DR. SALAHDEN GHAREB KADR



## Course book of Building Physics 2020



**Building Physics Components/ C H M S F L - Protection**

## 1. BUILDING MATERIALS

- NATURAL STONE
  - Granite & Marble
  - Limestone
  - Sandstone
- WOOD & PLYWOOD
- TILES

## 2. SCAFFOLDING CONSTRUCTION

# NATURAL STONE

| | |
|---|---|
| **Natural stone** | **Granite**, **Limestone**, **Marble**, **Sandstone** etc… Environment insensitive. Weather and Water resistant. Longe durability. |
| **Thermal insulation** | Thermal conductivity 2 - 3.5 W/ m . K. in winter cold \| in summer warm. Absorption of water 15-25%. Frost resistance 100%. |
| **Ecology and Sustainability** | Calcite or Calcium Carbonate mineral ($CaCO_3$)\| Dolomit $CaMg[CO_3]_2$ Environmentally friendly, Too much heavy. Natural stone must be built upon a strong foundation, to avoid settling and cracking. It has relatively **high compressive,** strength, but **lower tensile** strength. |
| **Healthy living** | Density (ϱ) 2500-3000 $kg/m^3$ \| Heat storage capacity 1000 J/ Kg . K. It can increase the thermal mass of a building, but needs an insulation for more interior thermal comfort. |
| **Sound controll** | Excellent stepping sound reduction by **Limestone** and **Sandstone** but bad sound protection by **Granite** & **Marble**\| It must be insulated for noise control. |
| **Economy** | It needs energy for quarrying & preparation, but difficult to transport |
| **Fire protection** | Optimum fire resistance \| Not flamable substance, It can protect the building from fire. |

# NATURAL STONE/ LIMESTONE






# NATURAL STONE

| | |
|---|---|
| **Thermal insulation** | Good thermal comfort: in Winter warm \| in Summer comfortable. Wood has lower tensile strength. It absorbs water and giving out again when the air dries and the temperature rises. It's a relatively good heat insulator. Ideal for underfloor heating. Pleasant walking sensation. It is robust and antistatic. It is carefree, durable, footwarm, hygienic and antibacterial. Thermal conductivity 0.13-0.2 W/ m . K. Absorption of water 25-30%. Frost resistance 100%. The thermal expansion of plywood is small. It has high thermal resistance. Exposure to extreme heat. |
| **Ecology and Sustainability** | It is 100% natural material and environmentally friendly, Light and flexible. Completely recyclable. Biodegradable & compostable |
| **Healthy living** | Good Heat storage capacity (c) 1600 J/ Kg . K \| The same temperature fluctuation \| Pleasant room climate. It is good vor allergy surfferer. |
| **Sound controll** | Good sound protection and footstep sound insulation |
| **Economy** | It needs energy only for preparation and light to transport. Wood is a natural building material with a multitude of uses. |
| **Fire protection** | Heat resistance but easily flamable. Very bad direct fire resistance, and requires effective means of protection especially when used in public buildings. It can not protect the inhabitant from the fire. It must be prepared to resistant the fire. |

# TILES AS A FLOOR AND WALL COVER



| | |
|---|---|
| **Area of use** | For indoor and outdoor use like kitchen, Bathroom, living room, balconie, terraces, gardens, entrance, halls, and corridors. |
| **Thermal insulation** | Not a good thermal comfort: in winter cold \| in summer not warm. Resistance to humidity and temperature changes. Ideal for underfloor heating. The thermal energy can be collected and be used if needed. Thermal conductivity 1.2-1.5 W/ m . K. |
| **Ecological and Sustainability** | Water \| Cement \| Sand and Natural stone<br>Not always environmentally friendly and heavy to transport. |
| **Healthy living** | Heat storage capacity (c) 1000 J/ Kg . K \| Pleasant room climate only in summer. It can increase the thermal mass of a building and needs an insulation for more interior thermal comfort. |
| **Sound controll** | Bad sound protection \| It must be insulated for noise control |
| **Economy** | It is not easy to manufacturing and difficult to transport |
| **Fire protection** | Optimum fire resistance \| Not flamable substance, It can protect the building from the fire. |

# TILES AS A FLOOR AND WALL COVER






## Definition of Scaffolding

**Scaffolding** is a temporary reusable construction, consisting of scaffold components made of wood or metal, steel or aluminum, which is used to prepare position of a **safe working platform** for the building construction, for repair and demolition of buildings and for other structures.

