



Technology and Environment 1

M4X01974

Thermal Insulation in Buildings

Part 2

20 credits

Aims of the Module

- **AIM(S)**
- To provide the student with knowledge of construction technology and environmental control systems appropriate to the design of non-domestic and multi storey buildings
- To provide the student with knowledge and analytical and synthetic skills relevant to the design of low carbon buildings
- To develop further the student's understanding of the performance of buildings through the analysis of precedent

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

- It is convenient to combine all these factors in an ambitious single measurement which describes the air-to-air behaviour of a particular construction.
- This measurement is called the overall *thermal transmittance*
- *coefficient* or U-value.

U-VALUES

- 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: $W/m^2 K$

U-VALUES

- The coefficient, or U-value, is measured as the rate of heat flow in watts through 1 m^2 of a structure when there is a temperature difference across the
- structure of 1 degree (K or $^{\circ}\text{C}$) .
- E.g. 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.

Elemental U-values

- Previous sections explained how variations in conditions, such as moisture content, will cause insulation properties to vary with position in a structure.
- The U-values for an element such as a wall or roof are calculated by using standard values for factors such as moisture contents of materials and rates of heat transfer at surfaces and in cavities.
- Although the standard assumptions represent practical conditions as far as possible, they will not always agree exactly with U-values measured on site.

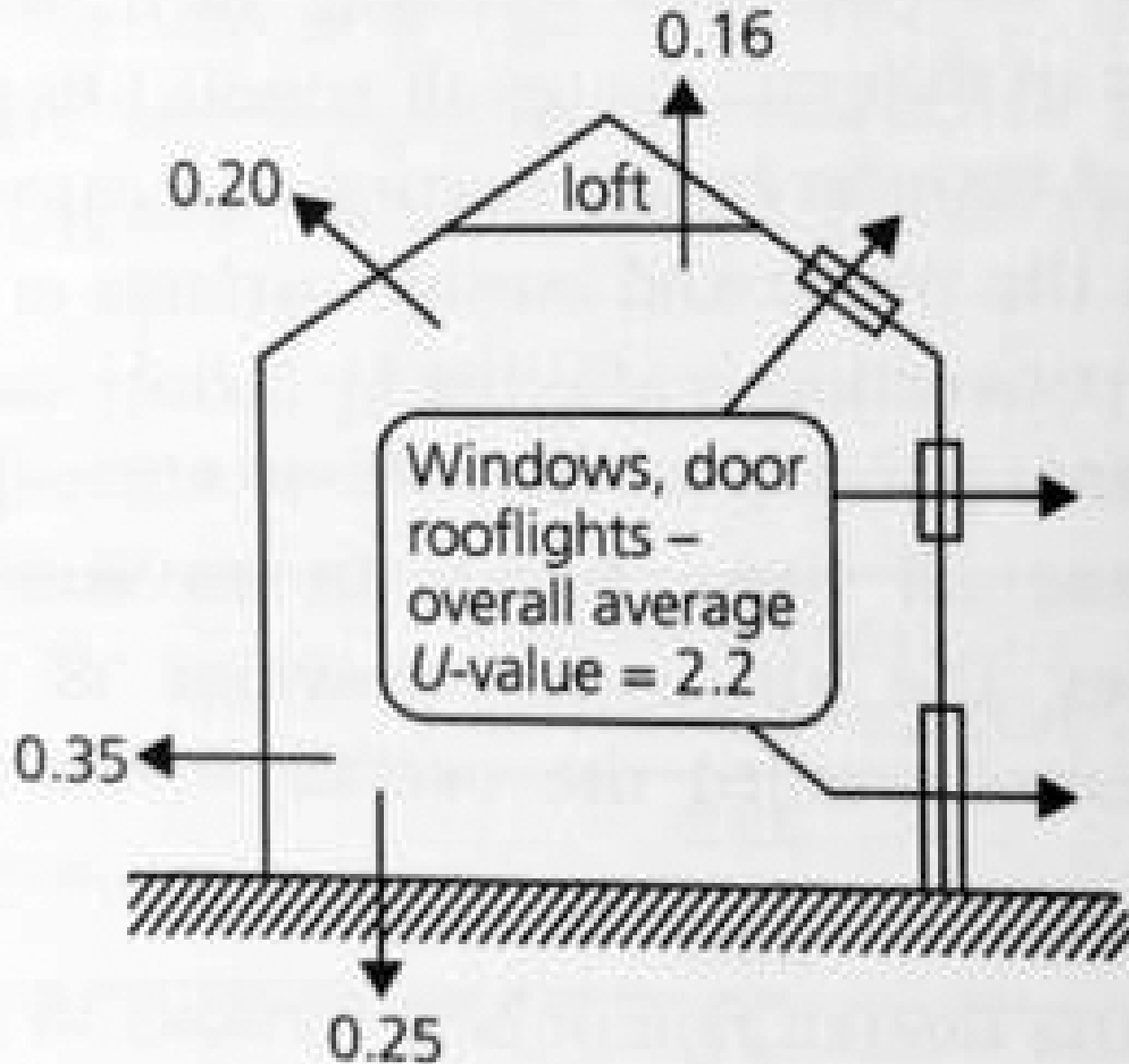
Elemental U-values

- Standard U-values of elements are also needed as a common basis for comparing the effectiveness of different forms of wall, window, roof and floor, for example. The U-values for some common forms of construction element are given in table 3.3.
- The table includes constructions that do not meet modern standards of insulation but are still found in existing buildings in Britain and Ireland.

