To: Kurdistan Engineering Union

Local Building Materials Used in Walls to Reduce Heat Energy Consumption

Prepared By:

Swar Ibrahim Mohammed

Senior Architect

Jan 2023

CONTENTS

INTRODUCTION

INTRODUCTION

A wall is a continuous, usually vertical structure, thin in proportion to its length and height, built to provide shelter as an external wall or divide buildings into rooms or compartments as an internal wall.

The prime function of an external wall is to provide shelter against wind, rain and the daily and seasonal variations of outside temperature normal to its location, for reasonable indoor comfort.

The most influential climatic phenomena that affects on human being in the interior spaces of the buildings is heat, so the term thermal insulation became more important in the modern life nowadays, its benefits is:

Economy and energy conservation

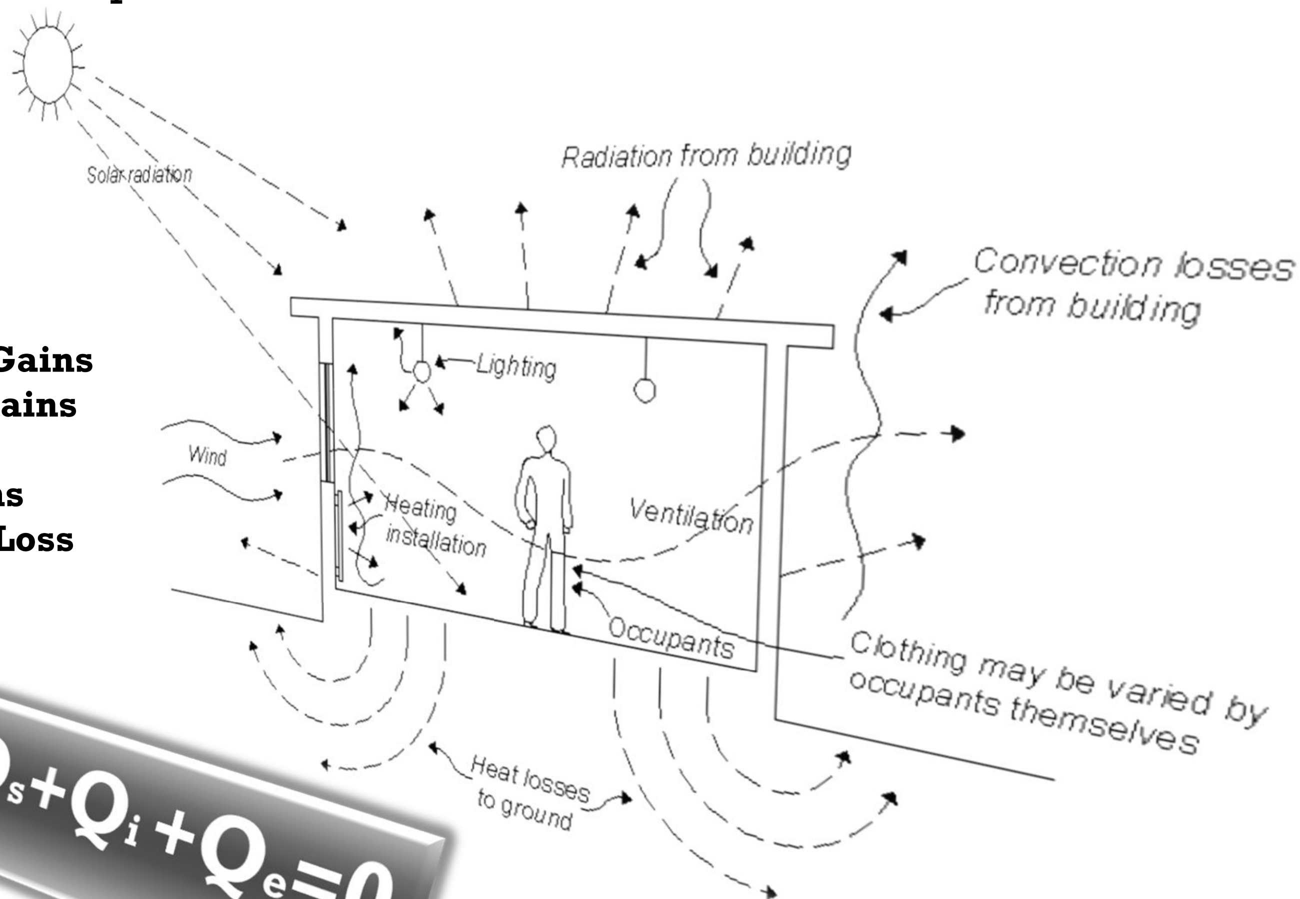
- reduce the size of heating plant required
- reduce annual energy consumption (and therefore environmental pollutants)
- Health, aesthetics and safety
- reduce the risk of condensation and consequent mould growth
- Thermal comfort
- reduce the time to heat a room up
- It can also reduce the effects of high external temperatures in summer (although thisdepends on the amount of solar gains).

SECTION ONE

1-1 HEAT BALANCE

Thermal balance occurs when the sum of all the different types of heat flow into and out of a building is zero. That is, the building is losing as much heat as it gains so it can be said to be in equilibrium. Thus:

Qc - Conduction Gains
Qv - Ventilation Gains
Qs - Solar Gains
Qi - Internal Gains
Qe - Evaporative Loss



$$Q_c + Q_v + Q_s + Q_i + Q_e = 0$$

1-1 HEAT BALANCE

❖Conduction of heat may occur through the walls either inwards or outwards,

❖The effects of solar radiation on opaque surfaces can be included in the above by using the sol air temperature concept.

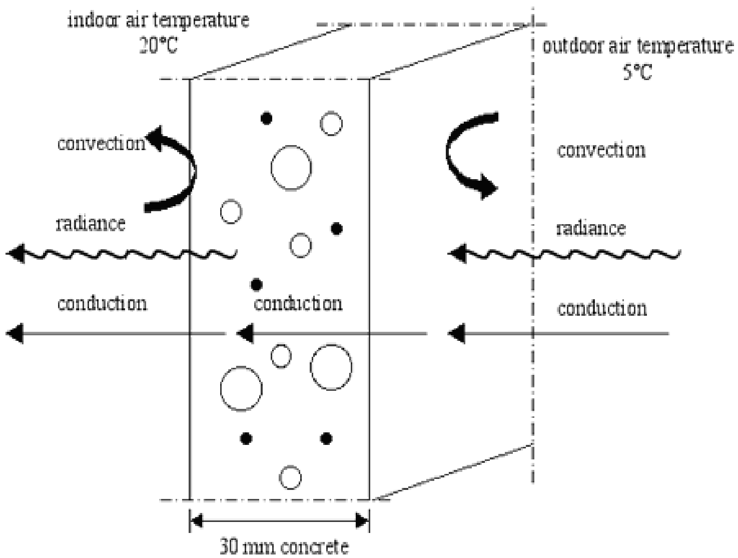
❖Heat exchange may take place in either direction with the movement of air

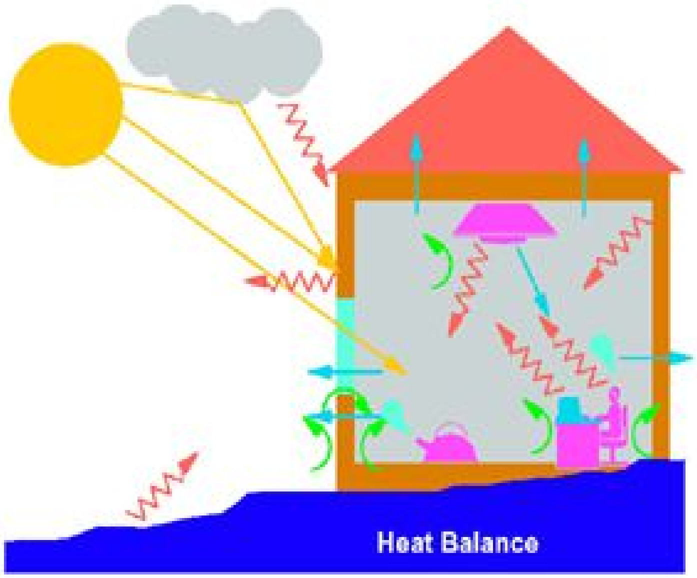
❖An internal heat gain may result from the heat output of human bodieses, lamps motors and appliances

❖Humans :Sitting, moderate movement ,Walking, lifting, pushing ,Sustained work.

❖There may be deliberate introduction or removal of heat (heating or cooling), using some form of outside energy supply.

❖If evaporation takes place on the surface of he building (e.g. roof pool) or within the building (human sweat or water in a fountain) the vapors are removed, this will produce a cooling effect.





1-2 THERMAL COMFORT

Space temperature

Industrial Issues

- Cold Storage
- Process and manufacturing plants

Human Comfort

Normally the same as it is related to the inside air condition which is related to the thermal comfort of human being

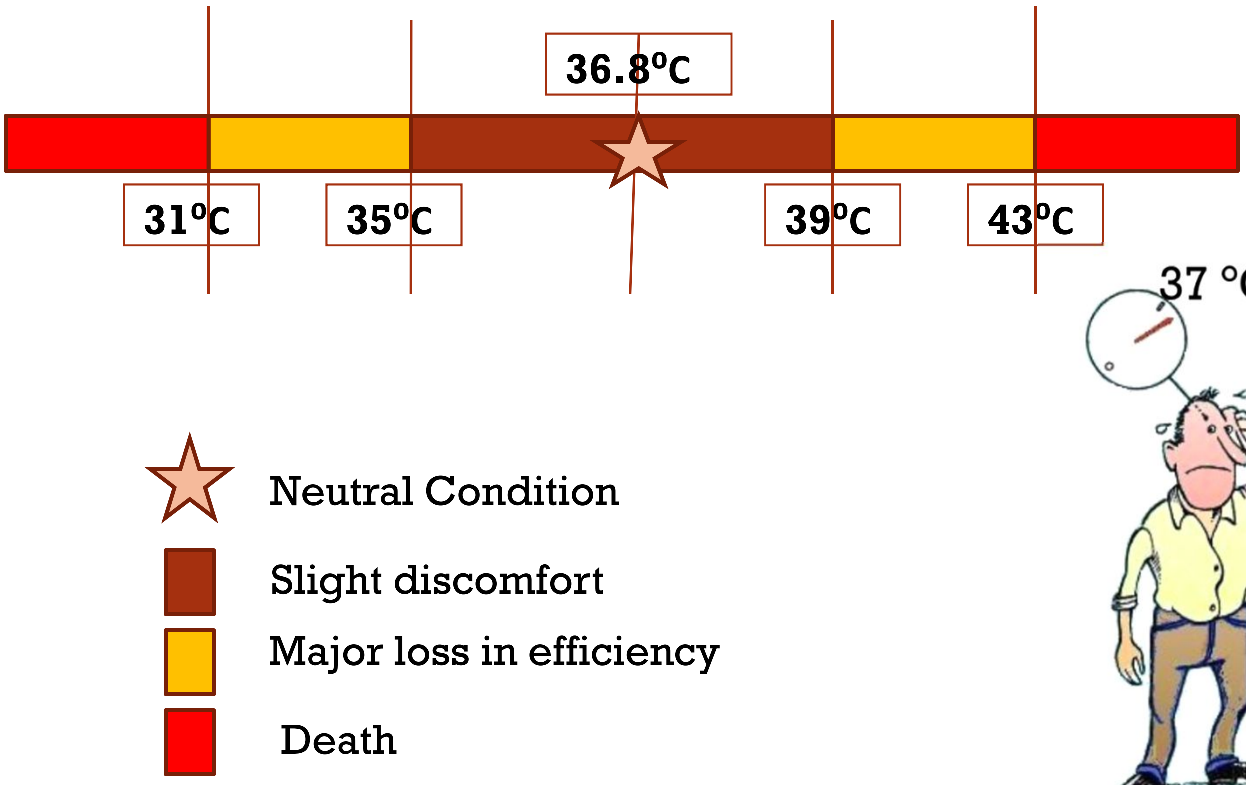
Human thermal comfort is defined by ASHRAE as the state of mind that expresses satisfaction with the surrounding environment (ASHRAE Standard 55).

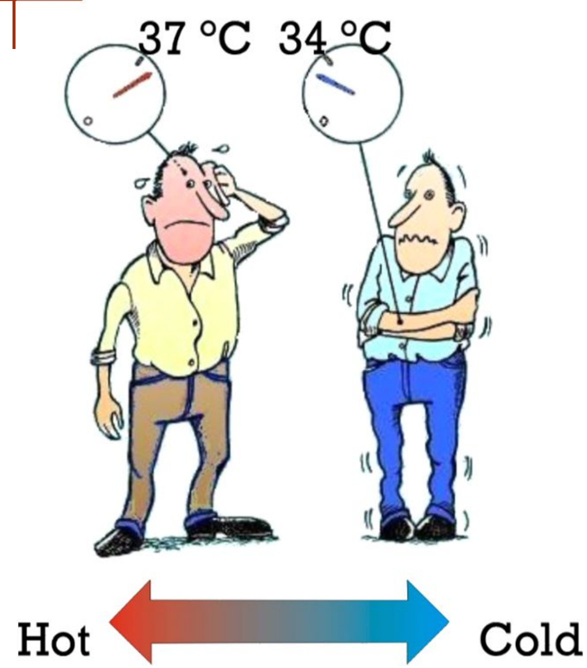
It may also be called neutral condition.

Thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate thus maintaining thermal equilibrium with the surroundings. Any heat gain or loss beyond this generates a sensation of discomfort. It has been long recognized that the sensation of feeling hot or cold is not just dependent on air temperature alone.

1-2 THERMAL COMFORT

- The Human body must be maintained in a narrow range to avoid discomfort , and within a wider range to avoid danger from heat or cold stress



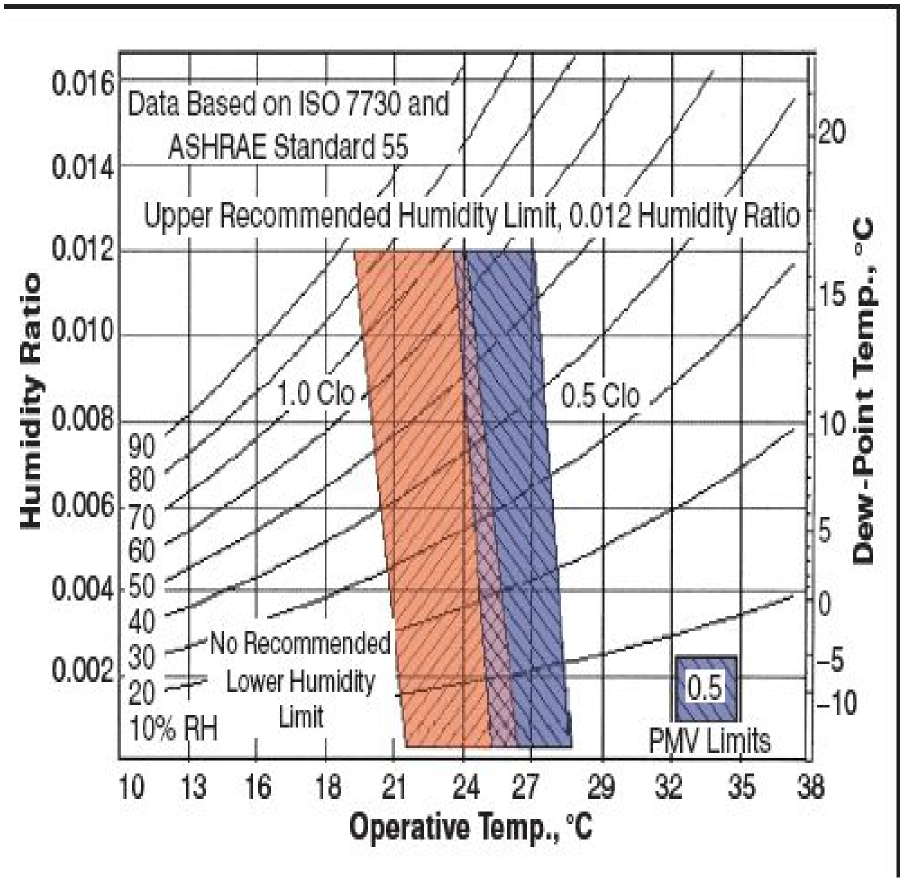


Operative Temperature:

Is a value combintion between humidity, metabolic rate, air speed, clothing insulation to determine the comfort zone.

Comfort zone is:

The combination of air temperature and the mean radiant temperature that people find thermally accepted

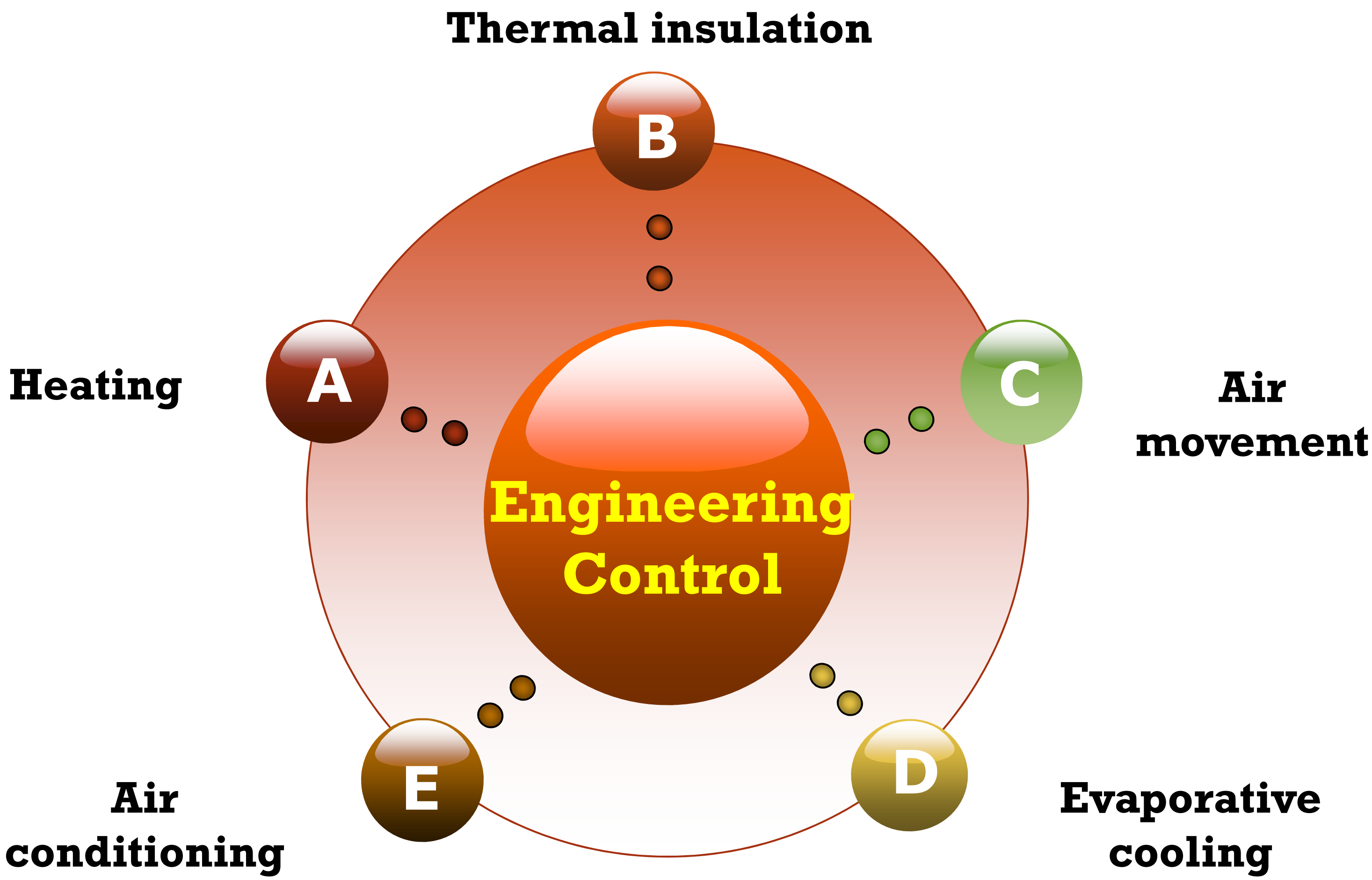


- ASHARE recommendations

Recommended comfort conditions for different seasons and clothing at 50% Relative humidity, air velocity of 0.15 m/s and an activity level of ≤ 1.2 met

Season	Clothing	I_{cl}	$T_{op.opt}$	Top range for 90% acceptance
Winter	Heavy slacks, long sleeve shirt and sweater	0.9 clo	22°C	20°C to 23.5°C
Summer	Light slacks and short sleeve shirt	0.5 clo	24.5°C	23°C to 26°C
	Minimal (shorts)	0.05 clo	27°C	26°C to 29°C

1-2 THERMAL COMFORT



1-3 RESISTANCE TO THE PASSAGE OF HEAT

Conduction

The rate at which heat is conducted through a material depends mainly on the density of the material. Dense metals conduct heat more rapidly than less dense gases. Metals have high conductivity and gases low conductivity. Conductivity is the amount of heat per unit area, conducted in unit time through a material of unit thickness, per degree of temperature difference. Conductivity is expressed in watts per meter of thickness of material per degree kelvin (W /mK) and usually denoted by the Greek letter Λ (lambda).

Convection

The density of air that is heated falls, the heated air rises and is replaced by cooler air. This in turn is heated and rises so that there is a

continuing movement of air as heated air loses heat to surrounding cooler air and cooler surfaces of ceilings, walls and floors. Because the rate of transfer of heat to cooler surfaces varies from rapid transfer through thin sheet glass in windows to an appreciably slower rate of transfer through insulated walls, and because of the variability of the rate of exchange of cold outside air with warm inside air by ventilation, it is not possible to quantify heat transfer by convection.

Usual practice is to make an assumption of likely total air changes per hour or volume (litres) per second and then calculate the heat required to raise the temperature of the incoming cooler air introduced by ventilation.

Radiation

Radiant energy from a body, radiating equally in all directions, is partly reflected and partly absorbed by another body and converted to heat. The rate of emission and absorption of radiant energy depends on the temperature and the nature of the surface of the radiating and receiving bodies. The heat transfer by low temperature radiation from heaters and radiators is small, whereas the very considerable radiant energy from the sun that may penetrate glass and that from high levels of artificial illumination is converted to appreciable heat inside buildings. An estimate of the solar heat gain and heat gain from artificial illumination may be assumed as part of the heat input to buildings.

1-4 TRANSMISSION OF HEAT

Because of the complexity of the combined modes of heat transfer through the fabric of buildings it is convenient to use a coefficient of heat transmission as a comparative measure of transfer through the external fabric of buildings. This air-to-air heat transmittance coefficient, the U value, takes account of the transfer of heat by conduction through the solid materials and gases, convection of air in cavities and across inside and outside surfaces, and radiation to and from surfaces. The U value, which is expressed as W /m^2K, is the rate of heat transfer in watts through one square metre of a material or structure when the combined radiant and air temperatures on each side of the material or structure differ by 1 degree kelvin (1 DC). A high rate of heat transfer is indicated by a high U value, such as that for single glazing of 5.3 (W/m^2K), and a low rate of heat transfer by a low U value, such as that for **PIR** insulation of 0.022 W/m^2K.

The U value may be used as a measure of the rate of transfer of heat through single materials or through a combination of materials such as those used in cavity wall construction.

1-5 CONTROLLING HEAT FLOW

EXCESSIVE heat flow through building assemblies results in wasted energy. unnecessarily high investment in oversized healing and cooling equipment. water damage in winter from condensation and frost on interior surfaces. and discomfort for the occupants of the building. In detailing a building. there are three basic ways of minimizing heat transmission and maximizing thermal comfort:

I. Control the conduction of heat through the building envelope.

2. Control the radiation of heat onto and through the building envelope.

3. Utilize thermal mass to regulate the flow of heat through the building envelope.

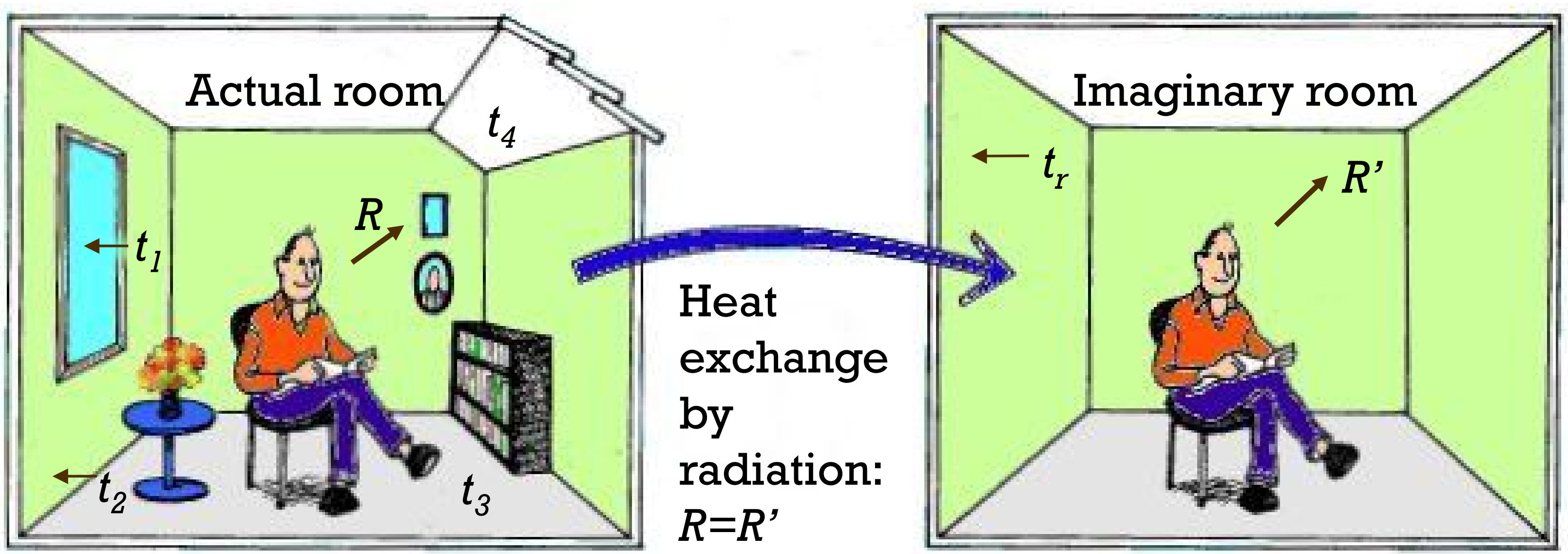
Each of these ways generates its own detail patterns.

