

Thermal Properties of building structures

Integrating Fabric and Services

“The first step in developing an integrated design is to **establish the function of the building envelope as the primary climatic modifier**, supported by the services to trim conditions. Good fabric design can minimise the need for services...”

For thermal performance we need to consider issues such as:

- Reducing heat loss through the fabric
- Reducing the heat loss through infiltration
- Reducing solar gain
- Using the mass of the building to smooth peaks in temperature
- Carefully placing thermal insulation

Heat Loss

This is the amount of heat energy that travels from the warm inside, to the colder outside and must be replaced to maintain comfort conditions. It is dependant upon the following factors:-

- Actual external temperature
- Required internal temperature
- Size and shape of building
- Building components **U-values**
- Air **infiltration** rate into the building

What is a U-value ?

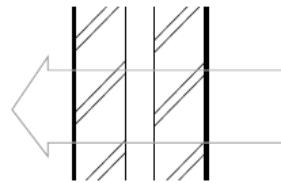
U is the symbol used to represent the thermal transmittance of a building envelope element.

It defines the ability of a given thickness of materials and airspaces to transmit heat under steady state conditions. It is a measure of the quantity of heat that will flow through 1m^2 , per one degree difference in temperature between either side of the element.

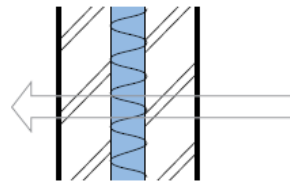
The units of thermal transmittance are $\text{W}/\text{m}^2\text{K}$