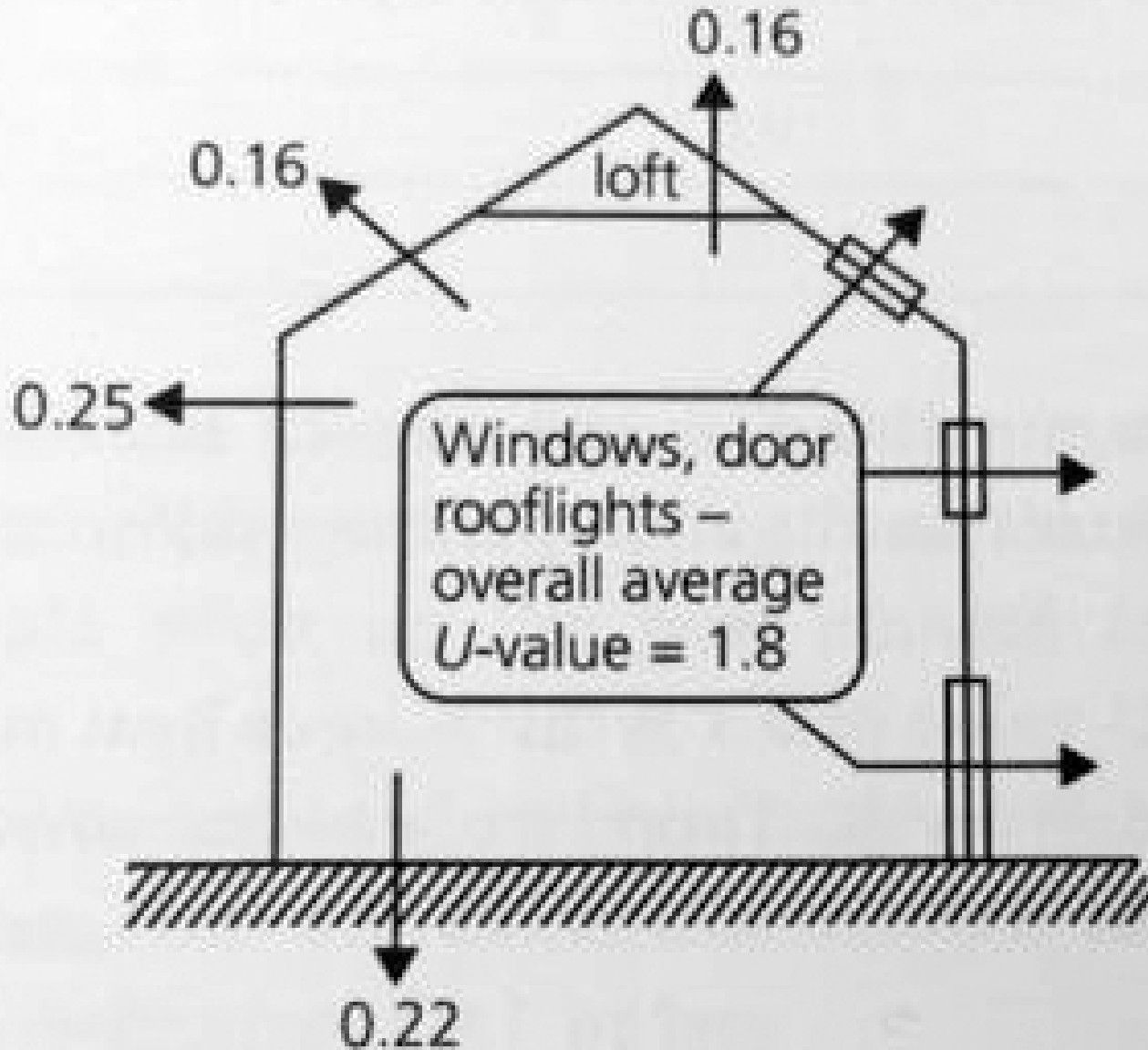
Elemental U-values

- Most forms of building regulations use U-values in a variety of ways to specify standards for thermal insulation and energy use.
- The U-values referred to here can be termed *elemental U-values* in order to distinguish them from other forms, such as *target U-values*, which include effects such as ‘*trade offs*’ between the insulation of elements and efficiency of heating systems.

Elemental U-values



Elemental U-values



Types of Wall Construction

- Solid

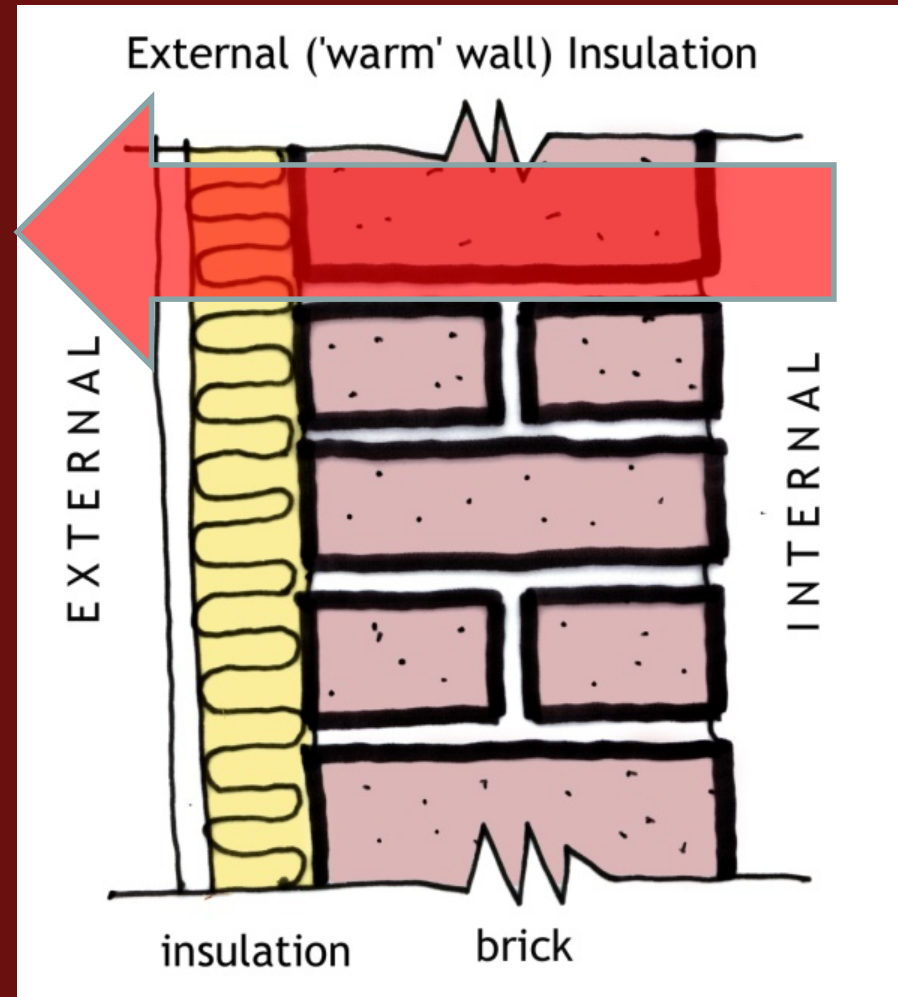
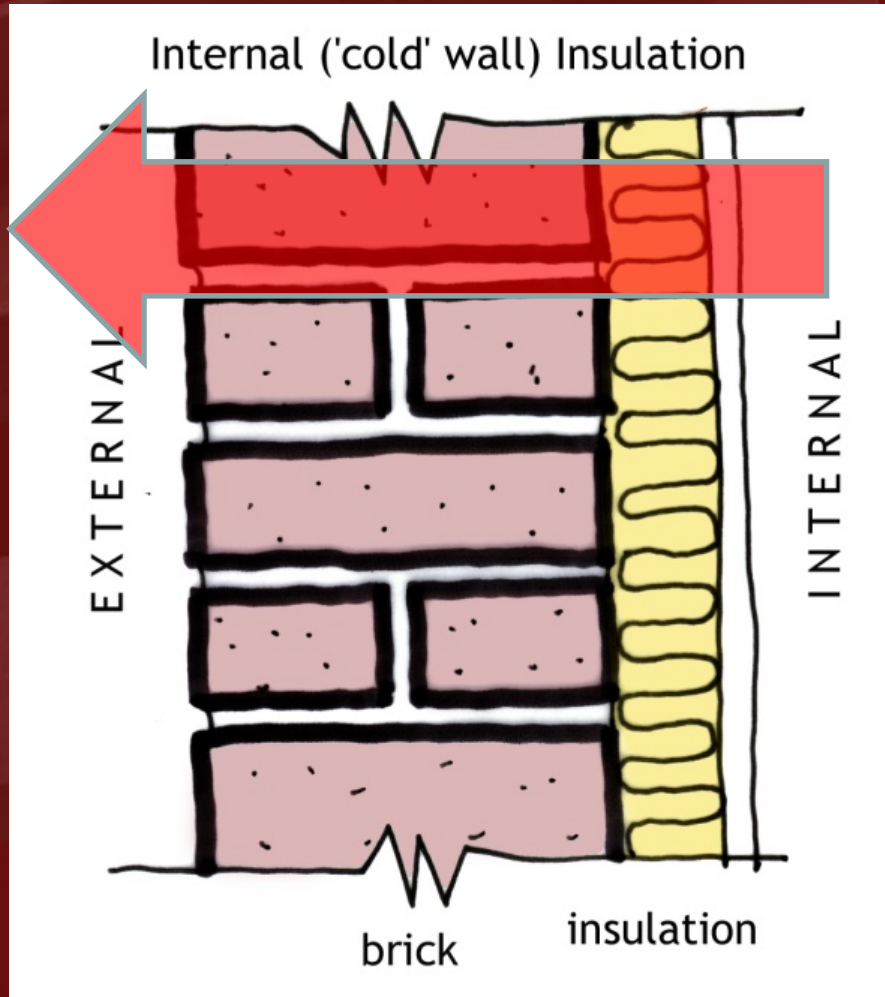
- Solid (permeable)
- External insulation
- Internal insulation

