winter, a concrete slab or masonry wall which is heated by the Sun will transfer some heat to the air in contact with it. This hot air will rise and flow to another location in the room or building The reverse process occurs in summer, with masonry walls absorbing heat from the warm air that has entered the building resulting in a cooling effect.**

Radiation — **Is the transfer of heat in the form of electromagnetic radiation. This can occur through space, as in the case of the Sun's energy, or other transparent and translucent media (glass or air). All bodies emit thermal radiation depending on their temperature and emissivity (colour). On cold winter nights, curtains should be drawn to reduce radiation losses through windows.**

The transfer of heat can be reduced but not stopped completely. Therefore, the design of a building and the selection of the building envelope materials (walls, windows and roof) should all complement each other. Building materials have different properties and can reduce the flow of heat in numerous ways.
For an energy efficient home it is important to use each material in the correct application. Some of the terms used in the building industry are explained below:

Thermal Transmittance — **The measure of the rate of heat loss (or transfer) through a material is referred to as the U-value. This value is used to rate the energy efficiency of building components.**

Thermal Resistance — **Is the measure of the resistance of a component to the conduction of heat. This is known as its R-value and is the reciprocal of the U-value. Due to their physical nature insulation materials have high R-values. These materials can reduce the rate of heat transfer but do not provide a time off-set (lag) in the transmission of heat. Insulation materials with higher R-values will perform better than low R-value counterparts.**

Thermal Mass (Capacitance) — **The measure of the ability of a material to store or retain heat energy. The thermal mass of high-density clay masonry materials provide a time lag in the transfer of heat making them more thermally effective than their R-value would indicate.**

Thermal Bridging — **The phenomenon whereby heat bypasses insulating materials to flow through highly conductive materials such as metal window frames, metal door jams, structural steelwork or concrete slabs. Thermal bridging should be avoided or minimized where possible.**

How important is thermal mass and building design?

Thermal mass is the ability of a material to retain heat energy when subjected to a temperature differential. Clay brickwork and concrete floors have relatively high thermal mass.

In summer, a high thermal mass wall can reduce the transfer of heat by absorbing the heat energy flowing in from the outside. This process is slow and results in a delay called thermal lag. The capacity to absorb large quantities of heat energy for a small rise in temperature combined with the thermal lag, effectively increases the R-value performance over the complete day-night cycle.

Maximum external air temperature is usually reached between noon and 2pm. A lag of six hours, which is typical for brick construction, means the maximum heat flow would not reach the interior until six hours later. By then external air temperature will usually have dropped and thermal flow will reverse, allowing the building to cool for the following day.

Buildings with high thermal mass "iron out" the temperature variations naturally, allowing temperature ranges more consistent with the ideal human comfort zone as shown in Figure 2. This is important to the environment, as the building has a reduced need for artificial heating and cooling, meaning less energy use and improved thermal comfort for building occupants.

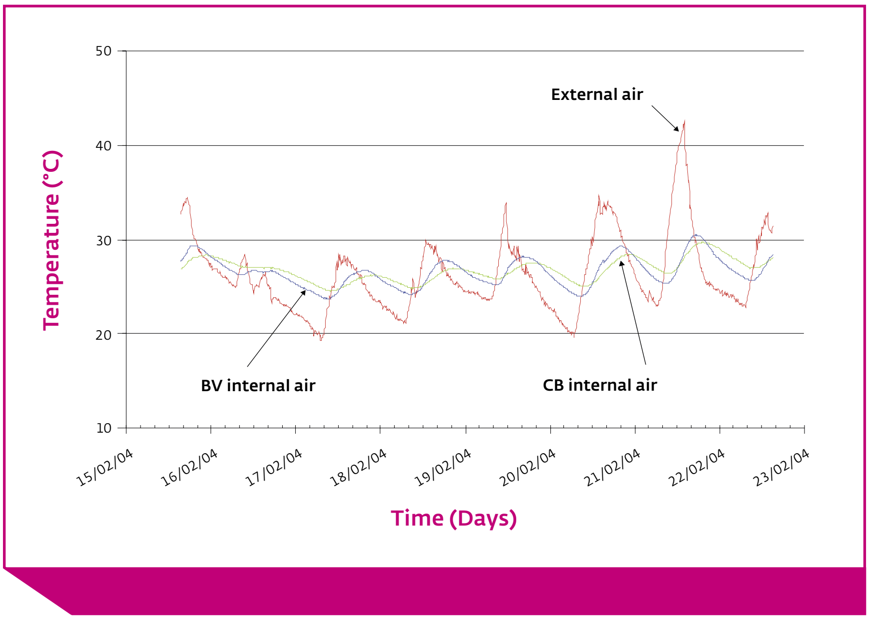


Figure 2 Comparison of internal temperature in cavity brick (CB) and brick veneer (BV).