1. CO TROLLING THE CONDUCTION OF HEAT

Most building materials are dense and conduct heat rapidly. In assembling layers of material 10 make a wall, roof , floor, foundation, window, or door, we almost always include one or more low-density materials with low thermal conductivities.

2. CONTROLLING THE RADIATION OF HEAT

There arc two very different sources of radiated heat that we must control in a building: One is the sun; the other is warm surfaces and objects within and around the building. Radiant heal from the sun strikes the building from a single direction at any given moment, but the direction changes constantly with time of day and lime of year in a pattern that we can predict with great accuracy. Solar radiation is transmitted across a broad spectrum of wavelengths. Most of its energy lies within the visible spectrum and the shorter infrared wavelengths. These wavelengths can be reflected efficiently by both while surfaces and bright metallic surfaces. Solar radiation can also be blocked effectively with simple shading devices.



3. UTILIZING THERMAL MASS

When exposed to warm air or solar radiation, large masses of such dense materials as soil, masonry, concrete. and water absorb and store considerable quantities of heat. They do so over a period of time that depends on the thickness of the material and its thermal properties; in a building, this period typically can be as much as 12 hours. In hot climates with large temperature differences between day and night, we can turn this delay to our advantage. We detail the building in such a wav that its thermal mass absorbs heat during the day and gives it off again at night, acting to maintain a comfortable temperature range inside the building while the outside air temperature fluctuates over much wider range. Thermal mass can also be useful in allowing a building to receive large amounts of solar radiation or heal from machinery during the day without overheating and then giving this heat back to the building at night when the building would otherwise tend to become cool

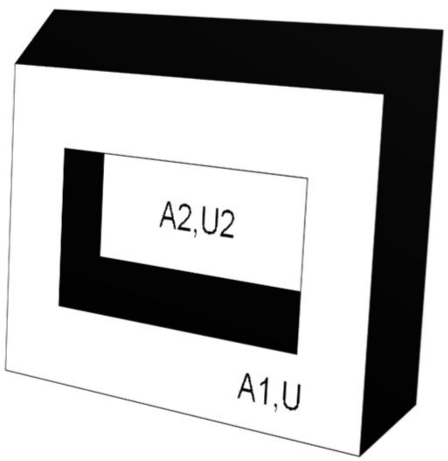
1-6 thermal transmittance U Value

U-value or **thermal transmittance** or **overall heat transfer coefficient** is the overall heat transfer rate under standard conditions through a particular section of construction.

- It is the rate of heat flow in watts through an area of 1m2 for a temperature difference across the structure of 1oC.
- It includes conduction through solids, and convection and radiation through air gaps in the construction and at the surfaces.
- Units: **W/m2K**
- Standard conditions enable comparisons of products of different manufacturers.

Average U-values

Note that U-values are not additive, but that thermal resistances are. If a wall or roof is composed of different constructions, then the overall U-value of the wall or roof depends upon the relative areas of the different constructions.



In this case:

U average= A1U1+A2U2/A1+A2

1-6 thermal transmittance
U Value

To understand the use of U-values it is necessary to distinguish between the thermal measurement expressions below:

❖ **Thermal conductivity (k-value)**

The heat (W) transmitted through unit area (rn') of a material of unit thickness (m) for unit temperature difference (K) between inside and outside environments, expressed as **W/mK** (or W/m DC).

❖ **Thermal resistivity (r-value)**

The reciprocal of thermal conductivity, i.e. **mK/W** (or m °C/W). It measures how well a material resists the flow of heat by conduction.

❖ **Thermal resistance (R-value)**

This means how well a *particular thickness* of material resists the passage of heat by conduction, calculated from the r-value in units of **m^2K/W** (or m^2 °C/W).

1-6 thermal transmittance
U Value

$$U = 1/RSI + Rso + RA + R1 + R2 + R3 \ldots$$

Where

RSI = thermal resistance of internal surface Rso

Rso = thermal resistance of external surface

RA = thermal resistance of air spaces within construction

R1, R2, R3 etc. = thermal resistance of successive components

$$R = \frac{1}{\text{k-value}} \times \frac{\text{thickness of material mm}}{1000}$$

$$R = I / U$$

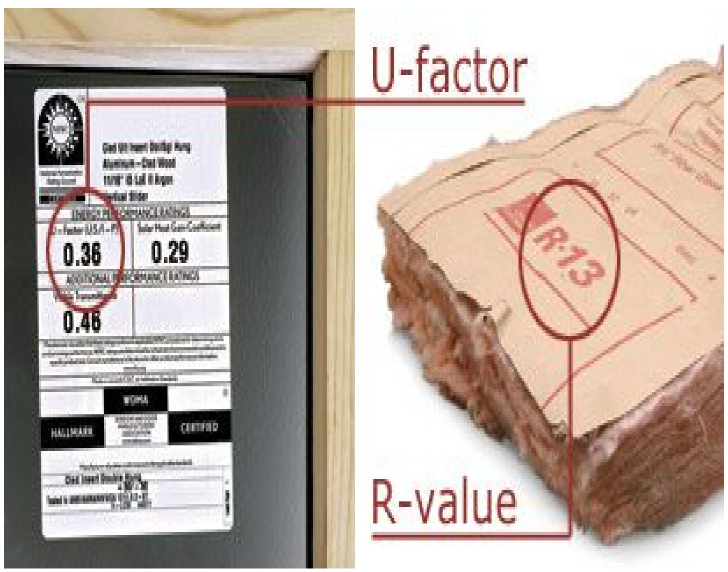
1-6 thermal transmittance
U Value

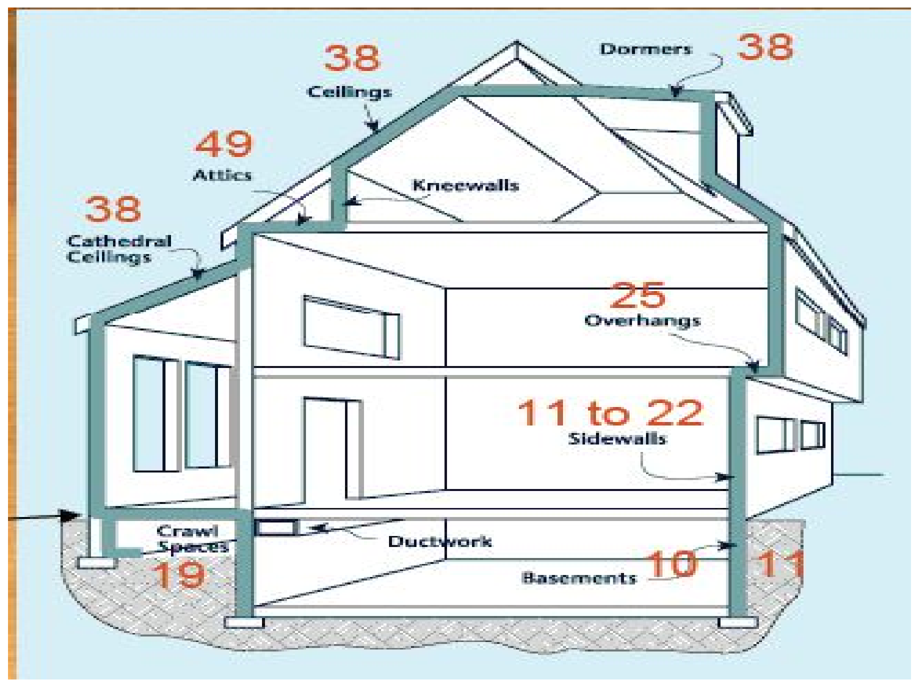
R-value

Created as a way to sell insulation, R-value is a measure of resistance to heat flow. The higher the number, the greater the insulating value.

Because doubling the R-value cuts heat loss in half, adding R-1 to R-1 will make a big difference; but adding R-1 to R-30 will reduce heat loss by only about 3%.

A good installation technique is the key to getting a good R-value. For instance, R-19 insulation installed incorrectly probably will perform at a level of R-13.





1-6 thermal transmittance U Value

K-values							
Thermal conductivity of typical building materials							
Material		kg/m'	W/mK	Material		kg/m'	W/mK
asphalt	19mm	1700	0.50	phenolic foam	board	30	0.020
blocks	lightweight	1200	0.38	plaster	gypsum	1280	0.46
	med. weight	1400	0.51		sand/cement	1570	0.53
	heavyweight	2300	1.63		vermiculite	640	0.19
bricks	exposed	1700	0.84	plasterboard	gypsum	950	0.16
	protected	1700	0.62	polystyrene	expanded	25	0.035
calcium silicate	board	875	0.17	polyurethane	board	30	0.025
chipboard		800	0.15	rendering	external	1300	0.50
concrete	aerated slab	500	0.16	roofing tiles	clay	1900	0.85
	lightweight	1200	0.38		concrete	2100	1.10
	dense	2100	1.40	screed		1200	0.41
felVbitumen	3 layers	960	0.50	stone	reconstructed	1750	1.30
fibreboard		300	0.06		sandstone	2000	1.30
fibreglass	quilt	25	0.04		limestone	2180	1.50
glass	sheet	2500	1.05		granite	2600	2.30
hardboard	standard	900	0.13	stone chippings		1800	0.96
mineral wool	quilt	12	0.04	timber	softwood	650	0.14
	slab	25	0.035	vermiculite	loose	100	0.65
mortar	normal	1750	0.80	woodwool	slabs	600	0.11

1-7 BUILDING INSULATION

The goal of insulation used in building construction is to slow down heat transfer. The same materials are required to keep buildings cooler in hot climates, or warmer in cold climates; methods may be different because of the necessity to manage humidity buildup differently. Occupied buildings always need to evacuate humidity. No substance can stop heat transfer from occurring.

As more insulation is installed, more comfort (thermal and soundproofing) is created, and operating costs are lowered. There is no objective test or standard for thermal insulation, although ASHRAE Standard 55 defines thermal comfort goals. The three means of Heat-transfer resistance reduce radiative, conductive and convective losses and gains. Local custom often determines the methods used to achieve comfort level goals.

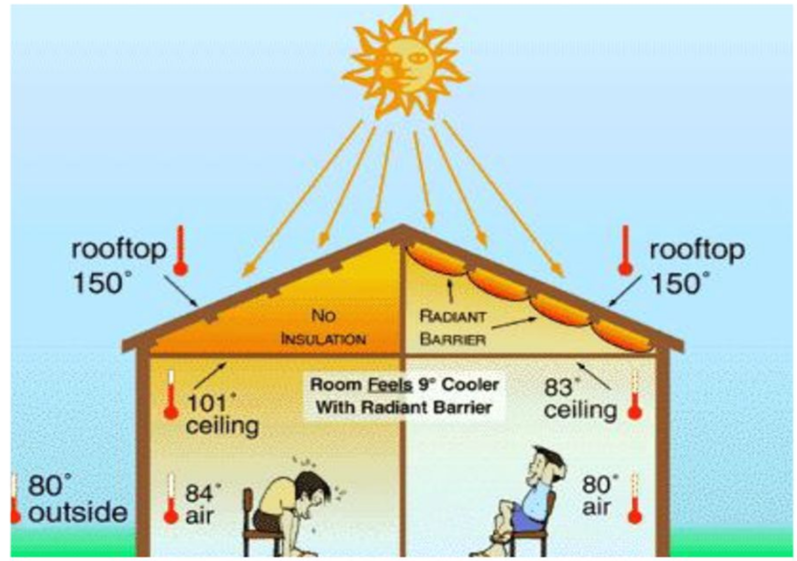
In some climates, large thermal mass can be used to damp daily swings in temperature. Adobe, earth, stone, and concrete are poor insulators but serve the purpose of regulating indoor temperature by damping, evening out nighttime and daytime lows and highs. If a house has an attic, indications that it is poorly insulated and poorly ventilated include the attic being extremely hot in the summer, and dew and frost forming on cold surfaces in the attic, such as on the underside of the roof sheathing, during the winter.

1-8 THERMAL INSULATION

The term **thermal insulation** can refer to materials used to reduce the rate of heat transfer, or the methods and processes used to reduce heat transfer.

Heat energy can be transferred by conduction, convection, radiation or when undergoing a phase change. For the purposes of this discussion only the first three mechanisms need to be considered

.



The flow of heat can be retarded by addressing one or more of these mechanisms and is dependent on the physical properties of the material employed to do this.

Conduction occurs when heat travels through a medium. The rate at which this occurs is proportional to the thickness of the material, the cross-sectional area over which it travels, the temperature gradients between its surfaces and its thermal conductivity.

1-8 THERMAL INSULATION

Convective heat transfer occur between two objects separated by a moving interface of fluid or gas. Convective currents driven by heat energy occur between the objects. The physical properties of the fluid or gas and the velocity at which the molecules travel influence the rate of transfer. Convection can reduced by dividing the convective medium into small compartments to prevent large currents from forming.

thermal insulation retard the flow of heat energy by performing one or more of the following functions:

1. Conserve energy by reducing heat loss or gain.
2. Control surface temperatures for personnel protection and comfort.
3. Facilitate temperature control of a process.
4. Prevent vapor flow and water condensation on cold surfaces.
5. Increase operating efficiency of heating/ventilating/cooling, plumbing, steam, process and power systems found in commercial and industrial installations.
6. Prevent or reduce damage to equipment from exposure to fire or corrosive atmospheres.
7. Assist mechanical systems in meeting USDA (FDA) criteria in food and cosmetic plants.

1-8-1 GENERIC TYPES AND FORMS OF INSULATION

Insulation will be discussed in this manual according to its generic types and forms. The type indicates composition (i.e. glass, plastic) and internal structure (i.e. cellular, fibrous). The form implies overall shape or application (i.e. board, blanket, pipe insulation).

- **TYPES**

1. **Fibrous Insulation:** Composed of small diameter fibers which finely divide the air space. The fibers may be perpendicular or horizontal to the surface being insulated, and they may or may not be bonded together. Silica, rock wool, slag wool and alumina silica fibers are used. The most widely used insulation of this type are glass fiber and mineral wool.
2. **Cellular Insulation:** Composed of small individual cells separated from each other. The cellular material may be glass or foamed plastic such as polystyrene (closed cell), polyurethane, polyisocyanurate, polyolefin, and elastomeric.
3. **Granular Insulation:** Composed of small nodules which contain voids or hollow spaces. It is not considered a true cellular material since gas can be transferred between the individual spaces. This type may be produced as a loose or pourable material, or combined with a binder and fibers to make a rigid insulation. Examples of these insulations are calcium silicate, expanded vermiculite, perlite, cellulose, diatomaceous earth and expanded polystyrene.

1-8-1 GENERIC TYPES AND FORMS OF INSULATION

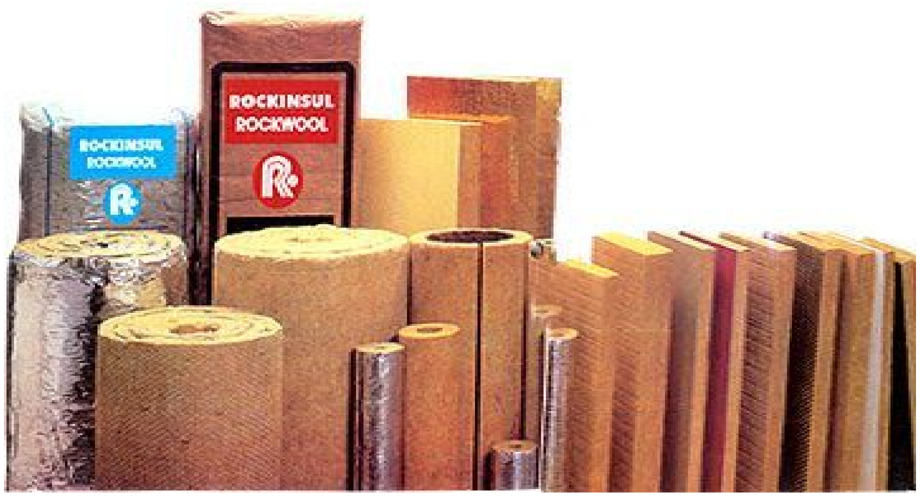
- **FORMS**

  Insulation is produced in a variety of forms suitable for specific functions and applications. The combined form and type of insulation determine its proper method of installation. The forms most widely used are:

- **1. Rigid boards, blocks, sheets, and pre-formed shapes such as pipe insulation, curved segment, lagging, etc.**: Cellular, granular, and fibrous insulations are produced in these forms.
- **2. Flexible sheets and pre-formed shapes:** Cellular and fibrous insulations are produced in these forms.
- **3. Flexible blankets**: Fibrous insulations are produced in flexible blankets.
- **4. Cements (insulating and finishing):** Produced from fibrous and granular insulations and cement, they may be of the hydraulic setting or air drying type.
- **5. Foam:** Poured or froth foam used to fill irregular areas and voids. Spray used for flat surfaces.

1-8-2 PROPERTIES OF INSULATION

- Not all properties are significant for all materials or applications. Therefore, many are not included in manufacturers' published literature or in the Table of Properties which follows in this section. In some applications, however, omitted properties may assume extreme importance (i.e. when insulations must be compatible with chemically corrosive atmospheres.)
- If the property is significant for an application and the measure of that property cannot be found in manufacturers' literature, effort should be made to obtain the information directly from the manufacturer, testing laboratory, or insulation contractors association.
- The following properties are referenced only according to their significance in meeting design criteria of specific applications. More detailed definitions of the properties themselves can be found in the Glossary



1-8-2 PROPERTIES OF INSULATION

- **1. THERMAL PROPERTIES OF INSULATION**
- Thermal properties are the primary consideration in choosing insulations. Refer to the Glossary for definitions.
- **a. Temperature limits:** Upper & lower temperatures within which the material must retain all its properties.
- **b. Thermal conductance "C":** The rate of heat flow for the actual thickness of a material.
- **c. Thermal conductivity "K":** The rate of heat flow based on 25 mm (one inch) thickness.
- **d. Emissivity "E":** Significant when the surface temperature of the insulation must be regulated as with moisture condensation or personnel protection.
- **e. Thermal resistance "R":** The overall resistance of a "system" to the flow of heat.
- **f. Thermal transmittance "U":** The overall conductance of heat flow through a "system".

.

1-8-2 PROPERTIES OF INSULATION

- **MECHANICAL AND CHEMICAL PROPERTIES OF INSULATION** Properties other than thermal must be considered when choosing materials for specific applications. Among them are:
- **a. Alkalinity (pH or acidity)**: Significant when corrosive atmospheres are present. Also insulation must not contribute to corrosion of the system. See Section III.
- **b. Appearance:** Important in exposed areas and for coding purposes.
- **c. Breaking load:** In some installations the insulation material must "bridge" over a discontinuity in its support.
- **d. Capillarity:** Must be considered when material may be in contact with liquids.
- **e. Chemical reaction:** Potential fire hazards exist in areas where volatile chemicals are present. Corrosion resistance must also be considered.
- **f. Chemical resistance**: Significant when the atmosphere is salt or chemical laden.
- **g. Coefficient of expansion and contraction:** Enters into the design and spacing of expansion/contraction joints and/or the use of multiple layer insulation applications.
- **h. Combustibility:** One of the measures of a material's contribution to a fire hazard.
- **s. Toxicity:** Must be considered in food processing plants and potential fire hazard areas.

1-8-2 PROPERTIES OF INSULATION

- **i. Compressive strength:** Important if the insulation must support a load or withstand mechanical abuse without crushing. If, however, cushioning or filling in space is needed as in expansion/contraction joints, low compressive strength materials are specified.
- **j. Density:** A material's density affects other properties of that material, especially thermal properties.
- **k. Dimensional stability:** Significant when the material is exposed to atmospheric and mechanical abuse such as twisting or vibration from thermally expanding pipe.
- **l. Fire retardancy:** Flame spread and smoke developed ratings should be considered.
- **m. Hygroscopicity**: Tendency of a material to absorb water vapor from the air.
- **n. Resistance to ultraviolet light:** Significant if application is outdoors.
- **o. Resistance to fungal or bacterial growth:** Is necessary in food or cosmetic process areas.
- **p. Shrinkage:** Significant on applications involving cements and mastics.
- **q. Sound absorption coefficient:** Must be considered when sound attenuation is required, as it is in radio stations, some hospital areas, etc.
- **r. Sound transmission loss value:** Significant when constructing a sound barrier.

1-8-3 MAJOR INSULATION MATERIALS

- The following is a general inventory of the characteristics and properties of major insulation materials used in commercial and industrial installations. See the Insulation Property Tables at the end of Section II for a comparative review.
- **1. CALCIUM SILICATE**
  Calcium silicate is a granular insulation made of lime and silica, reinforced with organic and inorganic fibers and molded into rigid forms. Service temperature range covered is 37.8°C to 648.9°C (100°F to 1200°F). Flexural strength is good. Calcium silicate is water absorbent. However, it can be dried out without deterioration. The material is noncombustible and used primarily on hot piping and surfaces. Jacketing is field applied.
- **2. GLASS**
- **a. Fibrous:** Available as flexible blanket, rigid board, pipe insulation and other pre-molded shapes. Service temperature range is -40.0°C to 37.8°C (-40°F to 1000°F). Fibrous glass is neutral; however, the binder may have a pH factor. The product is noncombustible and has good sound absorption qualities.
- **b. Cellular:** Available in board and bl°Ck form capable of being fabricated into pipe insulation and various shapes. Service temperature range is -267.8°C to 482.2°C (-450°F to 900°F). Good structural strength, poor impact resistance. Material is noncombustible, non-absorptive and resistant to many chemicals.
- **3. MINERAL FIBER (ROCK AND SLAG WOOL)**
  Rock and/or slag fibers are bonded together with a heat resistant binder to produce mineral fiber or wool available in loose blanket, board, pipe insulation,

and molded shapes. Upper temperature limit can reach 1037.8°C (1900°F). The material has a practically neutral pH, is noncombustible, and has good sound control qualities.

- **4. EXPANDED SILICA, OR PERLITE**
  Perlite is made from an inert siliceous volcanic rock combined with water. The rock is expanded by heating, causing the water to vaporize and the rock volume to expand. This creates a cellular structure of minute air cells surrounded by vitrified product. Added binders resist moisture penetration and inorganic fibers reinforce the structure. The material has low shrinkage and high resistance to substrate corrosion. Perlite is noncombustible and operates in the intermediate and high temperature ranges. The product is available in rigid pre-formed shapes and blocks.
- **5. ELASTOMERIC**
  Foamed resins combined with elastomers produce a flexible cellular material. Available in pre-formed shapes and sheets, elastomeric insulations possess good cutting characteristics and low water and vapor permeability. The upper temperature limit is 104.4°C (220°F). Elastomeric insulation is cost efficient for low temperature applications with no jacketing necessary. Resiliency is high. Consideration should be made for fire retardancy of the material.
- **6. FOAMED PLASTIC**
  Insulation produced from foaming plastic resins create predominately closed-cellular rigid materials. "K" values decline after initial use as the gas trapped

1-8-3 MAJOR INSULATION MATERIALS

- within the cellular structure is eventually replaced by air. Check manufacturers' data. Foamed plastics are light weight with excellent moisture resistance and cutting characteristics. The chemical content varies with each manufacturer. Available in pre-formed shapes and boards, foamed plastics are generally used in the low and lower intermediate service temperature range -182.8°C to 148.9°C (-297°F to 300°F). Consideration should be made for fire retardancy of the material.
- **7. REFRACTORY FIBER**
  Refractory fiber insulations are mineral or ceramic fibers, including alumina and silica, bound with extremely high temperature binders. The material is manufactured in blanket or rigid form. Thermal shock resistance is high. Temperature limits reach 1648.9°C (3000°F). The material is noncombustible.
- The use and design of refractory range materials is an engineering art in its own right and is not treated fully in this manual, although some refractory products can be installed using application methods illustrated here.
- **8. INSULATING CEMENT**
  Insulating and finishing cements are a mixture of various insulating fibers and binders with water and cement, to form a soft plastic mass for application on irregular surfaces. Insulation values are moderate. Cements may be applied to high temperature surfaces. Finishing cements or one-coat cements are used in the lower intermediate range and as a finish to other insulation applications. Check each manufacturer for shrinkage and adhesion properties.

9. Polyurethane Foams

All closed-cell polyurethane foam insulation made today is produced with a non-CFC (chlorofluorocarbon) gas as the blowing agent. This gas doesn't insulate as well as insulation made with a CFC gas, however it is less destructive to our planet's ozone layer. Foams made in this way have an aged R-value of R-6.5 per inch thickness. Their density is generally 2.0 lb/ft 3 (32.0 kilograms per cubic meter [kg/m3]). There are also low-density open-cell polyurethane foams (0.5 lb/ft 3 [8 kg/m3]). These are similar to conventional polyurethane foams, but are more flexible. Some low-density varieties use carbon dioxide (CO_2) as the blowing agent.

Low-density foams are sprayed into open wall cavities and rapidly expand to seal and fill the cavity. There is at least one manufacturer who offers a slow expanding foam. This type is intended for cavities in existing construction where there is no insulation. The liquid foam expands very slowly and thus reduces the chance of damaging the wall from over-expanding. The foam is water vapor permeable, remains flexible, and is resistant to wicking of moisture. It provides good air sealing and yields about R-3.6 per inch of thickness. It is also fire resistant and will not sustain a flame upon removal of the flame source.

10. Nitrogen-based Urea-Formaldehyde (UF) Foam

Urea-Formaldehyde (UF) foam was used in residential housing during the 1970's. However, after many health related court cases due to improper installation practices, it was removed from the residential market and is now used primarily for masonry walls in commercial/industrial buildings. This type of foam insulation uses compressed air as the expanding agent. Nitrogen-based, UF foam may take several weeks to cure completely. Unlike polyurethane insulation, this product does not expand as it cures and also allows water vapor to easily pass through it. UF foam also breaks down at prolonged temperatures above 190° F

(88° C) and contains no fire retardant chemicals. This insulation has an R-value of about 4.6 per inch and costs are competitive with loose-fill or poured-in insulation.

11. Phenolic Foam

This type of foam was somewhat popular years ago as a rigid foamboard insulation. It is currently available only as a foamed-in-place insulation. It has a R-4.8 value per inch of thickness and uses air as the blowing agent. One major disadvantage of phenolic foam that it can shrink up to 2% after curing. This makes ii less popular today, since there are alternatives that do not have this disadvantage.

12.Cementitious Foam

Air-Krete ? is a magnesium silicate, cementitious (cement-based) insulation that is foamed and pumped into closed cavities. The initial consistency of the foam is similar to shaving cream and after curing is similar to a thick pudding. It is easily damaged by water since it is made from minerals extracted from seawater. It is non-toxic and doesn't burn. It has an R-value of about 3.9 per inch and costs about as much as polyurethane foam.