- Cavity

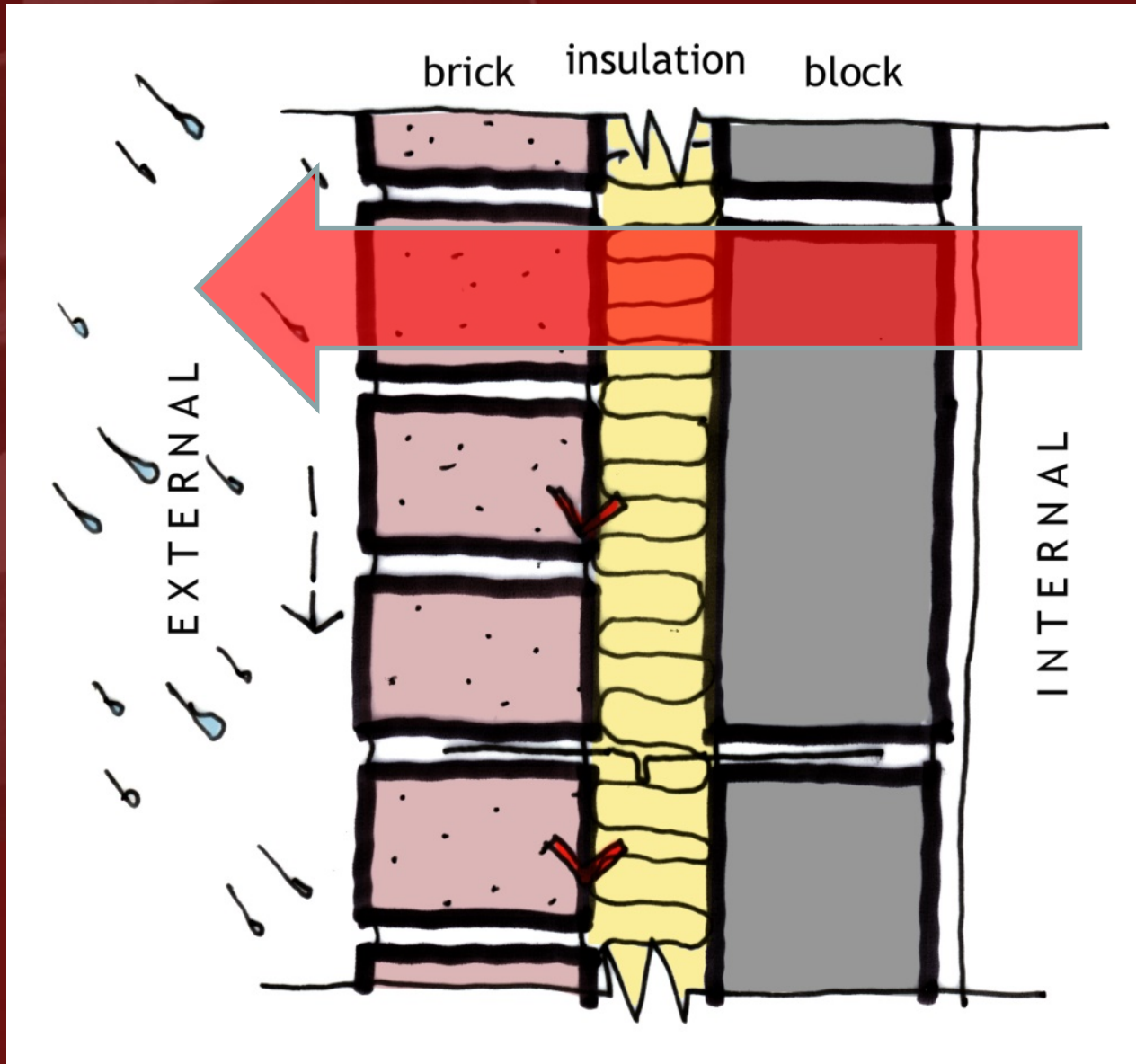
- Cavity (traditional)
- Cavity (part filled)
- Layered or filled cavity
- Cavity Timber Frame

