



Technology and Environment 1

M4X01974

Lecture 12 – **Thermal Insulation in Buildings**

Thermal Insulation in Buildings

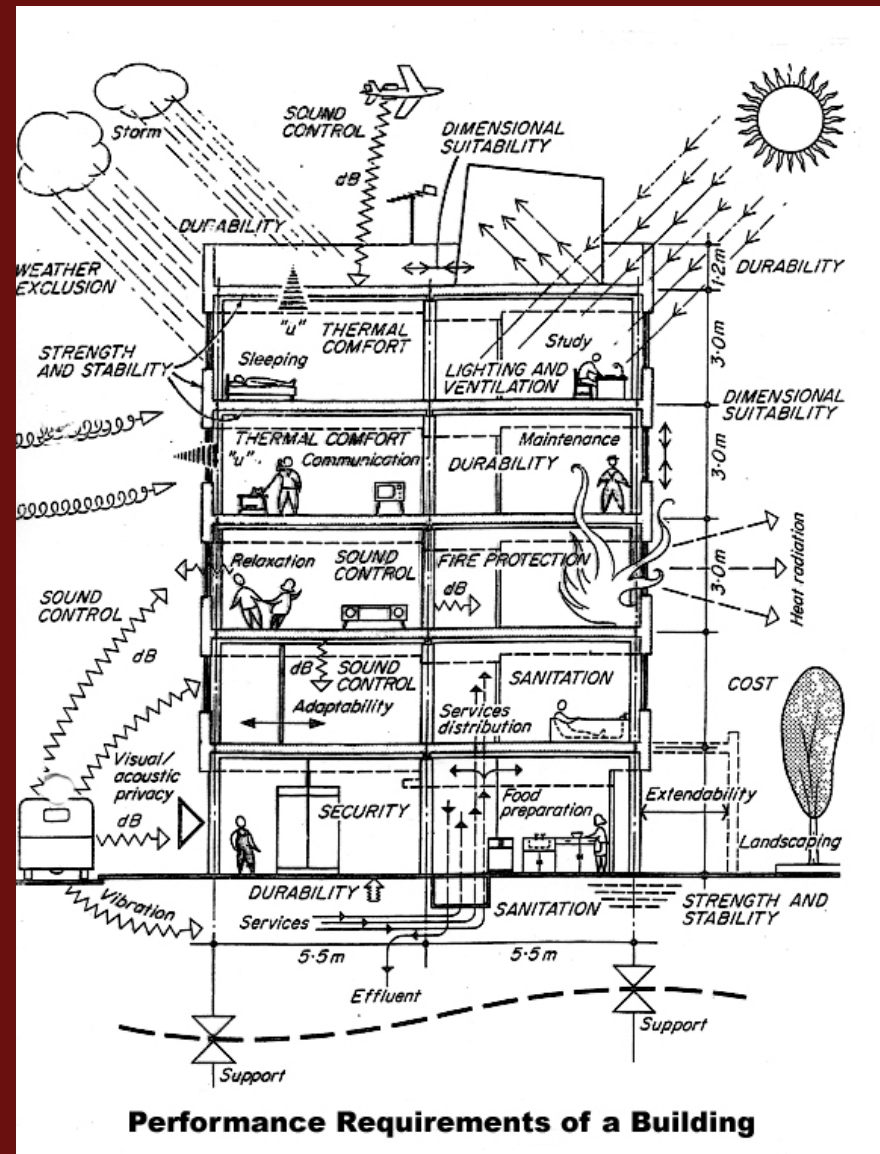
- Our human need for a comfortable environment and explained the thermal effects that play a large part in the governing of this environment. The transfer of thermal energy through the fabric of buildings is a dominant factor in the energy balance of buildings and is the focus of this presentation.
- Because thermal insulation is a major factor in reducing the heat loss from buildings adequate insulation should be a feature of good initial design.

Thermal Insulation in Buildings

- The relatively small cost of extra insulating materials is quickly paid for by the reduction in the size of the heating plant required and by the annual savings in the amount of fuel needed.
- These fuel savings continue throughout the life of the building.