The buildings were monitored to establish year-round thermal response

Thermal mass should be incorporated not only in external walls but in other areas, as:

- A concrete slab is an essential part of the equation as it increases mass significantly.
- Solid partition walls (as opposed to stud walls) also add significantly to the mass. (They have the additional benefit of reducing noise transmission between rooms.)

The BCA acknowledges the contribution of the mass of a cavity brick wall to its thermal capacitance by including a deemed-to-comply provision for clay masonry construction. This provides a cut-off of 220 kg of wall mass per square metre, over which wall insulation is not required. Put simply:

- Brick veneer (being generally less than 220 kg/m2) requires insulation.
- Cavity brickwork which is over this figure requires no insulation (depending on location and shading).

So how has masonry housing performed?

Three small test buildings were constructed in cavity brick and brick veneer as shown in Figure 3.

To ensure the study considered only the effect of the brickwork, two of the "test buildings" did not have any windows or other openings. The roofs were heavily insulated to minimise through-ceiling heat flow.

In this respect, the results represent an upper bound limit for summer and a lower bound limit for winter.

The third building, constructed twelve months later, contains a glass sliding door to evaluate the influence of glazing on the thermal performance of the building.

The buildings were comprehensively instrumented with temperature, humidity and heat flux sensors and were monitored to establish year-round thermal response.

Figure 3 Test building modules at The University of Newcastle.

The study found that "a large portion of the heat is reflected and radiated back to the external environment by the exterior surface of the brick.

The plots also show that significant amounts of the heat stored in the wall are released back to the exterior environment at night." This indicates the clay brick cavity walls allow heat flow in and out of the building.

This is demonstrated in Figure 4 and Figure 5.

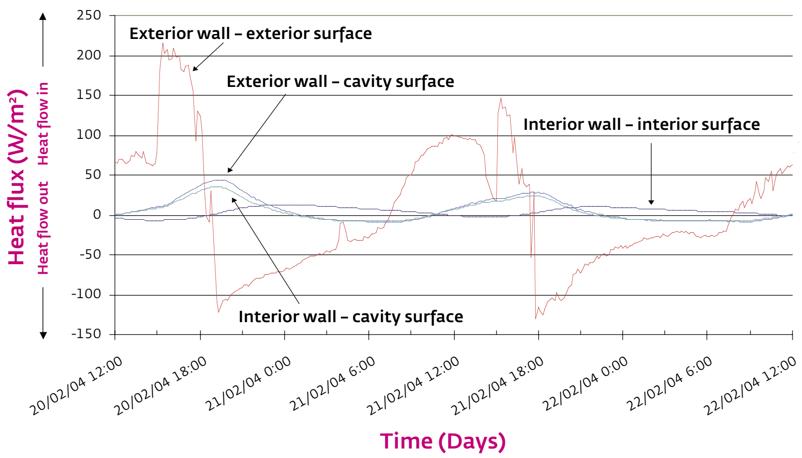


Figure 4 Heat flow through the west wall of the cavity brick building.

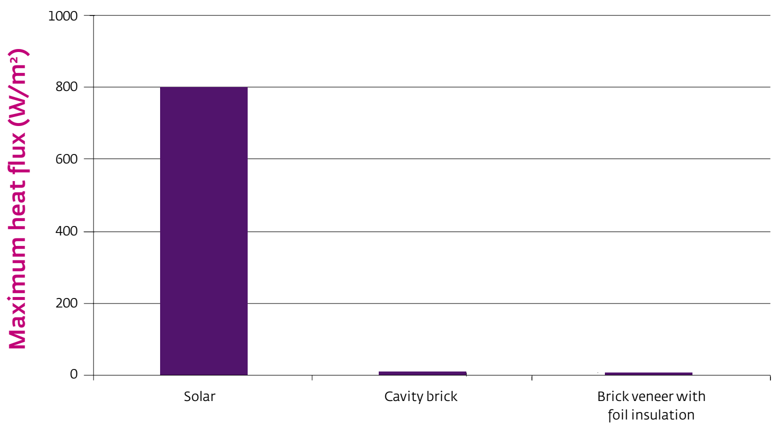


Figure 5 Typical heat flux for western wall under summer conditions.