- Clad

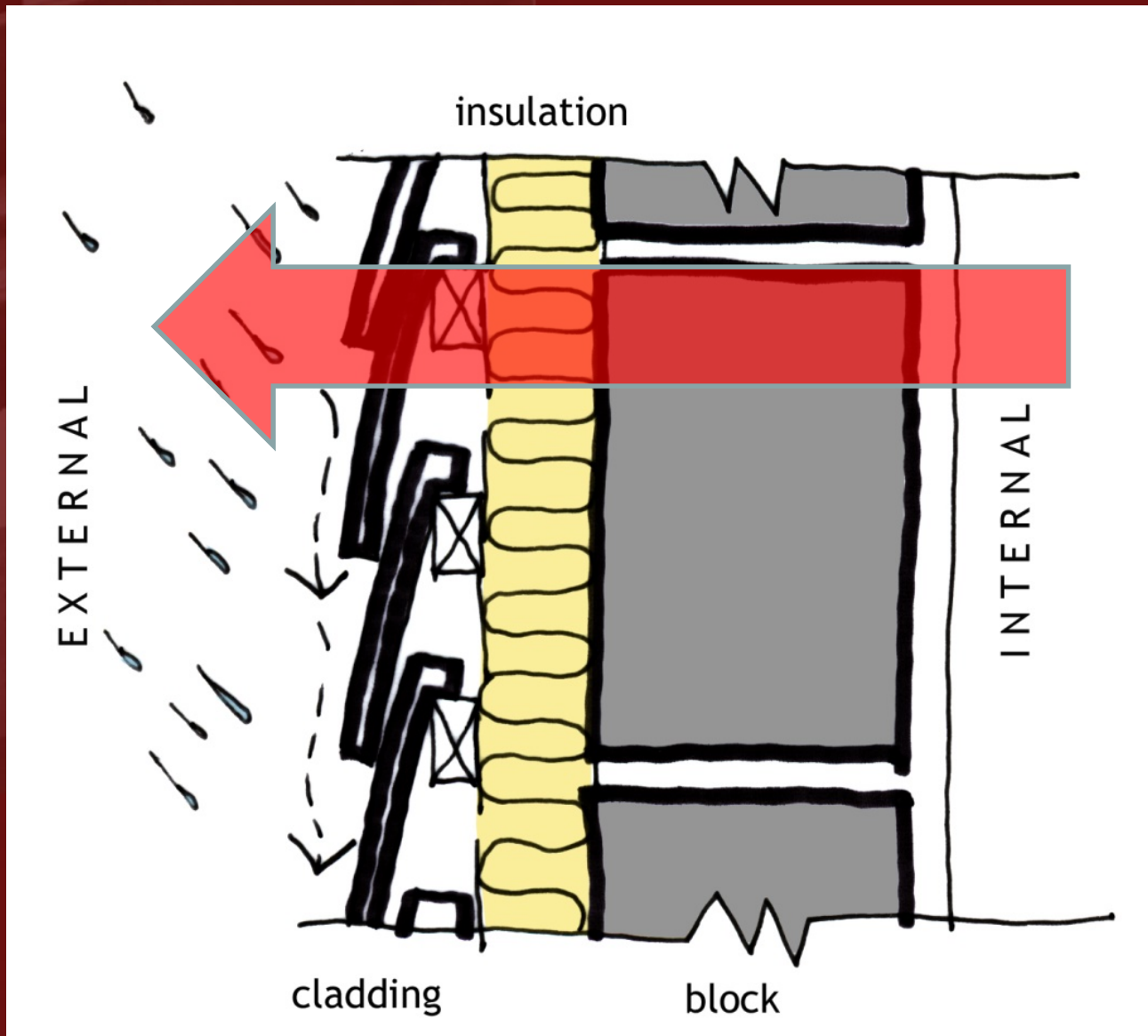
Solid walls



Layered or filled cavity walls

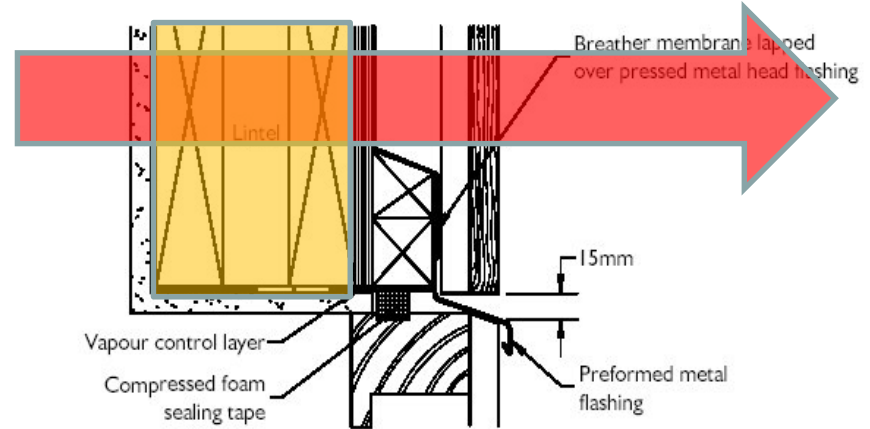


Clad walls

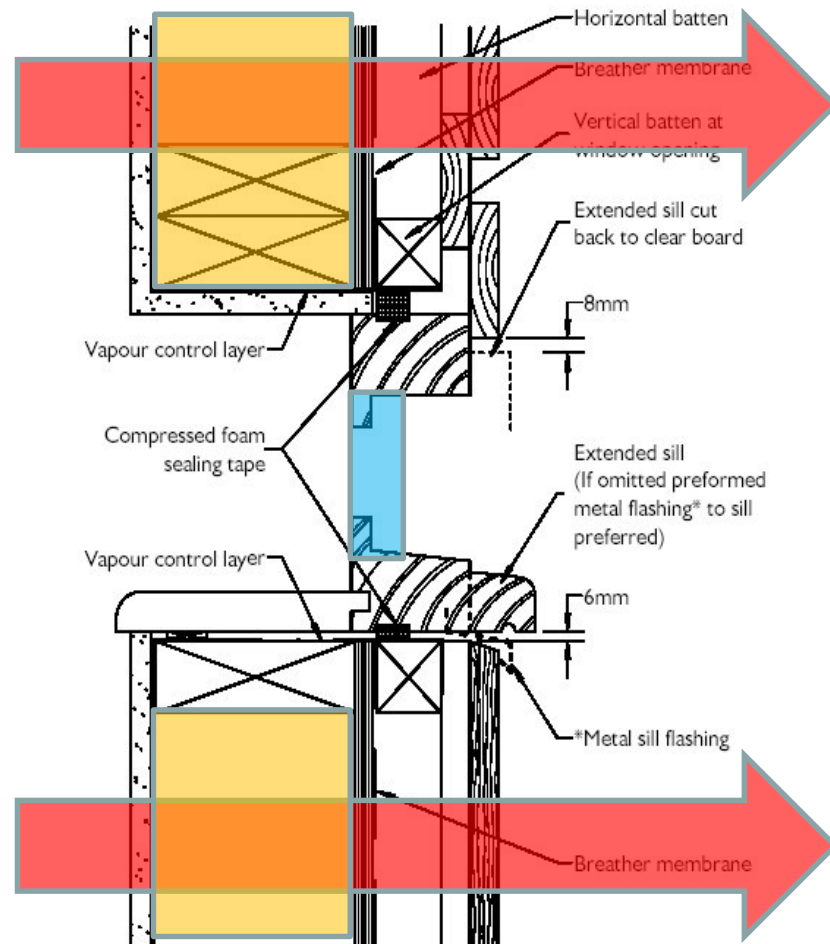


Timber frame walls

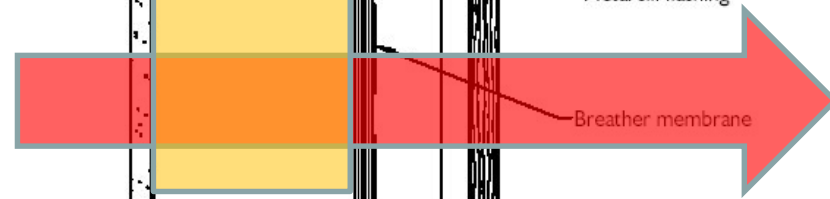
Head detail



Jamb detail



Sill detail

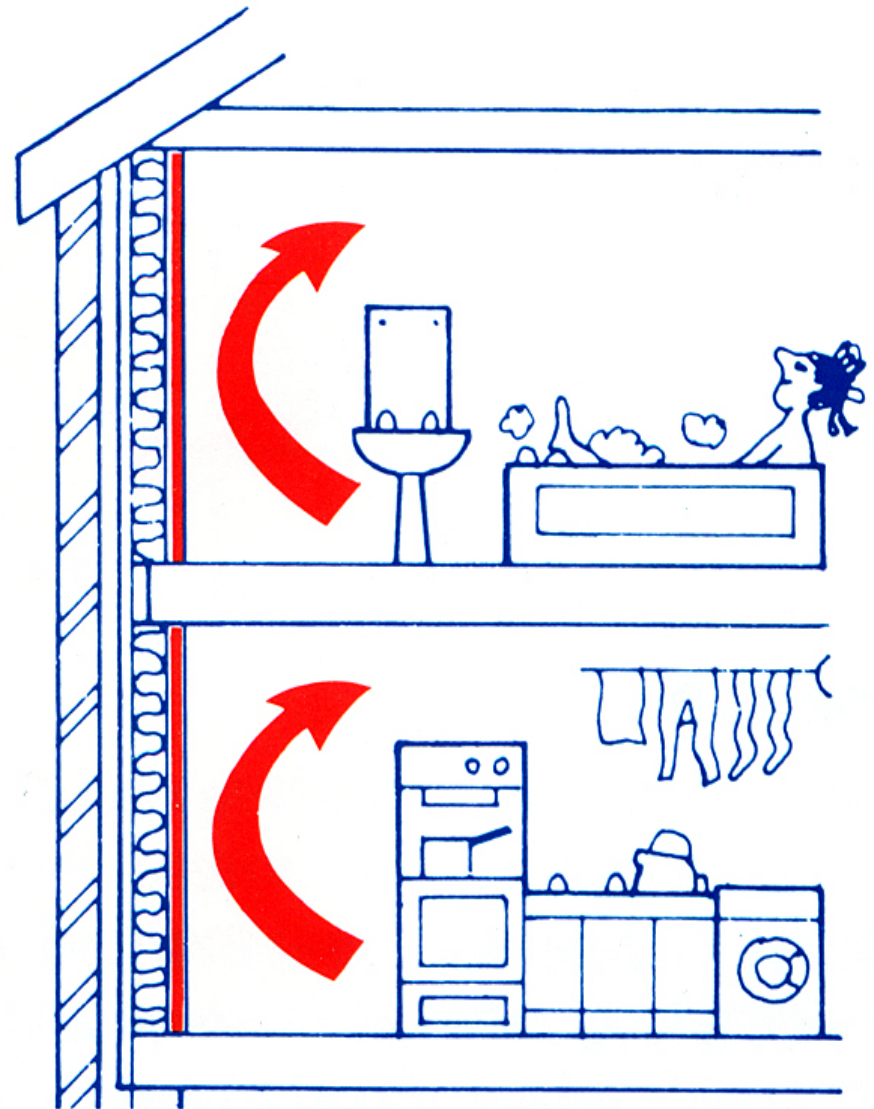


Elemental U-values

Table 3.3 *U*-values of common forms of construction

<i>Element</i>	<i>Composition</i>	<i>U-value (W/m² K)</i>
Solid wall	brickwork, 215 mm plaster, 15 mm	2.3
Cavity wall	brickwork, 103 mm clear cavity, 50 mm brickwork, 103 mm	1.6
Cavity wall	brickwork, 103 mm clear cavity, 50 mm lightweight concrete block, 100 mm lightweight plaster, 13 mm	0.58

Vapour Control



*vapour control layer
preventing moisture getting
into timber frame walls*

Elemental U-values

Element	Composition	U-value (W/m ² K)
Cavity wall	brickwork, 103 mm insulation in cavity, 50 mm lightweight concrete block, 100 mm lightweight plasterboard, 13 mm	0.48
Cavity wall	brickwork, 103 mm clear cavity, 50 mm aerated concrete block, 115 mm insulation board, 55 mm	0.30
Timber frame wall	brickwork, 103 mm clear cavity, 50 mm sheathing ply, 9mm insulation layer, 25 mm timber framed filled with insulation, 90 mm plasterboard, 2 sheets, each 13 mm	0.30
Pitched roof	tiles on battens and felt ventilated loft airspace mineral wool on joists, 100 mm mineral wool between joists, 100 mm plasterboard, 13 mm	0.20
Window	single glazing, metal frames	5.7
Window	single glazing, wood or PVC frames	4.8
Window	double glazing, wood or PVC frames, low emissivity, 6 mm gap	2.8
Window	triple glazing, wood or PVC frames, low emissivity, 12 mm gap	1.6

Key Notes: 'Insulation' materials in this table are taken to have thermal conductivity values of 0.03 W/m K or less; Floors: U-values are affected by the length of perimeter exposed to the outside. See table 3.6.

Thermal resistance, R-value

- U-values are calculated from the thermal resistances of the parts making up a particular part of a structure.
- The different layers and surfaces of a building element, such as a wall , oppose the transmission of heat by varying amounts.
- These differences are described by thermal resistances, or *R- values*.