Performance Requirements

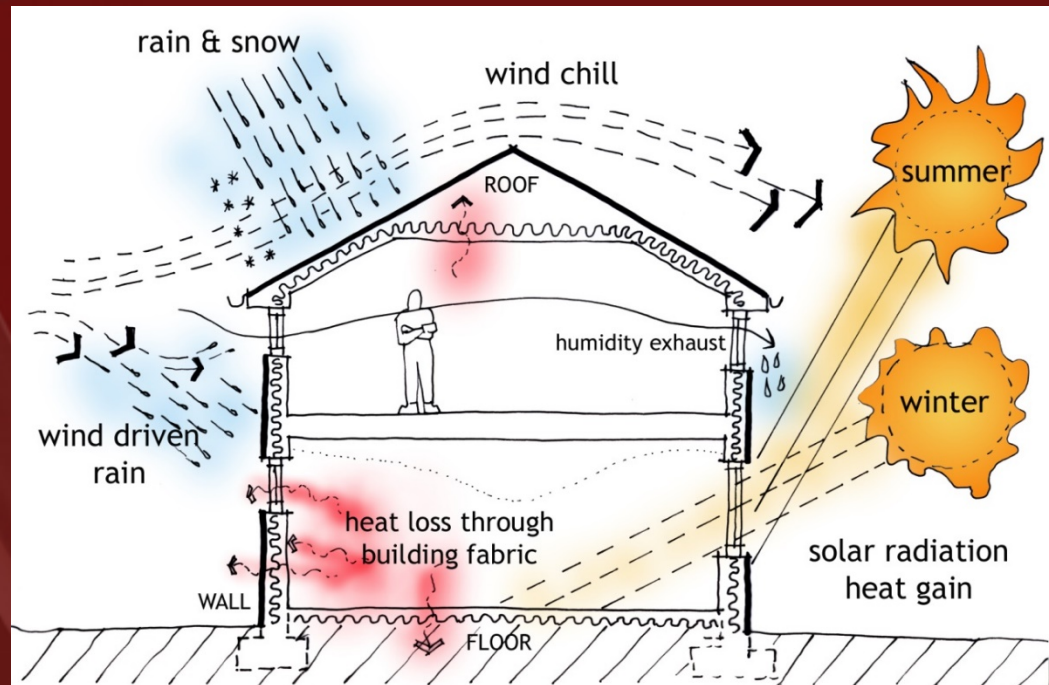
- What do we mean by performance requirements?



Functional Requirements

The primary requirements for a wall construction are,

- It must be stable
- It must provide a dry internal surface
- It must reduce heat loss from the building



Thermal Insulation in Buildings

- Assess buildings for insulation
- Appreciate the role of building codes relating to insulation
- Assess individual building elements for compliance with local building regulations
- Understand the causes and effects of thermal bridging
- Know about the temperature profiles inside structures and make calculations that predict possible effects.
- Understand why different structures respond to thermal effects at different rates.

Thermal Insulation in Buildings

This aims to explain the technical basis of thermal insulation and its effects so that you

- Appreciate the need for insulating buildings
- Examine the types of materials used to insulate buildings
- Make use of the terms and units associated with thermal insulation
- Calculate U-values for buildings
- Compare the insulation in different parts of buildings

Thermal Insulation in Buildings

- In order to maintain a constant temperature within a building we need to restrict the rate at which heat energy is exchanged with the surroundings.
- Keeping the heat inside a building for as long as possible conserves energy and reduces heating costs.
- Good thermal insulation will also reduce the flow of heat into a building when the temperature outside is higher than the temperature inside.

Thermal Insulation in Buildings

- In other words a well-insulated structure will, if ventilation and direct solar gain are controlled stay cooler in the summer than a poorly-insulated structure.

Thermal Insulation in Buildings

- Some people are reluctant to believe that insulation will help keep a building cooler in summer but it may be helpful to imagine the discomforts of living in a tent or garden shed.
- This 'building' will be very hot in summer for the same reason will be very cold in winter : lack of insulation.

Thermal Insulation in Buildings

- In a large building good thermal insulation will give savings in the energy needed to run the cooling plant.
- Some current office buildings use more energy for summer cooling than for winter heating.