Some example U-Values

Cavity wall construction



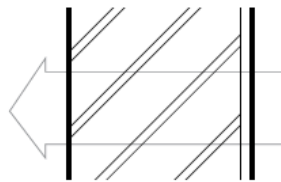
U-value = 1.5



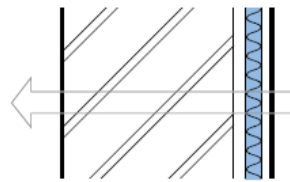
U-value = 0.46

60mm cavity
filled with
insulation

Solid brick wall (335mm thick)*



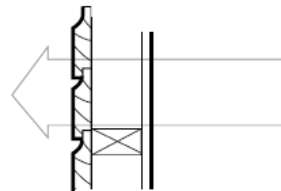
U-value = 1.7



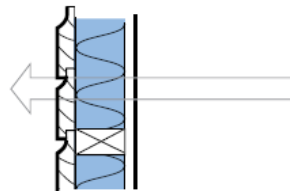
U-value = 0.45

50mm thick
insulated
plasterboard
lining

Timber-framed wall



U-value = 1.7



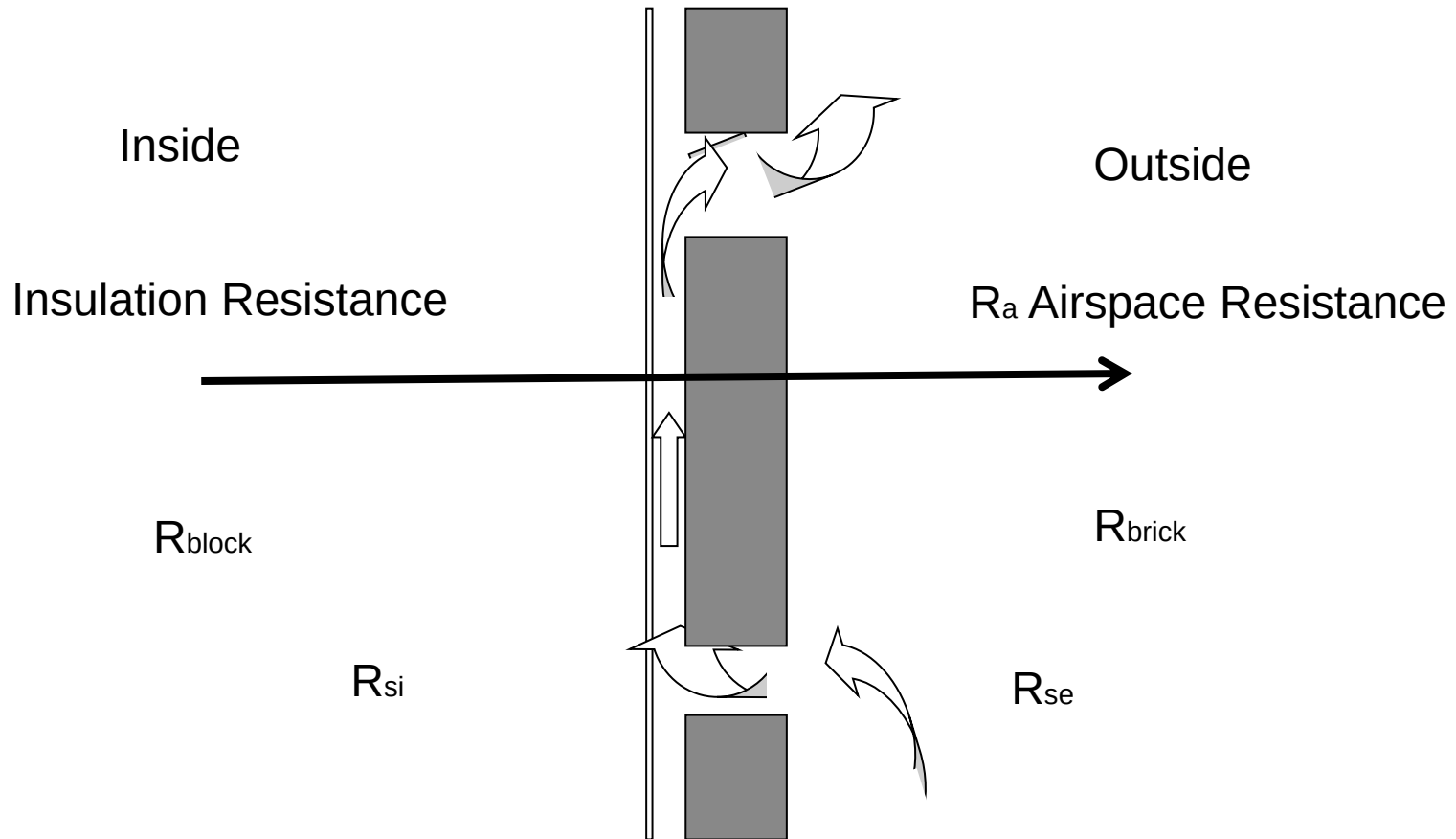
U-value = 0.38

50mm mineral
wool between
studs

How is a U value obtained ?

- Direct measurement of U value is possible, and is preferred, when laboratory facilities are available and justified.
- Numerical analysis can also be used, such as Finite Element Analysis, which takes into consideration the 3D effects of the building element. This requires appropriate software and trained operators.
- By far the most common method is the **Simplified Method**. (*see CIBSE Guide A section 3*)

Terms and Symbols used in computing U-values



Steady State Heat Loss Calculations

$$Q_f = U A (\Theta_i - \Theta_o)$$

Where:

Q_f is the fabric heat loss (W)

U is the U value (W/m²/K)

A is the area of the thermal element (m²)

Θ_i is the internal temperature (°C)

Θ_o is the external temperature (°C)

Building Regulations ADL2A

Summary Requirements

- Limiting heat gains and losses
- Providing efficient building services with effective controls
- Provide the owner with sufficient information so that the building can be operated and maintained so as to consume no more fuel and power than is reasonable in the circumstances

Limits on Design Flexibility

- Minimum U – values and thermal bridging limits
- Air Permeability
 - Reasonable limit for design air permeability is $10 \text{ m}^3/\text{hr.m}^2$ at 50 Pa
- Heating, Ventilation and Air Conditioning minimum efficiency standards

Thermal Mass

- Give examples of buildings that have a high thermal mass and how do you think they affect comfort and energy efficiency within a building
- Give examples of buildings that have a low thermal mass and how do you think they affect comfort and energy efficiency within a building?

Solar Gains

Issues to consider:

- Orientation
- Proximity of other buildings
- Surrounding surfaces
- Glazing/shading
- Admittance?
- Operating hours



Fabric and Services Interaction

Services issues	Cooling	Deep plan may need greater cooling and mechanical ventilation	Consider locating cooled zones on north facade to reduce potential cooling loads	Minimise solar gains	Minimise solar gains	Take care that facilities for summer cooling are airtight in winter	Store heat in thermal mass and effect on response times
	Heating	Deeper plan reduces heat loss area	Position less heated buffer zones on north facade to reduce heat loss	Solar gains contribute to heating	Minimise heat loss via atria i.e. avoiding heating	Minimise air infiltration to reduce heat loss	Store heat in thermal mass and effect on response times
	Electric lighting and daylight	Use shallow plan for maximum daylight penetration or lightwells/atria	Calculate sun angles and use north light or shading to limit solar gains	Increased glazing will increase daylight but may also increase solar gains and need for shading	Use atria to increase natural daylight		
	Natural ventilation	Use shallow plan to allow natural ventilation	Draw air from north facade to give cooler air	Ventilation depends on number of openable windows	Use atria to encourage natural air circulation	Seal building envelope and allow only controlled ventilation	Utilise effect of thermal mass on response of building to external conditions
	Mechanical ventilation and air conditioning	Consider shallow plan with mixed-mode to allow natural ventilation at certain times	Orientated to avoid solar gains	Reduce percentage glazing to minimise effect of solar gains on air conditioning	Consider atria with mixed mode to allow natural ventilation and daylight at certain times	Ensure building envelope is sealed	Utilise effect of thermal mass on response time of air conditioning
		Deep plan/ shallow plan	Orientation	Percentage glazing	Lightwells and atria	Airtightness	Thermal response

Fabric issues

Further Reading

- CIBSE Guide A – Chapter 3: Thermal properties of building structures