13. Foaming Insulation Vehicles

These are latex-based foamed adhesives that transport an insulating material (such as fiberglass) into a cavity. After the bubbles in the foam dissipates, it leaves the encapsulated insulation uniformly distributed in the cavity and it's R-value unchanged. It is intended for enclosed building cavities. It is not widely available in the U.S. Here are typical R-values attained for three types of insulation applied in this manner:

- Fiberglass: R-4.0 per inch
- Mineral Wool: R-3.8 per inch
- Cellulose: R-3.7 per inch

14. Structural Insulating Panels (SIP)

Structural insulating panels (SIP) often consists of a foamboard core sheathed on one or both sides with plywood, oriented strand board (OSB), or gypsum board (drywall.) The insulation is usually polystyrene or isocyanurate, but foam-straw composites are sometimes used too. Panels range in size, but are most common in 4 ´ 8 foot to 4 ´ 10 foot (1.2 ´ 2.4 meter to 1.2 ´ 3.04 meter).

Because of their structural trength, SIPs reduce the need for structural lumber, opportunities for air leaks, and installation errors common with stud frame (stick-built) construction. It is also faster to build SIP wall assembles than many other construction methods. Most comparison studies between stick-built and SIP house show significant energy saving with the SIPs. Because these panels also reduce sound transmission, some designers use them for interior partitions too.

SIP roof panels sometimes have a nailable layer only on one side. It's purpose is as a retrofit over an existing roof where additional insulation is desired but no attic exists under the roof deck. The insulated roof panels are also available with air channels just under the exterior sheathing for ventilated roof designs.

15. Insulating Concrete Forms (ICF)

An ICF system consists of interlocking foam board and occasionally hollow-core foam blocks. The foamboard forms are held vertical and parallel to each other by plastic or steel rods and ties. After adding the appropriate reinforcing steel rods (rebar) and poured concrete, the result is a very strong and insulated concrete wall. Such a building can be made from foundation to roofline. Some innovative builders make the roof of ICF as well.

Because of its flammability, any ICF exposed to the occupied space must be covered with an appropriate fire-resistant material. Most codes find half-inch (12.7mm) drywall acceptable. The exterior of the building can be finished with anything the designer finds desirable.

Other systems use the rigid insulation board in the center of the concrete wall. These are often referred to as "tilt-wall" construction. The walls are poured in a form on a flat deck and after curing are "tilted" upright into position by a crane. Because the insulation board is inside the wall it reduces problems relating to fire and insect infestation.

Insulation block systems are typically hollow core polystyrene blocks that interlock to create the ICF wall system. Steel reinforcing rods are often used inside the block cavities to strengthen the wall. One draw-back of stacked block ICFs is that the foam webbing around the concrete filled cores provides easy access for insects and ground water to enter the building. To minimize these problems, some manufacturers make insecticide treated forms and often promote a water proofing method for the foam blocks.

16. Concrete Block Insulations

Insulated concrete blocks take on many different shapes and compositions. The better concrete masonry units reduce the area of connecting webs as much as possible. The cores are filled with insulation-poured-in, blown-in, or foamed-in-except for those cells requiring structural steel reinforcing and concrete infill. This raises the average wall R-value.

Some block makers coat polystyrene beads with a thin film of concrete. The concrete serves to bond the polystyrene while providing limited structural integrity. Expanded polystyrene mixed with Portland cement, sand, and chemical additives are the most common group of ingredients. These make surface bonded wall assemblies with a wall R-value of R-1 per inch thickness.

Polystyrene inserts placed in the block cores increase the unit thermal resistance to about R-2 per inch.

Hollow-core units made with a mix of concrete and wood chips are also available. They are installed by stacking the units without using mortar (dry-stacking). Structural stability comes from the concrete fill and appropriate rebar throughout for structural walls. One detracting point of this type is that the wood component is subject to the effects of moisture and insects.

Two varieties of solid, precast autoclaved concrete masonry units are now available in the U.S: autoclaved aerated concrete (AAC), and autoclaved cellular concrete (ACC). This class of material has been commonly used in European construction since the late 1940s. Air makes up 80% (by volume) of the material. It has ten times the insulating value of conventional concrete. The R-1.1 per inch blocks are large, light, and have a flat surface that looks like a hard, fine sponge. Mastic or a thin mortar is used to construct a wall. The wall then often gets a layer of stucco as the finish. Autoclaved concrete is easily sawn, nailed, and shaped with ordinary tools. Since the material absorbs water readily, it requires protection from moisture.

Precast autoclaved cellular concrete uses fly ash instead of high-silica sand as its distinguishing component. Fly ash is a waste ash produced from burning coal in electric power plants. The fly ash is the material that differentiates ACC from AAC.

17. Specialized Devices

A wide variety of rigid insulation inserts are available to fill many critical locations in the insulated envelope of houses. Some examples are to use inserts as air chutes, insulation dams, concrete block fillers, and ice dam retarders.

Expanding foams efficiently seal and weatherize homes. Devices as simple as cardboard can be used to provide an insulation dam to help keep loose-fill insulating material around attic ductwork

18. Straw Panels

The process of fusing straw into boards without adhesives was developed in the 1930s. Panels are usually 2 to 4 inches (51-102 mm) thick and faced with heavyweight Kraft paper on each side. Although manufacturer 's claims vary, R-values realistically range from about R-1.4 to R-2 per inch. They also make effective sound-absorbing panels for interior partitions. Some manufacturers have developed SIPs from multiple-layered, compressed-straw panels.

19.Natural Fibers

Several natural fibers are being analyzed for their potential insulating properties. The most notable of these include cotton, wool, hemp, and straw.

Cotton based insulation consists of recycled cotton and plastic fibers that have been treated with the same flame retardant and insect/rodent repellent as cellulose insulation. It meets the same Class I standards for fire resistance as fiberglass insulation. Cotton insulation has similar thermal properties as fiberglass and cellulose insulation (R-3 or so per inch of thickness.) Some chemically sensitive consumers feel that this type of insulation is "healthier" to use than other types. However, field studies have proven that this is generally not the case, and other sources of indoor air pollution are of more concern than the type of insulation.

1-8-3 MAJOR INSULATION MATERIALS

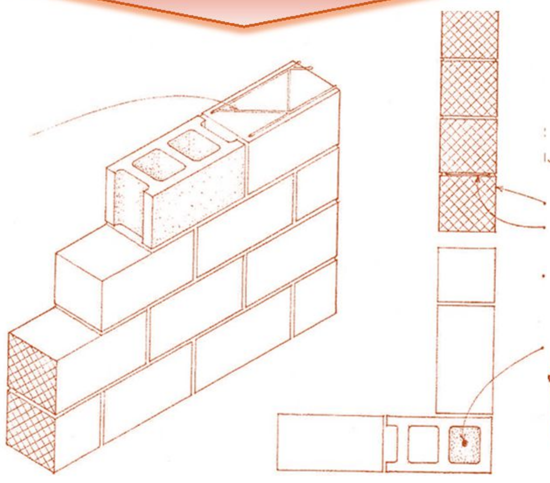
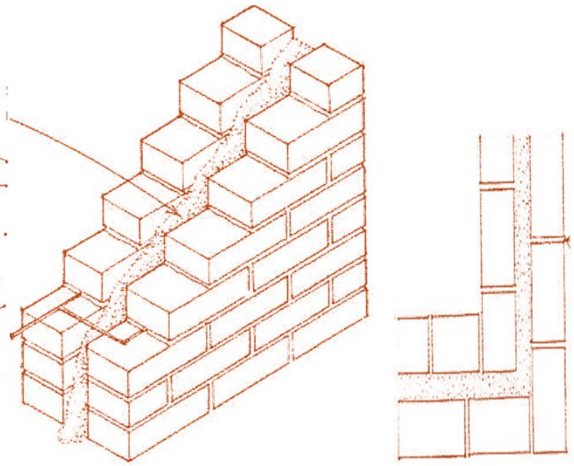
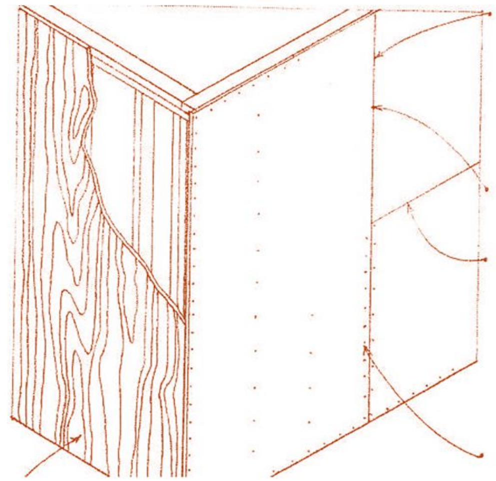
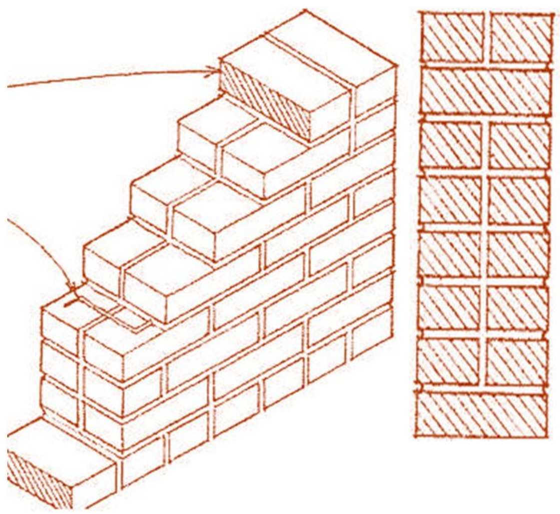
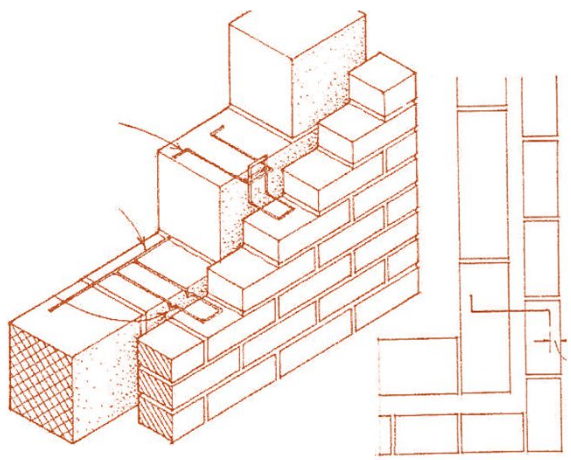
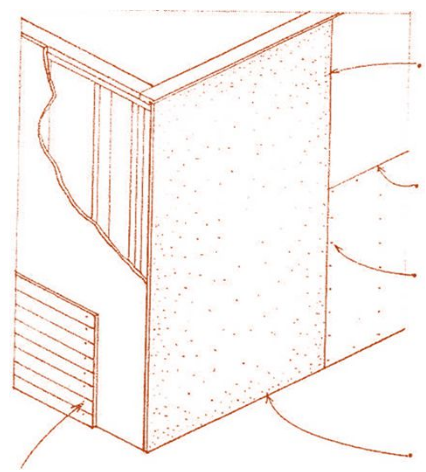
Wool and hemp insulation are relatively unknown in the U.S., but have been in use in other, less industrialized countries. Both products offer similar R-values to other fibrous insulation types (about R-3.5 per inch of thickness.)

Straw bale construction, popular 150 years ago on the Great Plains of the United States, is receiving renewed interest. Straw bales tested by the Oak Ridge National Laboratory yielded R-values of R-2.4 to R-3.0 per inch. But at least one straw bale expert claims R-2.4 per inch is more representative of typical straw bale construction due to the many gaps between the stacked bales.

1-8-3 MAJOR INSULATION MATERIALS

Form	Method of Installation	Where Applicable	Advantages
Blankets: Batts or Rolls •Fiber glass •Rock wool	Fitted between studs, joists and beams	All unfinished walls, floors and ceilings	Do-it-yourself Suited for standard stud and joist spacing, which is relatively free from obstructions
Loose-Fill (blown-in) or Spray-applied •Rock wool •Fiber glass •Cellulose •Polyurethane foam	Blown into place or spray applied by special equipment	Enclosed existing wall cavities or open new wall cavities Unfinished attic floors and hard to reach places	Commonly used insulation for retrofits (adding insulation to existing finished areas) Good for irregularly shaped areas and around obstructions
Rigid Insulation •Extruded polystyrene foam (XPS) •Expanded polystyrene foam (EPS or beadboard) •Polyurethane foam •Polyisocyanurate foam	Interior applications: Must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety Exterior applications: Must be covered with weather-proof facing	Basement walls Exterior walls under finishing (Some foam boards include a foil facing which will act as a vapor retarder. Please read the discussion about where to place, or not to place, a vapor retarder) Unvented low slope roofs	High insulating value for relatively little thickness Can block thermal short circuits when installed continuously over frames or joists
Reflective Systems •Foil-faced paper •Foil-faced polyethylene bubbles •Foil-faced plastic film •Foil-faced cardboard	Foils, films, or papers: Fitted between wood-frame studs joists, and beams	Unfinished ceilings, walls, and floors	Do-it-yourself All suitable for framing at standard spacing. Bubble-form suitable if framing is irregular or if obstructions are present Effectiveness depends on spacing and heat flow direction

1-9 WALL SECTIONS AND THERMAL INSULATION

SOLID WALLS	CAVITY WALLS	STUD WALLS
		
		

1. SOLID WALLS

Up to the early part of the twentieth century walls were generally built as solid brickwork of adequate thickness to resist the penetration of rain to the inside face and to safely support the loads common to buildings both large and small.

At the time it was accepted that the interior of buildings would be cold during winter months when heating was provided by open fires and stoves, fired by coal or wood, to individual rooms. The people of northern Europe accepted the inevitability of a degree of indoor cold and dressed accordingly in thick clothing both during day and night

Resistance to weather

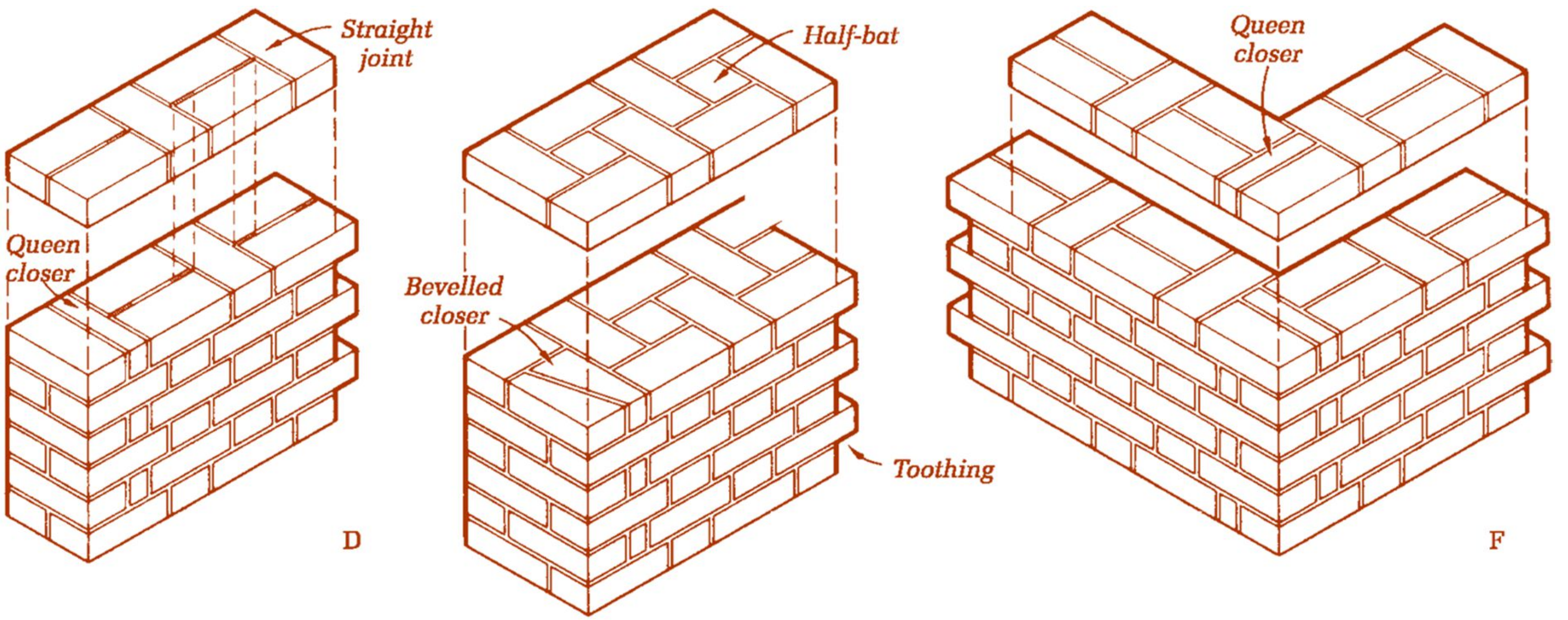
A solid wall of brick will resist the penetration of rain to its inside face by absorbing rainwater that subsequently, in dry periods, evaporates to outside air. The penetration of rainwater into the thickness of a solid wall depends on the exposure of the wall to driving rain and the permeability of the bricks and mortar to water.

The permeability of bricks to water varies widely and depends largely on the density of the brick. Dense engineering bricks absorb rainwater less readily than many of the less dense facing bricks. It would seem logical, therefore, to use dense bricks in the construction of walls to resist rain penetration

1-9-1 SOLID WALLS

External weathering to walls of brick and block

In exposed positions such as high ground, on the coast and where there is little shelter from trees, high ground or surrounding buildings it may well be advisable to employ a system of weathering on the outer face of both solid and cavity walling to provide protection against wind driven rain. The two systems used are external rendering and slate or tile hanging.



1-9-1 SOLID WALLS

Thermal insulation

A requirement of the Building Regulations is that measures be taken, in new buildings, for the conservation of fuel and power. There is no requirement for particular forms of construction to meet the requirement. The practical guidance to the regulation, contained in Approved Document L for dwellings, is based on assumed levels of heating to meet the expectation of indoor comfort of the majority of the largely urban population of this country who are engaged in sedentary occupations.

The advice in the Approved Document is based on an assumption that walls will be of cavity construction with the insulation in the cavity, which is the optimum position for insulation. In consequence it is likely that insulated cavity wall construction will be the first choice for the walls of dwellings for some time to come.

The regulations do make allowance for the use of any form of construction providing the calculated energy use of such buildings is no greater than that of a similar building with recommended insulated construction.

Thermal insulation

A requirement of the Building Regulations is that measures be taken, in new buildings, for the conservation of fuel and power. There is no requirement for particular forms of construction to meet the requirement. The practical guidance to the regulation, contained in Approved Document L for dwellings, is based on assumed levels of heating to meet the expectation of indoor comfort of the majority of the largely urban population of this country who are engaged in sedentary occupations.

The advice in the Approved Document is based on an assumption that walls will be of cavity construction with the insulation in the cavity, which is the optimum position for insulation. In consequence it is likely that insulated cavity wall construction will be the first choice for the walls of dwellings for some time to come.

The regulations do make allowance for the use of any form of construction providing the calculated energy use of such buildings is no greater than that of a similar building with recommended insulated construction.

Internal insulation

Internal insulation may be fixed to the solid brick walls of existing buildings where, for example, there is to be a change of use from warehouse to dwelling to enhance the thermal insulation of the external walls.

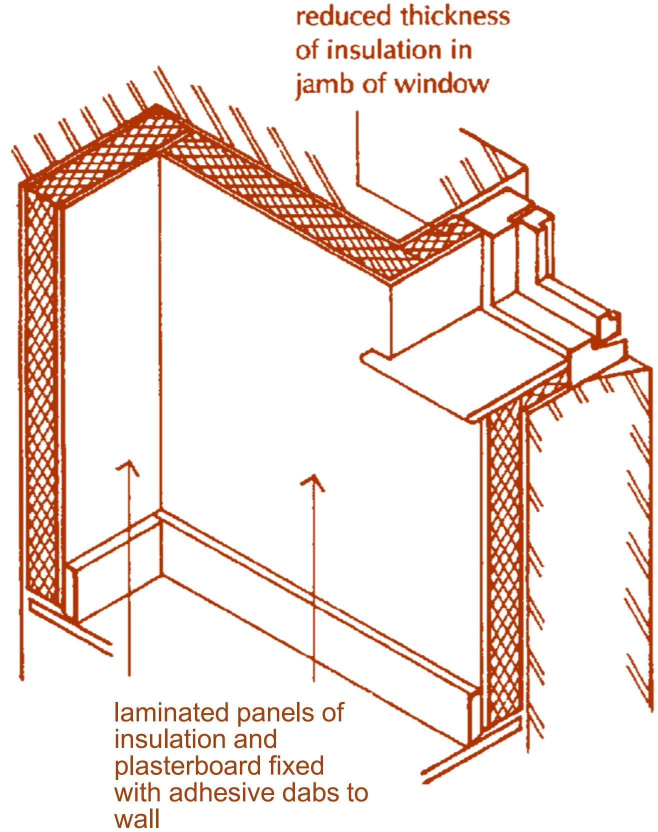
1-9-1 SOLID WALLS

Insulating materials are lightweight and do not generally have a smooth hard finish and are not, therefore, suitable as the inside face of the walls of most buildings. It is usual to cover the insulating layer with a lining of plasterboard or plaster so that the combined thickness of the inner lining and the wall have a U value of 0.45 W/m^2K, or less.

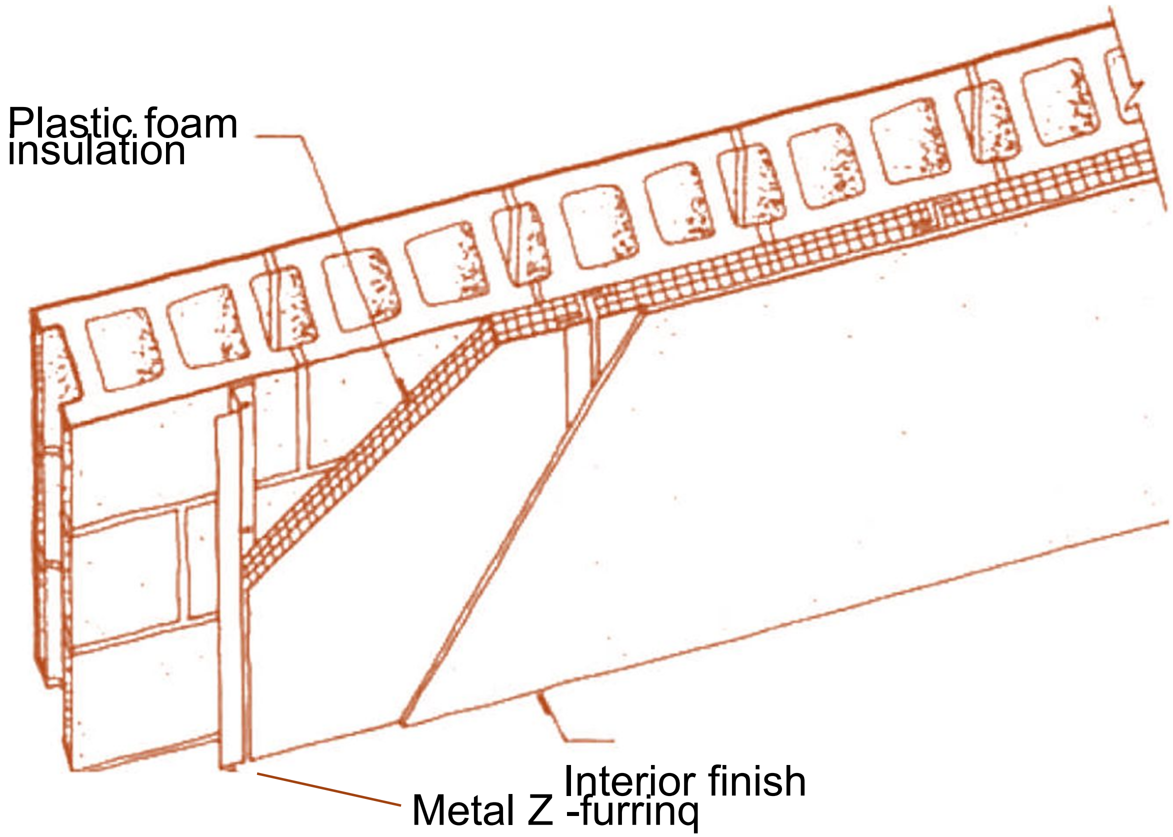
Internal linings for thermal insulation are either of preformed, laminated panels that combine a wall lining of plasterboard glued to an insulation board or of separate insulation material that is fixed to the wall and then covered with plasterboard or wet plaster. The method of fixing the lining to the inside wall surface depends on the surface to which it is applied.