Thermal Insulation in Buildings

- Another benefit of good thermal insulation is that the risk of surface condensation is reduced because the internal surfaces of a room are kept at a temperature which is above the dew point of the air.
- Surface condensation is unsightly, unhealthy and damages decorations. Well-placed thermal insulation also reduces the time taken for a room to heat up to a comfortable temperature such as in room that is unoccupied during the day.

Thermal Comfort

- The body exchanges heat with the environment through
- Convection (transfer of heat through fluid, in most cases air, due to the tendency of heat to rise)
- Evaporation (the changing of a liquid to a vapour)
- Radiation (energy sent out as electromagnetic waves or subatomic particles)
- Conduction (transmittance of heat directly through a material)

Mechanisms for Heat Transfer

- **Conduction**
- **Convection**
- **Radiation**

Insulating materials

- A thermal insulator is a material which opposes the transfer of heat between different temperatures. In present-day buildings the main method of transfer is by conduction, but the mechanisms of convection and radiation are also relevant.
- In some circumstances there is also a contribution from the process of condensation which releases heat energy when water vapour changes to water liquid.
- A vacuum provides a perfect insulation against conduction but is not practical everyday purposes.

Rockwool Insulation



Rigid Polyisocyanurate Insulation



Mineral wool rigid Insulation



Sprayed foam Insulation



Insulating materials

- The best practical arrangement is to look for materials that have atoms spaced well apart; such materials will also have low densities.
- Gases have widely spaced atoms and gases therefore provide good insulation against conduction.