Figure 6 illustrates the amount of heat energy on the surface of the west wall is 700-900 W/m2 which falls to about 200 W/m2 in the external wall.

The attenuation of heat reduces to 50 W/m2 in the cavity, with finally only 6 W/m2 of heat energy on average passing through the wall.

The study indicated that the amount of heat energy penetrating the west wall was minuscule. However, the researchers drew attention to "the significant volume of heat flux through the window" as shown in Figure 7.

The heat flux entering the building through the window is significantly greater than the heat flux entering through the walls.

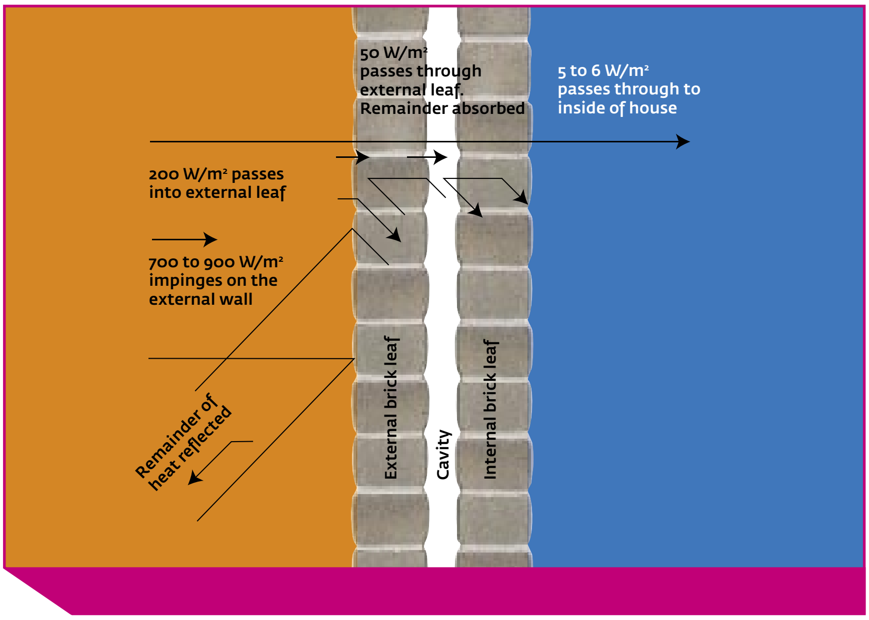


Figure 6 Heat flux through west walls in summer.

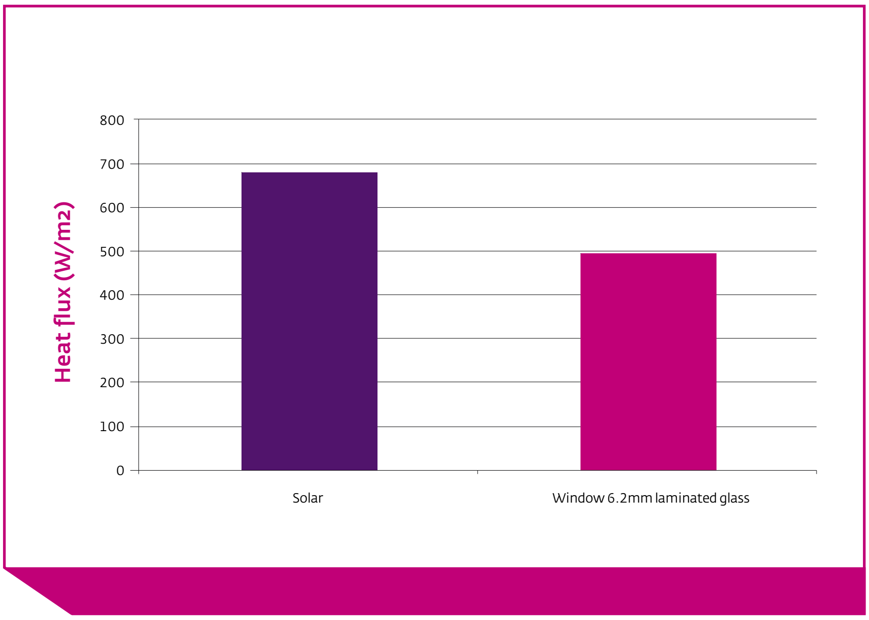


Figure 7 Typical maximum heat flux for north facing window for September.

