BUILDING TECHNOLOGY file

CSIRO AUSTRALIA

Number Four
June 1995

Thermal insulation reduces heat flow through the building envelope. When correctly used it will reduce the cost of heating and cooling to maintain comfortable conditions and improve comfort within the building, especially if no heating or cooling system is in operation.

Thermal Insulation

Fibrous insulations come in numerous colours and sizes.

Apart from thermal performance considerations, there are many factors which should be taken into account when specifying and selecting thermal insulation.

How thermal insulation works

Materials which provide thermal insulation do so by resisting the flow of heat through them. Thermal resistance is provided to some degree by all building materials. In some mild climates, or with some building materials which themselves have adequate insulating properties, the provision of specific insulation materials within the building structure may not be necessary. However in general the incorporation of insulation materials provides improved thermal performance, so that the building is easier to heat and cool, and/or is more comfortable to occupy.

Thermal insulation materials are broadly grouped into two categories – bulk and reflective.

Proper installation procedures should be followed.

Bulk insulation generally works by using the low thermal conductivity of still air for its insulating effect. By filling a void between two surfaces with a low density material (which is mainly air), convection processes which would otherwise allow circulating air currents to carry heat across the space are eliminated. At the same time, radiation heat exchange between the two surfaces is absorbed or blocked by the bulk material. Reflective insulations prevent this radiation exchange through a different mechanism, relying on the fact that some surfaces, particularly shiny metal, are very good reflectors of heat. It is a property of such surfaces, in fact, that they simultaneously reflect away incoming heat energy and also do not radiate their own heat energy. Only one surface or side of the airspace needs a reflective surface to behave in this way and greatly reduce radiation heat transfer. However, unless it is evacuated (as in a vacuum flask), a reflective airspace is still subject to convective air movement. This process depends on physical factors including orientation and temperature difference. Therefore there is no one value of thermal resistance for airspaces. However under many typical conditions they have a thermal performance similar to that of bulk insulation of the same thickness.

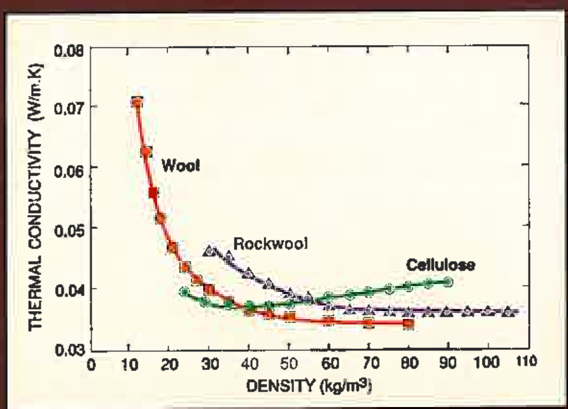
Thermal properties testing at CSIRO.

Choice of materials

There is a wide choice of thermal insulation materials. Criteria for selection may include the following:

- cost
- suitability for application
- durability in application
- ease of installation
- thermal resistance
- fire performance
- possible health hazard
- acoustic benefit (if any)

Density affects thermal performance



Numerous Australian Standards exist covering the manufacture and packaging of these materials. However a single joint standard to cover all thermal insulation materials to be used in buildings is in preparation.

Glass-fibre and Rockwool Collectively these materials are referred to as mineral wool or mineral fibre. Glass-fibre insulation is made from spun fibres of glass. In Australia it is only available widely in batt or blanket form and incorporates an adhesive binder. Its density and thickness are able to be precisely controlled in production so that a very wide range of products is available. Low density batts and blankets are very common and are highly flexible, which facilitates convenient installation. Rockwool is similar to glass fibre but the starting mineral is volcanic rock which is melted and spun into fibre. It is available in loose-fill form (without binder) for horizontal applications (such as ceilings) as well as batt and blanket form incorporating adhesive binder. Being denser these products generally offer good thermal performance for a given thickness but are otherwise similar in properties and use to fibreglass. Both have good fire performance as they contain only very small amounts of combustible material. They also have good sound-absorption qualities. They may cause temporary skin irritation and handling precautions should be taken.