Rockwool Insulation

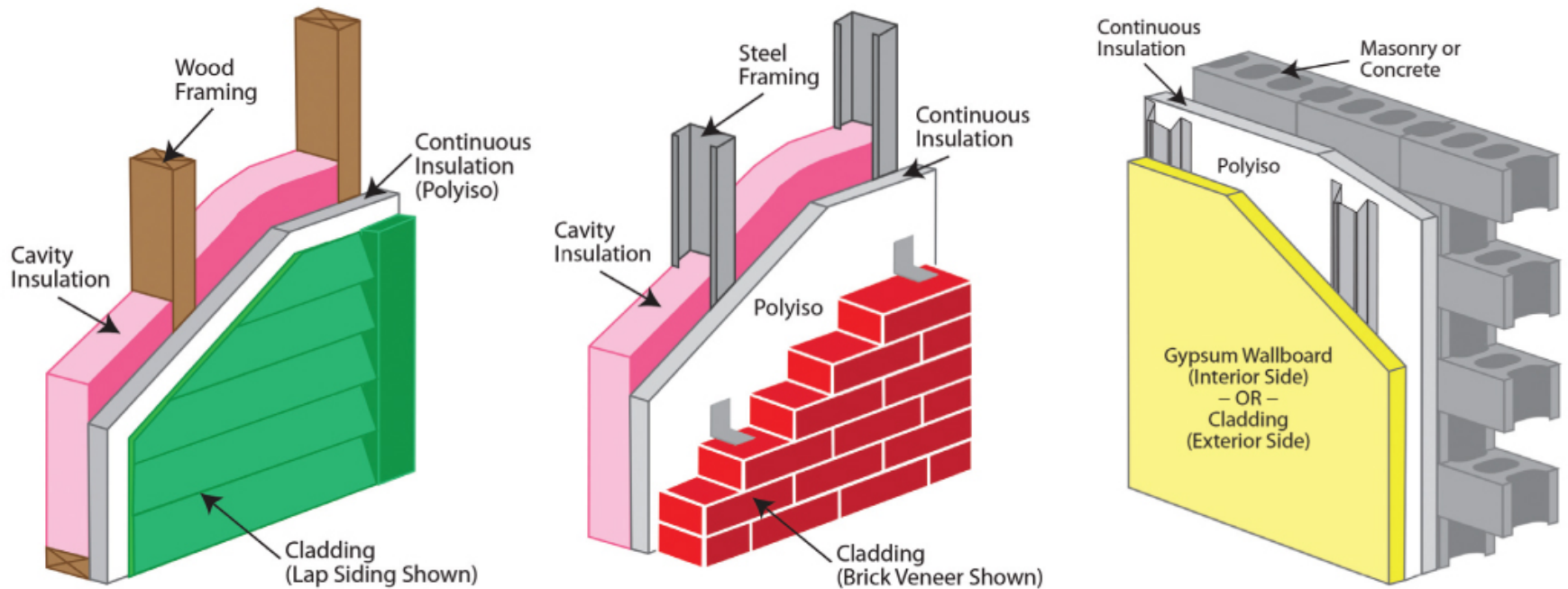


Insulating materials

- Air, which is a mixture of gases, is commonly used as the 'active ingredient' for insulation in materials such as glass fibre and aerated concrete.
- Air is not of course, the active construction material and the need for insulation must be balanced against other requirements such as strength and rigidity.
- For air to act as an insulator it must be held still, because if air is allowed to move it will transfer heat by convection. The primary purpose of fibreglass or expanded plastic is therefore to trap and to hold air still.

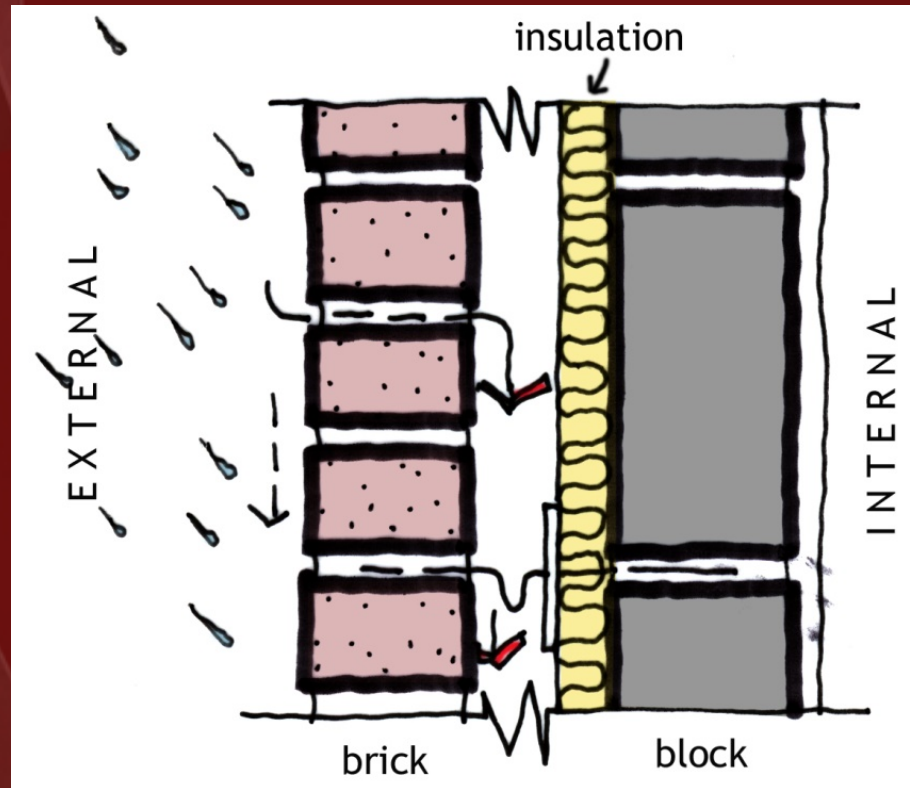
Insulation locations in wall constructions

Figure 1



Cavity (part filled)

- Building legislation – energy conservation
- Construction
 - Insert rigid slabs of insulation
 - Held & supported by wall ties
- Performance
 - Thermal performance



Insulating materials

- Also, any surface such as a wall or human skin holds a boundary layer of stationary air which provides a certain amount of thermal insulation against conduction.

Insulating materials

- Heat transfer by radiation is restricted by using surfaces that do not readily absorb or emit radiant heat.
- Such surfaces, which look shiny, reflect the electromagnetic waves of heat radiation and this insulation against radiant heat depends only upon the surface appearance.
- When we use aluminium foil as an insulator for example, it is the shiny surface of the material that is important.
- Aluminium is actually a good conductor of heat, but because the foil is thin conduction effect is small.