The R-Value – is it the right measure?

Another issue highlighted by the research is a deficiency in using the Thermal Resistance Value, or R-value of the wall, to measure the thermal efficiency of a building.

During a hot spell in February 2004, the data from the brick veneer and cavity brick buildings indicated that the "greater mass of cavity brickwork construction reduces the internal day-night temperature swing when compared to the insulated brick veneer despite the latter form of construction having a higher Thermal Resistance Value", see Figure 8.

The thermal mass of clay bricks provides a time delay for heat transfer through the walls known as thermal lag. This is demonstrated in Figure 8.

It can be seen that high density walling materials do not fair well when assessed purely on the criteria of "R-value", however, when assessed on Thermal Capacitance clay bricks outperform their lightweight counterparts. It is for this reason that clay bricks are thermally more effective than the "R" value alone would indicate.

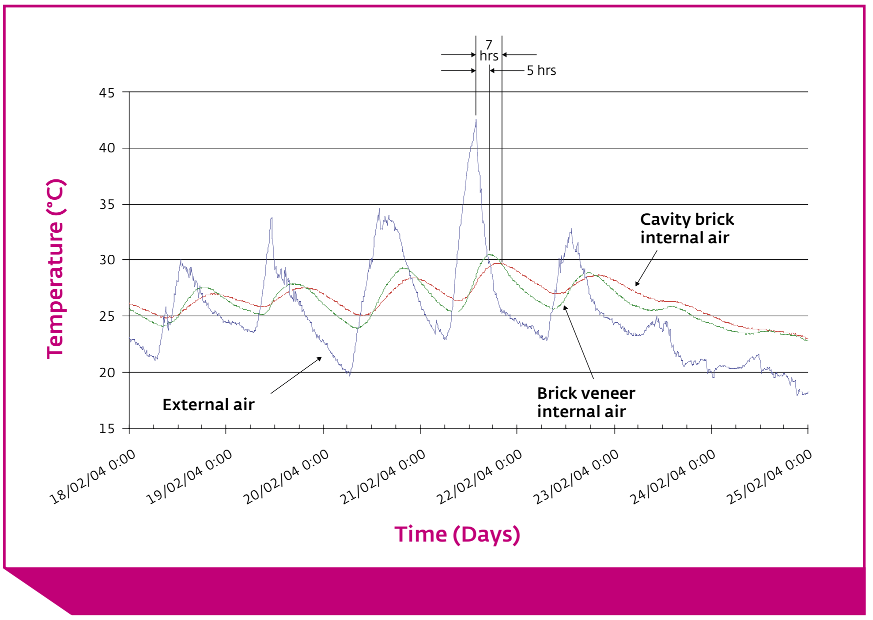


Figure 8 External and internal air temperatures for cavity brick and brick veneer buildings, February 2004.

Roof insulation – more important than we thought?

The incident solar radiation on the exterior building surfaces in summer is shown in Figure 9. The maximum amount of solar radiation is received by the roof and is in the order of 1000W/m2. The radiation falling on the north wall is low due to the higher solar altitude and is further attenuated by the eave providing shade on the wall.

The solar radiation levels in Figure 9 highlight the duration of time that the roof receives heat gain. That is, the roof receives over twice the amount solar radiation when compared to the east and west walls.

In summer, the temperature of the roof surface exceeds 60°C for nearly seven hours a day.

This is demonstrated in Figure 10, which also shows the corresponding temperatures for the air space in the ceiling, above and below the bulk insulation and the internal room temperature.

The research indicates that the elevated temperatures measured in the roof space demonstrate the value of roof insulation and the need to focus greater resources in this area of construction.

