

Sustainability



Sustainable Building Solutions: Thermal Mass



BlueScope Steel Ltd. (BlueScope Steel) has made a commitment to continually improve the company's environmental footprint and the sustainability of its products and services.

This is the seventh in a series of technical bulletins relating to sustainability issues that directly or indirectly impact the steel value chain. In writing these bulletins BlueScope Steel wishes to inform and educate the market, based on the latest available and verifiable information.

This technical bulletin details how thermal mass can be used to help create energy efficient thermal comfort across Australia's diverse climate zones.

Thermal mass is the term used to describe the ability of materials to absorb and store heat. There are a number of ways that both high and low thermal mass materials can be used to help create energy efficient buildings. In many climate zones reverse mass construction can be a sustainable

choice, while in hot, arid or tropical regions, lightweight construction may be more appropriate. Regardless of climate zone, a low mass roof is usually preferable.

Steel is a lightweight, low thermal mass material, therefore, can be used in both low and reverse mass designs.

Other technical bulletins in this series related to the use of thermal mass, and other steel products, to help provide indoor thermal comfort and create a sustainable built environment include:

1. Zero-Carbon and Carbon Neutral Developments;
2. Urban Heat Islands
3. Voluntary Green Buildings Ratings Tools in Australia;
5. Mandatory Sustainability Requirements for Residential Buildings in Australia; and
8. Steel in Sustainable Buildings.

1. Energy Efficiency and Thermal Mass

Increasing energy efficiency – which reduces energy demand – is one of the easiest and most effective ways to increase environmental, social and economic sustainability. Because 50%¹ of Australia's energy needs are met by coal-fired power plants, in most regions a decrease in energy demand would likely reduce the amount of greenhouse gases (GHGs) and other pollutants released to the atmosphere. Reducing GHG concentrations is key to slowing climate change and its associated effects such as increased species extinction rates, changes to rainfall patterns and sea-level rise. A reduction in particulates in the air may positively affect the health of local communities – particularly infants, the elderly and those predisposed to asthma or bronchial complaints. Energy efficient buildings should provide occupants with thermal comfort with reduced dependence on mechanical heating and cooling systems, which not only saves energy, but also saves money. Further, because

meeting peak demand is already a challenge for most Australian supply grids, if energy demand at peak-time can be reduced, the need to develop additional power stations – which are expensive and potentially sources of GHGs and pollutants – may also be deferred.

There are numerous design features, fixtures and fittings that can be utilised to gain energy efficiency in new buildings, significant retrofits or renovations: thermal mass is one of these tools. *Thermal mass* is the ability of any material to absorb and store heat energy, and can be thought of in terms of how much energy is needed to change the temperature of a material. High thermal mass materials include concrete, bricks and tiles; lightweight materials such as steel and timber have low thermal mass and store very little heat energy. Low thermal mass materials respond to temperature changes comparatively quickly, whereas high thermal mass materials take longer to heat or cool (Table 1).

The *total* thermal mass of a building, and *where* thermal mass is located within the structure, is important to managing the discomforts – and associated energy demands – of climate extremes. Local *climate* i.e. average temperature, humidity, diurnal variation* and seasonal variation, is the most important factor in determining how thermal mass should be used. Designs and materials that may assist in providing thermal comfort in cool regions, such as Tasmania, may be less suited for the hot, humid conditions experienced in cities such as Darwin and Townsville.

2. General Guidelines for the use of Thermal Mass in Buildings

There are basic principles about using thermal mass to gain thermal benefits in a building. Climate is the most important factor: specifically *diurnal temperature* variation and *average summer and winter temperatures*.

Diurnal temperature influences the ability of the thermal mass to absorb heat and assist in cooling the building, or to release heat to assist in heating the building. In general, in regions where the diurnal temperature range is less than 6°C, thermal mass has little benefit². Where the range is between 7 and 10°C thermal mass may be beneficial

Table 1: Properties of low and high thermal mass materials.

