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Thermally Efficient Design with Precast

What is thermal efficiency?
Thermal efficiency is part of energy efficiency and energy efficiency is one part of sustainability. Sustainability includes not only energy but also considerations of water, materials, food, waste and air quality, to name but a few. Thermal efficiency in a building is achieved when minimal energy is consumed, so as to maintain thermal comfort.

How a building or building element such as a wall, floor or roof performs thermally has a significant impact on its energy consumption. Energy consumption in Australia normally means greenhouse gas emissions, as most energy used in buildings is coal-fired electricity.

SECTION J OF THE BCA
Edition 46 of National Precaster (November 2007) outlines the new Section J of the Building Code of Australia (BCA), specifically written to establish energy efficiency measures. Section J covers most of the elements of a building that contribute to its energy consumption:

- Building fabric
- External glazing
- Building sealing
- Air movement
- Air conditioning and ventilation systems
- Artificial lighting and power
- Hot water supply
- Access for maintenance.

For the precast industry, the relevant part of Section J is that of Building Fabric (p.439, BCA Volume 1). This section must be read with the identified class of building (Part A3) and climate zone (see Climate Zone Map in Part A1 – Interpretation [the definitions]). In particular:

J1.2 – Thermal construction general
Covers insulation and refers to the thermal properties of materials listed in Specification

J1.2

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J1.3 – Roof and ceiling construction
Specifies requirements for insulation values – see Specification J1.3

J1.5 – Walls
Specifies requirements for insulation values with options from tables J1.5a or J1.5b and Specification J1.5

J1.6 – Floors
Specifies requirements for insulation values with options from table J1.6 and Specification J1.6.

Thermally efficient buildings rely on three key factors: climate, physics and design.

THREE KEY FACTORS: CLIMATE, PHYSICS AND DESIGN

Climate
Every building site comes with a piece of climate, for free!

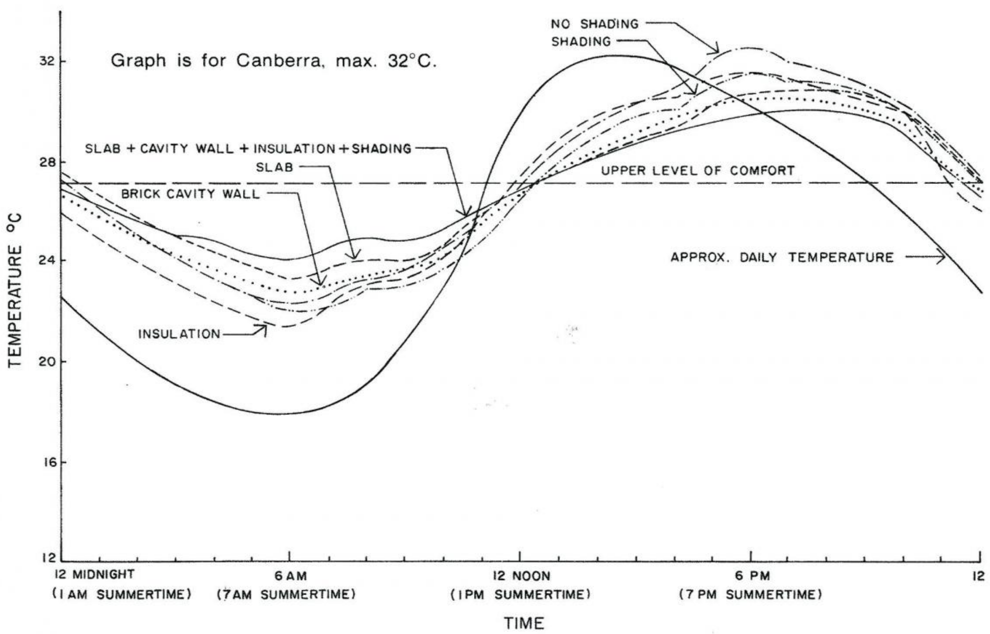
Climate is a non-steady state which creates periodic heat flow. Diurnal variations (i.e. variations within the course of a single day) create repetitive cycles of temperature: peaks during the day and troughs during the night.

In Australia, environmental heat generally flows into a building during the day and out of the building at night. The performance of the building envelope in modifying these environmental heat flows dictates the indoor temperatures experienced in the building.

Human comfort requires that indoor temperatures are kept constant or within a narrow zone of temperature and humidity. The thermal performance of the building envelope is therefore critical and needs to be designed and constructed appropriately.

Thermal design needs to consider the thermal performance of the materials used in the building envelope. Controlling air temperature alone is not an accurate determiner of human comfort. The

INTERNAL TEMPERATURE VARIATIONS ON A HOT SUMMER DAY FOR HOUSES OF VARIOUS CONSTRUCTIONS



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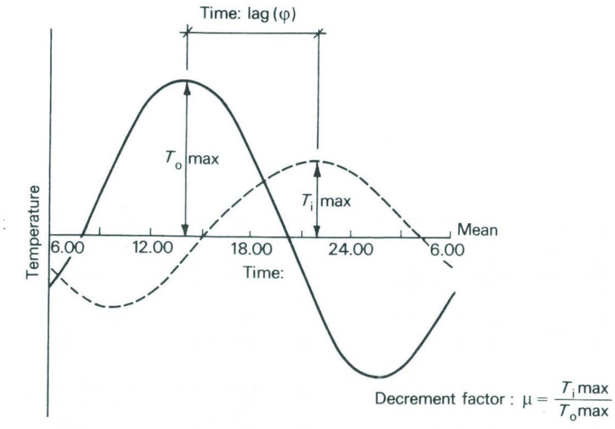
Environmental Temperature – which combines surrounding surface temperatures with the air temperature – must be controlled. The 'sensible' radiant heat gain or loss to the surrounding surfaces is the critical factor for human comfort. Human thermal comfort is not possible where the air temperature and the mean radiant surface temperature differ by more than 5°C.