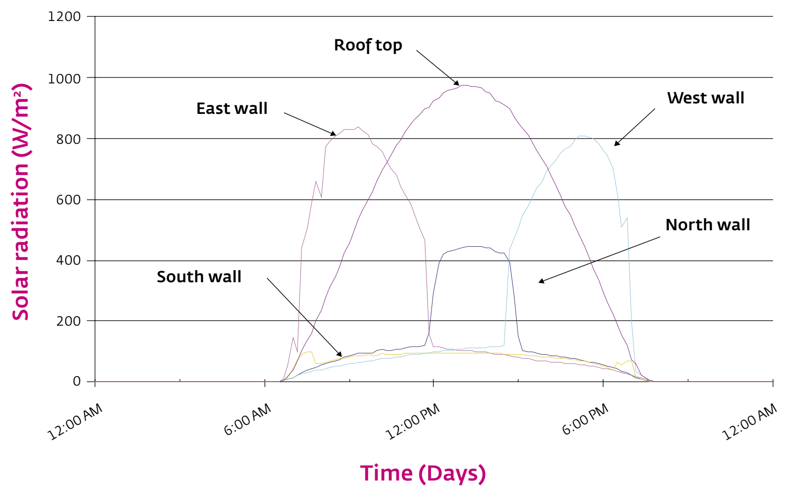


Figure 9 Solar radiation on the exterior building surface, 20 February 2004.

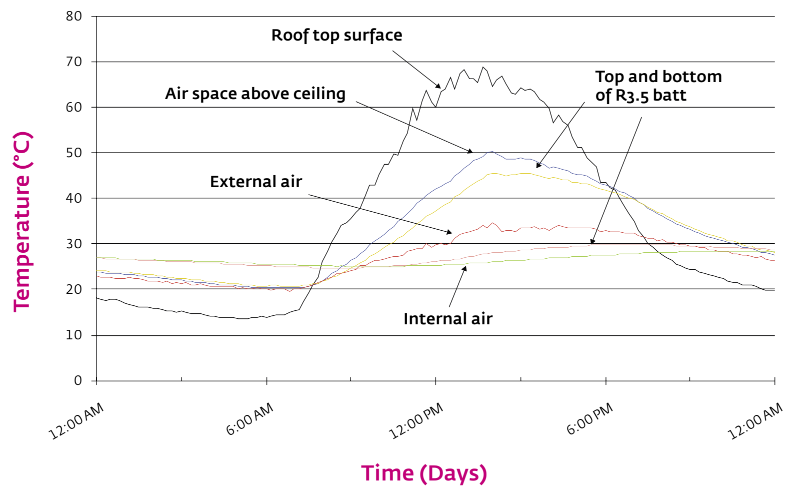


Figure 10 Roof temperature for cavity brick building, 20 February 2004.

The effect of glazing

The performance of the building was influenced by the heat entering the window.

The incoming solar radiation via the window becomes the dominant driver for the internal temperature. This is shown by the daily peaks in Figure 11.

Note that the maximum internal air temperature coincides with the peak external temperature.

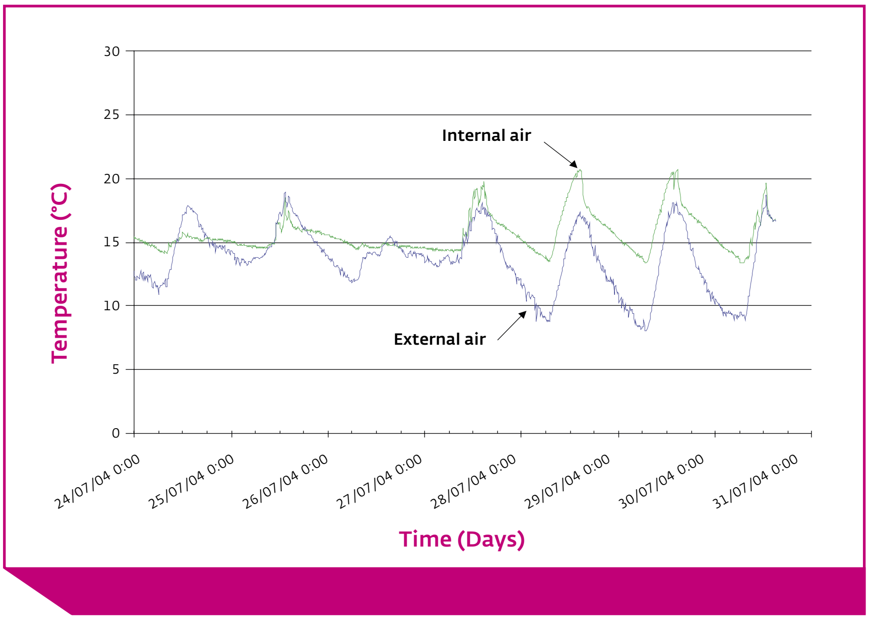


Figure 11 Internal and external air temperatures for the cavity brick building with north facing window in winter.