Thermal resistance, R-value

- Thermal resistance R is a measure of the opposition to heat transfer offered by a particular component in a building element.
- Unit : $\text{m}^2 \text{ K/W}$
- The idea of thermal resistance is comparable to electrical resistance. The term *Conductance* (C) is sometimes used to express the reciprocal of thermal resistance, where $C = 1/R$.

Thermal resistance, R-value

Thermal resistance

- There are three general types of thermal resistance which need to be determined, either by calculation or by seeking published standard values.
- Material resistances
- Surface resistances
- Airspace resistances

Thermal resistance, R-value

- Material resistances
- The thermal resistance of each layer of material in a structure depends on the rate at which the material conducts heat and the thickness of the material.
- Assuming that a material is homogeneous, this type of resistance can be calculated by the following formula.
- $R = d/\lambda$
 - where R = thermal resistance of that component ($\text{m}^2 \text{ K/W}$)
 - d = thickness of the material (m)
 - λ = thermal conductivity of the material (W/m K)

Thermal resistance, R-value

Surface resistances

- The thermal resistance of an open surface depends upon the conduction, convection and radiation at that surface. The air in contact with a surface forms a stationary layer which opposes the flow of heat.
- Surface resistances are usually found by consulting standard values that have been found by measurement or by advanced calculations. Some useful values are given in table 3.5.

Factors that affect surface resistances are:

- direction of heat flow: upward or downward
- climatic effects: sheltered or exposed
- surface properties: normal building materials with high emissivity or polished metal with low emissivity.

Thermal resistance, R-value

Airspace resistances

- The thermal resistance of an airspace or empty cavity depends on the nature of any conduction, convection and radiation within the cavity.
- Airspace resistances are usually found by consulting published standard values. Some useful airspace resistances are given in table 3.5.

The following factors affect airspace resistances:

- thickness of the airspace
- flow of air in airspace: ventilated or unventilated
- lining of airspace: normal surfaces or reflective surfaces of low emissivity

Thermal resistances

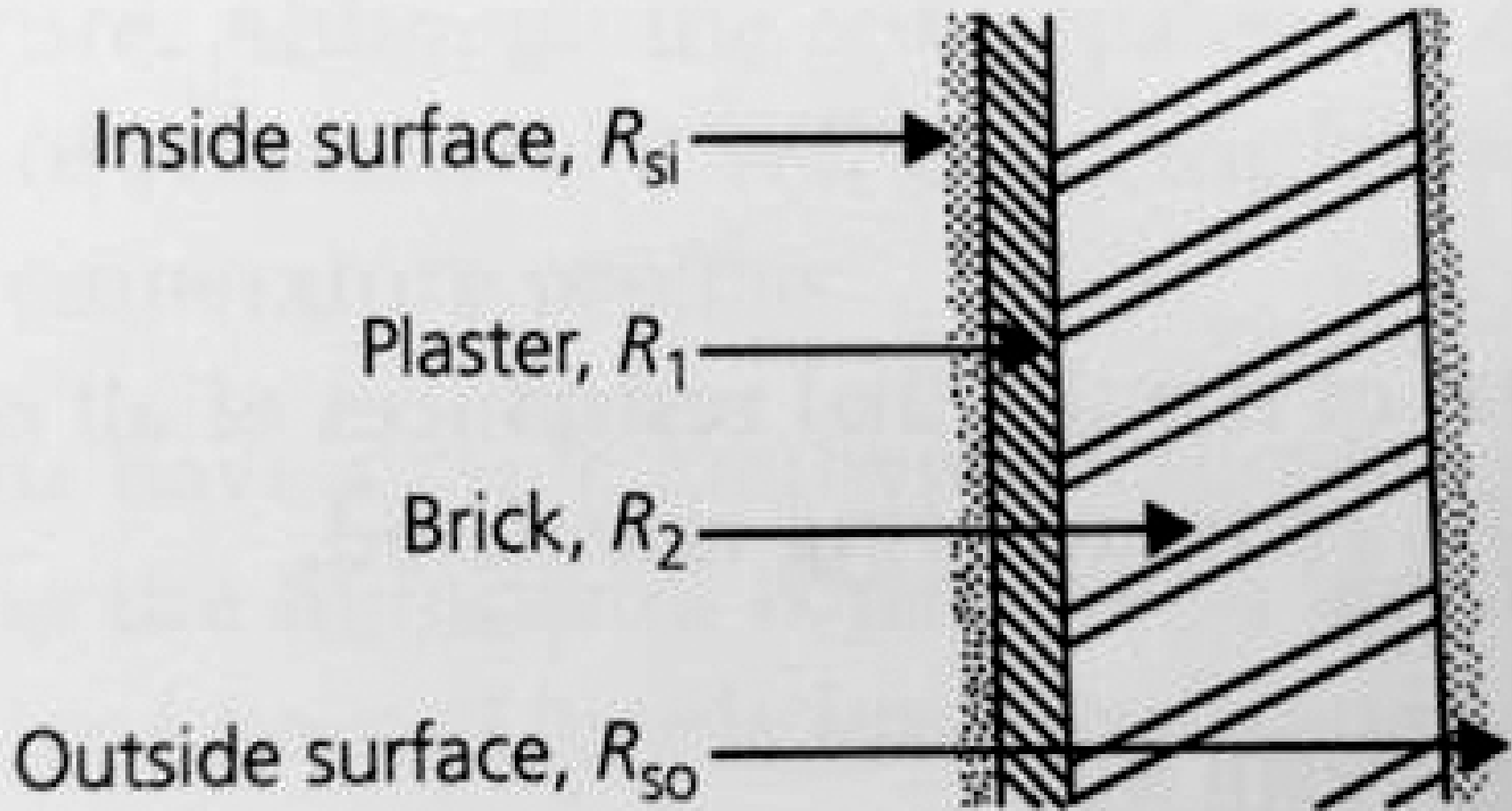


figure 3.3

Thermal resistances

Table 3.5 Standard thermal resistances

Type of resistance	Construction element	Heat flow	Surface emissivity*	Standard resistances [†] (m ² K/W)
Inside surfaces	Walls	Horizontal	High	0.12
			Low	0.30
	Roofs (pitched or flat) Ceilings/Floors	Upward	High	0.10
			Low	0.22
	Ceilings/Floors	Downward	High	0.15
			Low	0.56
Outside surfaces (normal exposure) [†]	Walls	Horizontal	High	0.06
			Low	0.07
	Roofs	Upward	High	0.05
			Low	0.05
Airsaces (including boundary surfaces)	Unventilated, 5mm	Horizontal or Upward	High	0.11
			Low	0.18
	Unventilated, 20 mm or greater	Horizontal or Upward	High	0.18
			Low	0.35
	Ventilated loft space with flat ceiling, unsealed tiled pitched roof			0.11