Types of Thermal Insulator

- Thermal insulators used in construction are made from a wide variety of materials and marketed under numerous trade names. These insulation products can be grouped by form under the general headings given below.
- **Rigid preformed materials.** Example: aerated concrete blocks.
- **Flexible materials.** Example: fibreglass quilts.
- **Loose fill materials.** Example: expanded polystyrene granules.
- **Materials formed on site.** Example: foamed polyurethane.
- **Reflective materials.** Example: aluminium foil.

Rigid Polyisocyanurate foil backed board insulation



Types of Thermal Insulator

- The materials considered here are designed for the insulation of heat transfer at the relatively low temperatures of weather conditions and human comfort.
- There are other specialised materials for insulating against heat transfer under the high temperature conditions encountered in boilers, furnaces and flues.

Properties of thermal insulators

- When choosing materials for the thermal insulation of buildings the physical properties of the material need to be considered.
- An aerated concrete block for example must be capable of carrying a load.

Properties of thermal insulators

- The properties listed below are relevant to many situations, although different balances of these properties may be acceptable for different purposes:
- **thermal insulation suitable for the purpose**
- **strength or rigidity suitable for the purpose**
- **moisture resistance**
- **fire resistance**
- **resistance to pests and fungi**
- **compatibility with adjacent materials**
- **harmless to humans and the environment.**

Properties of thermal insulators

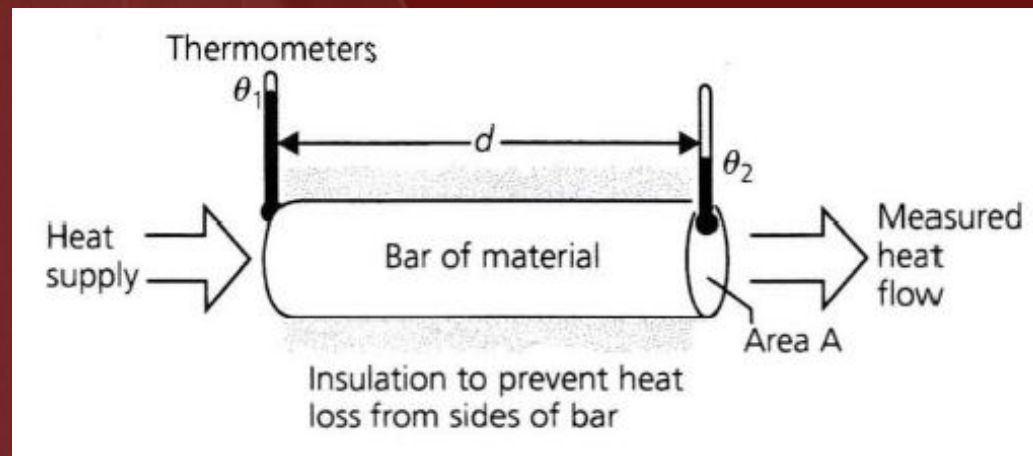
- The measurement of thermal insulation is described in the following sections. As well
- as resisting the passage of moisture it is important that a material is able to regain its insulating properties after being made wet, perhaps during the construction of a building.
- The fire resistance of many plastic materials, such as ceiling tiles, is seriously altered by the use of certain types of paints and therefore manufacturer's instructions must be followed. Some materials are incompatible with one another and this should be considered when installing the materials. For example, bituminous products may attach plastic based materials.

Thermal Conductivity, *lamda* value

- In order to calculate heat transfer and to compare different materials we need a measurement to quantify just how well a material conducts heat.
- Thermal conductivity (λ) *lamda* is a measure of the rate at which heat is conducted through a particular material under specified conditions.
- **Unit: W/m K**

Measurement of Thermal Conductivity

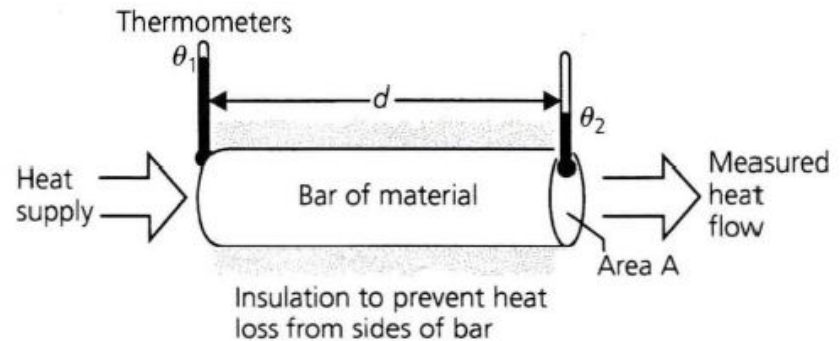
- The coefficient of thermal conductivity (lambda value or k -value), is measured as heat flow in watts across a thickness of 1m of material for a temperature difference of 1 degree K (Kelvin) and a surface area of 1sq m.
- Different techniques of practical testing are needed for different types of material but the measurements required are shown schematically in figure below:



Measurement of Thermal Conductivity

- The following general formula is then used to calculate the value of thermal conductivity for material tested.

$$\frac{H}{t} = \frac{\lambda A (\theta_1 - \theta_2)}{d}$$



- Where - λ = coefficient of thermal conductivity for that material (W/m K)
- H/t = rate of heat flow between the faces (J/s = W)
- A = cross-sectional area of the sample (m²)
- $\theta_1 - \theta_2$ = temperature difference between the faces (°C or K)
- d = distance between the faces (m)

Measurement of Thermal Conductivity

- *NOTE: k is a common UK symbol for coefficient of thermal conductivity λ is used worldwide as a symbol for coefficient of thermal conductivity*
- **Resistivity $r = 1/\lambda$** is the alternative index of conduction in materials and is the reciprocal of thermal conductivity, so that $r = 1/\lambda$. Similarly the unit of resistivity is the reciprocal of the unit λ -value unit: m K/W
- <http://www.vesma.com/tutorial/uvalue01/uvalue01.htm>

Values of Thermal Conductivity

Typical building materials

	Density (kg/m ³)	Thermal Conductivity λ (W/m K)
Aluminium alloy, typical	2700	190
Asphalt roofing	2100	0.70
Bitumen/felt layers	1100	0.23
Brickwork, exposed	1700	0.77
Brickwork, internal	1700	0.56
Concrete, reinforced 1% steel	2300	2.3
Concrete, high density	2400	1.93
Concrete, medium density	1800	1.13
Concrete block, lightweight aggregate	1400	0.57
Concrete block, aerated	600	0.18

	Density (kg/m ³)	Thermal Conductivity λ (W/m K)
Copper, commercial	9840	160
Fibreboard	400	0.1
Glass, window pane	2560	0.022
Mortar, exposed	1750	0.94
Mortar, protected	1750	0.88
Plaster, dense	1300	0.57
Plaster, lightweight	600	0.18
Insulation, expanded polystyrene (EPS) board	15	0.04
Insulation, mineral wool batt	25	0.038
Insulation, mineral wool quilt	12	0.042
Insulation, phenolic foam board	30	0.025
Insulation, polyurethane board	30	0.025
Rendering, external	1300	0.57
Screed, floor	1200	0.41
Steel, mild structural	7900	60
Stone, chippings	2000	2.0
Stone, sandstone	2600	2.6
Stone, soft limestone	1800	1.1
Timber, softwood	500	0.13
Timber, hardwood	700	0.18
Timber, plywood, chipboard	500	0.13
Tiles, ceramic wall	7900	17.0
Tiles, clay roof	2000	1.0
Tiles, concrete roof	2100	1.5

NOTE: Use manufacturers' data for precise values.

U - Values

- **Thermal transmittance, U-value**
- Heat is transferred through an element of a building, such as a wall by a number of mechanisms.
- Layers of different materials conduct heat at different rates; in any cavity there is heat transfer by conduction and convection in the air and by radiation effects.
- At the inside and outside surfaces of the wall the heat transfer by radiation and convection is affected by factors such as surface colour and exposure to climate.