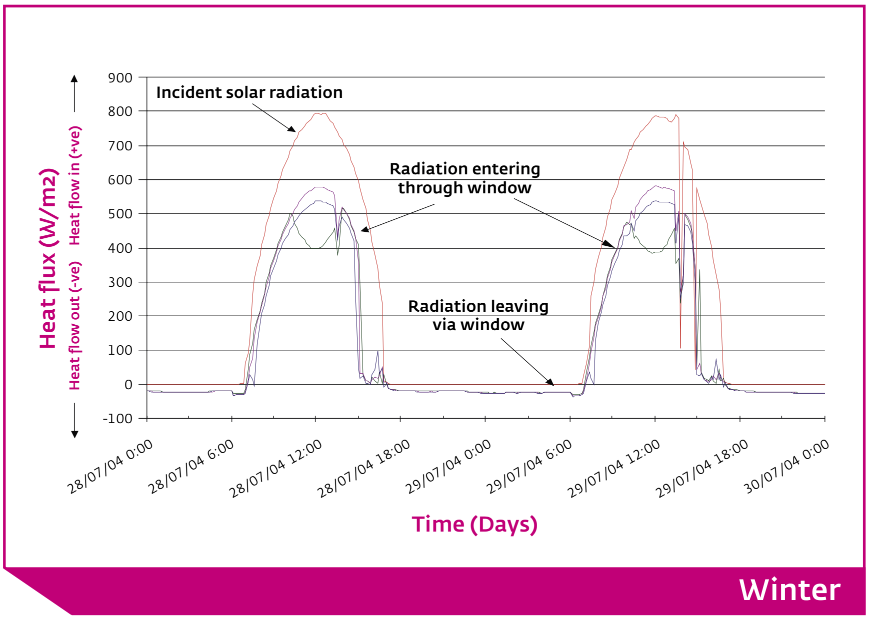
The heat exchange occurring through the window for both winter and summer conditions is shown in Figure 12.

In winter the peak incident solar radiation falling on the north-facing window is in the order of 800W/m2 with 500-600W/m2 entering the building.

At 3pm the heat entering via the window, decreases sharply and coincides with the observed drop in internal air temperature.

In summer due to the higher solar altitude no direct solar radiation is observed on the north face of the building, but the reflected and diffuse radiation still enters the building.

The diffuse radiation enters the building throughout the day, from 6.30am until 7.30pm, and peaks in the order of 120W/m2 at 12.30pm.



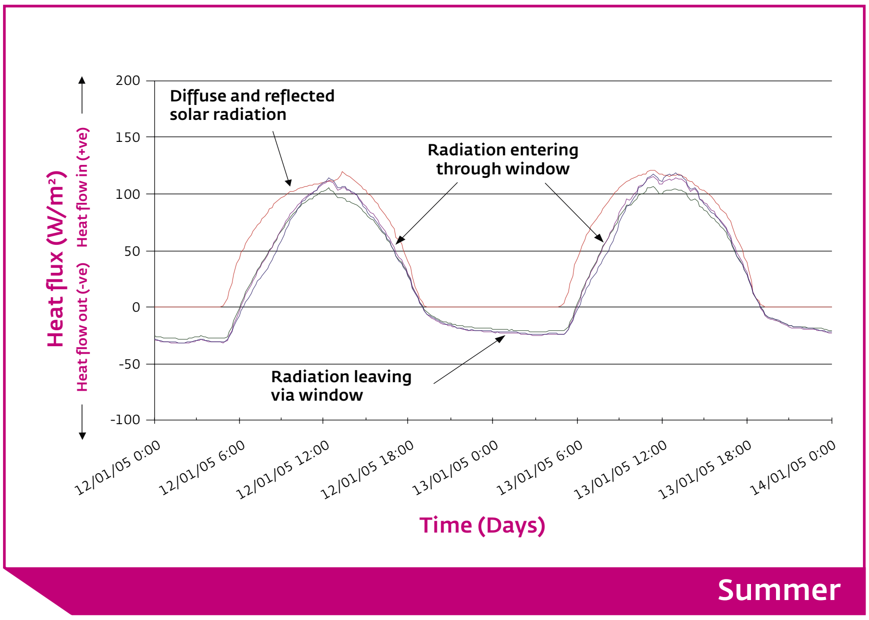


Figure 12 Heat exchange via the window for cavity brick building with north facing window.