**Scaffolding**, also called **scaffold** or **staging,** is a structure used to support a work team and materials in the construction, maintenance and repair of buildings, bridges and all other structures.

### According to bearing System, there are different Scaffolding:

1- Stand Scaffolding

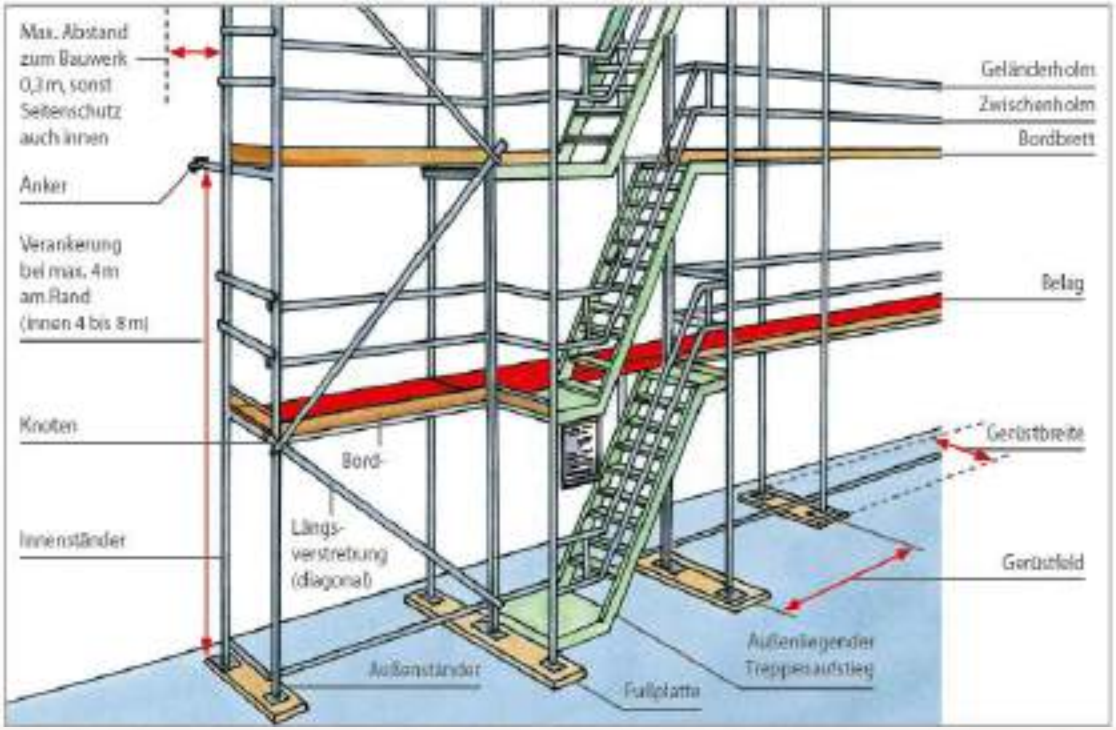
2- Hanging Scaffold

3- Projecting or Cantilever Scaffolding

4- Console Scaffolding

### Main scaffolding materials are:

1. Steel
2. Aluminium
3. Wood



# SCAFFOLDING CONSTRUCTION

DR. SALAHDEN GHAREB KADR

FOURTH LECTURE


# LOCALLY SCAFFOLDING CONSTRUCTION



## Different DINS for scaffolding in Germany

| | |
|---|---|
| Working Scaffold | DIN EN 12 811 |
| Protection Scaffolding | DIN 44 20 |
| Caring Scaffolding | DIN EN 12 812 |
| Moving Scaffold | DIN EN 10 65 |

## Thermal Bridges

- **Thermal bridge**, **Cold bridge** or **Heat bridge**, is an area of an object which has a higher heat transfer than the surrounding materials due to absent or reduction of thermal insulation.

**Thermal bridges** reduces the property of energy efficiency of the building and can allow water condensation and make thermal comfort problems.