Cellulose Fibre Cellulose fibre is made from pulverised newsprint or other paper with the addition of about 20% by weight of fire - retardant chemicals. Its use is almost exclusively as a loose fill ceiling insulation. It tends to have a characteristic density of around 30-40 kg/m³ and to have consistent thermal performance. Like other loose-fill materials it may settle a certain amount and allowance for this should be made in installation. When properly fire retarded it is generally regarded as having satisfactory fire performance. It is easy to handle but may contain high levels of dust.

Rigid Cellular Polystyrene Widely used for other purposes such as packaging, foamed polystyrene has good insulating qualities. It is manufactured for thermal insulation as rigid boards and in the form of beads for loose filling of cavities. It softens at temperatures above 80°C and after exposure to many common organic solvents. It is combustible but for building applications, flame-retardant chemicals are added which improves its fire performance. Boards are available in both moulded bead and extruded forms. Both types may be used for structural applications, the extruded form typically under concrete slabs where its lower water absorbency is of advantage and the moulded bead form typically laminated to steel facings in cool room construction where its lower cost and better dimensional stability are of value. However both forms are widely used in other building applications.

Polyurethane and Polyisocyanurate Foams These cellular plastics are available as either rigid materials or as foamed on site. When new they have very high thermal performance for their thickness, partly due to the presence of trapped foaming gases which are better insulators than air. These may diffuse out over time and after aging the thermal performance may be only slightly better than polystyrene. Polyurethane may be sprayed onto inside or outside surfaces and is often used this way in agricultural buildings. It is fragile and should be protected from impact and from the sun. Polyisocyanurate has better performance and has a higher service temperature than polyurethane. Flame retardant grades of polyurethane are available.

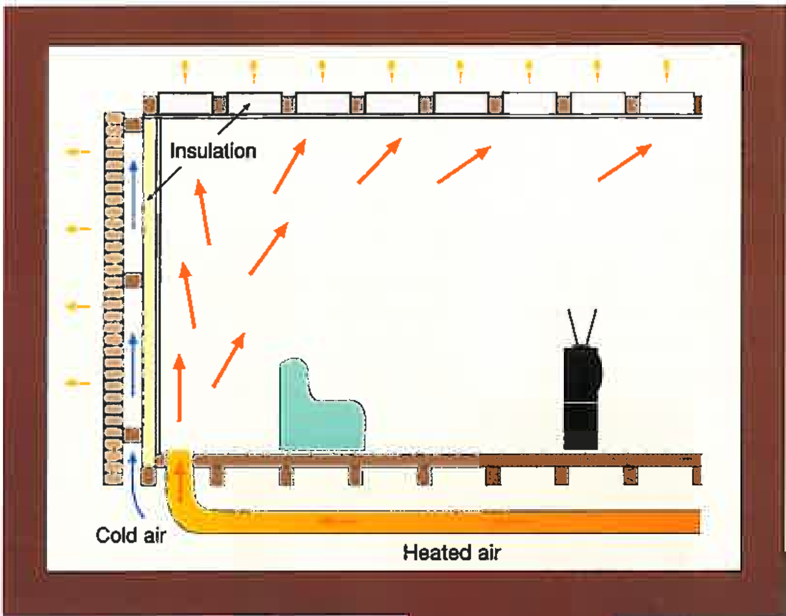
Polyester Fibre and Sheep's Wool These two materials are made by similar technologies and are often sold as mixtures or blends in batt form. Sheep's wool is also often sold as a loose fill. They are generally produced as low density products for reasons of economy and may need to be relatively thick to achieve target thermal performance. Although wool is one of the better organic fibres with regard to fire performance, very low density wool and polyester have both received some scrutiny. Batts of either material may be handled with no special precautions and have no known health hazards. Batts incorporating a significant percentage of polyester are generally stronger, more uniform and more flexible than products made from 100 % wool. Some types of loose-fill sheep's wool may inadvertently be blown in at extremely low density in the first instance. As such they will perform poorly and settle greatly over time.

Vermiculite and Perlite These two minerals have horticultural uses but are also used as insulation, either as loose fills or as additives in the production of low density cementitious or plaster products which have improved thermal properties. Vermiculite is a steam-expanded (exfoliated) form of mica and perlite is a volcanic material. Both are granulated and available in various size grades. Both are non-combustible and have a high service temperature.