The Australian Glass and Glazing Association has stated that in summer, 87 % of heat enters a building through ordinary clear glass windows and conversely in cool climates 55 % of heat is lost through the windows.

The amount of solar radiation entering through the window is beneficial in winter when this heat energy can be stored by the thermal mass of internal brick walls and the concrete slab.

The heat exchange via the slab in the test buildings under summer and winter conditions is shown in Figure 13.

The area of the slab receiving direct solar radiation absorbs approx. 210W/m2 of incoming flux in winter. The heat stored by the slab is then released back into the air space at a steady 30W/m2 from 3pm to 7am as the room temperature drops.

This reduces the amount of artificial heating required to maintain comfortable temperatures.

The research shows that thermal mass not receiving direct solar radiation still absorbs indirect radiation which contributes to the heat released in the evening.

In winter, the thermal mass of the brick walls and concrete slab have the ability to store heat and then release it in the evening.

In summer, the thermal mass acts to absorb heat from the room due to its large heat storage capacity.

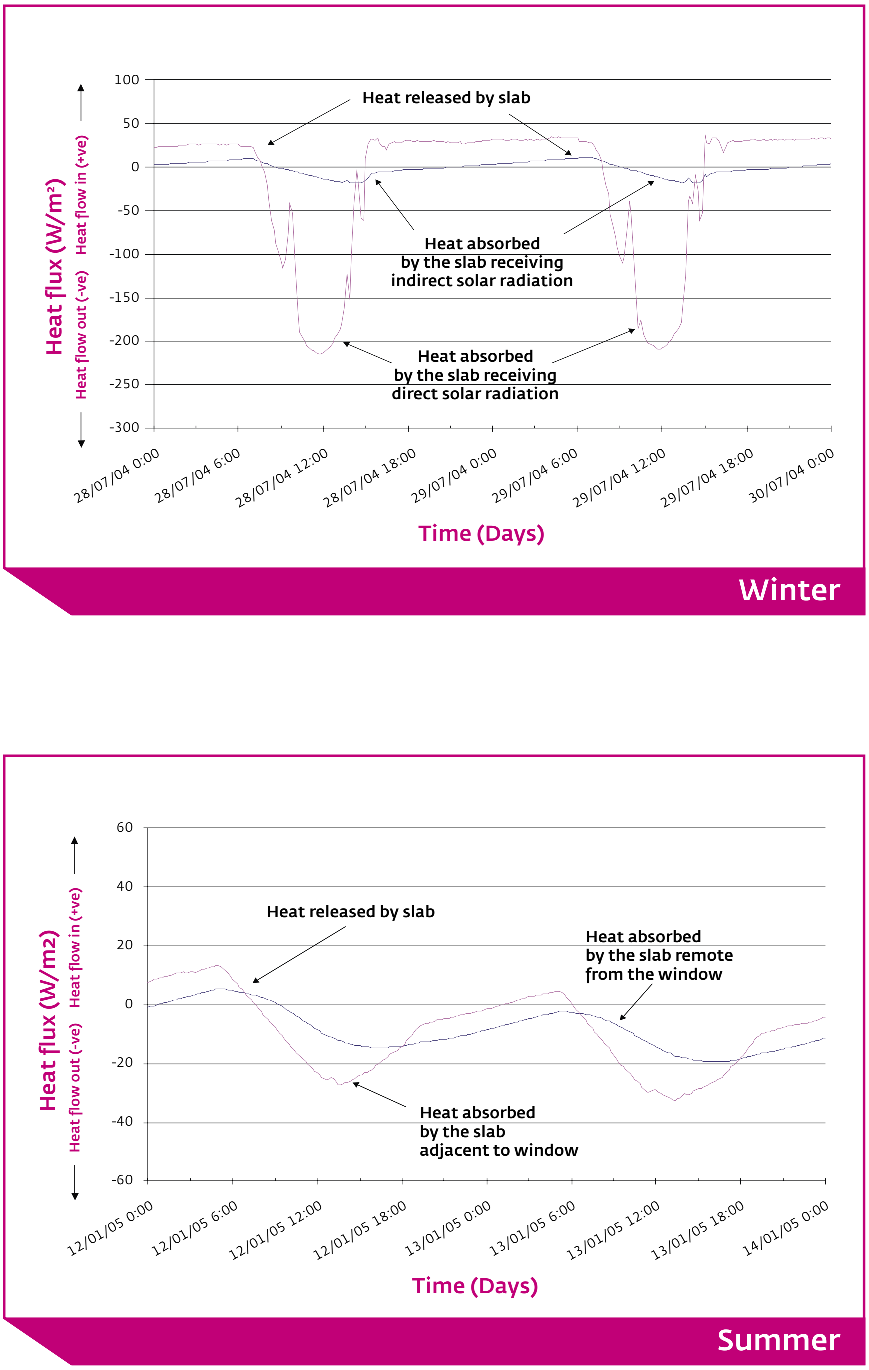


Figure 13 Heat exchange via the slab for cavity brick building with north facing window.

Comparison to lightweight

Recently a fourth test building was added to the thermal monitoring program at The University of Newcastle. The building was built using insulated lightweight walls and was comprehensively instrumented with temperature, humidity and heat flux sensors.

During a heatwave in January 2006, where temperatures reached 46.7°C, the benefit of thermal mass was fully realised. The results are shown in Figure 15 below and demonstrate that the lightweight module spent approximately 8 hours above 30°C while the insulated brick module did not reach 30°C. The peak temperature of the day was reached at approximately 5.15pm and the peak temperature in the lightweight building was reached at 5.30pm. The temperature profile inside the lightweight building corresponds with the outside temperature. In contrast the insulated cavity brick building reached it's peak temperature of 29°C at approximately 10.00pm demonstrating the time in the transmission of heat lag provided by the cavity brick walls.