FIXING TYPES:

1. Adhesive fixing
2. Mechanical fixing



1-9-1 SOLID WALLS



Inside Furring and Insulation on Concrete Masonry Wall

1-9-1 SOLID WALLS

Internal insulating materials.		
Solid wall internal		U value
insulation	Thickness	W/m^{2}K
Glass fibre		
laminated panel glass fibre slab	30,40,60	0.031
and plasterboard		
Rockwool		
laminated panel rockwool slab	25,32,40,50	0.033
and plasterboard		
EPS		
laminated panel EPS board and	25,32,40,50	0.037
plasterboard		
XPS		
boards keyed for plaster	25,50,75,110	0.033
PIR		
boards reinforced with glass fibre	25,30,35,40	0.022
tissue both sides		
PUR		
laminated panel PUR board and	12.5, 15, 20, 25,	0.022
plasterboard	30	
EPS expanded polystyrene		
XPS extruded polystyrene		
PIR rigid polyisocyanurate		
PUR rigid polyurethane		

External insulation

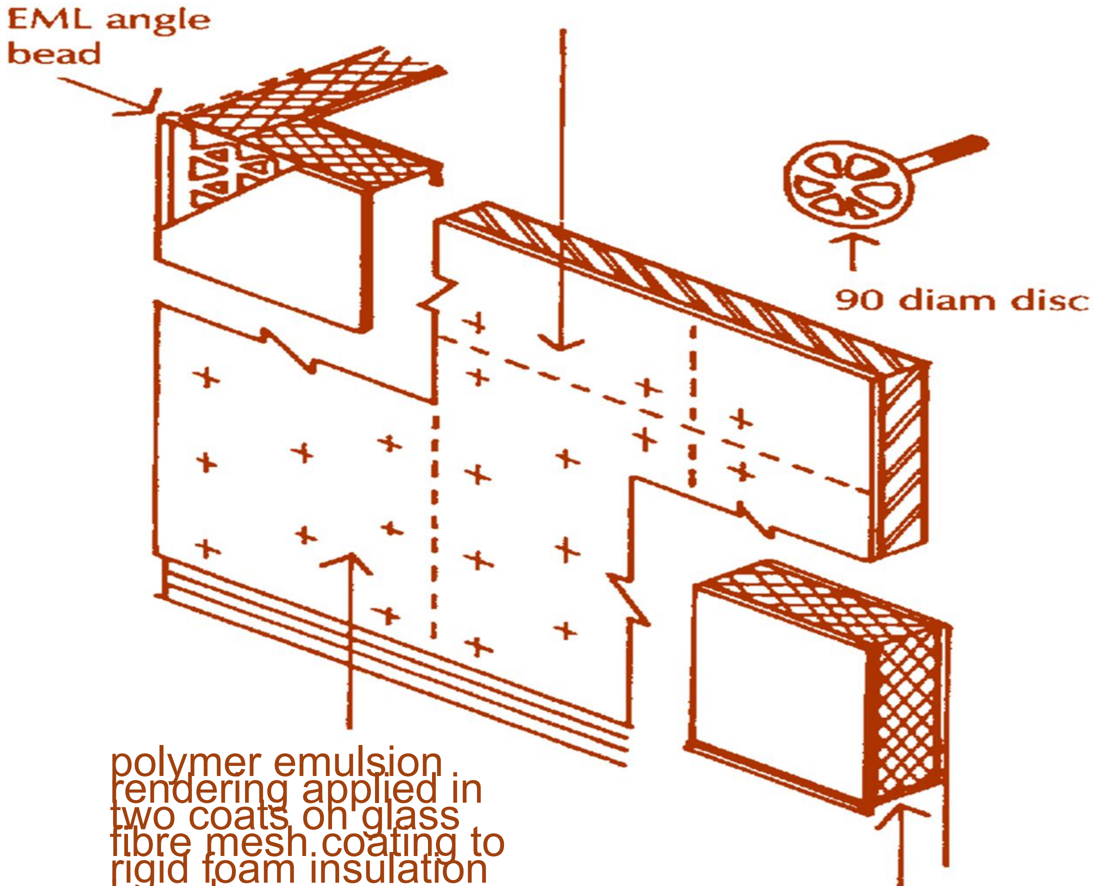
Insulating materials by themselves do not provide a satisfactory external finish to walls against rain penetration or for appearance sake and have to be covered with a finish of cement rendering, paint or a cladding material such as tile, slate or weatherboarding. For rendered finishes, one of the inorganic insulants, rockwool or cellular glass in the form of rigid boards, is most suited. For cladding, one of the organic insulants such as XPS, **PIR** or PUR is used because their low U values necessitate least thickness of board.

As a base for applied rendering the insulation boards or slabs are first bedded and fixed in line on dabs of either gap filling organic adhesive or dabs of polymer emulsion mortar and secured with corrosion resistant fixings to the wall. As a key for the render coats, either the insulation boards have a keyed surface or expanded metal lath or glass fibre mesh is applied to the face of the insulation. The weather protective render is applied in two coats by traditional wet

render application, by rough casting or by spray application and finished smooth, coarse or textured. Coarse, spatter dash or textured finishes are preferred as they disguise hair cracks that are due to drying shrinkage of the rendering.

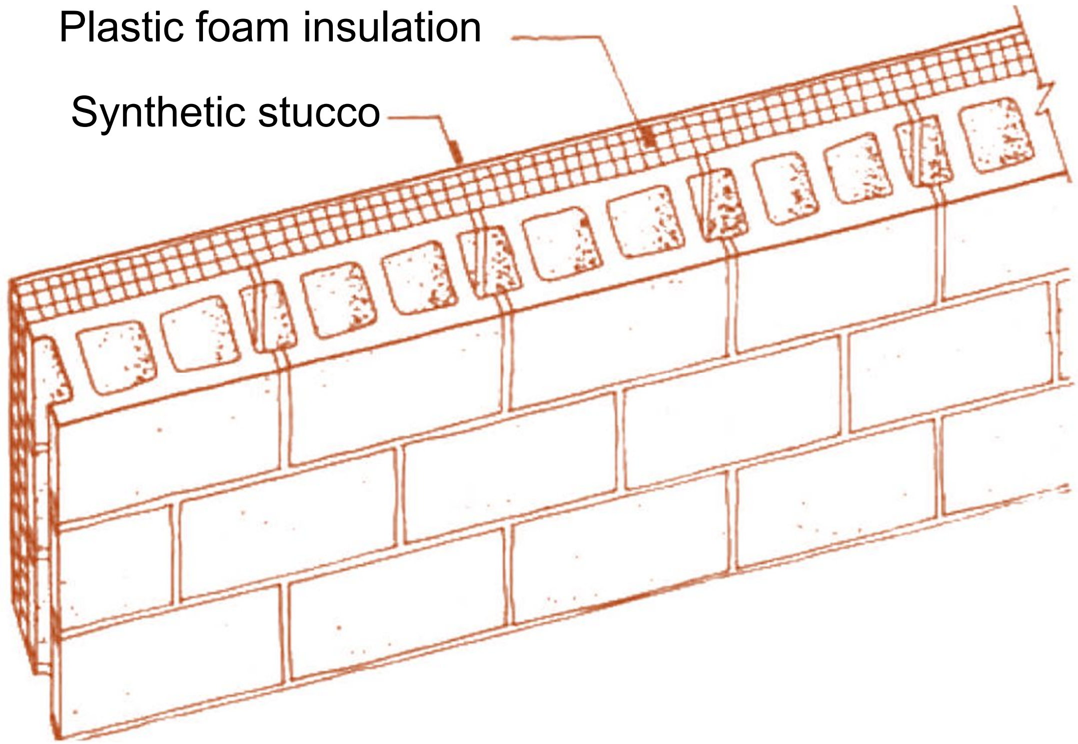
1-9-1 SOLID WALLS

insulation boards fixed externally with stainless steel supports driven into holes in wall



polymer emulsion rendering applied in two coats on glass fibre mesh coating to rigid foam insulation boards

1-9-1 WALL SECTIONS AND THERMAL INSULATION



8, Exterior Insulation and Finish System(E:IFS)on Concrete Masonry Wall

1-9-1 SOLID WALLS

External insulating materials.		
Solid wall external	Thickness	U value
insulation	mm	W/m^2K
Rockwool		
rigid slab with polymer cement	30,40, 50, 60, 75,	0.033
finish	100	
Cellular glass		
boards for rendering on EML	30, 35,40, 50, 60,	0.042
	70	
XPS		
boards T & G on long edges for	25,50	0.025
cladding		
PIR		
boards behind cladding	25,30,35,40	0.022
PUR		
boards behind cladding	20,25,30,35,40,	0.022
	50	
XPS extruded polystyrene		
PIR rigid polyisocyanurate		
PUR rigid polyurethane		

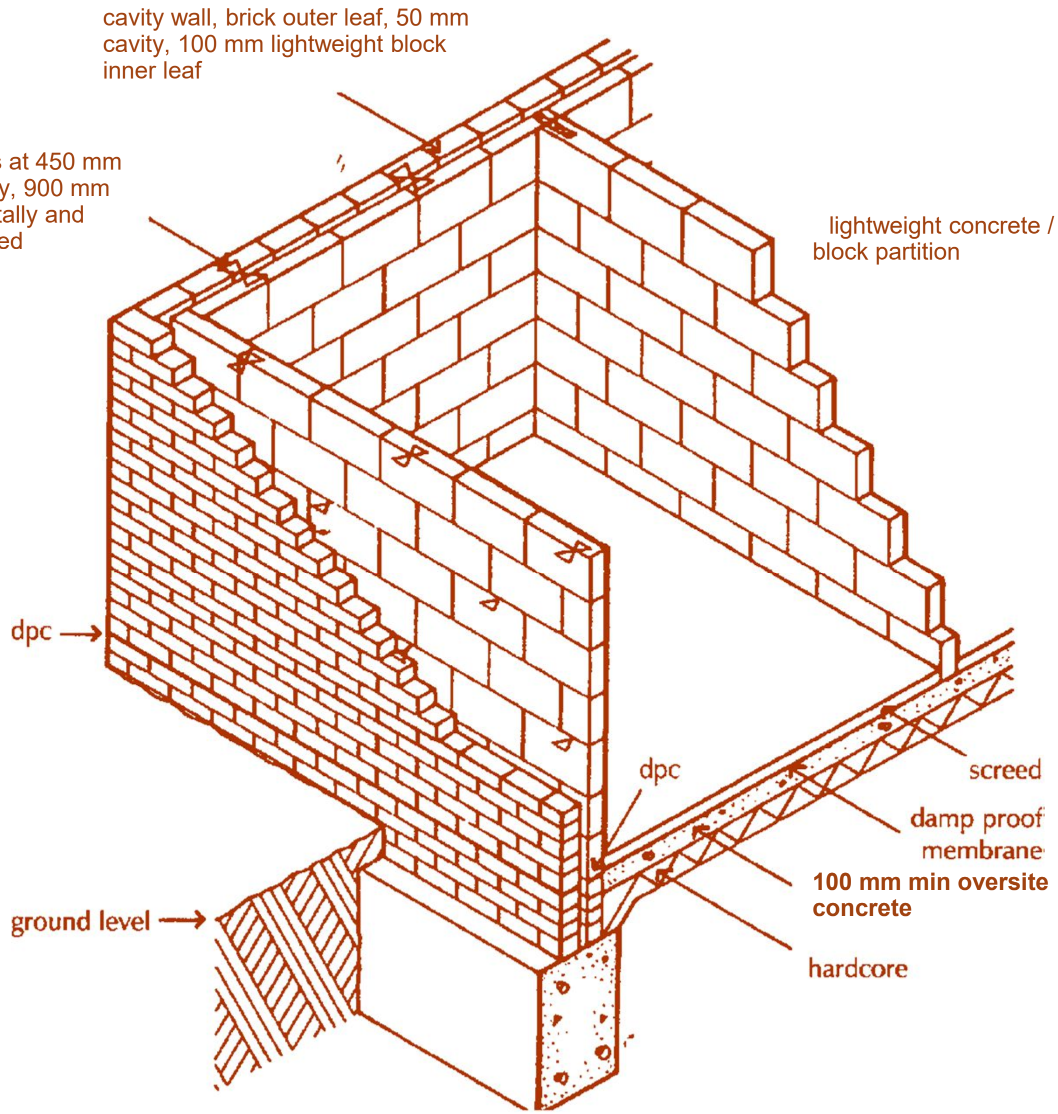
2. CAVITY WALLS

Resistance to weather

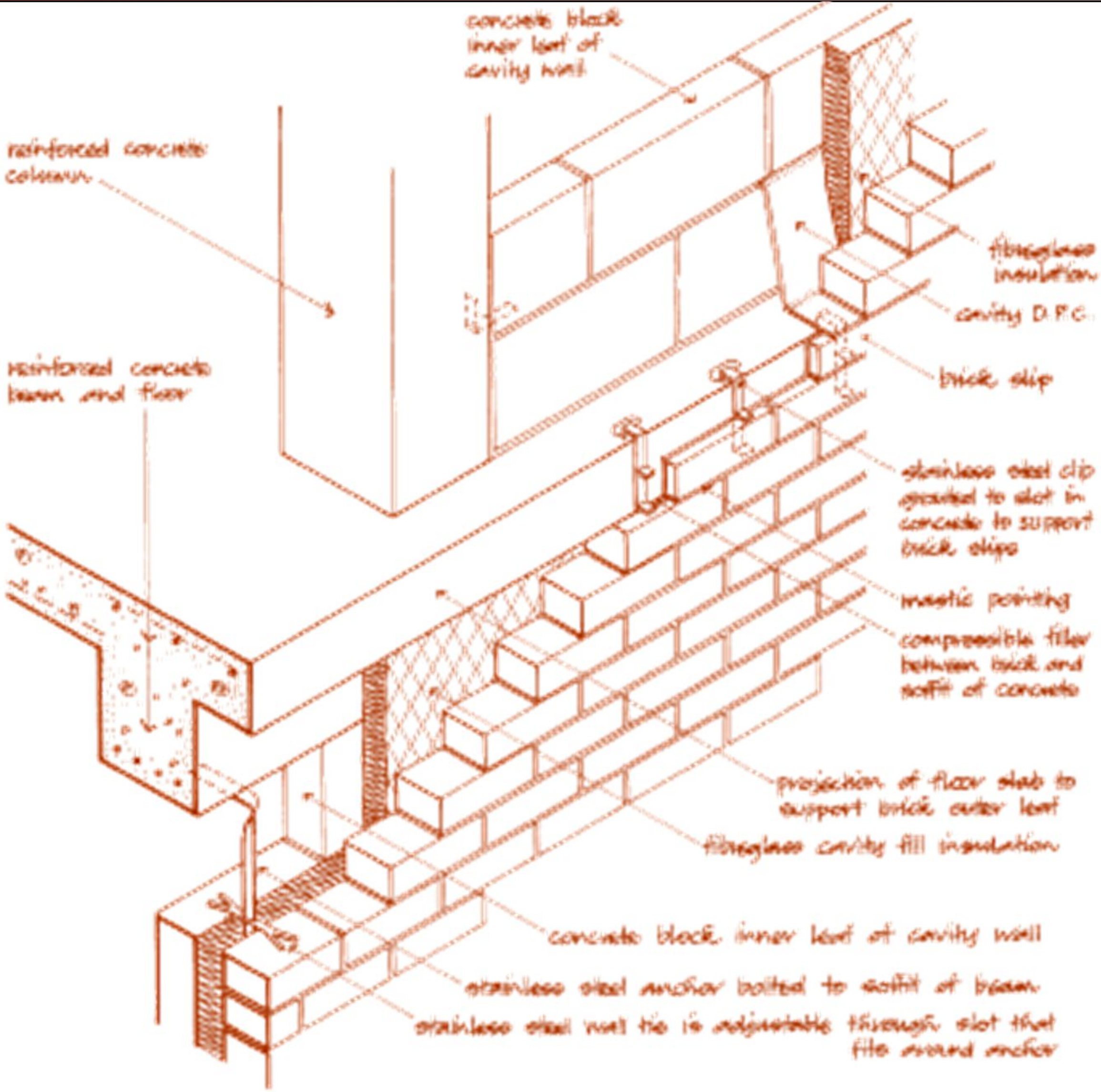
Between 1920 and 1940 it became more usual for external walls of small buildings to be constructed as cavity walls with an outer leaf of brick or block, an open cavity and an inner leaf of brick or block. The outer leaf and the cavity serve to resist the penetration of rain to the inside face and the inner leaf to support floors, provide a solid internal wall surface and to some extent act as insulation against transfer of heat.

The idea of forming a vertical cavity in brick walls was first proposed early in the nineteenth century and developed through the century. Various widths of cavity were proposed from the first 6 inch cavity, a later 2 inch cavity followed by proposals for 3, 4 or 5 inch wide cavities. The early cavity walls were first constructed with bonding bricks laid across the cavity at intervals, to tie the two leaves together. Either whole bricks with end closers or bricks specially made to size and shape for the purpose were used. Later on, during the middle of the century, iron ties were used instead of bond bricks and accepted as being adequate to tie the two leaves of cavity walls.

1-9-2 CAVITY WALLS

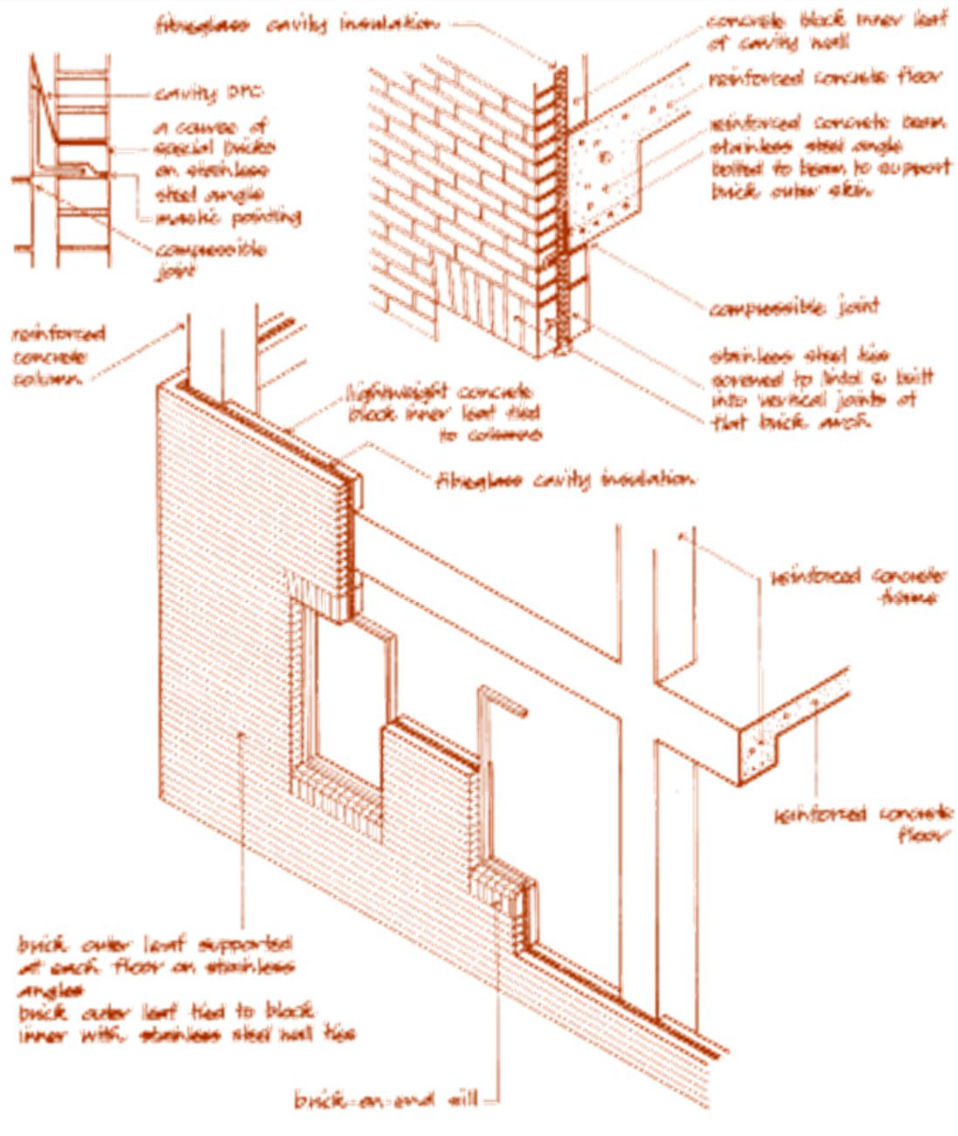


1-9-2 CAVITY WALLS



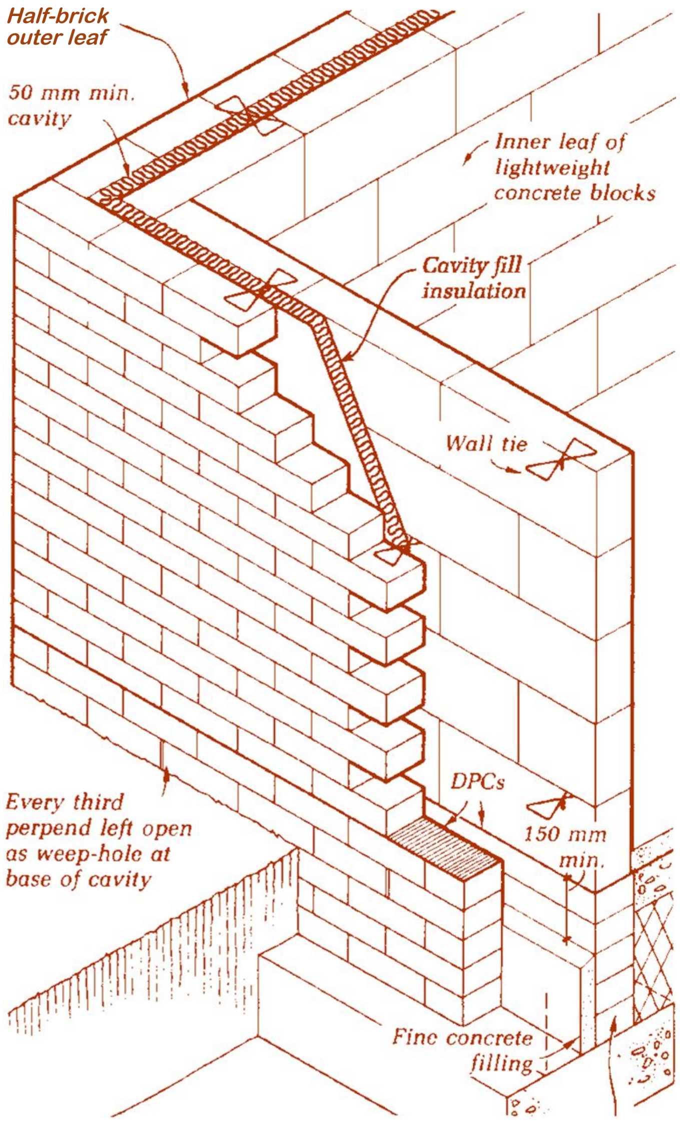
Brick cladding to reinforced concrete frame

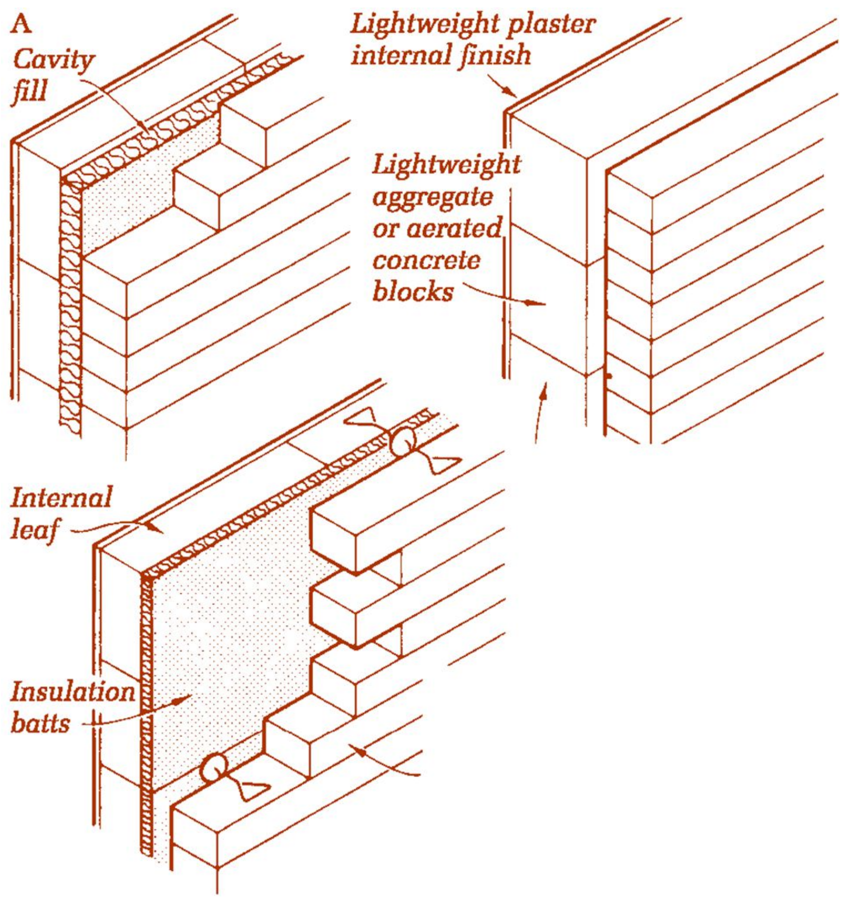
1-9-2 CAVITY WALLS



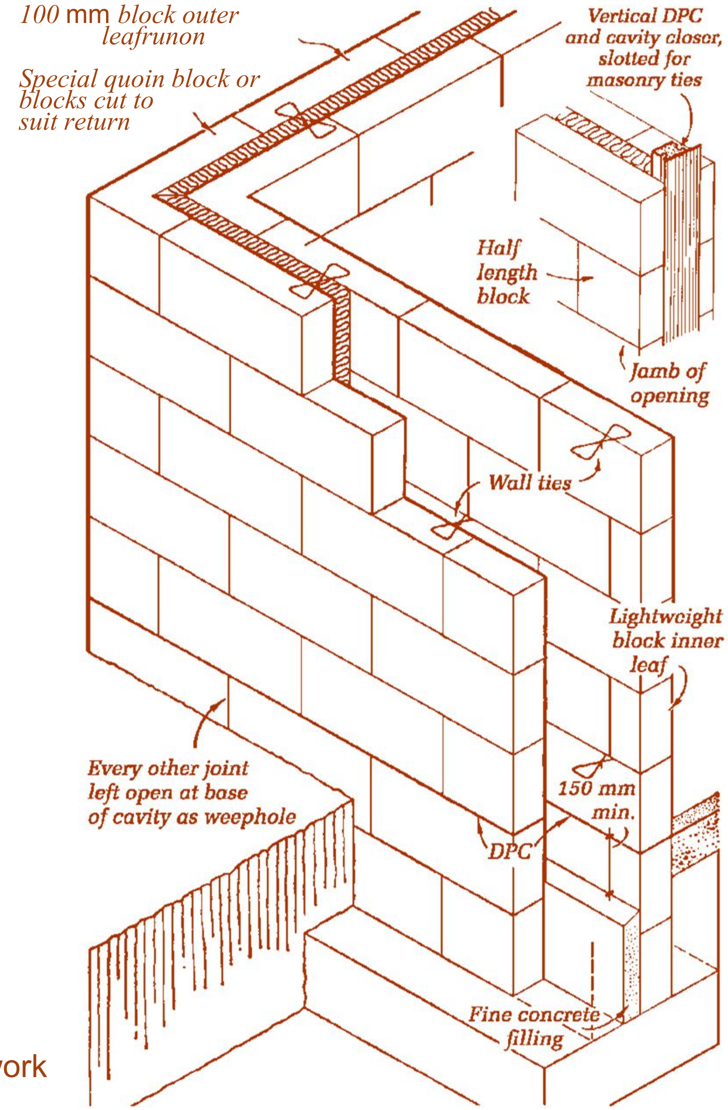
Brick cladding to reinforced concrete structural frame