PROPERTY	LOW THERMAL MASS	HIGH THERMAL MASS
Heats up quickly	✓	✗
Cools down quickly	✓	✗
Takes a lot of energy to alter temperature	✗	✓
Stores thermal energy	✗	✓
Lightweight	✓	✗

(depending on the climate)². The most benefit is likely to be gained in regions that experience a diurnal range of more than 10°C².

Appropriately located thermal mass acts to regulate indoor temperatures around the average daily temperature. If the average summer temperature is above or near the upper comfort range, then thermal mass may be detrimental. If average winter temperatures are below or near the lower comfort range, then thermal mass can be beneficial if it is warmed by solar radiation or another heat source. When thermal mass is utilised to capture winter solar radiation, it must also be protected from summer sun, otherwise the benefit may be limited.

3. Locating Thermal Mass

Thermal mass is typically best placed inside the building: *reverse mass construction* is therefore considered an effective way to locate thermal mass, particularly in cool and temperate climates that experience a large diurnal temperature range. Reverse mass designs place dense materials on the inside of an insulated frame, the opposite of many conventional building techniques that locate dense materials – such as bricks and tiles – on the outside

of the building. Slab-on-ground is also a good way to incorporate mass inside buildings.

In summer, internal thermal mass absorbs the heat that enters the building because it has a lower initial temperature than the surrounding air. With the building absorbing the heat, internal air temperatures are lower during the day, providing comfort for occupants, with reduced need for supplementary cooling. During summer nights, heat is slowly released, and must be extracted from the building via natural ventilation or exhaust fans: in cool regions it may be desirable to allow some of the heat to remain in house. Overall, internal temperatures at night will be higher than if there was low internal thermal mass, they are however likely to be within the accepted *comfortable range*, without using air-conditioning. The exception to this is under extended heatwave conditions, when high thermal mass can increase discomfort³.

In winter, high thermal mass in floors and walls can be incorporated into passive solar designs so that radiant heat from the sun is absorbed through north, east and west-facing windows. During the evening the heat will be gradually released back into the room as the air



* The difference between minimum and maximum temperature across a day.

temperature drops. This maintains a comfortable temperature in the early evening and reduces the need for supplementary heating.

Wide diurnal temperature ranges are particularly important in temperate and warm climates during the summer months if high internal mass construction is to operate successfully. If evening temperatures are not low enough, the heat stored in the building will not be able to dissipate fully, and high thermal mass materials will not be able to absorb heat – and cool the building – the following day. For this reason, regions with an average temperature difference between night and day consistently less than 6°C, are considered unsuitable to benefit from the use of high thermal mass². Further, particularly in residential dwellings during consistently warm periods, the heat released into the dwelling at night may make conditions uncomfortable and increase energy demand for mechanical cooling. This may negate the energy savings made throughout the rest of the year, and affect the wellbeing and productivity of occupants, if their ability to sleep is affected.

In hot, arid or tropical climates low thermal mass construction may be preferable, particularly in bedrooms, as it allows them to cool down quickly at the end of the day. If walls and roofs are

made from high thermal mass materials that store large amounts of heat during the day, the heat released into the dwelling in the evening may result in uncomfortable sleeping conditions. In areas occupied during the day, high thermal mass materials, such as slab-on-ground, can be used to create cool living or working spaces, but as in warmer temperate areas, attention must be paid to how the heat will be dissipated in the evening. In hot, arid areas that experience cool evenings in winter – such as Alice Springs – incorporating thermal mass into the walls or floors can also help reduce winter heating costs.

In all climates, it is generally better to have low thermal mass roofs (with appropriate insulation) because roofs cannot be shielded from the sun during the hot months the way walls and floors can, therefore heat will accumulate during the day and contribute to uncomfortable conditions and energy use on supplementary cooling or heat extraction at night.

4. An Integrated Approach

As indicated in the previous section, for reverse mass construction to help maintain thermal comfort, thermal mass cannot be used in isolation. Insulation; ventilation; passive solar design techniques; and the colour, texture

and finish of materials can all affect the performance of thermal mass.