Reflective Insulations The most general form of reflective insulation is double-sided reflective foil insulation, often called reflective foil laminate. It is commonly available in roll form consisting of a core of fibre-reinforced kraft paper faced with aluminium foil (usually) on both sides. Its traditional uses include sarking (to control liquid water) and vapour barrier (to control water vapour) as well as thermal insulation. Reflective insulations control heat flow between adjacent surfaces. The thermal insulation property really belongs to the airspace, made reflective by the presence of reflective foil, rather than to the foil itself.

Several other forms of reflective foil which use plastic film instead of a paper as the core, and may use evaporated aluminium films rather than thin aluminium foils, are available. As previously mentioned, thermal performance depends upon the characteristics of the airspace and the infra-red reflectance of the foil. The only criterion related to the reflective foil itself is its infra-red reflectance (often the term emittance is quoted but this is numerically related). Bright aluminium foil achieves a reflectance of 0.95 (ie. 95 %) or better. Most products achieve this, or close to this, and so are thermally indistinguishable.

Antiglare coatings are often inked or sprayed onto foil surfaces to reduce glare problems during construction.



Insulation, ventilation and building design all combine to determine overall thermal performance.

They typically produce a slightly reduced infra-red reflectance and a consequent small loss in thermal performance.

Insulation materials are available which combine several stacked reflective surfaces within the one product or combine reflective and bulk materials to advantage.

Solar Reflective Paints Although they are not thermal insulations, solar reflective paints can help keep buildings cool in summer by reflecting away the hot sun. Paints which have high solar reflectance are those closest to pure white in colour and all such white paints have this characteristic. Despite occasional claims to the contrary, they have low infra-red reflectance and provide no thermal benefit inside a building or outside at times when the sun is not shining.

Performance and R value

The measure of insulation performance is 'thermal resistance' or 'R value'. In Australia and most other countries it is in metric units (m^2.K/W). It is the numerical measure of the resistance of a particular material to the flow of heat. For a particular bulk material, R value is directly proportional to thickness. For reflective materials many factors influence R value. Tables are available listing the performance of reflective airspaces for certain values of thickness, temperature difference, orientation and surface reflectance. For bulk materials, refer to the accompanying table which lists the thermal resistance of 100 mm of a number of representative materials. Note that many materials are available, or may be installed, at different densities and that this will substantially influence the thermal resistance at a particular thickness.

The overall thermal resistance of a building element is the sum of the contributing parts if they are in series. If there is a more complicated arrangement of components then the R value may be difficult to determine. If there are parallel paths of different materials then those of low thermal resistance may act as a 'heat bridge', drastically reducing the overall thermal resistance. This may occur with, for example, incomplete coverage of ceiling insulation leaving some air gaps. It is usual in calculations of overall thermal resistance to include the small 'air film' resistances on each side of the building element which are a measure of the rate of heat transfer between the surface and the surrounding air.

TABLE 1 Thermal resistance of selected materials

Material at 100 mm thickness	Density (kg/m3)	Thermal Resistance (m2.K/W)
Airspace (typical vertical reflective)	-	0.6
Aluminium (solid metal)	2600	0.0005
Bricks (typical)	1800	0.15
Cellulose fibre (loose-fill)	30	2.5
Glass - fibre batt (typical low density)	8	2.0
Glass - fibre batt (typical medium density)	16	2.6
Polyester fibre batt (typical low density)	8	1.6
Polyester fibre batt (typical medium density)	16	2.2
Polystyrene (rigid foamed moulded beads)	16	2.8
Polystyrene (rigid foamed extruded)	30	3.3
Polyurethane (rigid foamed aged)	24	3.7
Rockwool batt	40	2.8
Rockwool (loose-fill)	40	2.7
Soil (typical)	1500	0.1
Timber (eucalyptus)	750	0.6
Timber (pine)	500	1.0
Wool batt (typical low density)	8	1.7
Wool batt (typical medium density)	16	2.2
Wool (typical loose-fill low density)	8	1.5
Wool (typical loose-fill medium density)	16	2.2

The thermal performance of membranes is determined by their infra-red reflectance.

Compiled and published by the CSIRO Division of Building, Construction and Engineering

PO Box 56 Highett, Vic., Australia, 3190
Telephone (03) 9252 6000
Facsimile (03) 9252 6244

PO Box 310, North Ryde, NSW, Australia, 2113
Telephone (02) 934 3444
Facsimile (02) 934 3555