Senate Enquiry on Federal Government's Energy Efficient Homes Packages (ceiling Insulation)
Environment, Communications and the Arts References Committee
Senate, Parliament House
Canberra
Email: eca.sen@aph.gov.au

December 20, 2009

Things Done Right
Existing buildings will always be dominant in our total building stock. As roof spaces are normally readily accessible retrofitting insulation in the roof is a practical approach that can make a significant contribution to reducing winter heat loss and summer heat gain.

Things Done Wrong
Whoever organized the timing for the introduction of this package obviously has not spent much time in a roof space during the warmer months of the year. If environmental conditions in the roof spaces where insulation was installed had been monitored it would have been obvious that the thermal conditions would exceed safety limits on the grounds of Occupational Health and Safety. Any such program in future, for roof spaces, should be carried out during cooler months.

Considerations for Future Programs

The intention of the Building Code of Australia to double insulation levels from May 1, 2010, should be seriously reviewed.

Law of Diminishing Returns
To the extent that cooling costs are proportional to cooling loads, a reliable value can be attached to each unit of conductance and if data on conductances are available it is a relatively simple matter to determine how much bulk insulation – such as fibreglass - to use. Increased insulation is subject to diminishing returns.

If 10mm will reduce the U-value (conductance) from 30 W/m^2 deg C to 15 W/m^2 deg C, it will take 20mm of the insulation material to reduce conductance further to 7.5 W/m^2 deg C. The 20mm extra (insulation) will cost roughly twice as much for the extra insulation and will have only half as much effect as the first 10mm. Is this what we should be doing?

Horses for Courses
Not all insulation has the same characteristics. Bulk insulation, such as fibreglass, is somewhat effective in reducing heat transfer by conduction and convection. Radiant barriers, such as reflective foil, are highly effective at controlling heat transfer by radiation. More than 80% of heat transfer downward

through roof spaces is by radiation. For the hot summer conditions, experienced over virtually the whole of Australia, radiant barriers should be mandatory in all **roof** construction. If bulk insulation, such as fibreglass, is installed directly under metal roofs, which is frequently the case, it will be subjected to temperatures up to 100 deg C, but only rated for R-values for an external temperature of 23 deg C! This needs to change.

Diodal Effect of Radiant Barriers

It is often overlooked that radiant barriers, while highly efficient at controlling downward heat flow in summer, have a much lower resistance to upward heat transfer after sundown. This has the effect of providing excellent protection from solar heat gain during the day but allowing rapid cooling of the interior of the building after sundown as demonstrated by full-scale studies at The Australian Institute of Tropical Architecture at James Cook University. Relying solely on bulk insulation in roofs will slow down the cooling of buildings in winterless climates after sundown (BCA Climates zones 1 and 2).

Need for Research into Heat Transfer through Roof Spaces

Combining bulk insulation and radiant barriers can be extremely effective however the heat transfer in roof spaces are extremely complex and also include effects due to moisture exchanges and roof space ventilation. Significant research on these matters has been conducted by the Oak Ridge National Laboratory both in **field studies** as well as full-scale simulation in their Large-Scale Climate Simulator. As building construction in the USA is different to that in Australia it is important that Australia conducts similar research to gain a better knowledge of the complex nature of heat exchanges through roof spaces under Australian climatic conditions. Too much reliance is being placed on simplistic computer programs.

Critical Difference between Radiation and other Modes of Heat Transfer

Current techniques for calculating heat transfer in buildings avoid the complexities of radiant heat transfer by lumping a crude allowance for radiation together with conductive and convective heat transfer. More precise techniques are available but are generally ignored.

Combining heat transfer, by conduction and convection, with radiation is problematic for the following reasons. Heat transfer by conduction and convection is proportional to temperature, $(t_1 – t_2)$. Heat transfer by radiation is proportional to $(t_1^4 – t_2^4)$ where t is in degrees Kelvin (deg C + 273).

Long wave (infrared) radiation is an important contributor to heat transfer across cavities in roof and wall construction. For simplicity in building design, resistance to such heat transfer is usually lumped in with resistance to heat transfer by conduction and convection into a single R value (m^2.K/W) for the cavity. It is important to note that heat transfer by conduction and convection is proportional to the difference between surface temperature t_1 in degrees Kelvin raised to the

4^{th} power and surface temperature t_2 in degrees Kelvin raised to the 4^{th} power. This simplification of lumping radiation with conduction and convection can result in significant error, particularly in countries like Australia where lightweight metal roofing and high intensities of solar radiation often result in metal roof temperatures up to 100° C.

Consider heat transfer across a horizontal cavity in a low pitch metal decked roof. On a comfortable overcast day the zinc/aluminium finish metal roof temperature is likely to be approximately 60° C (333K) and the ceiling temperature is around 25°C (298 K), a temperature difference of 35° C (35K). The AIRAH Handbook suggests an R value of $0.17 m^2.K/W$ for a 100 mm horizontal cavity with high emittance surfaces when heat flow is downwards. For a temperature difference of 35K the heat transfer per square metre would be 206 Watts (35/0.17). Now consider downward heat transfer across the same horizontal roof on a hot day when the metal roof is around 90° C (363K) and the ceiling temperature is around 55° C (328K), a temperature difference of 35° C (35K). The R value of $0.17 m^2.K/W$ and temperature difference of 35K remain the same the heat transfer per square metre would be the same 206 Watts (35/0.17).

The equation for the net radiant heat transfer across a cavity between two large parallel plates can be derived (Geankoplis, 1983) using Plank's law, Kirchhoff's law and the Stefan-Boltzmann law as:

$$Q = A (\sigma [t_1^4 - t_2^4] / [1/\varepsilon_1 + 1/\varepsilon_2 -1]) \qquad W$$

Where:
Q = Net radiant heat exchange in Watts
A = Sample surface area of each of the large parallel plates taken as $1 m^2$
σ = A constant for blackbody radiation taken as 5.676×10^{-8},$W/m^2 \bullet K^4$
t_1 = Surface temperature of plate 1 in degrees Kelvin
t_2 = Surface temperature of plate 2 in degrees Kelvin
ε_1 = Long wave emissivity of surface of plate 1
ε_2 = Long wave emissivity of surface of plate 2

Using this equation and assuming both surfaces have an emissivity of 0.9, the net radiant heat transfer across the cavity in the first example with surface temperatures of 298 K and 333 K is 205 $Watts/m^2$. The net radiant heat transfer across the cavity in the second example with surface temperatures of 328 K and 363 K is 269 W/m^2 for the second example.

This is a 31% increase in net radiant heat transfer across the cavity even though the temperature difference is the same, but higher on the temperature scale, or mean temperature of surfaces.

Heat transfer by conduction in building materials such as concrete, masonry, timber etc is assumed to be directly proportional to the temperature difference across them.

Condensation and Vapour Barriers

Unlike European and North American constructions industries the Australian construction industry is not conversant with installation and need for vapour barriers to control condensation. Structural collapse has occurred in air-conditioned timber-framed buildings in tropical areas due to condensation and resulting rotting of timber. Bulk insulation materials can also be seriously impaired when exposed to condensation.

The placement of vapour barriers is a complex design issue and there is a need for significant education on this topic throughout the Australian construction industry. Without such education condensation will continue to cause serious problems.

Dr Richard Aynsley, Director,
Building Energetics Pty Ltd

Former UNESCO Professor or Tropical Architecture, James Cook University