For reverse mass designs to be effective, *insulation* must be included in the building. Insulation stops heat flowing into or out of buildings, so complements thermal mass. Bulk insulation is good for keeping heat in or out of the building envelope, while reflective insulation is most effective at stopping heat entering the building. A combination of both types may be appropriate, depending on the climate zone. An airtight building envelope can also enhance the effectiveness of insulation.

Ventilation is key to removing the heat stored in buildings with high internal thermal mass in the evening, which is vital in most climate zones across Australia in the summer. One of the most energy efficient solutions is to design to create, or take advantage of, natural air movement. This means orienting the building to the prevailing summer wind direction to take advantage of natural breezes, and integrating them with breeze paths through the building. Existing or proposed vegetation, landscape or topographic features, and the location of windows and doors should all be considered when deciding on building orientation and room configuration. For example, blocks of tall vegetation can act as a barrier and reduce wind speed, but when more





sparsely planted, shorter trees can create turbulence and enhance wind flow. *One-room-thick designs* – which have windows and doors on both (or all) sides of the room – optimise opportunities for capturing the breeze and removing heat from a room during the evening. In private homes, high ceilings and overhead fans can enhance air circulation with minimal additional energy use. If mechanical extraction is necessary, as may be the case in commercial buildings that are unoccupied at night, the energy efficiency of the system selected becomes very important to the overall sustainability of the building.

Orientation and room configuration also affect *passive solar heating* and *passive cooling*. In cooler climates passive heating on winter days is important to ensure that high thermal mass materials are able to absorb energy to reradiate at night. If there is no passive solar heating, high thermal mass may increase winter energy requirements. This is because each time supplementary heating is used, the internal thermal mass needs to be heated before the internal air temperature will rise. Therefore, a high internal thermal mass design that does not take advantage of passive solar heating can increase the overall energy

required to maintain thermal comfort. In particular, north-facing window-area should be maximised to capture winter sun. However, eaves should also be incorporated into the design to exclude summer sun and minimise the heat absorbed during summer days, which will be reradiated at night. In cool and temperate climates, deciduous trees can provide effective shading during the summer, and allow sun to enter the building and heat the thermal mass during the winter. In tropical regions, shading buildings with evergreen trees, verandas, balconies, fixed canopies or shading hoods can increase thermal comfort all year round.

The *colour, texture* and *finish* of the floor and wall coverings selected affects the ability of internal thermal mass to absorb heat. For example, carpets or cork tiles laid over concrete slab floors insulate the thermal mass of the slab from incoming heat, which delays the receipt and release of energy into and out of the slab. This can result in an increase in internal temperature of 1-2°C³. In winter this may improve thermal comfort and partially offset any increase in heating energy requirements due to absorption of heat by the thermal mass. However, in summer 1-2°C may cause discomfort to occupants and increase the need

for supplementary cooling. In warmer climates, hard floor finishes may be a better choice: ceramic tiles, slate or vinyl on a slab floor increase the thermal mass of the floor, and its ability to store heat and cool the room in summer.

Any benefit from high thermal mass walls is limited if they are finished with plasterboard. The plasterboard isolates the thermal mass from the indoor conditions.

Dark coloured finishes absorb more solar radiation than light coloured finishes. Dark finishes on high thermal mass can increase the temperature of a room by 2-3°C year-round³.

The effect of choices to maximise thermal comfort and the efficiency of thermal mass must be balanced with other aspects of energy efficiency and sustainability. For example, in cold climates, the thermal storage gained by incorporating dark, textured walls in a building, should be balanced against the affect on internal light levels, and a potential increase in artificial light use. Light-coloured reflective surfaces maximise both daylight and artificial light, whereas dark surfaces absorb light.

The intended occupancy of the building should also be considered, and often influences how thermal mass can be

used most efficiently. For example, if a building is to be occupied intermittently i.e. a home where the occupants are at work during the day or a holiday home, lightweight construction may be the best choice, regardless of climate zone. Because low thermal mass materials respond to changes in thermal conditions quickly, the home will heat up or cool down swiftly, without expending energy on heating or cooling the structure.