U - Values

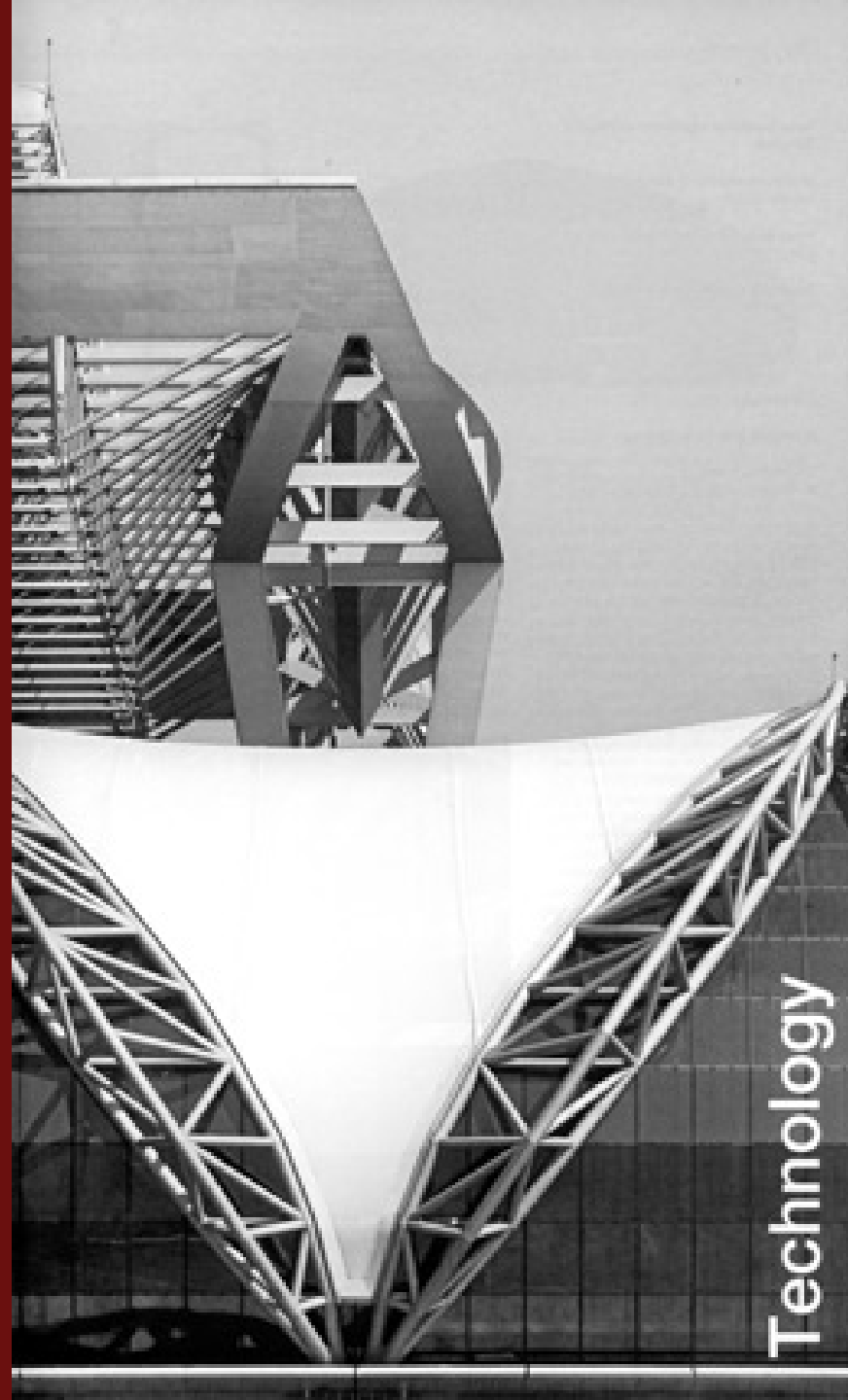
Thermal transmittance, U-value

- A U-Value is a measure of the overall rate of heat transfer, by all mechanisms under standard conditions, through a particular section of construction - Unit: $W/m^2 K$
- The coefficient, or U-value, is measured as the rate of heat flow in watts through 1 m² of a structure when there is a temperature difference across the structure of 1 degree (K or °C)

U - Values

Thermal transmittance, U-value

- For example, a wall with a U-value of $0.3 \text{ W/m}^2 \text{ K}$ loses heat at half the rate of a wall with a U-value of $0.6 \text{ W/m}^2 \text{ K}$.
- Therefore, the cost of replacing heat lost through the first wall will be half the cost of that for the second wall.
- Lower U-values mean better thermal insulation



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