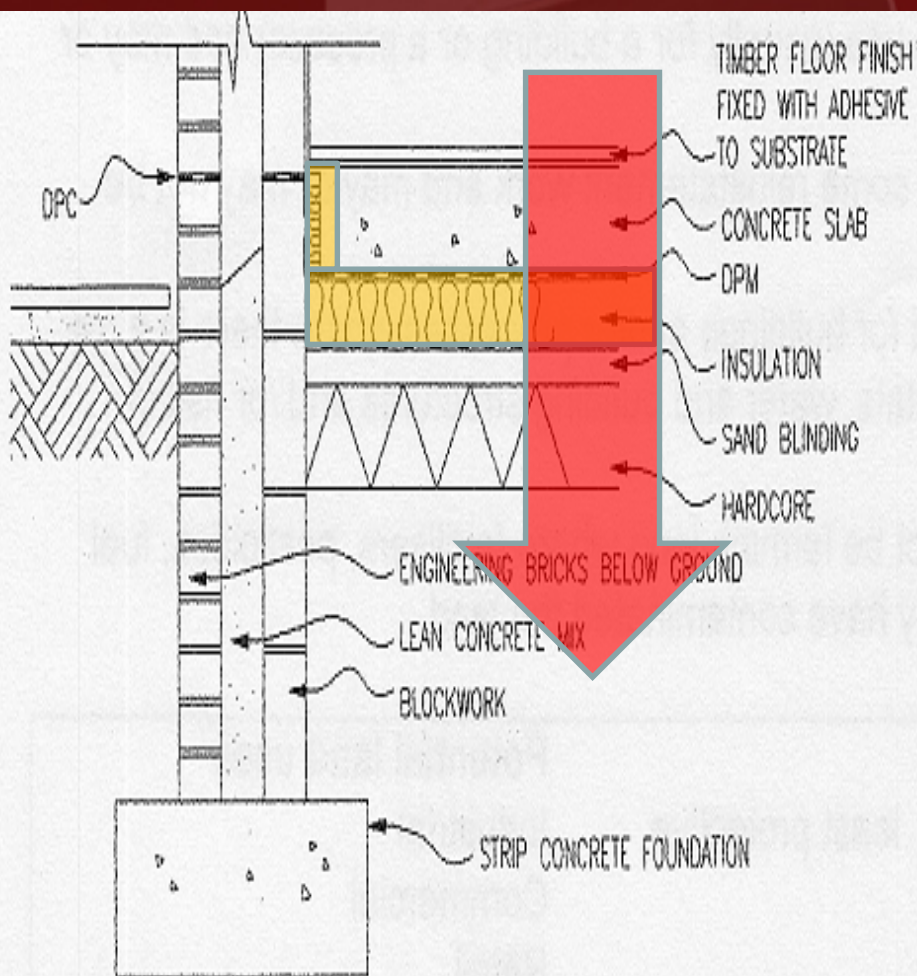
Thermal resistance

Total thermal resistance

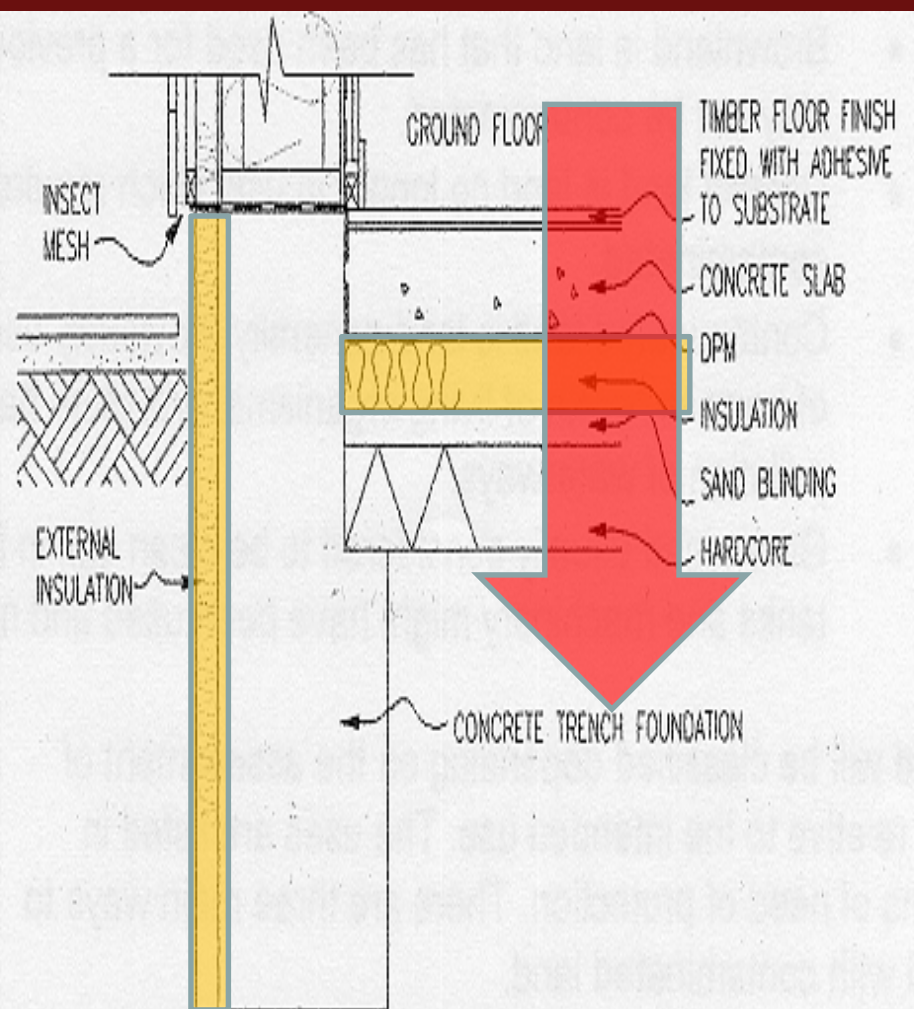
- The thermal resistances of consecutive layers in a structural element, such as a wall or roof can be likened to electrical resistances connected in series.
- Thus the total thermal resistance is the sum of the thermal resistances of all the components in a structural element. As figure 3.3
- $R_T = R_{si} + R^1 + R^2 + R_{so}$

Where $R_T = \sum R$

$\sum R$ is the total of the thermal resistances of all components occurring in a section through the element being calculated.



Strip foundation with cavity wall



Trench foundation with timber frame

U- values for floors

- When heat leaves a building through a ground floor, the path of the heat flow has to curve through the ground back to the outside air at the edge of the building.
- Heat losses through the floor are highest near the exposed edges of the floor, and heat losses are lowest near the centre of the floor where the ground itself adds to the insulation.
- The calculation of the U- values for ground floors is complex.
- The ratio of exposed floor edges to total floor area is important to consider.

P/A where – P = floor perimeter length (m)

A = area of floor (m²)