1-9-2 CAVITY WALLS





1-9-2 CAVITY WALLS



Cavity wall construction in block work

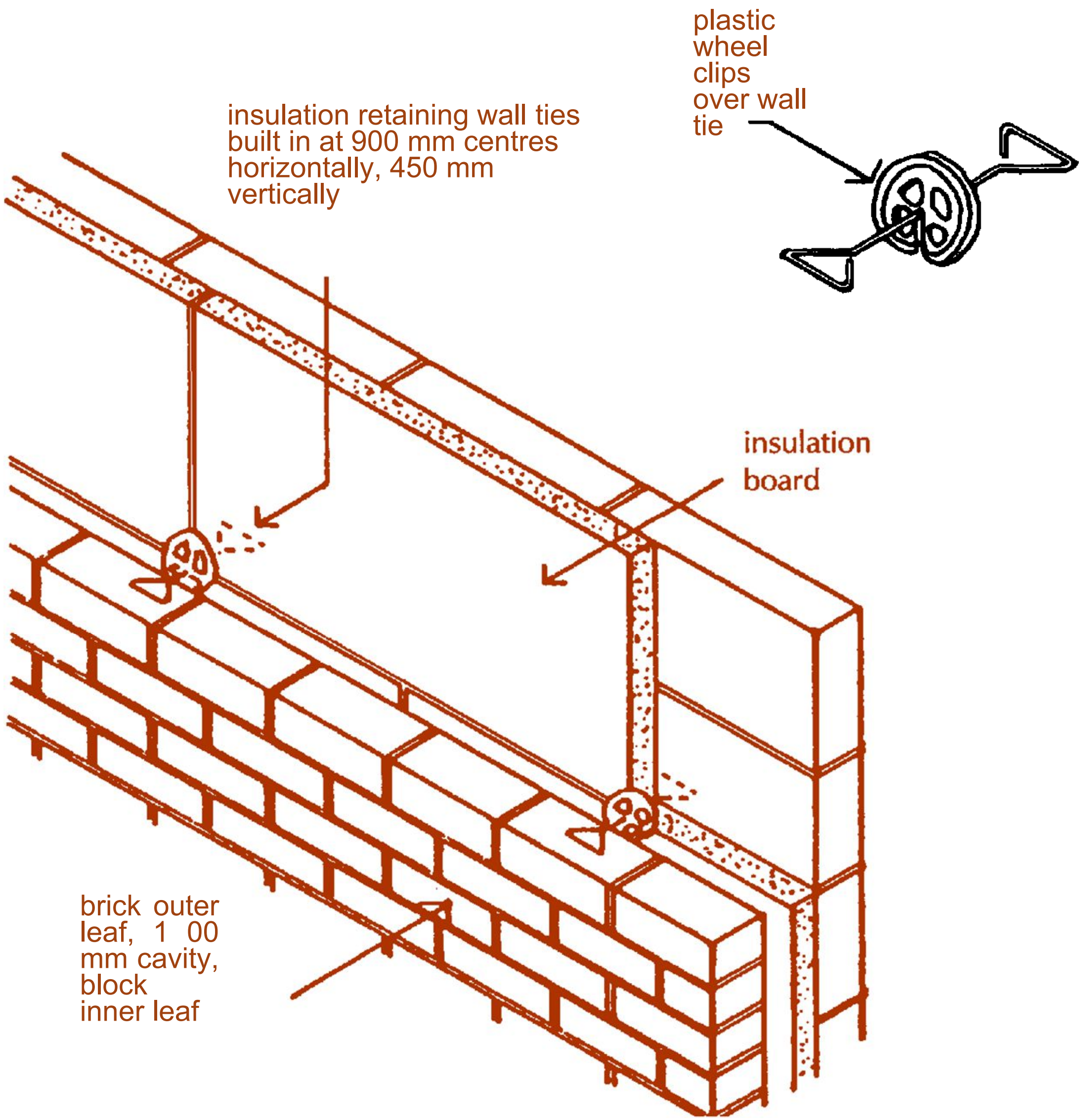
1-9-2 CAVITY WALLS

Cavity wall insulation -- Partial fill

The purpose of the air space in a cavity wall is as a barrier to the penetration of rainwater to the inside face of the wall. If the clear air space is to be effective as a barrier to rain penetration it should not be bridged by anything other than cavity ties. If the cavity is then filled with some insulating material, no matter how impermeable to water the material is, there will inevitably be narrow capillary paths around wall ties and between edges of insulation boards or slabs across which water may penetrate. As a clear air space is considered necessary as a barrier to rain penetration there is good reason to fix insulation material inside a cavity so that it only partly fills the cavity and a cavity is maintained between the outer leaf and the insulating material. This construction, which is described as partial fill insulation of cavity, requires the use of some insulating material in the form of boards that are sufficiently rigid to be secured against the inner leaf of the cavity.

In theory a 25 mm wide air space between the outer leaf and the cavity insulation should be adequate to resist the penetration of rain providing the air space is clear of all mortar droppings and other building debris that might serve as a path for water. In practice, it is difficult to maintain a clear 25 mm wide air gap because of protrusion of mortar from joints in the outer leaf and the difficulty of keeping so narrow a space clear of mortar droppings. Good practice, therefore, is to use a 50 mm wide air space between the outer leaf and the partial fill insulation.

1-9-2 CAVITY WALLS



1-9-2 CAVITY WALLS

The materials used as insulation for the fabric of buildings may be grouped as inorganic and organic insulants. Inorganic insulants are made from naturally occurring materials that are formed into fibre, powder or cellular structures that have a high void content, as for example, glass fibre, mineral fibre (rockwool), cellular glass beads, vermiculite, calcium silicate and magnesia or as compressed cork. Inorganic insulants are generally incombustible, do not support spread of flame, are rot and vermin proof and generally have a higher U value than organic insulants. The inorganic insulants most used in the fabric of buildings are glass fibre and rockwool in the form of loose fibres, mats and rolls of felted fibres and semi-rigid and rigid boards, batts and slabs of compressed fibres, cellular glass beads fused together as rigid boards, compressed cork boards and vermiculite grains.Organic insulants are based on hydrdocarbon polymers in the form of thermosetting or thermoplastic resins to form structures with a high void content, as for example polystyrene, polyurethane, isocyanurate and phenolic. Organic insulants generally have a lower U value than inorganic insulants, are combustible, support spread of flame more readily than inorganic insulants and have a comparatively low melting point.

Insulation thickness

A rough guide to determine the required thickness of insulation for a wall to achieve a U value of 0.45 W/m^2K is to assume the insulant provides the whole or a major part of the insulation by using 30 mm thickness with a U value of 0.02,46 with 0.03, 61 with 0.04, 76 with 0.05 and 92 with 0.06 W/m^2K.

1-9-2 CAVITY WALLS

Table 4 Insulating materials.			
	Thickness	U valve	
Cavity wall partial fill	mm	W/m²K	
Glass fibre			
rigid slab 455 x 1200 mm	30,35,40,45	0.033	
Rockwool			
rigid slab 455 x 1200 mm	30,40,50	0.033	
Cellular glass			
450 x 600	40,45,50	0.042	
EPS			
boards 450 x 1 200 mm	25,40,50	0.037	
XPS			
boards 450 x 1200 mm	25,30,50	0.028	
PIR			
boards 450 x 1200 mm	20,25,30,35,50	0.022	
PUR			
boards 450 x 1200 mm	20,25,30,35,40,50	0.022	
EPS expanded polystyrene			
XPS extruded polystyrene			
PIR rigid polyisocyanurate			
PUR rigid polyurethane			

Total fill

The thermal insulation of external walls by totally filling the cavity has been in use for many years. There have been remarkably few reported incidents of penetration of water through the total fill of cavities to the inside face of walls and the system of total fill has become an accepted method of insulating cavity walls.

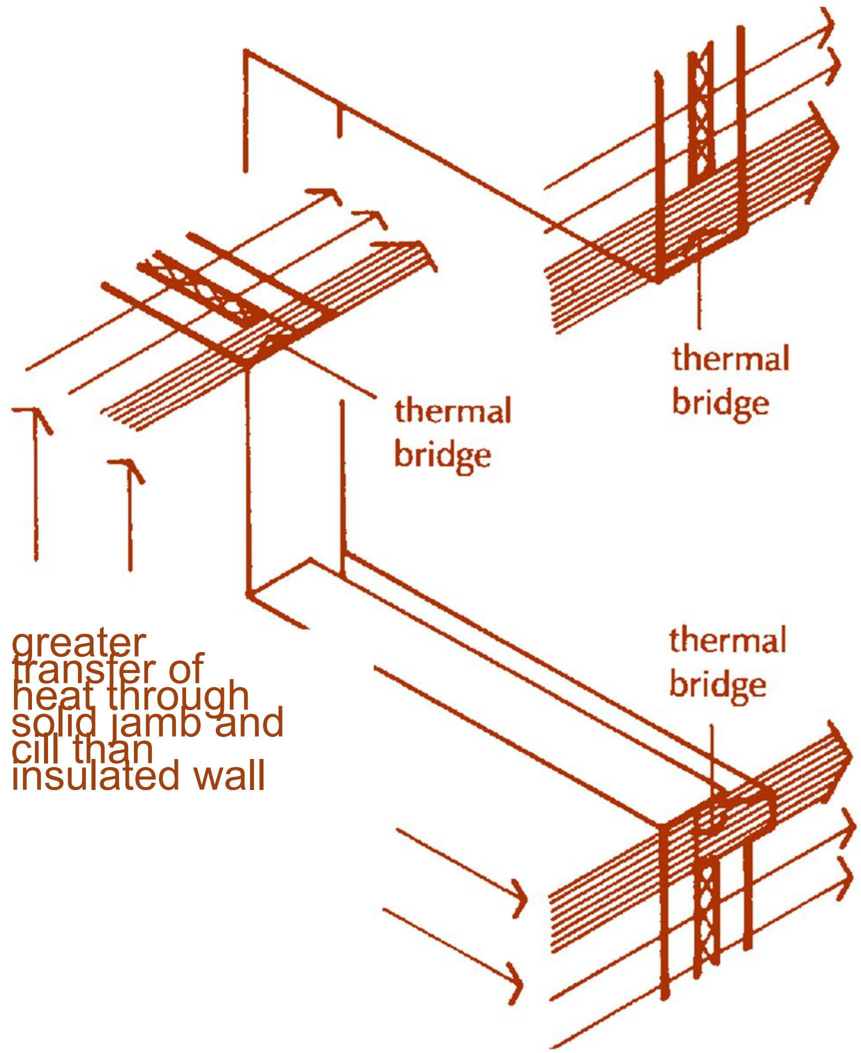
The method of totally filling cavities with an insulant was developed after the steep increase in the price of oil and other fuels in the mid-1960s, as being the most practical way to improve the thermal insulation of existing cavity walls. Small particles of glass or rock wool fibre or foaming organic materials were blown through holes drilled in the outer leaf of existing walls to completely fill the cavity.This system of totally filling the cavity of existing walls has been very extensively and successfully used. The few reported failures due to penetration of rainwater to the inside face were due to poor workmanship in the construction of the walls. Water penetrated across wall ties sloping down into the inside face of the wall, across mortar droppings bridging the cavity or from mortar protruding into the cavity from the outer leaf. From the few failures due to rain penetration it would seem likely that the cavity in existing walls that have been totally filled was of little, if any, critical importance in resisting rain penetration in the position of exposure in which the walls were situated. None the less it is wise to provide a clear air space in a cavity wherever practical, against the possibility of rain penetration.

Thermal bridge

A thermal bridge, more commonly known as a cold bridge in cold climates, is caused by appreciably greater thermal conductivity through one part of a wall than the rest of the wall. Where the cavity in a wall is partially or totally filled with insulation and the cavity is bridged with solid filling at the head, jambs or cill of an opening, there will be considerably greater transfer of heat through the solid filling than through the rest of the wall. Because of the greater transfer of heat through the solid filling illustrated in Fig. 84, the inside face of the wall will be appreciably colder in winter than the rest of the wall and cause some loss of heat and encourage warm moist air to condense on the inside face of the wall on the inside of the cold bridge. This condensation water may cause unsightly stains around openings and encourage mould growth. Thermal bridges around openings can be minimised by continuing cavity insulation to the head of windows and doors and to the sides and bottom of doors and windows. Of late an inordinate fuss has been made about 'cold bridges' as though a cold bridge was some virulent disease or a heinous crime. Solid filling of cavities around openings will allow greater transfer of heat than the surrounding insulated wall and so will window glass, both single and double, and window frames. To minimise heat transfer, cavity insulation should continue up to the back of window and door frames.

Where solid filling of cavities around openings is used the area of the solid filling should be included with that of the window and its frame for heat loss calculation.

1-9-2 WALL SECTIONS AND THERMAL INSULATION



greater transfer of heat through solid jamb and cill than insulated wall

1-9-2 CAVITY WALLS

Cavity wall total fill	Thickness mm	U Value
Glass fibre semi-rigid batt 455 x 1200 mm glass fibres for blown fill	50, 65, 75, 100	0.036 0.039
Rockwool semi-rigid batt 455 x 900 mm granulated for blown fill	50, 65, 75, 100	0.036 0.037
EPS beads for blown fill		0.04

3. STUD WALLS

- **Resistance to weather**

The traditional weather envelope for timber walls is timber weatherboarding nailed horizontally across the stud frame. The weather boards are shaped to overlap to shed water. Some typical sections of boarding are illustrated in .The wedge section, feather edge boarding, is either fixed to a simple overlap or rebated to lie flat against the studs as illustrated. The shaped chamfered and rebated and tongued and grooved shiplap boarding is used for appearance sake, particularly when the boarding is to be painted for protection and decoration.

To minimize the possibility of boards twisting it is practice to use boards of narrow widths of as little as 100 and usually 150 mm.

As protection against rain and wind penetrating the weatherboarding it is usual to fix sheets of roofing underlay or breather paper behind the weatherboarding. Breather paper serves to act as a barrier to water and at the same time allow the release of moisture vapour, under pressure to move through the sheet.

Instead of nailing weatherboarding directly to the studs of the wall frame it is usual to fix either diagonally fixed boarding or sheets of plywood across the external faces of the stud frame. The boarding and ply sheets serve as a brace to the frame and as a sheath to seal the frame against weather.

Resistance to the passage of heat

Timber is a comparatively good insulator having a U value of 0.13 for softwood and 0.15 for hardwood. The sections of a timber frame do not by themselves generally afford sufficient insulation to meet the requirements of the Building Regulations and a layer of some insulating material has to be incorporated in the construction.

The layer of insulation is fixed either between the vertical studs of the frame or on the outside or inside of the framing. The disadvantage of fixing the insulation between the studs is that there may be a deal of wasteful cutting of insulation boards to fit them between studs and to the extent that the U value of the timber stud is less than that of the insulation material, there will be a small degree of thermal bridge across the studs . The advantage of fixing the insulation across the outer face of the timber frame is simplicity in fixing and the least amount of wasteful cutting and that the void space between the studs will augment insulation and provide space in which to conceal service pipes and cables . The disadvantage of external insulation is that the weathering finish such as weatherboarding has to be fixed to vertical battens screwed or nailed through the insulation to the studs. Unless the

insulation is one of the rigid boards it may be difficult to make a fixing for battens sufficiently firm to nail the battens to.

Internal insulation is usually in the form of one of the insulation boards that combine insulation with a plasterboard finish.

1-9-3 STUD WALLS

❖ **Insulation for timber walls**

The inorganic materials glass fibre and rockwool are most used for insulation between studs as there is no advantage in using the more expensive organic materials, as the thickness of insulation required is not usually greater than the width of the studs. Either rolls of loosely felted fibres or compressed semi-rigid batts or slabs of glass fibre or rockwool are used. The material in the form of rolls is hung between the studs where it is suspended by top fixing and a loose friction fit between studs, which generally maintains the insulating material in position for the comparatively small floor heights of domestic buildings. The friction fit of semi-rigid slabs or batts between studs is generally sufficient to maintain them, close butted, in position. For insulating lining to the outside face of studs one of the organic insulants such as XPS or **PIR** provides the advantage of least thickness of insulating material for given resistance to the transfer of heat. The more expensive organic insulants, in the form of boards, are fixed across the face of studs for ease of fixing and to save wasteful cutting.

A vapour check should be fixed on to or next to the warm inside face of insulants against penetration of moisture vapour. Organic insulants, such as XPS, which are substantially impervious to moisture vapour can serve as a vapour check, particularly when rebated edge boards are used and the boards are close butted together.

1-9-3 STUD WALLS

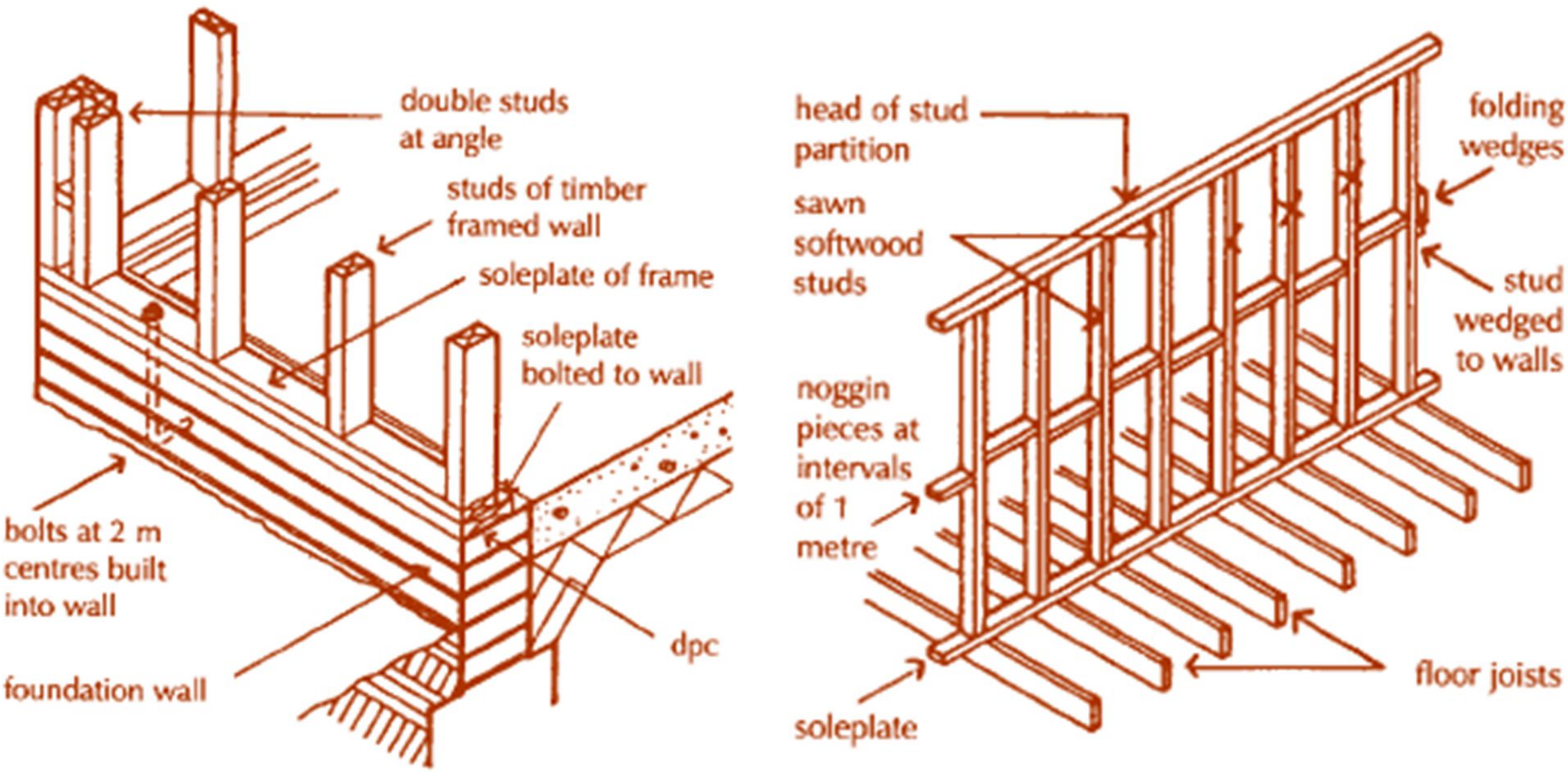
- **Brick and timber framed wall**

The external walls of small buildings such as houses have been constructed as a cavity wall with a brick outer leaf and a timber framed inner leaf or frame. This seemingly perverse form of construction which combines the 'wet trade' form of construction with a 'dry trade' form of construction may be justified by the permanence and appearance of an outer brick wall. The external brick leaf may well overcome the prejudice of buyer and building society surveyor that timber is a temporary building form, by providing the sense of weather resistance and durability that brickwork gives.A sensible argument for this odd form of construction could be speed of erection and completion of building work by combining the rapid framing of a timber wall, floor and roof structure that could be completed and covered in a matter of a few days, with a brick outer leaf and speedy installation of electrical, water and heating services and dry linings.

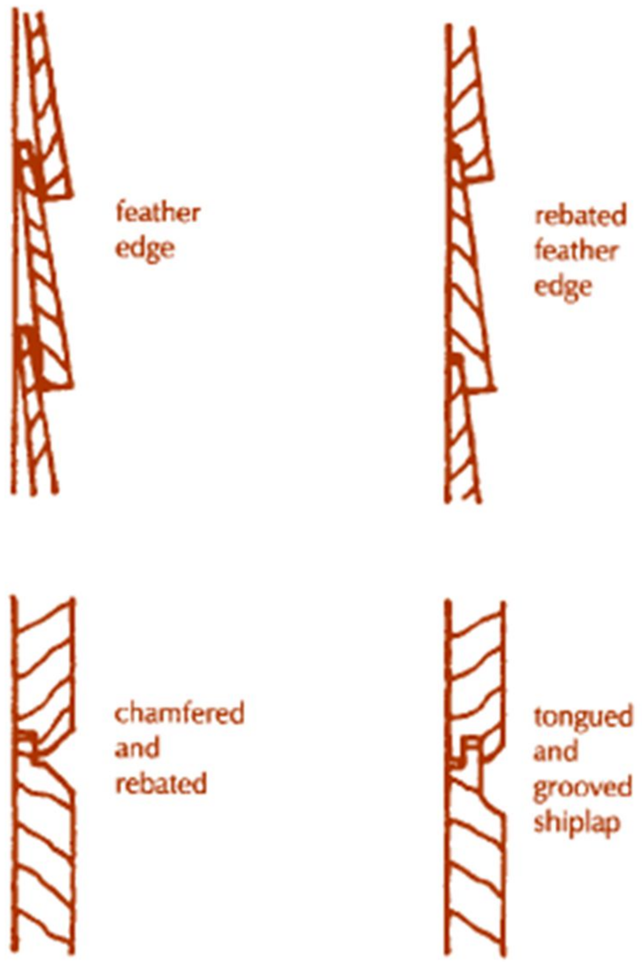
For resistance to weather a brick outer leaf is generally accepted as being thick enough to prevent penetration of rain to the inside

For thermal resistance one of the thermal insulation boards is fixed to a vapour check and plywood sheathing nailed to the stud frame. The thermal insulation is carried up in the cavity to unite with the roof insula tion laid on a vapour check. The plywood shea thing is used to diagonally brace the stud frame.

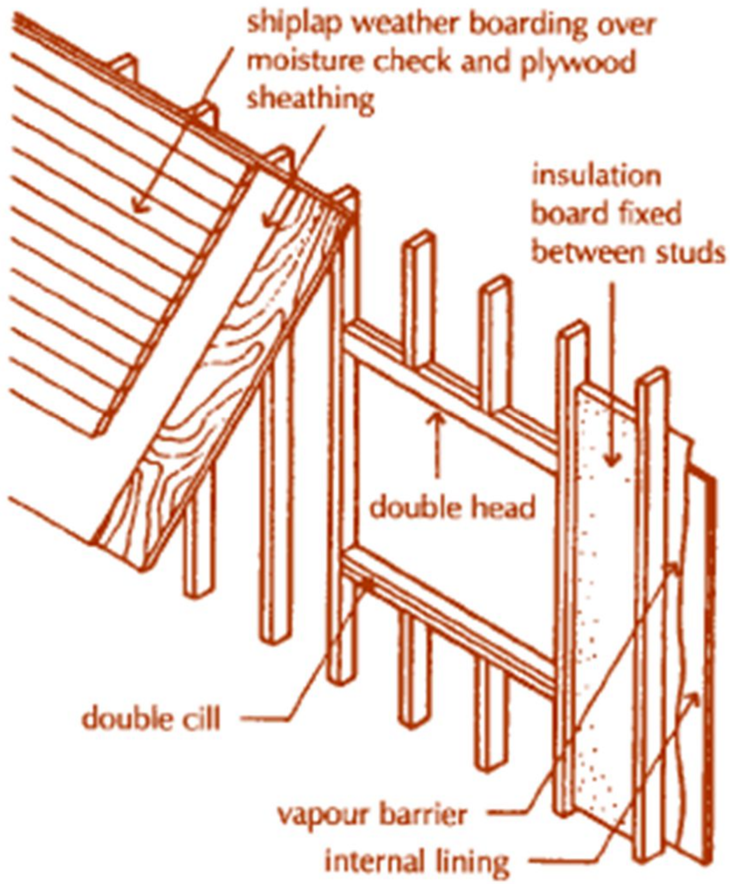
1-9-3 STUD WALLS



1-9-3 STUD WALLS

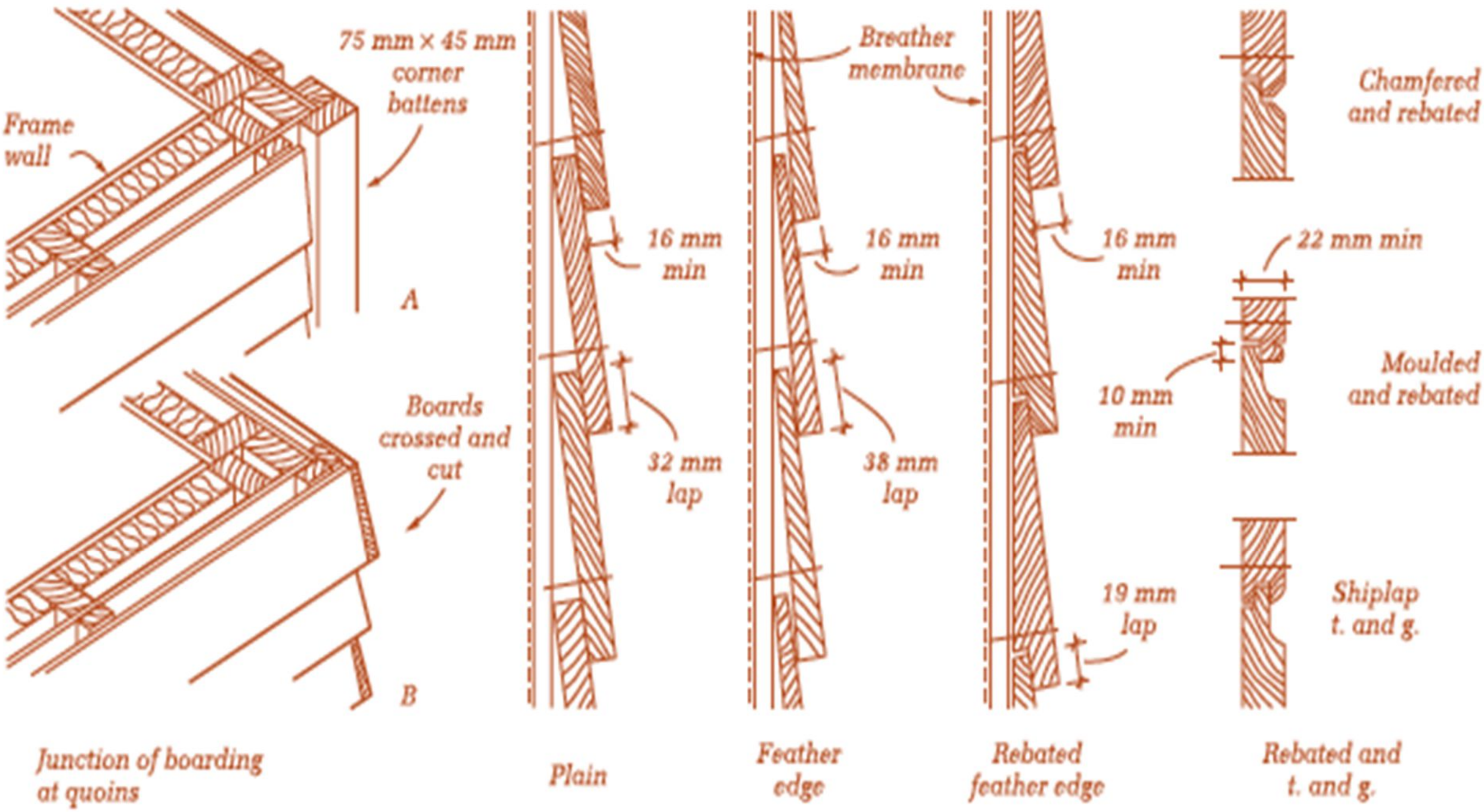


Timber weatherboarding.