This important observation confirmed that although insulated lightweight walls reduce the amplitude of heat entering the building they do not provide any thermal lag. In comparison the lag time provided by the cavity brick walls delays the maximum temperature to later in the evening.

The findings are preliminary but as the chart in Figure 15 shows, the lightweight module was subject to greater temperature variations than the insulated cavity brick module over the same period. This variance can only be attributed to the greater thermal mass of the cavity brick module, as both walls have similar R-values.

Figure 14 Lightweight test building module at The University of Newcastle

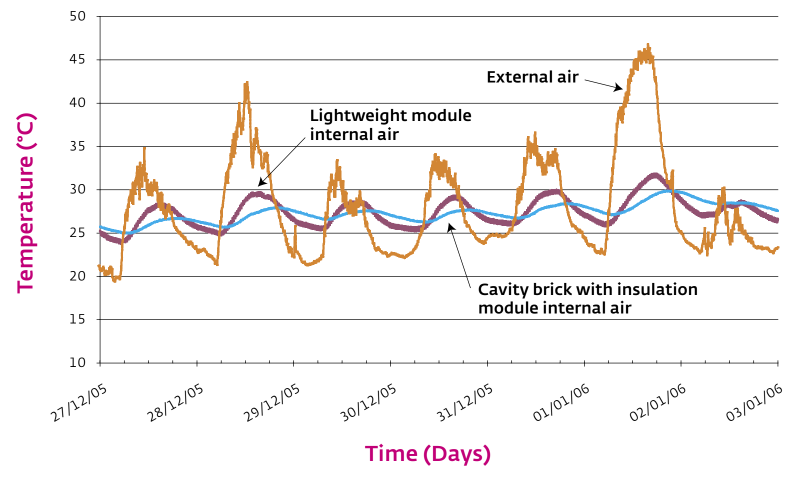


Figure 15 External and internal air temperatures for lightweight and insulated cavity brick modules, January 2006.

Clay bricks have been used for thousands of years and have stood the test of time

Conclusion

Whilst the research will be ongoing, the results published to date have shown that the use of thermal mass levels out the temperature swings during the heat of summer and the cold of winter.

This is important to the environment, as the building does not need the same level of artificial cooling during the peak electricity demands of summer as other forms of construction. This results in greater comfort for the building occupants and less frequent use of air conditioning.

Clay bricks have been used for thousands of years and have stood the test of time.

Made from inert natural ingredients clay bricks provide excellent durability, unsurpassed life cycle, and low maintenance.

This construction material has demonstrated superior levels of thermal comfort for energy efficient and sustainable design, without resorting to artificial heating and cooling.

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