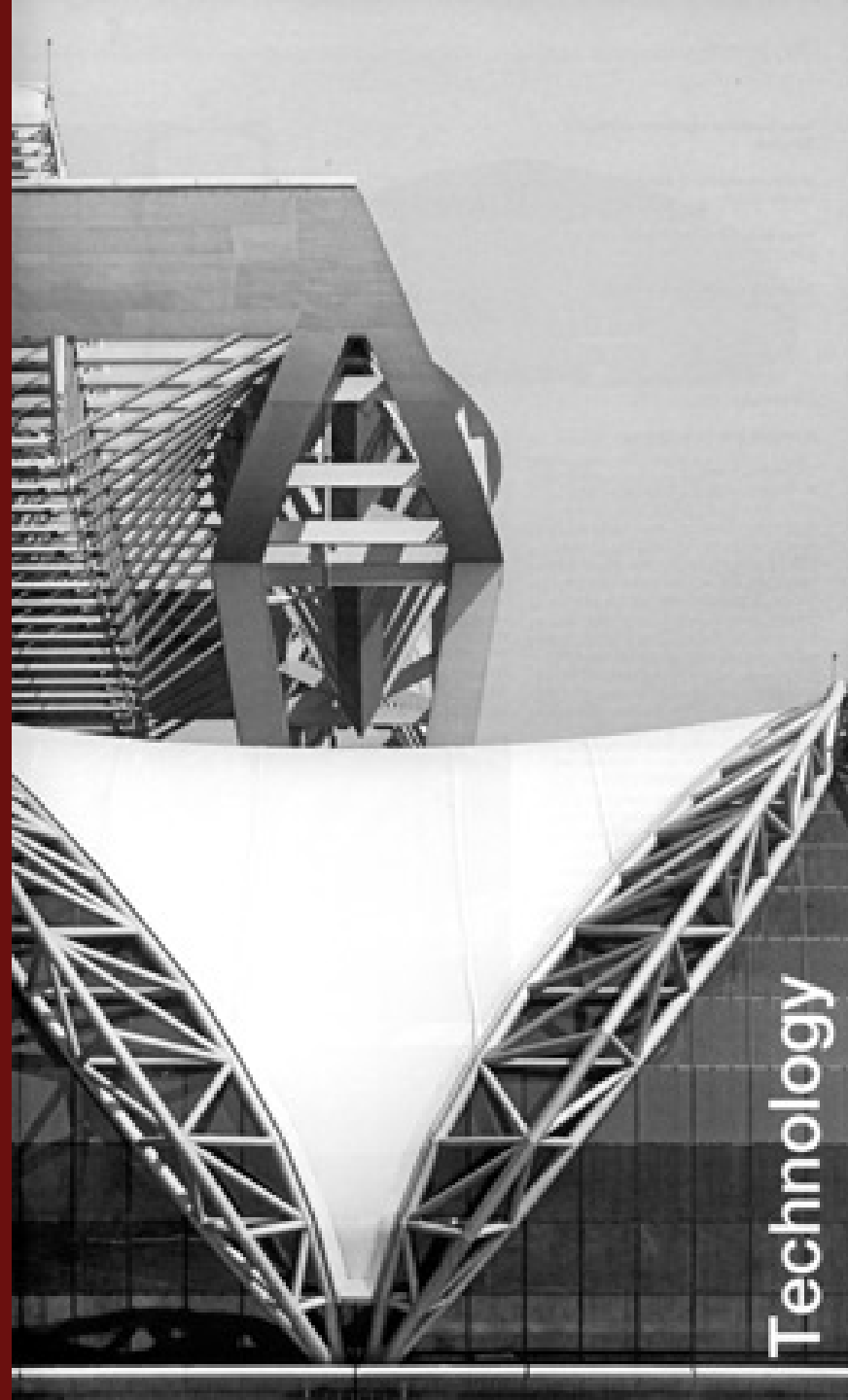
Values of Thermal Conductivity

Typical building materials

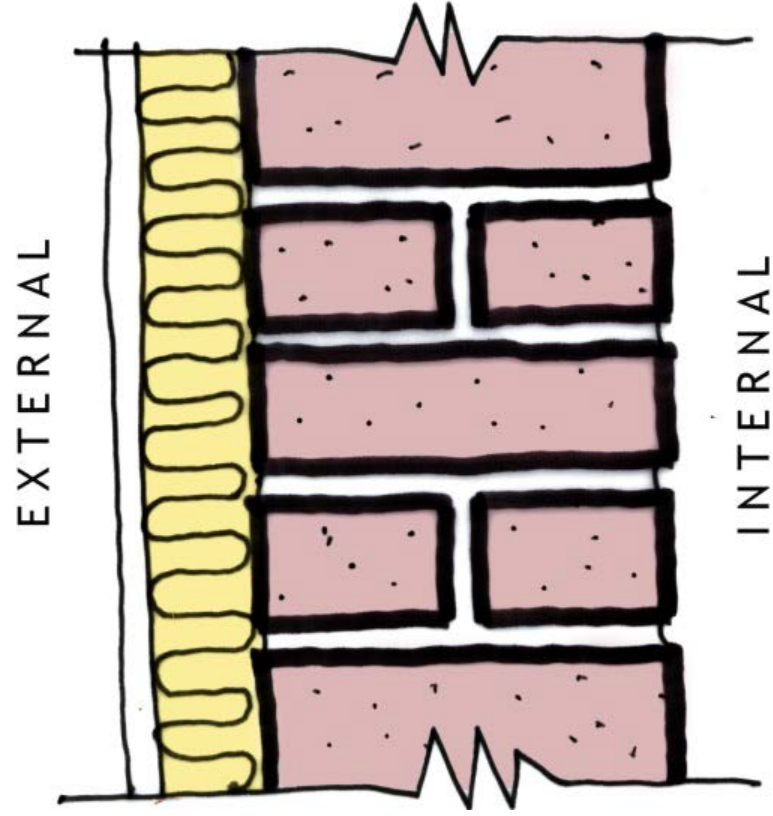
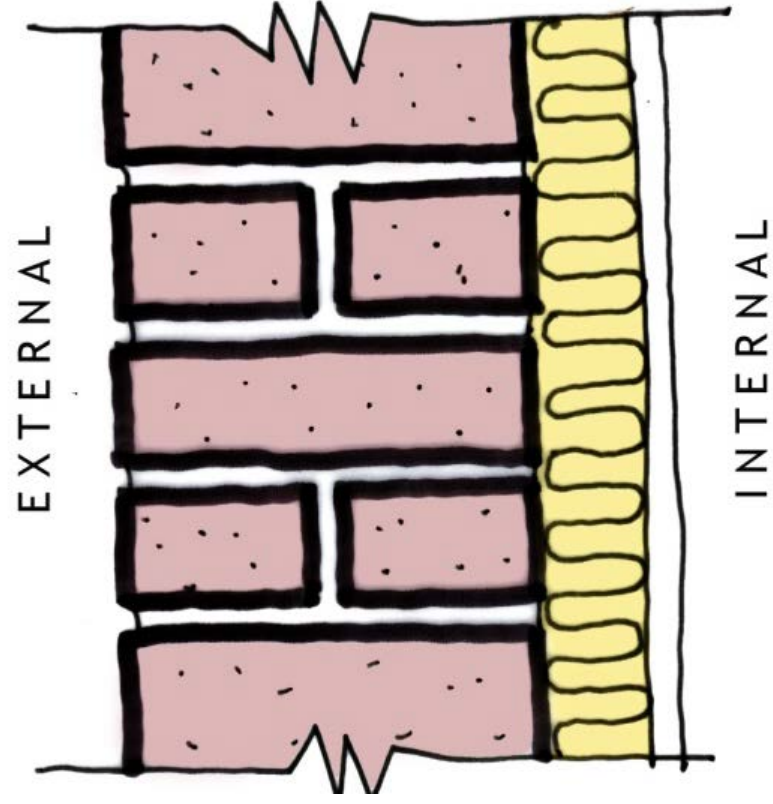
	Density (kg/m ³)	Thermal Conductivity λ (W/m K)
Aluminium alloy, typical	2700	190
Asphalt roofing	2100	0.70
Bitumen/felt layers	1100	0.23
Brickwork, exposed	1700	0.77
Brickwork, internal	1700	0.56
Concrete, reinforced 1% steel	2300	2.3
Concrete, high density	2400	1.93
Concrete, medium density	1800	1.13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

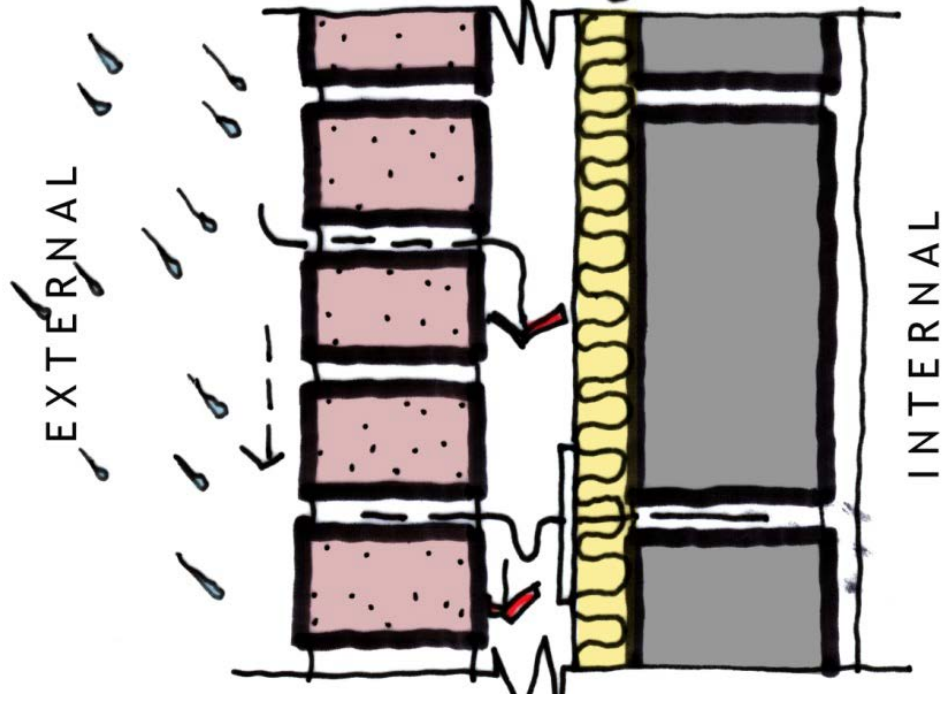
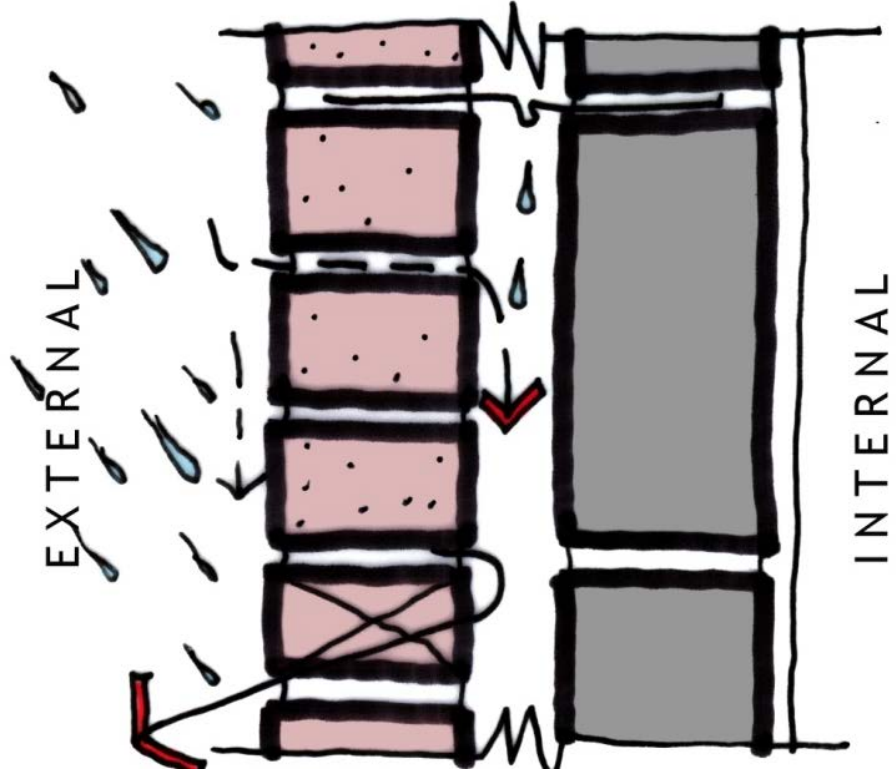
	Density (kg/m ³)	Thermal Conductivity λ (W/m K)
Copper, commercial	9840	160
Fibreboard	400	0.1
Glass, window pane	2560	0.022
Mortar, exposed	1750	0.94
Mortar, protected	1750	0.88
Plaster, dense	1300	0.57
Plaster, lightweight	600	0.18
Insulation, expanded polystyrene (EPS) board	15	0.04
Insulation, mineral 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