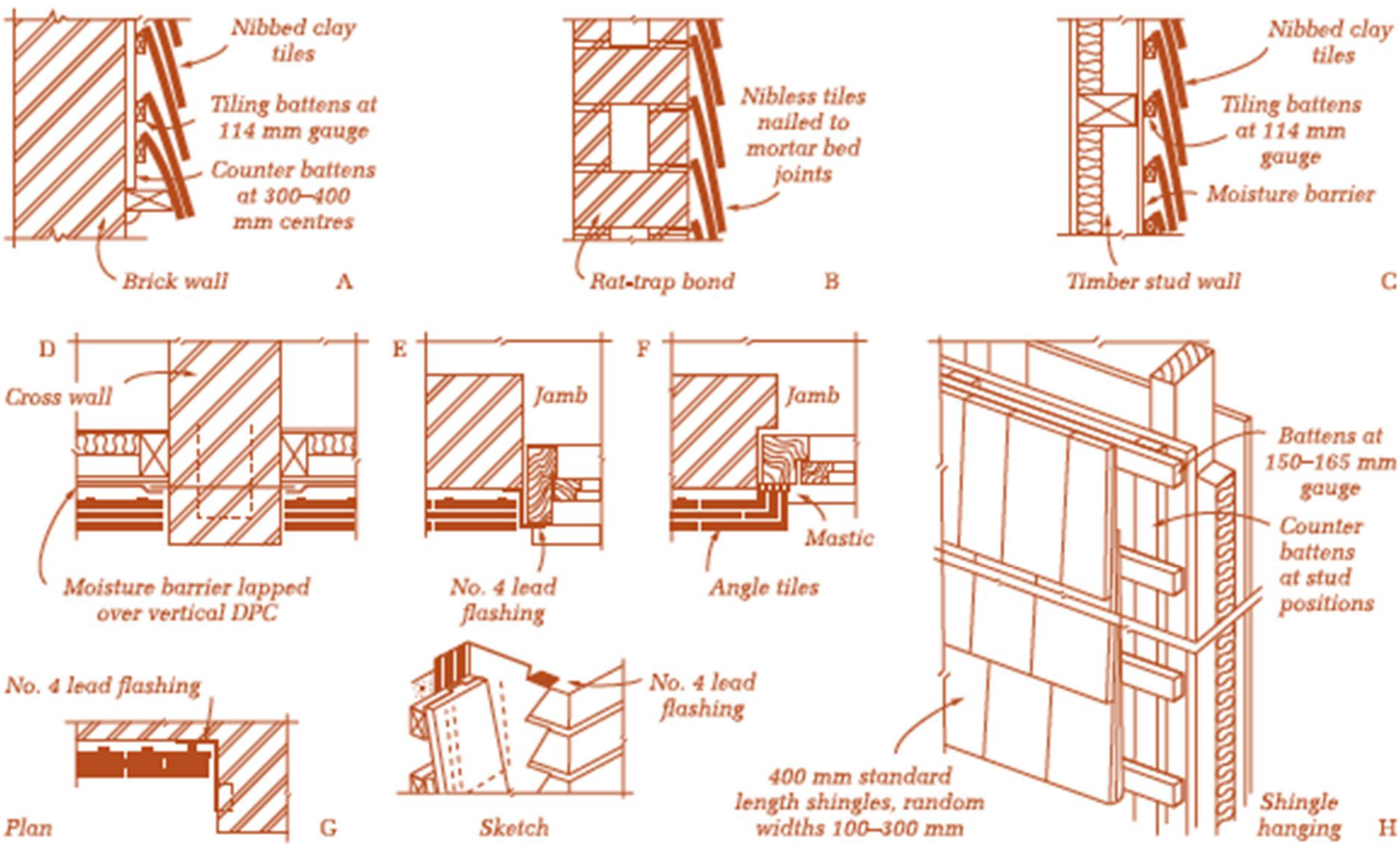


Weather envelope.

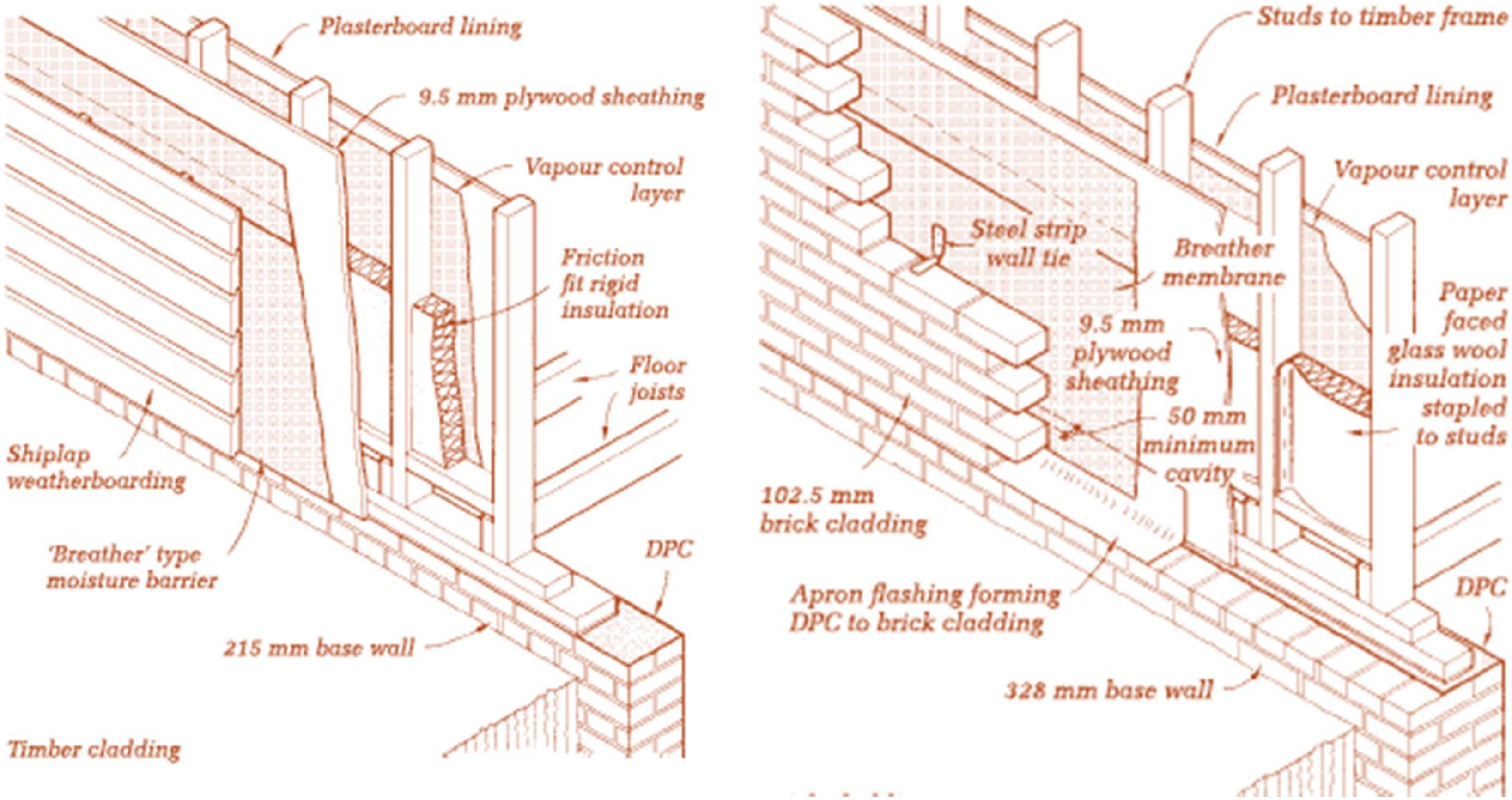
1-9-3 STUD WALLS



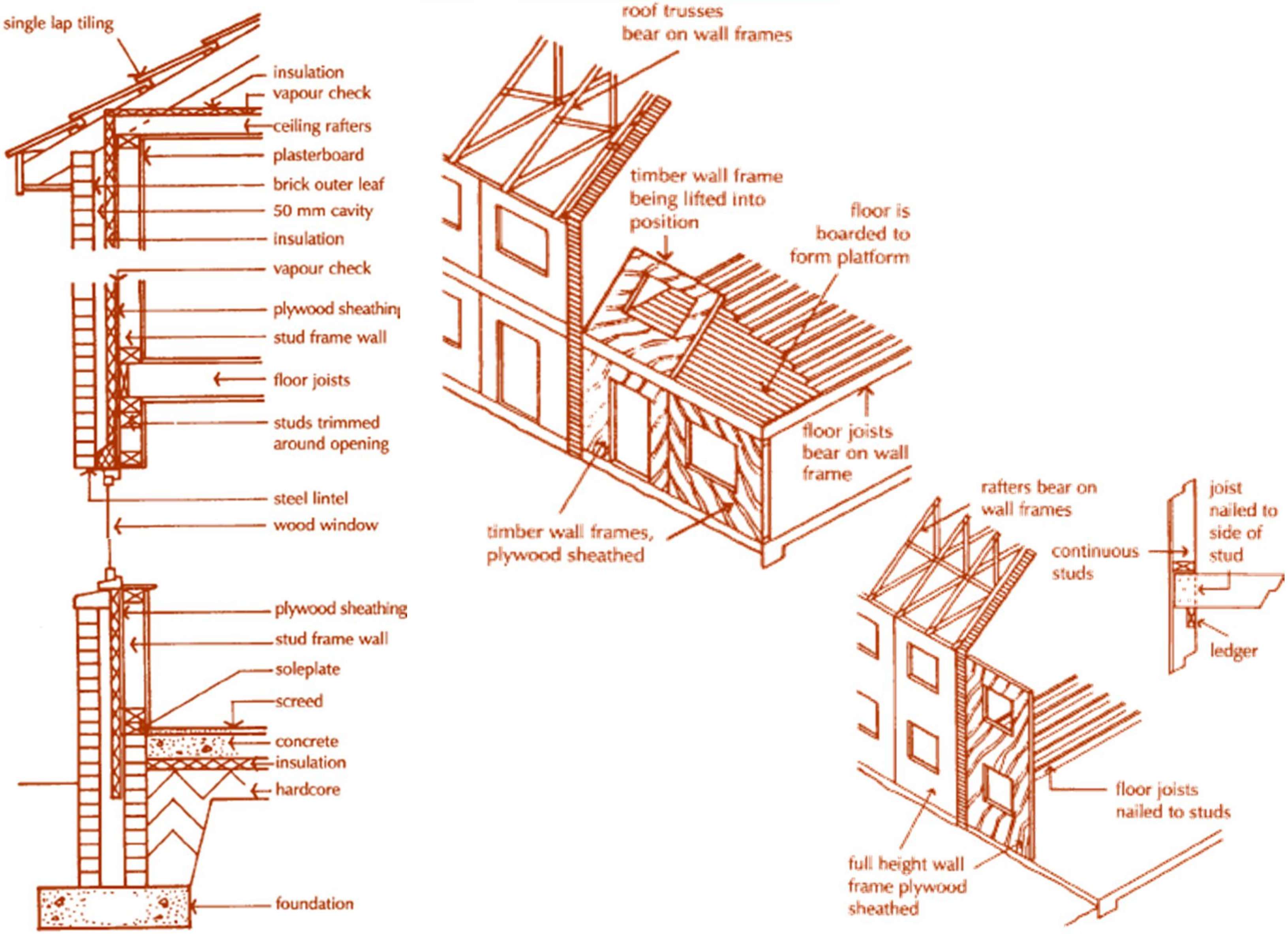
1-9-3 STUD WALLS



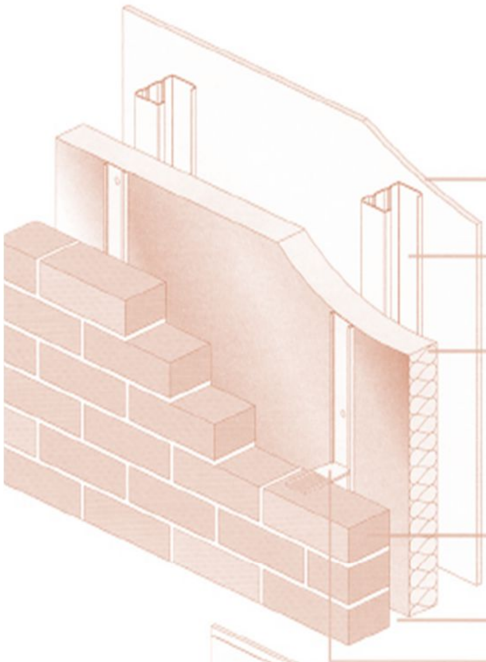
1-9-3 STUD WALLS

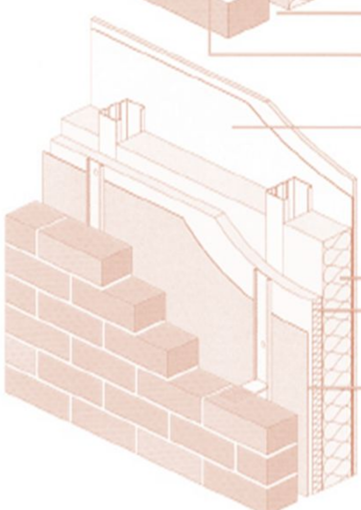


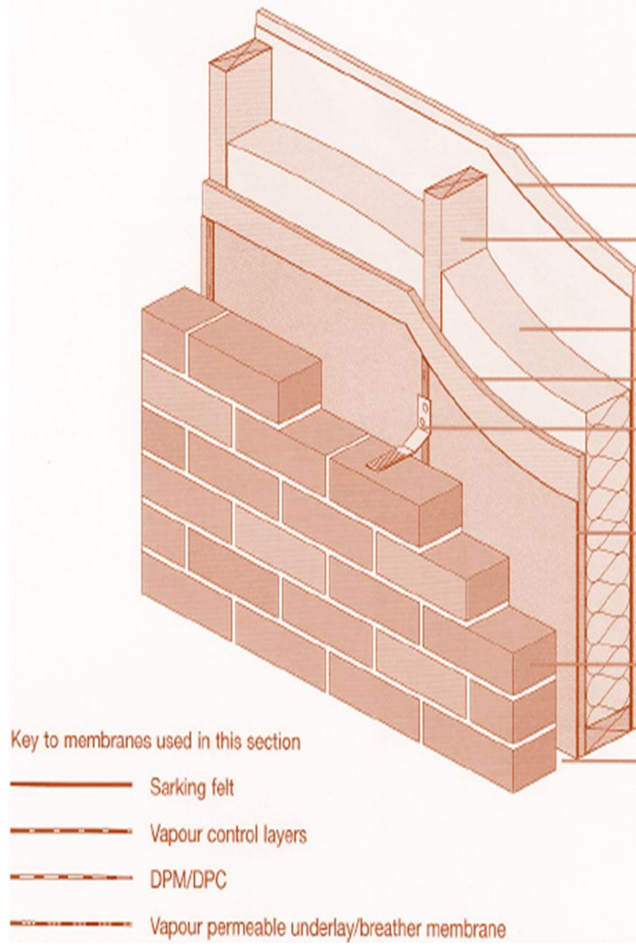
1-9-3 STUD WALLS



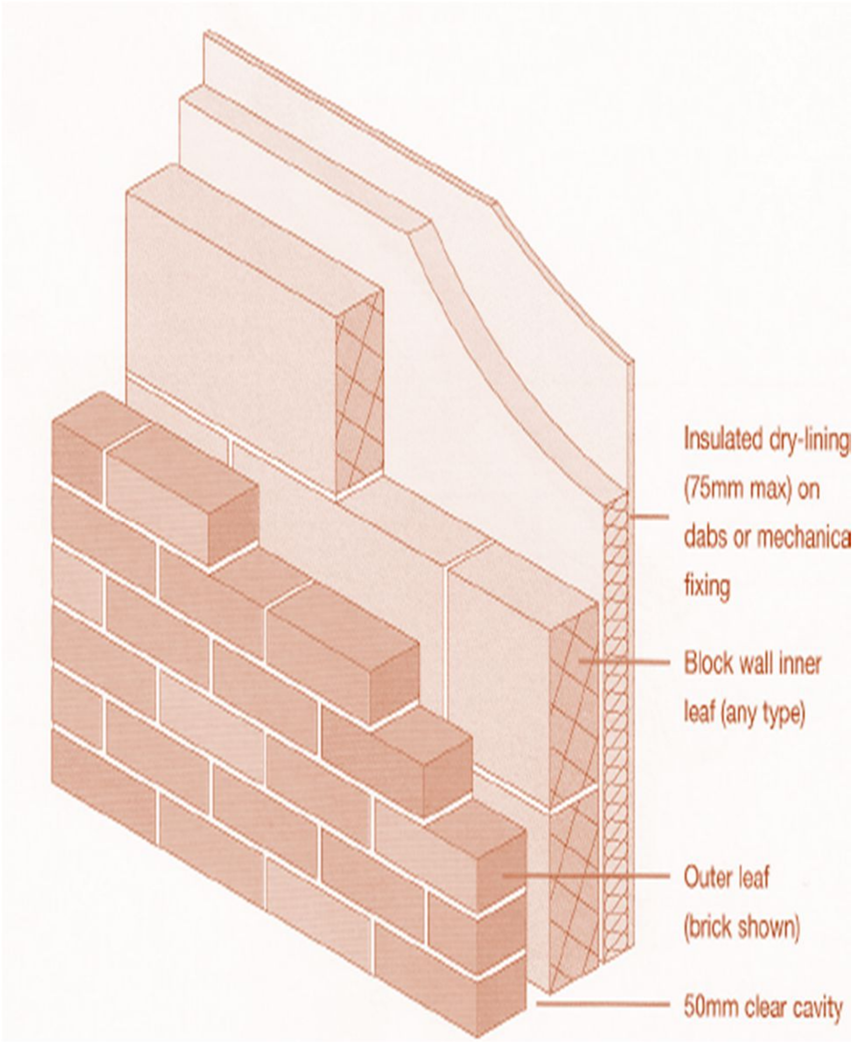
1-9-3 STUD WALLS

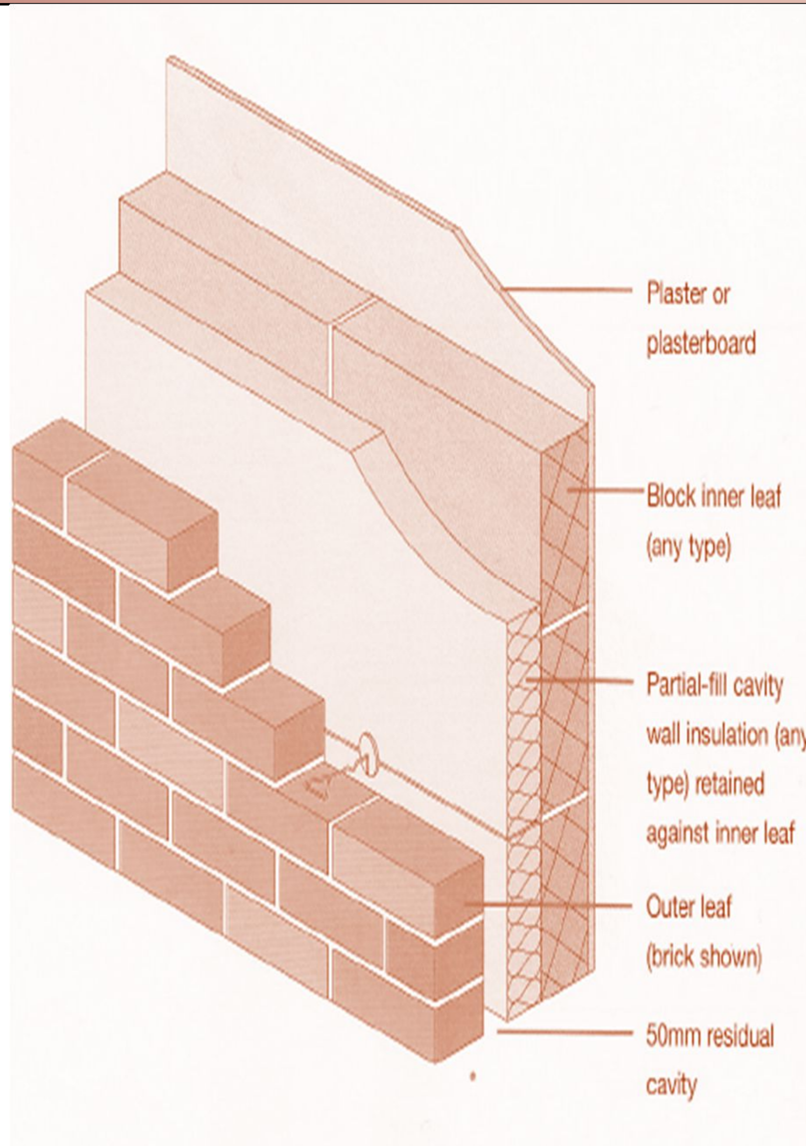






1-9-3 STUD WALLS





1-9-3 STUD WALLS

Insulating materials.