- **Thermal bridges** are weaknesses in a building's structure where allow more heat transfer at a higher level to the lower of the surrounding envelope area.
- **Thermal bridge** is an area with a higher Heat transmittance coefficient U-value. On the basis of a lower insulation takes in this place more heat loss with a lower surface temperature.
- **Thermal bridges** are localized areas with higher thermal conductivity than their neighbouring areas.

**The rate of heat flow though a thermal bridge depends on a number of factors:**

- The temperature difference between inside and outside and between heat source & surfaces
- The thermal conductivity of the materials
- The cross sectional area of the thermal bridge
- How easily heat can get into and out of the thermal bridge

**Thermal bridges occur in four ways:**

- Material thermal bridges; with different thermal conductivity
- Geometrical thermal bridges; with different Heat input & Heat release
- Temperature difference thermal bridge; with high temperature difference
- Constructive thermal bridge; through leaks in the building envelope

**Material thermal bridges** The most obvious kind of thermal bridge occurs a different thermal conductivity of together used materials.

**Geometrical thermal bridges** can occur when the heat-emitting surface is smaller than the heat absorbing surface. Building corners without insullation are a typical example.

**Constructive thermal bridges** can occur through leaks and cracks in the building envelope.

**Geometric, construction and material thermal bridges can be broken down into subtypes:**

- **Linear** thermal bridges like a lintel
- **Point** thermal bridges masonry wall ties
- **Repeating** thermal bridges timber studs in an insulated wall
- **Non-repeating** thermal bridges a structural column in an insulated wall

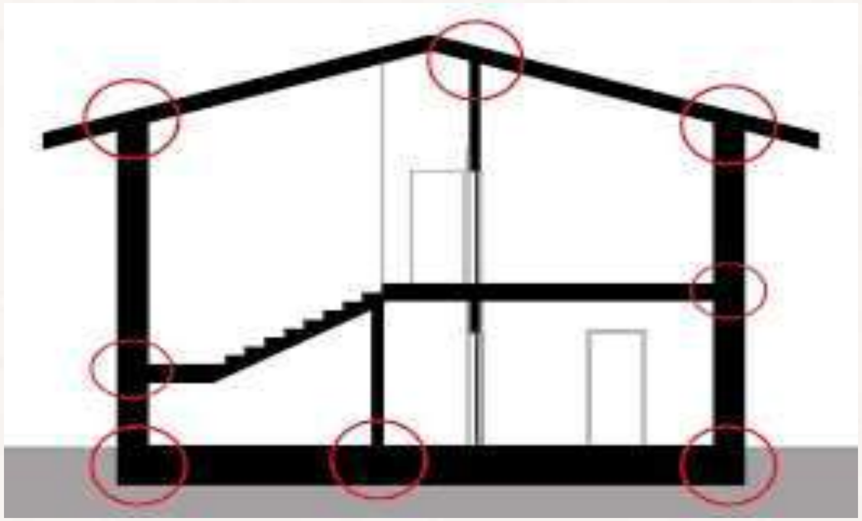
**The effect of thermal bridges:**

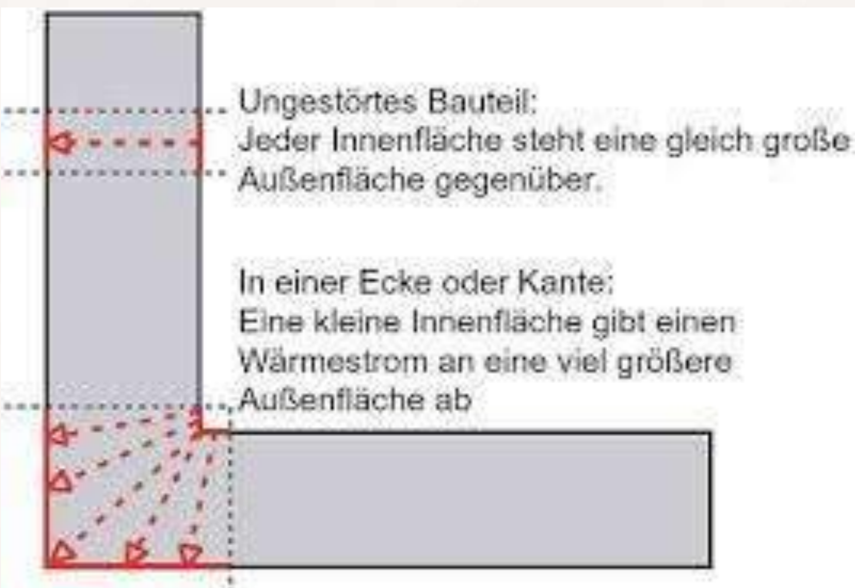
- Higher energy consumption **due to more heat flow (Φ)**
- Mold formation **due to high moisture formation**
- Uncomfortable living space **due to more heat loss in the space**