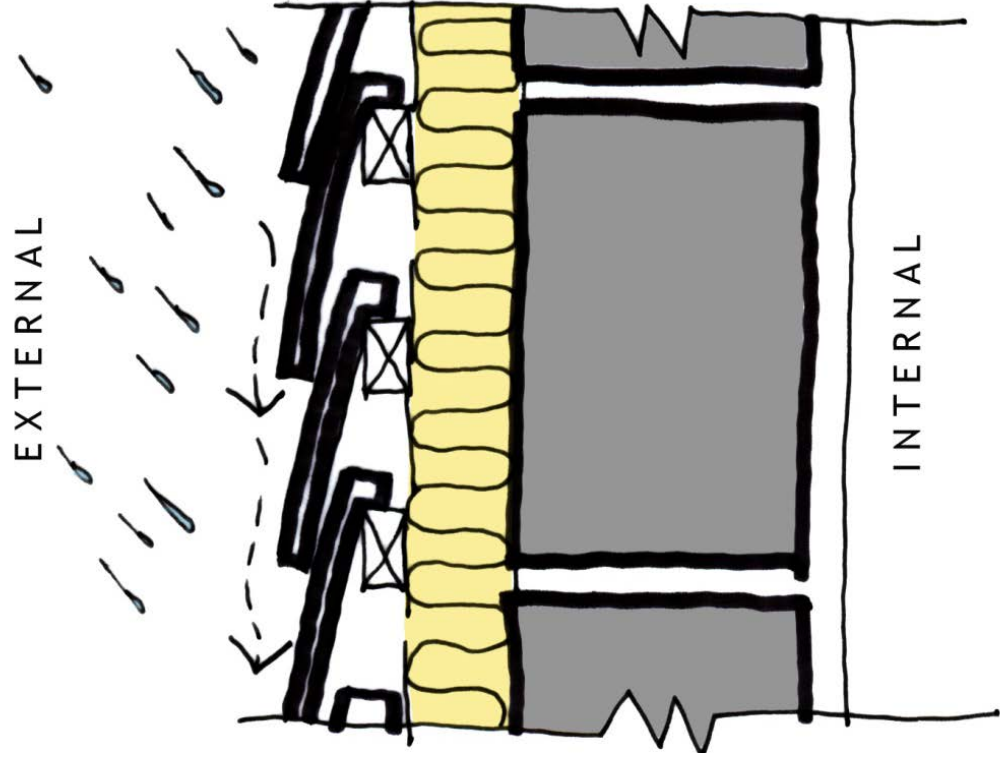
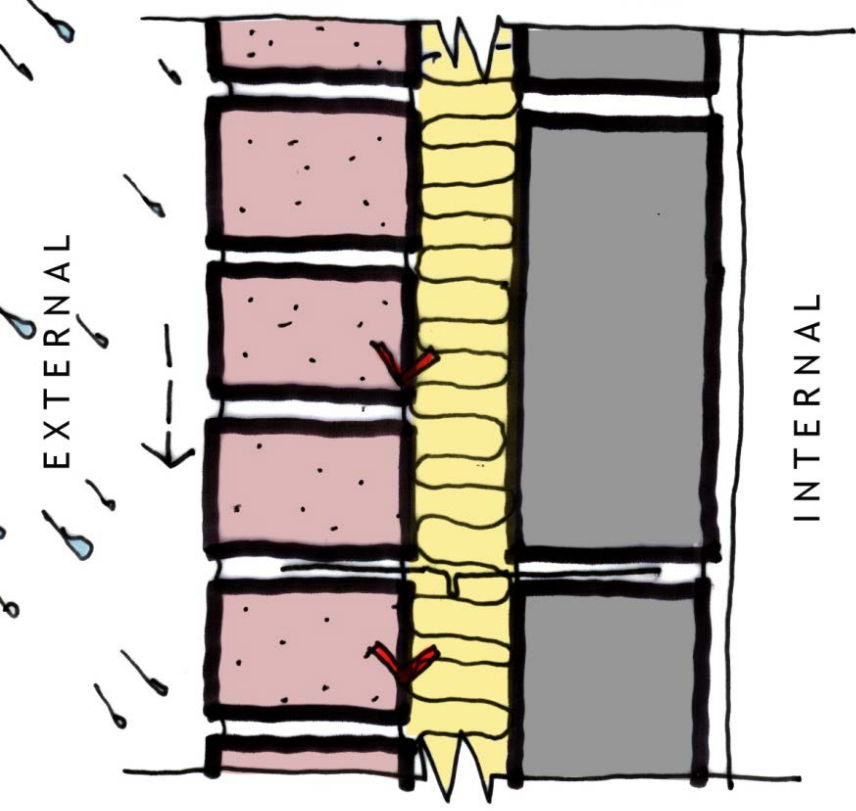
NOTE: Use manufacturers' data for precise values.



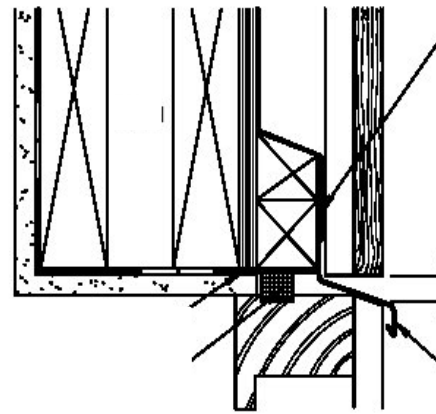
Technology



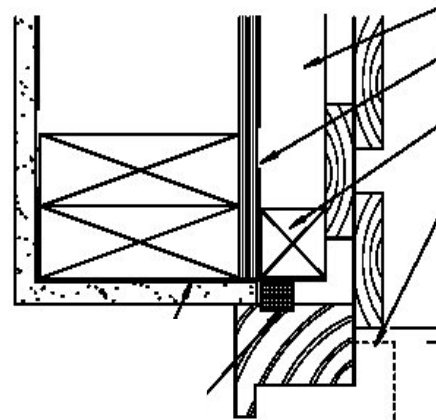




Head detail



Jamb detail



Sill detail