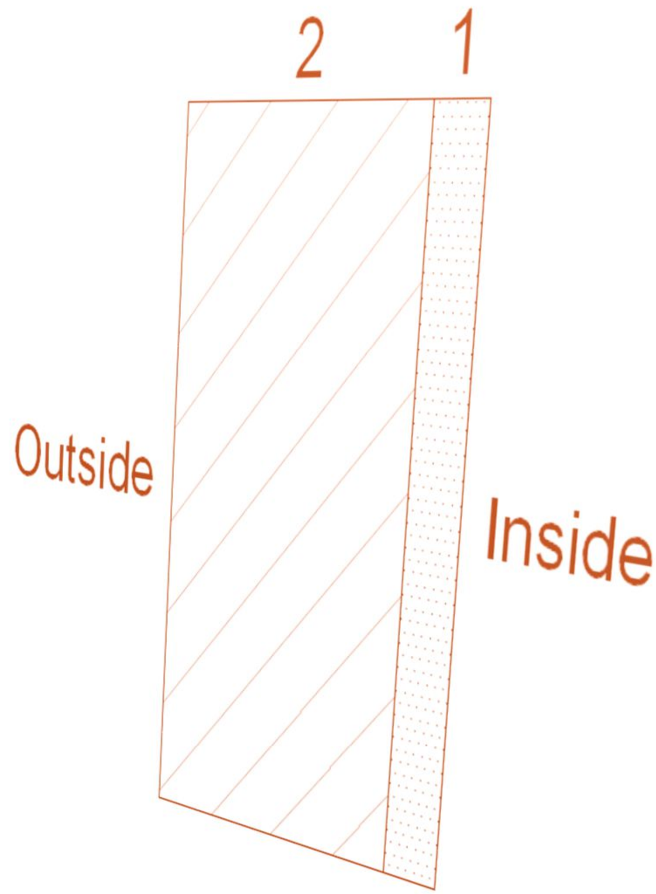
	Thickness mm	U value
Timber framed wall (insulation between studs)		
Glass fibre rolls semi-rigid batts	50,80,90,100 80,90,100,120,140, 160	0.04 0.04
Rockwool rolls semi-rigid slabs	60,80,90,100,150 60,80,90,100	0.037 0.037
Timber framed wall (insulation fixed to face of studs)		
XPS boards T & G on long edges	25,50	0.025
PIR boards with heavy duty aluminium facings	20,25,30,35,50	0.02

XPS extruded polystyrene PIR rigid polyisocyanurate

SECTION TWO

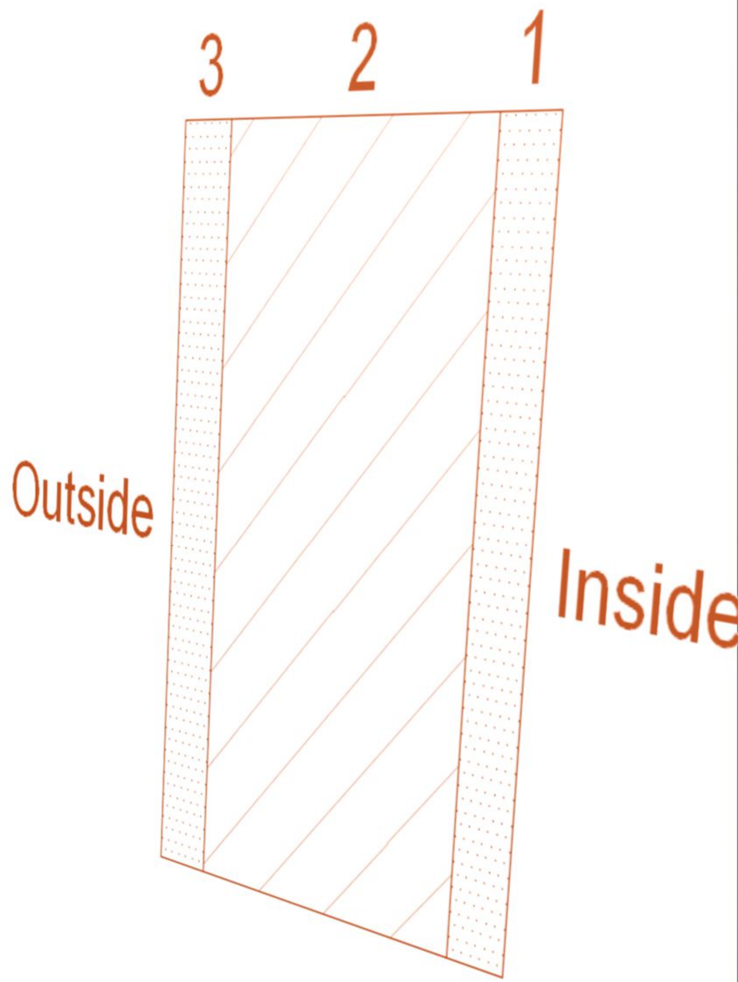
2-1 LOCAL WALL SECTIONS

Wall composition	U-value W/m²C
20mm gypsum finishing+400mm stone	2.476
20mm gypsum finishing+200mm concrete block	2.604
20mm gypsum finishing+240mm brick	1.936
20mm gypsum finishing+360mm brick	1.459
20mm gypsum finishing+240mm thermstone	0.813



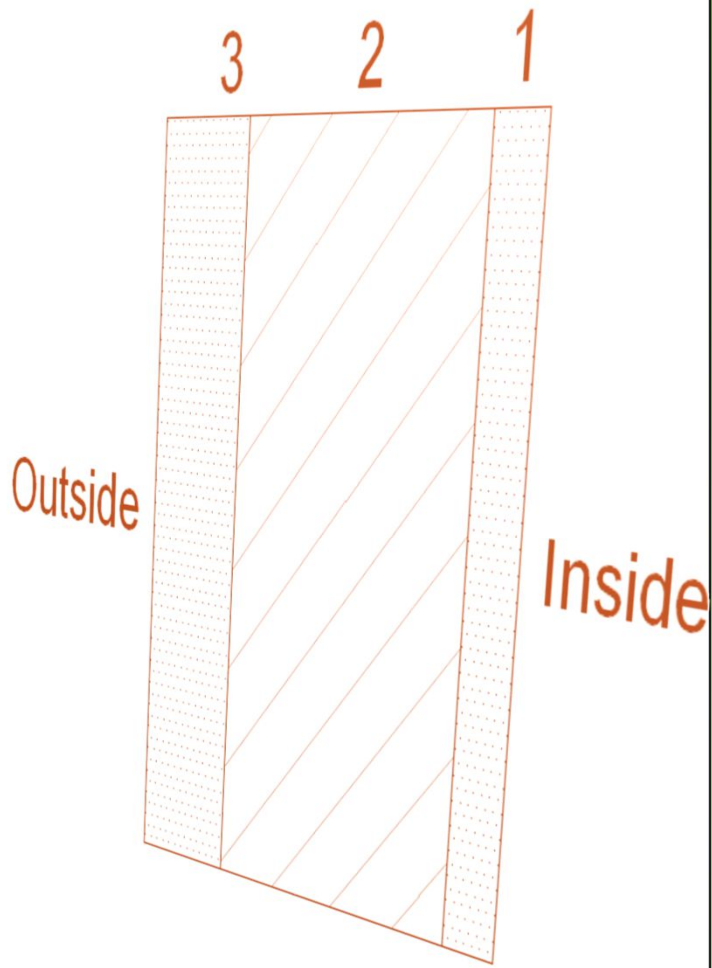
2-1 LOCAL WALL SECTIONS

Wall composition	U-value W/m²C
20mm gypsum finishing+400mm stone+20mm cement rendering	2.311
20mm gypsum finishing+200mm concrete block+20mm cement rendering	2.430
20mm gypsum finishing+240mm brick +20mm cement rendering	1.834
20mm gypsum finishing+360mm brick +20mm cement rendering	1.403
20mm gypsum finishing+240mm thermstone +20mm cement rendering	0.800



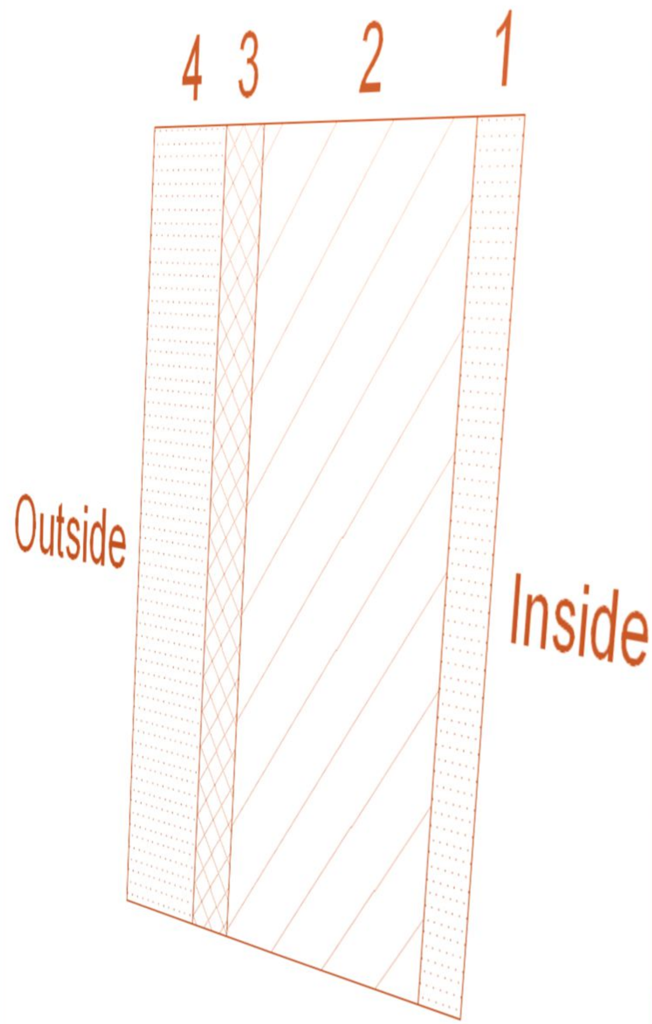
2-1 LOCAL WALL SECTIONS

Wall composition	U-value W/m²C
20mm gypsum finishing+200mm concrete block+50mm stone finishing (halan)	2.265
20mm gypsum finishing+200mm concrete block+80mm stone finishing (halan)	2.184
20mm gypsum finishing+200mm concrete block+100mm stone finishing (halan)	2.134
20mm gypsum finishing+240mm brick+50mm stone finishing (halan)	1.834
20mm gypsum finishing+240mm brick+80mm stone finishing (halan)	1.777
20mm gypsum finishing+240mm brick+100mm stone finishing (halan)	1.732
20mm gypsum finishing+360mm brick+50mm stone finishing (halan)	1.403
20mm gypsum finishing+360mm brick+80mm stone finishing (halan)	1.368
20mm gypsum finishing+360mm brick+100mm stone finishing (halan)	1.346
20mm gypsum finishing+240mm thermstone+50mm stone finishing (halan)	0.811
20mm gypsum finishing+240mm thermstone+80mm stone finishing (halan)	0.800
20mm gypsum finishing+240mm thermstone+80mm stone finishing (halan)	0.794



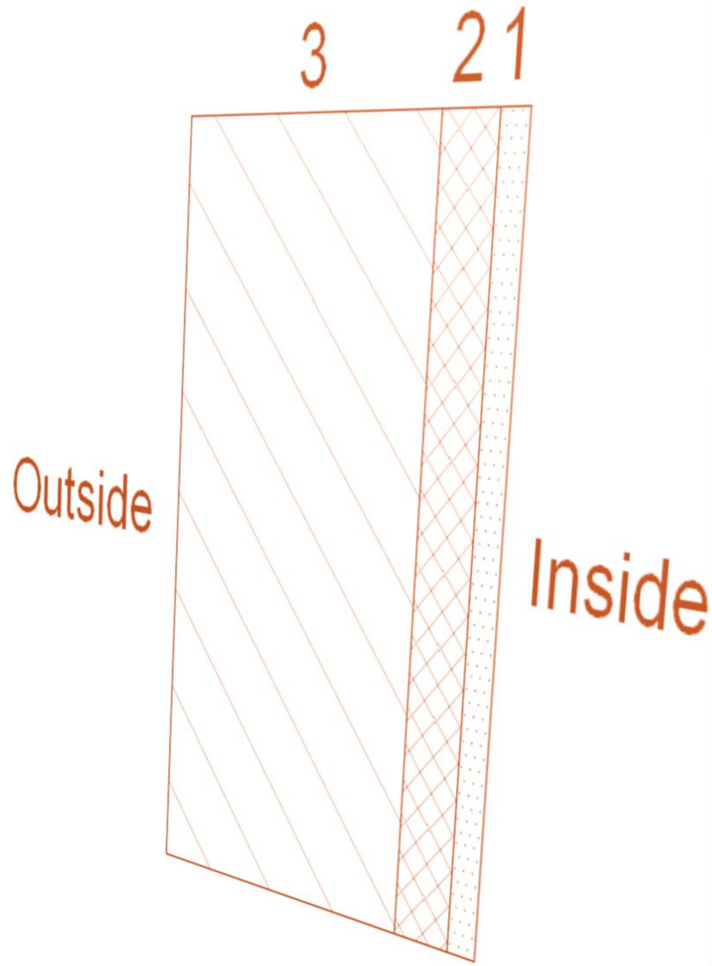
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
20mm gypsum finishing+400mmstone+50mm mineral wool insulation+50mm stone finishing (halan)	Mineral wool 0.042	**0.596**
20mm gypsum finishing+400mmstone+50mm mineral wool insulation+80mm stone finishing (halan)	Mineral wool 0.042	**0.590**
20mm gypsum finishing+240mm brrick+50mm mineral wool insulation+120mm brick finishing	Mineral wool 0.042	**0.526**
20mm gypsum finishing+240mm brrick+25mm styropor insulation+120mm brick finishing	Styropor 0.040	**0.818**
20mm gypsum finishing+240mm brrick+50mm styropor insulation+120mm brick finishing	Styropor 0.040	**0.539**
20mm gypsum finishing+360mm brrick+50mm mineral wool insulation+120mm brick finishing	Mineral wool 0.042	**0.585**
20mm gypsum finishing+360mm brrick+25mm styropor insulation+120mm brick finishing	Styropor 0.040	**0.715**
20mm gypsum finishing+360mm brrick+50mm styropor insulation+120mm brick finishing	Styropor 0.040	**0.494**
20mm gypsum finishing+240mm thermstone+25mm styropor insulation+120mm brick finishing	Styropor 0.040	**0.492**
20mm gypsum finishing+240mm thermstone+50mm styropor insulation+120mm brick finishing	Styropor 0.040	**0.360**



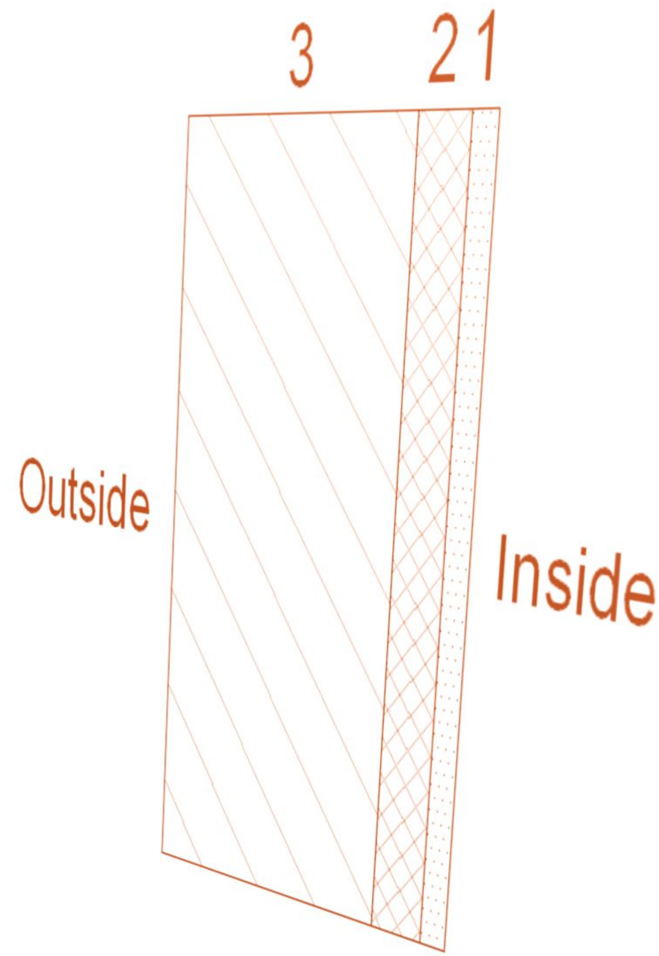
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
15mm wood finishing+50mm mineral wool insulation+400mm stone	Mineral wool 0.042	**0.578**
15mm wood finishing+50mm fiber glass insulation+400mm stone	Fiber glass 0.036	**0.528**
15mm wood finishing+25mm styropor+400mm stone	Styropor 0.040	**0.891**
15mm wood finishing+50mm styropor+400mm stone	Styropor 0.040	**0.574**
15mm wood finishing+50mmmineral wool+240mm brick	Mineral wool 0.042	**0.494**
15mm wood finishing+50mmfiber glass+240mm brick	Fiber glass 0.036	**0.528**
15mm wood finishing+25mm styropor+240mm brick	Styropor 0.040	**0.812**
15mm wood finishing+50mm styropor+240mm brick	Styropor 0.040	**0.534**
15mm wood finishing+50mm mineral wool+360mm brick	Mineral wool 0.042	**0.487**
15mm wood finishing+50mm fiber glass+360mm brick	Fiber glass 0.036	**0.460**



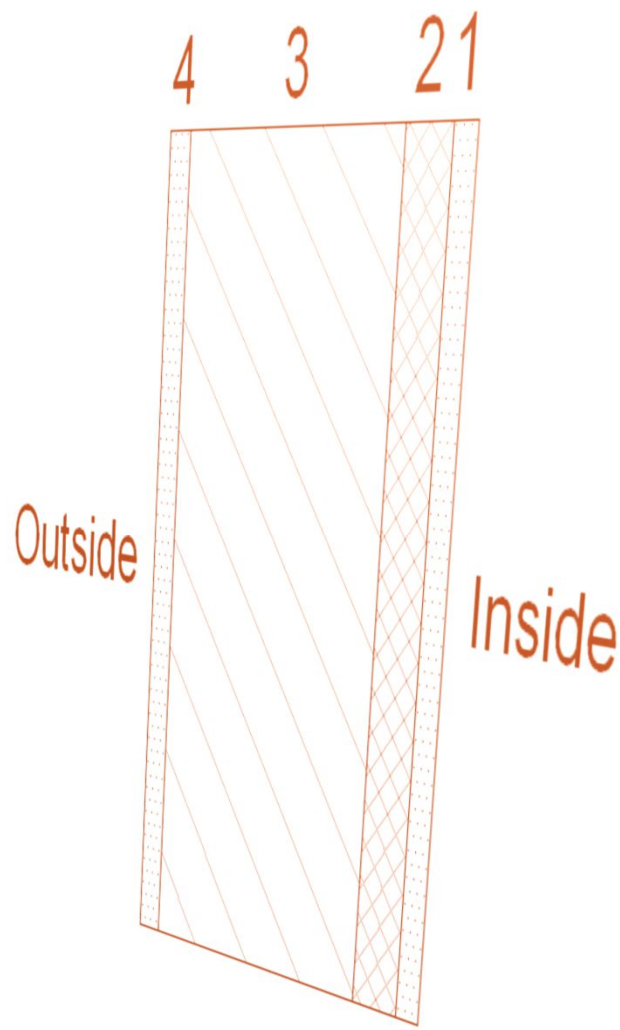
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
15mm wood finishing+25mm styropor +360mm brick	Styropor 0.040	**0.710**
15mm wood finishing+50mm styropor +360mm brick	Styropor 0.040	**0.484**
15mm wood finishing+50mm mineral wool+200mm concrete block	Mineral wool 0.042	**0.563**
15mm wood finishing+50mm fiber glass+200mm concrete block	Fiber glass 0.036	**0.551**
15mm wood finishing+25mm styropor+200mm concrete block	Styropor 0.040	**0.965**
15mm wood finishing+50mm styropor+200mm concrete block	Styropor 0.040	**0.602**
15mm wood finishing+50mm mineral wool+240mm thermstone	Mineral wool 0.042	**0.335**
15mm wood finishing+50mm fiber glass+240mm thermstone	Fiber glass 0.036	**0.360**
15mm wood finishing+50mm styropor+240mm thermstone	Styropor 0.040	**0.344**



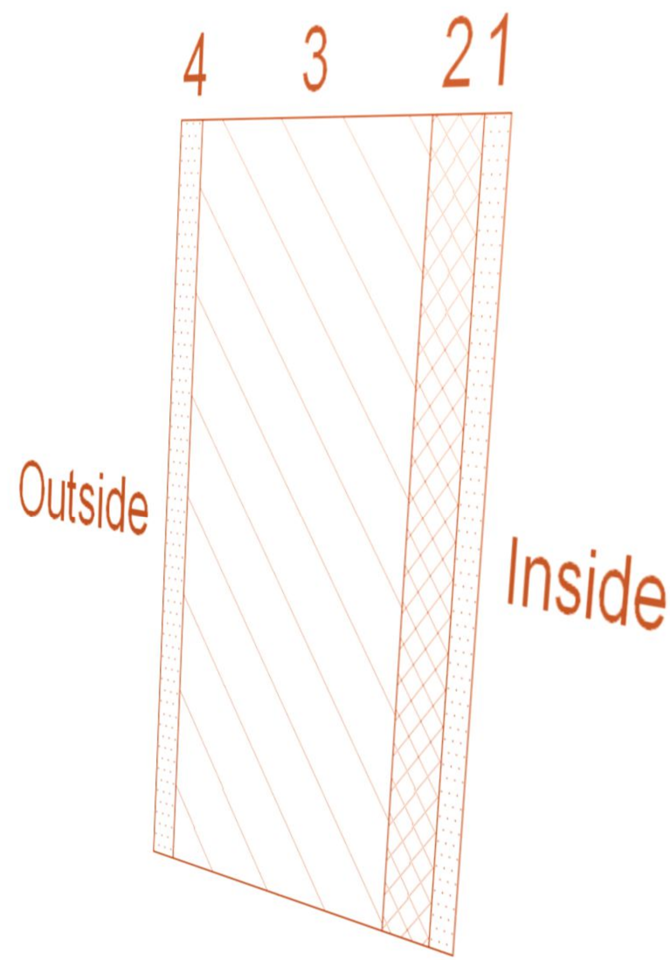
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
15mm wood finishing+50mm mineral wool insulation+400mm stone+20mm cement rendering	Mineral wool 0.042	**0.553**
15mm wood finishing+50mm fiber glass insulation+400mm stone+20mm cement rendering	Fiber glass 0.036	**0.517**
15mm wood finishing+25mm styropor+400mm stone+20mm cement rendering	Styropor 0.040	**0.869**
15mm wood finishing+50mm styropor+400mm stone+20mm cement rendering	Styropor 0.040	**0.562**
15mm wood finishing+50mmmineral wool+240mm brick+20mm cement rendering	Mineral wool 0.042	**0.520**
15mm wood finishing+50mmfiber glass+240mm brick+20mm cement rendering	Fiber glass 0.036	**0.494**
15mm wood finishing+25mm styropor+240mm brick+20mm cement rendering	Styropor 0.040	**0.789**
15mm wood finishing+50mm styropor+240mm brick+20mm cement rendering	Styropor 0.040	**0.528**
15mm wood finishing+50mm mineral wool+360mm brick+20mm cement rendering	Mineral wool 0.042	**0.482**
15mm wood finishing+50mm fiber glass+360mm brick+20mm cement rendering	Fiber glass 0.036	**0.454**



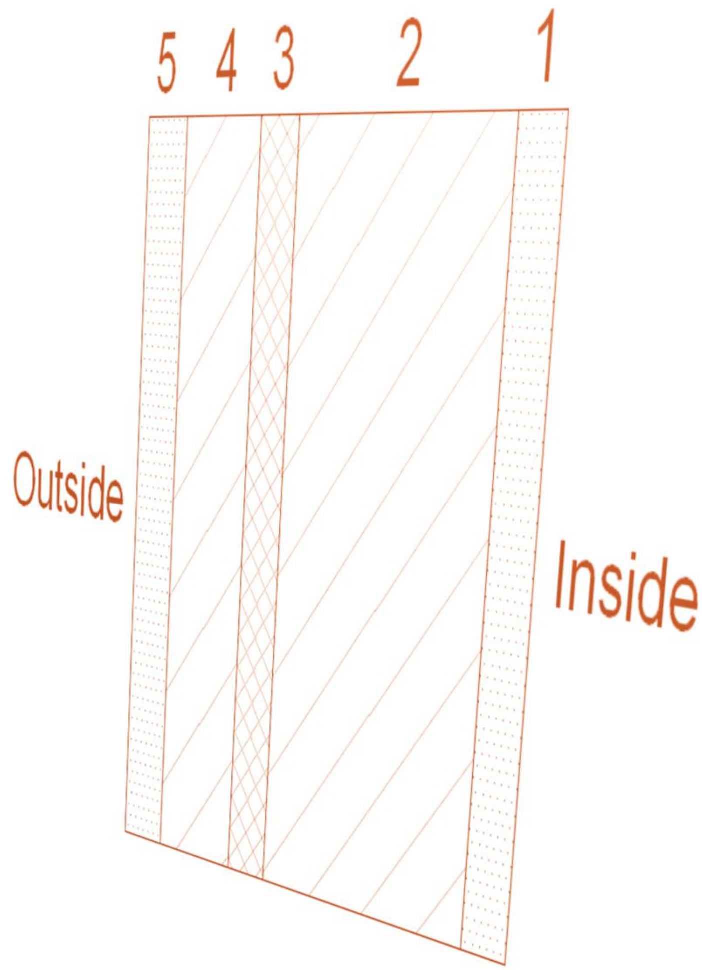
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
15mm wood finishing+25mm styropor +360mm brick+20mm cement rendering	Styropor 0.040	**0.698**
15mm wood finishing+50mm styropor +360mm brick+20mm cement rendering	Styropor 0.040	**0.483**
15mm wood finishing+50mm mineral wool+200mm concrete block+20mm cement rendering	Mineral wool 0.042	**0.553**
15mm wood finishing+50mm fiber glass+200mm concrete block+20mm cement rendering	Fiber glass 0.036	**0.545**
15mm wood finishing+25mm styropor+200mm concrete block+20mm cement rendering	Styropor 0.040	**0.623**
15mm wood finishing+50mm styropor+200mm concrete block+20mm cement rendering	Styropor 0.040	**0.547**
15mm wood finishing+50mm mineral wool+240mm thermstone+20mm cement rendering	Mineral wool 0.042	**0.380**
15mm wood finishing+50mm fiber glass+240mm thermstone+20mm cement rendering	Fiber glass 0.036	**0.360**
15mm wood finishing+50mm styropor+240mm thermstone+20mm cement rendering	Styropor 0.040	**0.377**



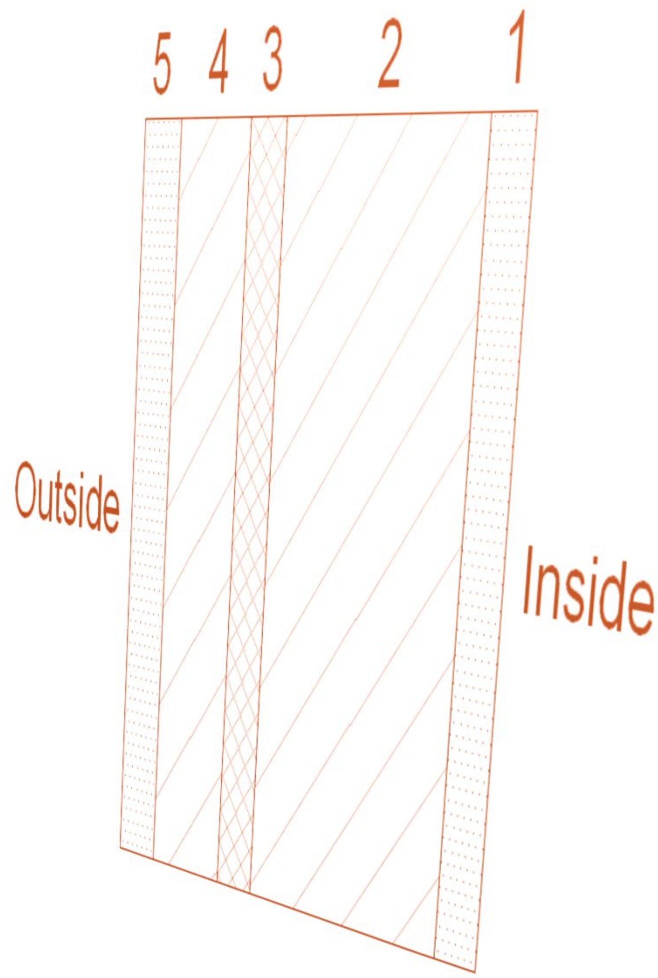
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
20mm gypsum finishing+120mm concrete wall+50mm fiber glass+120mm brick+20mm cement rendering	Fiber glass 0.036	**0.573**
20mm gypsum finishing+120mm concrete wall+25mm styropor+120mm brick+20mm cement rendering	Styropor 0.040	**0.920**
20mm gypsum finishing+120mm concrete wall+50mm styropor+120mm brick+20mm cement rendering	Styropor 0.040	**0.567**
20mm gypsum finishing+120mm concrete wall+50mm mineral wool+30mm concrete wall+20mm cement rendering	Mineral wool 0.042	**0.549**
20mm gypsum finishing+120mm concrete wall+50mm fiber glass+80mm concrete wall+20mm cement rendering	Fiber glass 0.036	**0.621**
20mm gypsum finishing+120mm concrete wall+25mm styropor+80mm concrete wall+20mm cement rendering	Styropor 0.040	**1.046**