5. How BlueScope Steel Products Can Help Create Thermal Comfort

BlueScope Steel products can be used to compliment high thermal mass materials in reverse mass construction, and to achieve many of the additional design elements necessary to gain the full benefit of using thermal mass to achieve year-round thermal comfort. BlueScope Steel products can also be used in low mass, lightweight designs, such as those particularly suited to tropical climates and buildings that are occupied intermittently.

Steel cladding and roofing made from COLORBOND® or ZINCALUME® steels can be used in conjunction with steel framing to create both reverse mass and low mass designs. Because steel building components are produced with consistency and tight tolerances that are maintained over the life of the building, they can be used to create extremely airtight building envelopes. A steel envelope can therefore help enhance the effectiveness of insulation in all climate zones. COLORBOND®, COLORBOND®



Metallic, COLORBOND® Coolmax® and ZINCALUME® steels can also be used to create lightweight, low thermal mass, roofs which – with climate appropriate insulation – allow heat to move in and out of the building as necessary. It must be remembered that because roofs cannot be protected from solar heating in the summer the way walls and floors can, low thermal mass is generally preferable. Low thermal mass roofs are especially advantageous in the residential sector. They allow any heat accumulated in the home during the day to be reradiated quickly once the sun sets – reducing the need for mechanical air-conditioning and creating comfortable conditions for sleep.

High strength, lightweight steel building products allow large central spaces to be enclosed with minimum material

use. This material efficiency makes one-room-thick and high ceiling designs more sustainable, and potentially less costly. If oriented correctly, one-room-thick buildings can also be effective designs for maximising passive solar heating. The potentially large glazed areas allow the sun to heat the building – and high thermal mass materials – during colder months.

Lightweight steel construction can also increase the design flexibility of the decking and/or eaves required to shade high thermal mass materials from the sun in summer. For example, DECKFORM® steel can be used to create functional eaves: second (or subsequent) storey decks create additional outdoor living space and provide shade to both outdoor and indoor areas below.

Literature Cited

1. **Australian Bureau of Statistics (2007)** Australia's Environment: Issues and Trends 2007. Australian Bureau of Statistics, Canberra. 100pp.
2. **Reardon, C., McGee, C. and Milne, G. (2008)** *Passive Design: 4.9-Thermal Mass*. In, *Your Home Technical Manual*. 4th ed. Department of the Environment, Water, Heritage and the Arts, pp 114-118.
3. **Sustainable Energy Authority Victoria (2007)** Sustainable Energy: Thermal Mass. Victorian Government, Melbourne. 6pp.

For more information on BlueScope Steel or its products please visit bluescopesteel.com.au or call 1800 022 999.

The information contained in this Bulletin is of a general nature only, and has not been prepared with your specific needs in mind. You should always obtain specialist advice to ensure that any materials, approaches and techniques referred to in this Bulletin meet your specific requirements.

BlueScope Steel Limited makes no warranty as to the accuracy, completeness or reliability of any estimates, opinions or other information contained in this Bulletin, and to the maximum extent permitted by law, BlueScope Steel Limited disclaims all liability and responsibility for any loss or damage, direct or indirect, which may be suffered by any person acting in reliance on anything contained in or omitted from this document.

COLORBOND®, ZINCALUME®, DECKFORM® and Coolmax® are registered trade marks of BlueScope Steel Limited.

BlueScope Steel is a registered trade mark of BlueScope Steel Limited.

Please ensure you have the current Sustainability Technical Bulletin as displayed at www.bluescopesteel.com.au

© 2010 BlueScope Steel Limited. All rights reserved. No part of this Bulletin may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without written permission of BlueScope Steel Limited. BlueScope Steel Limited ABN 16 000 011 058. BlueScope Steel (AIS) Pty Ltd ABN 19 000 019 625.