Physics

Concrete is the perfect material to satisfy the requirements for human thermal comfort. The physics of heat flow in buildings is the reason why.

Physics tells us that energy flows by conduction, convection and radiation. In building envelopes, the conductivity of a material is central. The reciprocal of a material's conductivity is its resistivity (refer to Section J Specifications above). While concrete is a good conductor (in other words it has low resistivity), it has a high density and a high volumetric heat capacity.

This gives concrete a very high thermal mass (the capacity to store energy). Concrete also has two other characteristics which make it an ideal material for use inside a building envelope: the time lag for heat to travel through the material and the decrement factor (the reduction in amplitude of the indoor building temperature). These combine to create the thermal lag or thermal fly-wheel effect which allows concrete to flatten out the temperature peaks and troughs inside a building: it takes a long time to heat up and a long time to cool down (see diagram).



Concrete	Time lag	Decrement
100mm	3 hours	0.45 (55% reduction)
200mm	6 hours	0.20 (80% reduction)
300mm	9 hours	0.10 (90% reduction)

For concrete to be an appropriate material for thermal design and energy efficiency in a building, it needs to be fully insulated from the outside climate. Section J of the BCA focuses on insulation and the conductivity of materials, as these reduce energy consumption and increase thermal comfort by increasing the mean radiant surface temperatures of the building envelope. As a result, less energy is consumed and therefore there are fewer greenhouse gas emissions contributing to climate change.

Insulation on the outside of the building envelope also reduces the incidence of condensation. Any material with warmth on one side and 'coolth' on the other can have condensation occur on the warm side if the dew point is reached. Insulation and/or a vapour barrier will prevent condensation.

For thermal mass to be effective, it should also be exposed to the interior and its occupants, not covered up with cosmetic finishes such as plasterboard.

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Design

If heat inflows and outflows from a building are other than zero, the building will need heat input (heating) or removal (cooling). The difference between the climatic conditions and the nominated building internal conditions creates the level of heating or cooling required. This can be satisfied by passive (climatic thermal design) or active (HVAC) measures. Appropriate climatic thermal design of buildings can eliminate or significantly reduce building heating and cooling requirements. High thermal mass inside a building has its most significant impact on reducing cooling, a benefit for a world facing global warming.

Design factors affecting the thermal design of buildings are:

- Shape
- Fabric
- Fenestration
- Ventilation.

Precast solutions for thermal performance

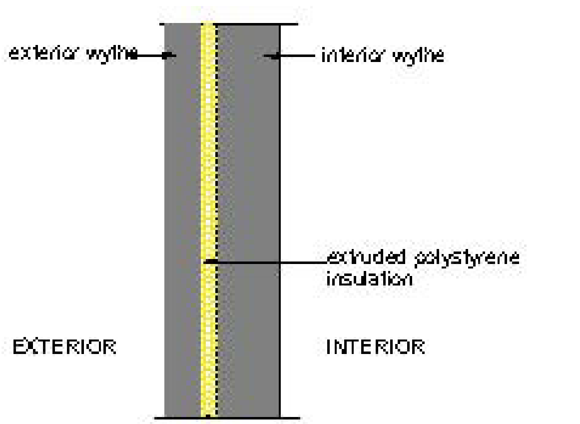
It is widely accepted now that thermal bridging – conduction paths between the inside and the outside – has a significant detrimental effect on building performance. As well, the combination of thermal mass on the inside and insulation on the outside of a building envelope significantly increases comfort and also reduces energy consumption.

Precast concrete sandwich panels

Knowing this, the precast industry has developed a new way of detailing, to eliminate thermal bridging and to develop heavyweight, mass interiors that are insulated from the exterior: precast sandwich panels.

Precast sandwich panels consist of two layers of concrete that are factorymade with a central layer of uninterrupted rigid insulation. They typically have a narrow (say 50 - 75mm) outer precast skin which is attached through the insulation to a wider (say 100 - 200mm) load bearing inner precast section, using non-conductive ties (connectors). Precast sandwich panels achieve the ideal thermal solution as they combine high internal mass insulated from the outside in a form of construction that has no thermal bridging.

PRECAST SANDWICH WALL PANEL



To make precast concrete sandwich panels, a first concrete slab is formed, into which one end of the connectors are embedded. A layer of rigid insulation is positioned over the connectors and a second layer

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of concrete is cast to cover the protruding ends of the connectors. The connectors provide resistance to shear in at least two directions.

Other thermally efficient precast design solutions

As well as sandwich panels, precast hollowcore flooring can also be used to achieve energy efficient heating and cooling systems. Systems such as TermoDeck use the high thermal mass of the hollowcore flooring to maintain comfortable and stable internal temperatures.

Patterns can also be cast into the surface of precast walling, using form-liners or custom made moulds, which can create self shading of the element.

National Precast together with Professor Terry Williamson from the University of Adelaide has developed R-value Calculators for sandwich panel walls, single layer walls and precast flooring. The Calculators increase the R-value that is offered by insulated precast, by including in the R-value, the benefit of thermal mass. A printable certificate can be used for BCA Alternative Solution compliance. View the Calculators and the Industry Standare which validates them, here.