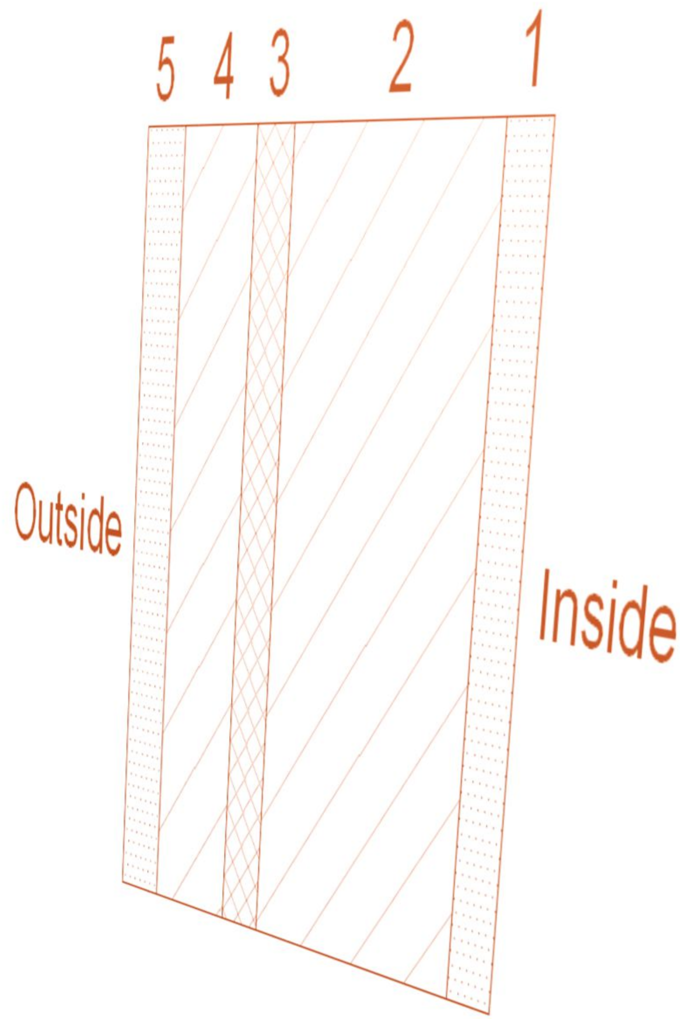
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
20mm gypsum finishing+120mm concrete wall+50mm styropor+80mm concrete wall+20mm cement rendering	Styropor 0.040	**0.551**
20mm gypsum finishing+120mm concrete wall+50mm mineral wool+100mm concrete block+20mm cement rendering	Mineral wool 0.042	**0.561**
20mm gypsum finishing+120mm concrete wall+50mm fiber glass+100mm block wall+20mm cement rendering	Styropor 0.040	**0.591**
20mm gypsum finishing+120mm concrete wall+25mm mineral wool+100mm concrete block+20mm cement rendering	Styropor 0.040	**0.965**
20mm gypsum finishing+120mm concrete wall+50mm styropor+100mm concrete block+20mm cement rendering	Styropor 0.040	**0.584**
20mm gypsum finishing+120mm concrete wall+50mm mineral wool+120mm brick+20mm cement rendering	Styropor 0.040	**0.521**



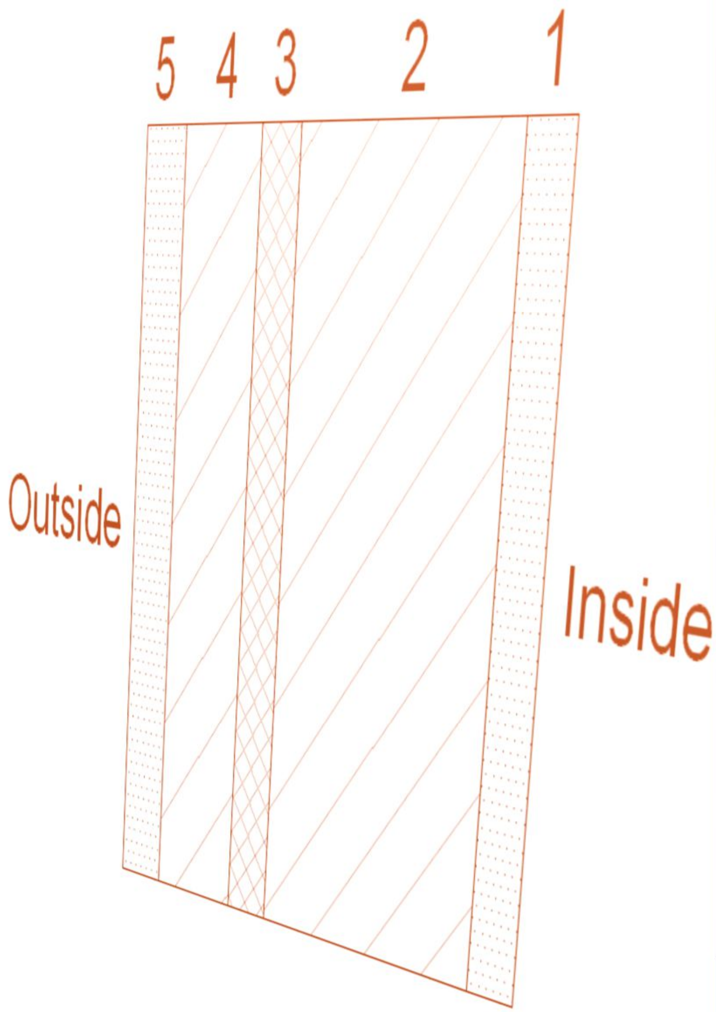
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
20mm gypsum finishing+200mm concrete wall+50mm mineral wool+80mm brick+20mm cement rendering	Mineral wool 0.042	**0.526**
20mm gypsum finishing+200mm concrete wall+50mm fiber glass+80mm concrete wall+20mm cement rendering	Fiber glass 0.036	**0.603**
20mm gypsum finishing+200mm concrete wall+25mm styropor+80mm concrete wall+20mm cement rendering	Styropor 0.040	**1.000**
20mm gypsum finishing+200mm concrete wall+50mm styroporl+80mm concrete wall+20mm cement rendering	Styropor 0.040	**0.597**
20mm gypsum finishing+200mm concrete wall+50mm mineral wool+120mm brickl+20mm cement rendering	Mineral wool 0.042	**0.509**
20mm gypsum finishing+200mm concrete wall+50mm fiber glass+120mm brickl+20mm cement rendering	Fiber glass 0.036	**0.560**



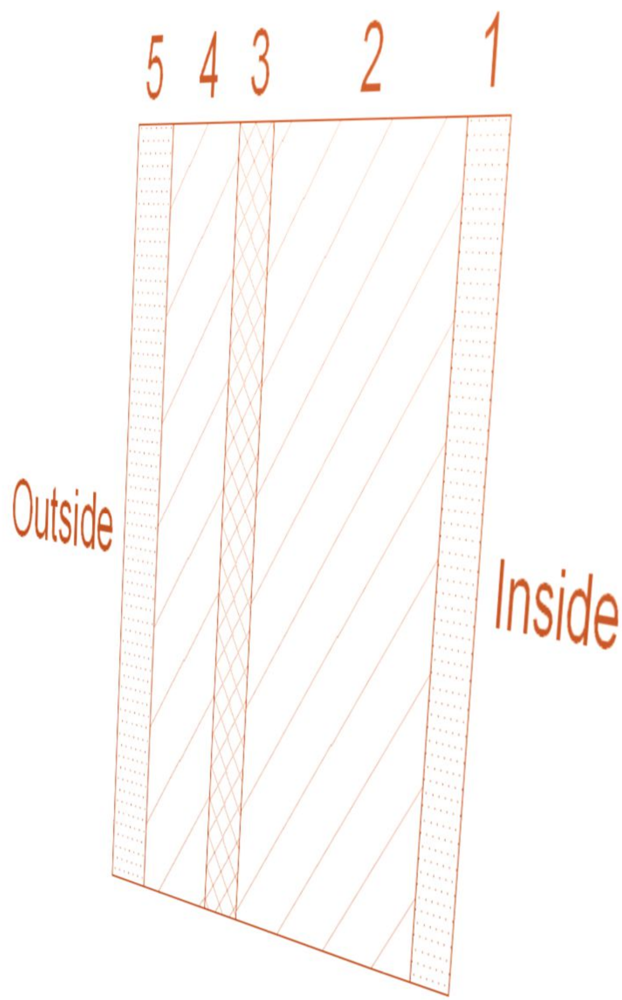
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
20mm gypsum finishing+200mm concrete wall+25mm styropor+120mm brick+20mm cement rendering	Styropor 0.040	**0.883**
20mm gypsum finishing+200mm concrete wall+50mm styropor+120mm brickl+20mm cement rendering	Styropor 0.040	**0.553**
20mm gypsum finishing+200mm concrete wall+50mm mineral wool+80mm concrete wall+20mm cement rendering	Mineral wool 0.042	**0.556**
20mm gypsum finishing+200mm concrete wall+50mm fiber glass+80mm concrete wall+20mm cement rendering	Fiber glass 0.036	**0.567**
20mm gypsum finishing+200mm concrete wall+25mm styropor+80mm concrete wall+20mm cement rendering	Styropor 0.040	**0.922**
20mm gypsum finishing+200mm concrete wall+50mm styropor+80mm concrete wall+20mm cement rendering	Styropor 0.040	**0.567**



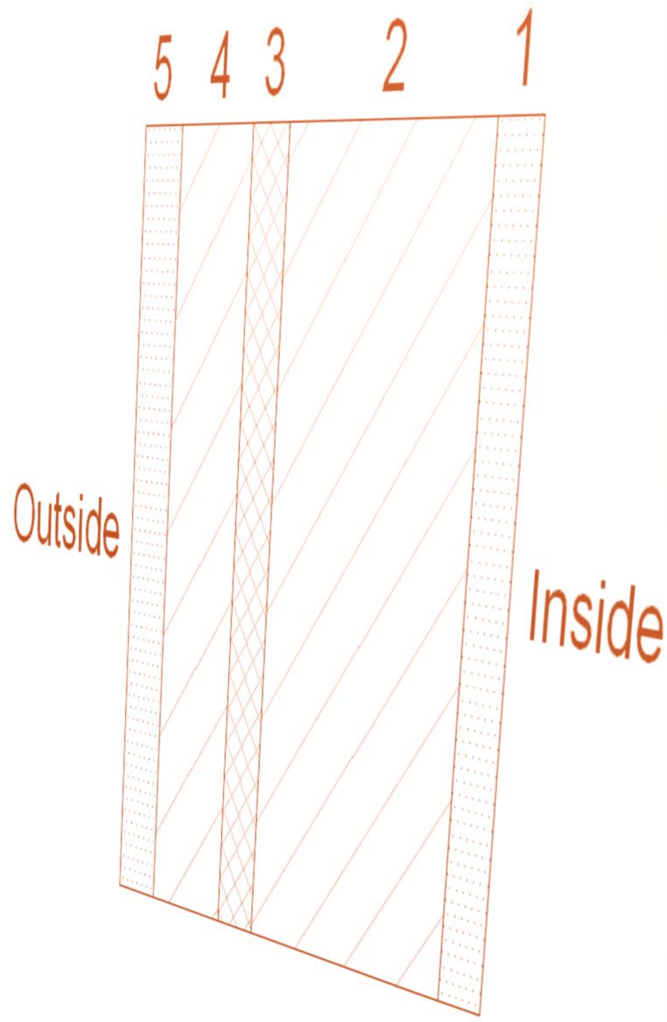
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
20mm gypsum finishing+200mm concrete wall+50mm mineral wool+100mm concrete block+20mm cement rendering	Mineral wool 0.042	**0.561**
20mm gypsum finishing+200mm concrete wall+50mm fiber glass+100mm concrete block+20mm cement rendering	Fiber glass 0.036	**0.511**
20mm gypsum finishing+200mm concrete wall+25mm styropor+100mm concrete block+20mm cement rendering	Styropor 0.040	**0.858**
20mm gypsum finishing+200mm concrete wall+50mm styropor+100mm concrete block+20mm cement rendering	Styropor 0.040	**0.544**
20mm gypsum finishing+200mm concrete wall+50mm mineral wool+120mm brick+20mm cement rendering	Mineral wool 0.042	**0.538**
20mm gypsum finishing+120mm brick+50mm mineral wool+100mm concrete block+20mm cement rendering	Mineral wool 0.042	**0.564**



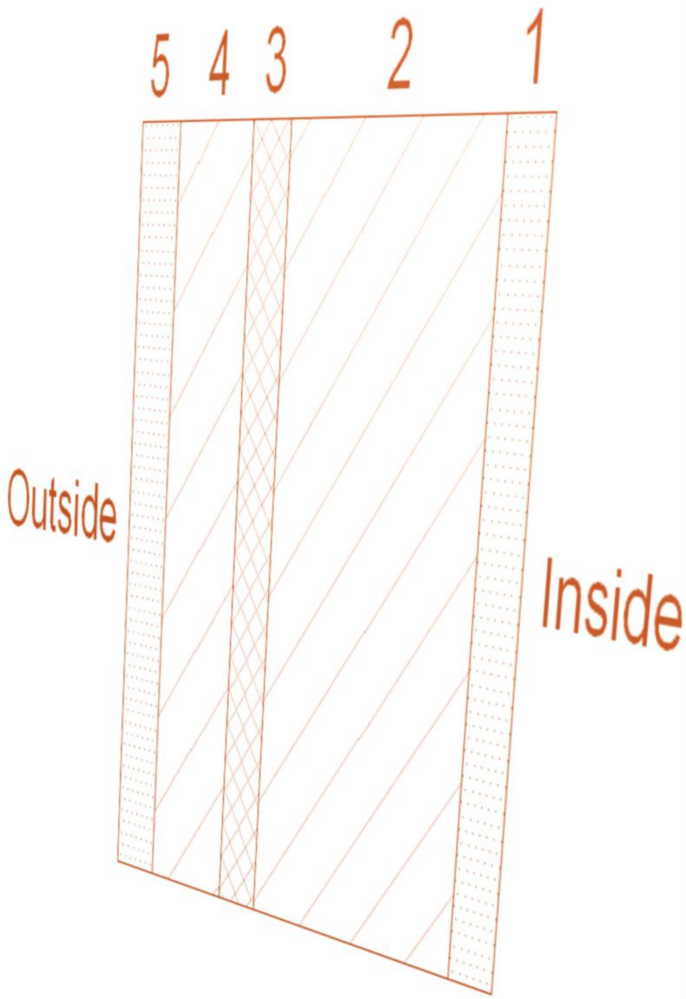
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
20mm gypsum finishing+120mm brick+50mm fiber glass+100mm concrete block+20mm cement rendering	Fiber glass 0.036	**0.555**
20mm gypsum finishing+120mm brick+50mm fiber glass+100mm concrete block+20mm cement rendering	Styropor 0.040	**0.874**
20mm gypsum finishing+120mm brick+50mm styropor+100mm concrete block+20mm cement rendering	Styropor 0.040	**0.540**
20mm gypsum finishing+120mm brick+50mm mineral wool+120mm brick+20mm cement rendering	Mineral wool 0.042	**0.538**
20mm gypsum finishing+120mm brick+50mm fiber glass+120mm brick+20mm cement rendering	Fiber glass 0.036	**0.539**
20mm gypsum finishing+120mm brick+25mm styropor+120mm brick+20mm cement rendering	Styropor 0.040	**0.835**



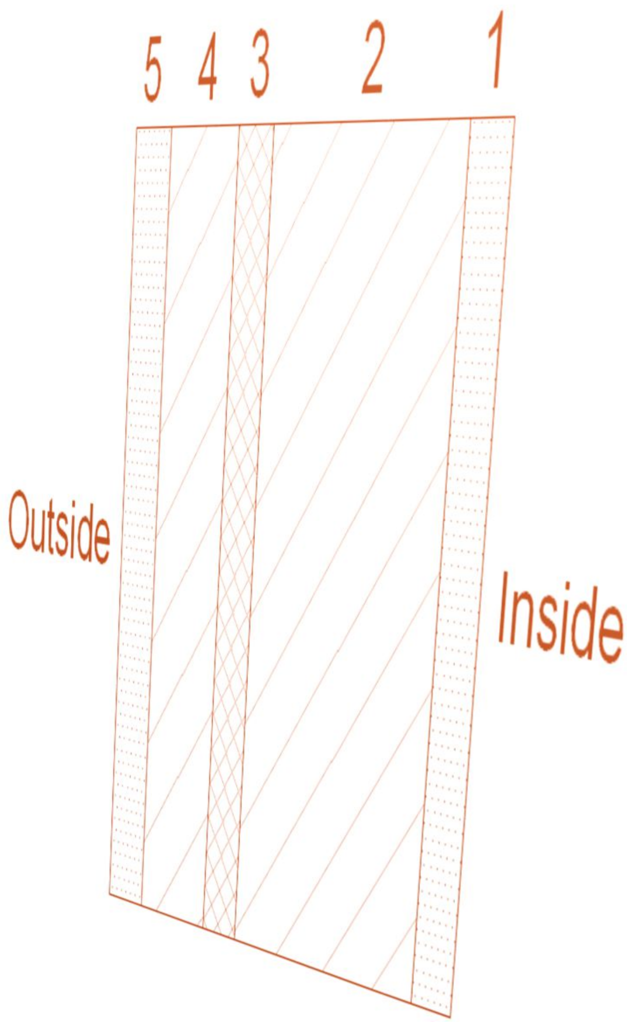
2-1 LOCAL WALL SECTIONS

Wall composition	U-value for insulating material W/m^2C	Total U-value W/m^2C
20mm gypsum finishing+120mm brick+50mm styropor+120mm brick+20mm cement rendering	Styropor 0.040	**0.534**
20mm gypsum finishing+200mm concrete block+50mm fiber glass+120mm brick+20mm cement rendering	Fiber glass 0.036	**0.534**
20mm gypsum finishing+200mm concrete block+25mm styropor+120mm brick+20mm cement rendering	Styropor 0.040	**0.823**
20mm gypsum finishing+200mm concrete block+50mm styropor+120mm brick+20mm cement rendering	Styropor 0.040	**0.529**
20mm gypsum finishing+120mm brick+50mm mineral wool+80mm concrete wall+20mm cement rendering	Mineral wool 0.042	**0.555**
20mm gypsum finishing+120mm brick+50mm fiber glass+80mm concrete wall+20mm cement rendering	Fiber glass 0.036	**0.581**



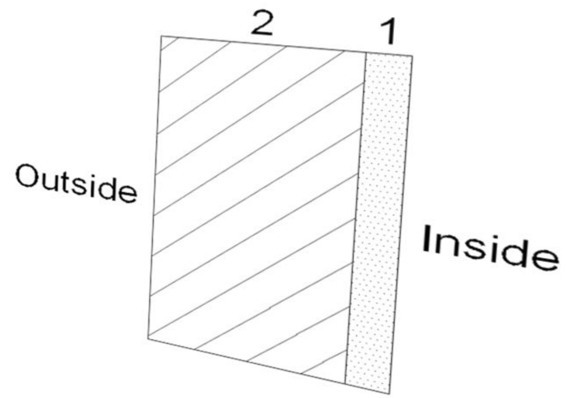
2-1 LOCAL WALL SECTIONS

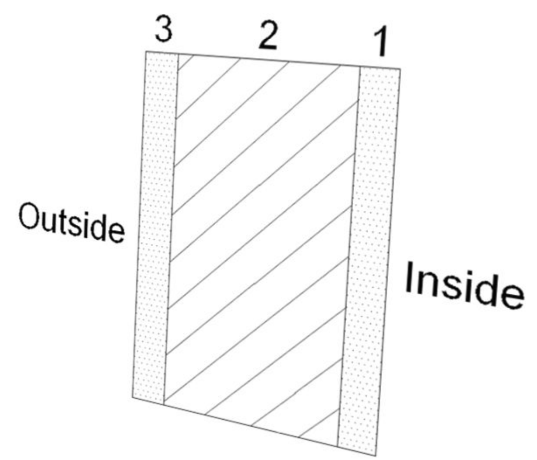
Wall composition	U-value for insulating material W/m²C	Total U-value W/m²C
20mm gypsum finishing+120mm brick+25mm styropor+80mm concrete wall+20mm cement rendering	Styropor 0.040	**0.594**
20mm gypsum finishing+120mm brick+50mm styropor+80mm concrete wall+20mm cement rendering	Styropor 0.040	**0.574**
20mm gypsum finishing+120mm brick+50mm mineral wool+100mm concrete block+20mm cement rendering	Mineral wool 0.042	**0.564**
20mm gypsum finishing+120mm brick+50mm fiber glass+100mm concrete block+20mm cement rendering	Fiber glass 0.036	**0.555**



2-2 COMMON LOCAL WALL SECTIONS

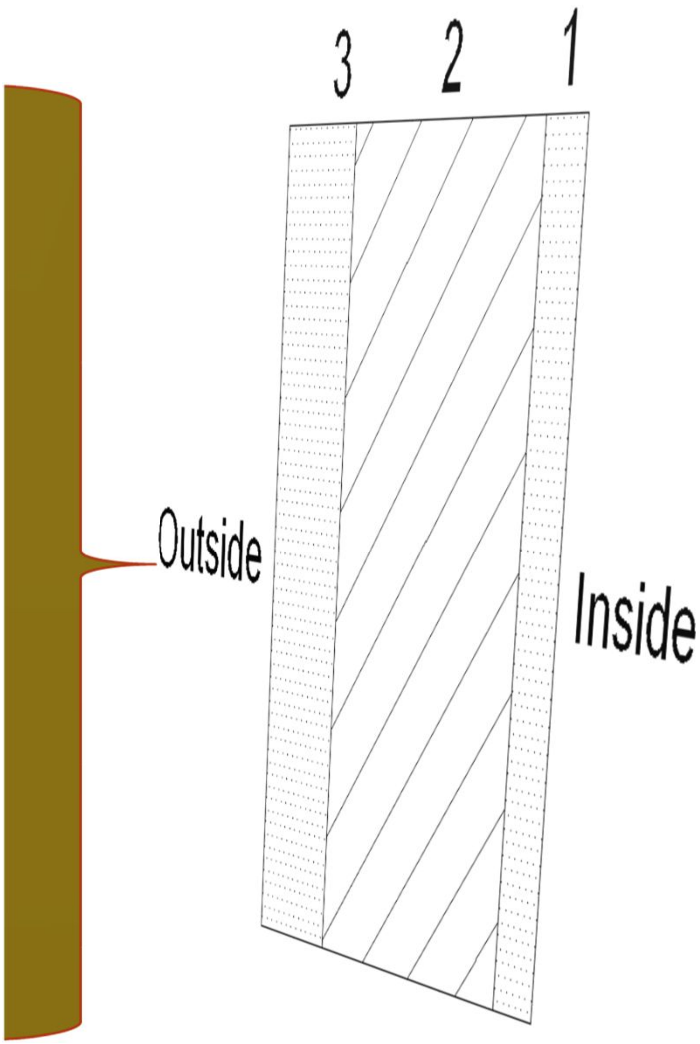
Wall composition	U-value W/m²C
20mm gypsum finishing+200mm concrete block	2.604
20mm gypsum finishing+240mm brick	1.936
20mm gypsum finishing+360mm brick	1.459
20mm gypsum finishing+200mm concrete block+20mm cement rendering	2.430
20mm gypsum finishing+240mm brick +20mm cement rendering	1.834
20mm gypsum finishing+360mm brick +20mm cement rendering	1.403





2-2 COMMON LOCAL WALL SECTIONS

Wall composition	U-value W/m²C
20mm gypsum finishing+200mm concrete block+50mm stone finishing (halan)	2.265
20mm gypsum finishing+200mm concrete block+80mm stone finishing (halan)	2.184
20mm gypsum finishing+200mm concrete block+100mm stone finishing (halan)	2.134
20mm gypsum finishing+240mm brick+50mm stone finishing (halan)	1.834
20mm gypsum finishing+240mm brick+80mm stone finishing (halan)	1.777
20mm gypsum finishing+240mm brick+100mm stone finishing (halan)	1.732
20mm gypsum finishing+360mm brick+50mm stone finishing (halan)	1.403
20mm gypsum finishing+360mm brick+80mm stone finishing (halan)	1.368
20mm gypsum finishing+360mm brick+100mm stone finishing (halan)	**1.346**



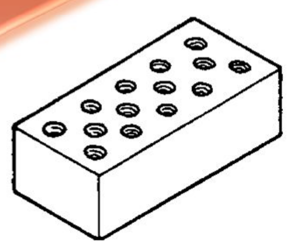
2-3THE DERIVATION FROM WALL SECTIONS

15 SECTIONS

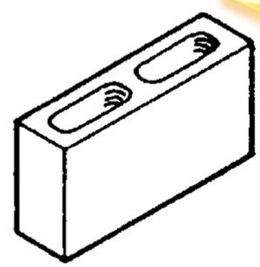
- **U Value 1-2** (66.6 %)
  - 5 sections its U-value is 1-1.5
  - 5 sections its U-value is 1.5-2
- **U Value 2-3** (33.3 %)
  - 4 sections its U-value is 2-2.5
  - 1 sections its U-value is 2.5-3

Min. U-value 1.346

BRICK



Max. U-value 2.604



CONCRETE BLOCK

CONCLUSIONS

CONCLUSIONS

- **Importance of thermal insulation are:**

1. To prevent heat flow through the wall in the different seasons of the year so the users of the building can live in a comfort atmosphere physically, psychologically, and even mentally.
2. To reduce energy consumption.

- Using thermal insulated materials in multi layer walls is opposite proportion with the energy cost (fluid consumption)

  So the relationship is:

  Number of wall layers = 1 / energy cost

- In our local case study
- that the best basic building material with low U-value is ***brick***
- the worst basic building material with high U-value is ***concrete block***.

- ***Energy saving*** in buildings constructed by ***brick*** is ***more*** than ***energy saving*** in buildings constructed by ***concrete block***.
- Adding layers for wall sections to obtain a high energy saving must economical and not very expensive.
- It is important to know what kind of insulating materials we must use and where?

REFERENCES

- MITCHELL`S – STRUCTURE AND FABRIC 2007
- MORRIS G. DAVIES – BUILDING HEAT TRANCFER 2004
- RICK BEST & GERARD DE VALENCE – DESIGN AND CONSTRUCTION BUILDING IN VALUE 2003
- R.BARRY –THE CONSTRUCTION OF BUILDINGS / VOLUME ONE 1999
- R.BARRY –THE CONSTRUCTION OF BUILDINGS / VOLUME FOUR 1996
- EDWARD ALLEN – ARCHITECTURAL DETAILING 1992
- CASE STUDY IN SULAIMANI CITY
- PETER BURBERRT- ENVIRONMENT AND SERVICE 1986
- INTERNET WEB SITES