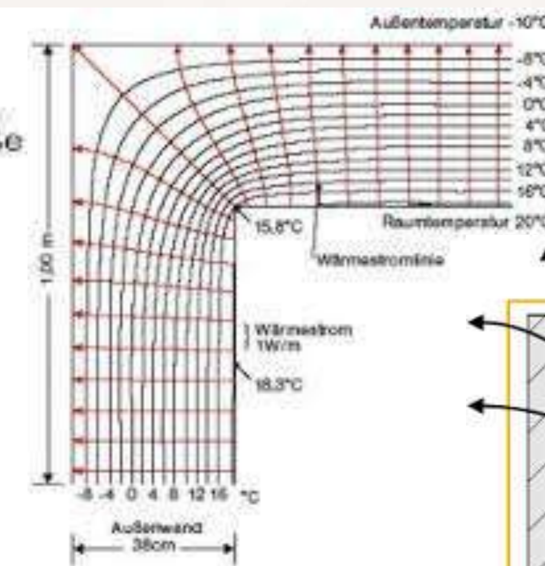
# THERMAL BRIDGE IN THE BUILDINGS

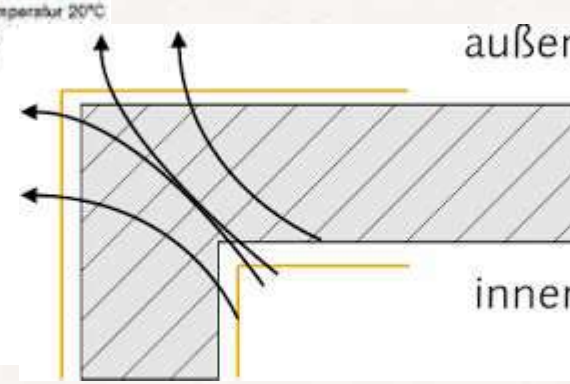
DR. SALAHDEN GHAREB KADR

FOURTH LECTURE





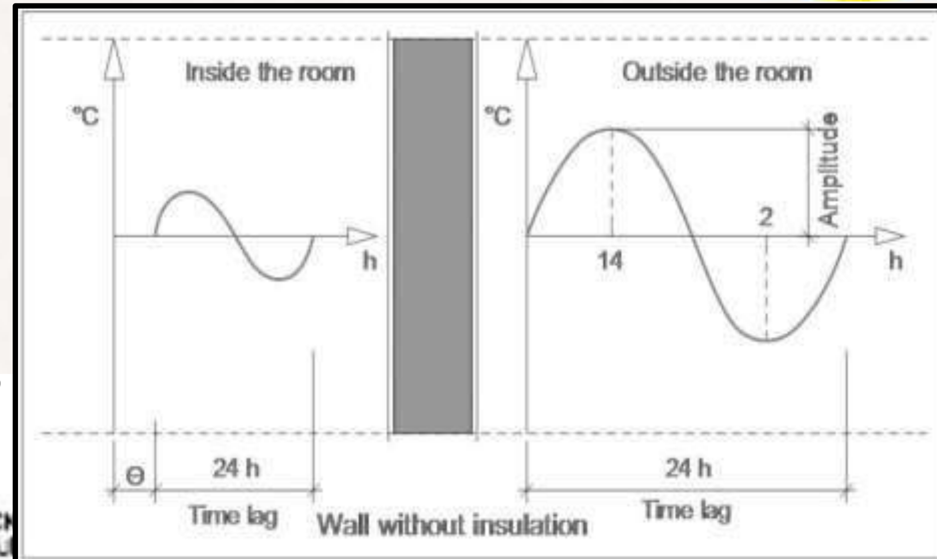



# Thermal mass or Heat storage capacity

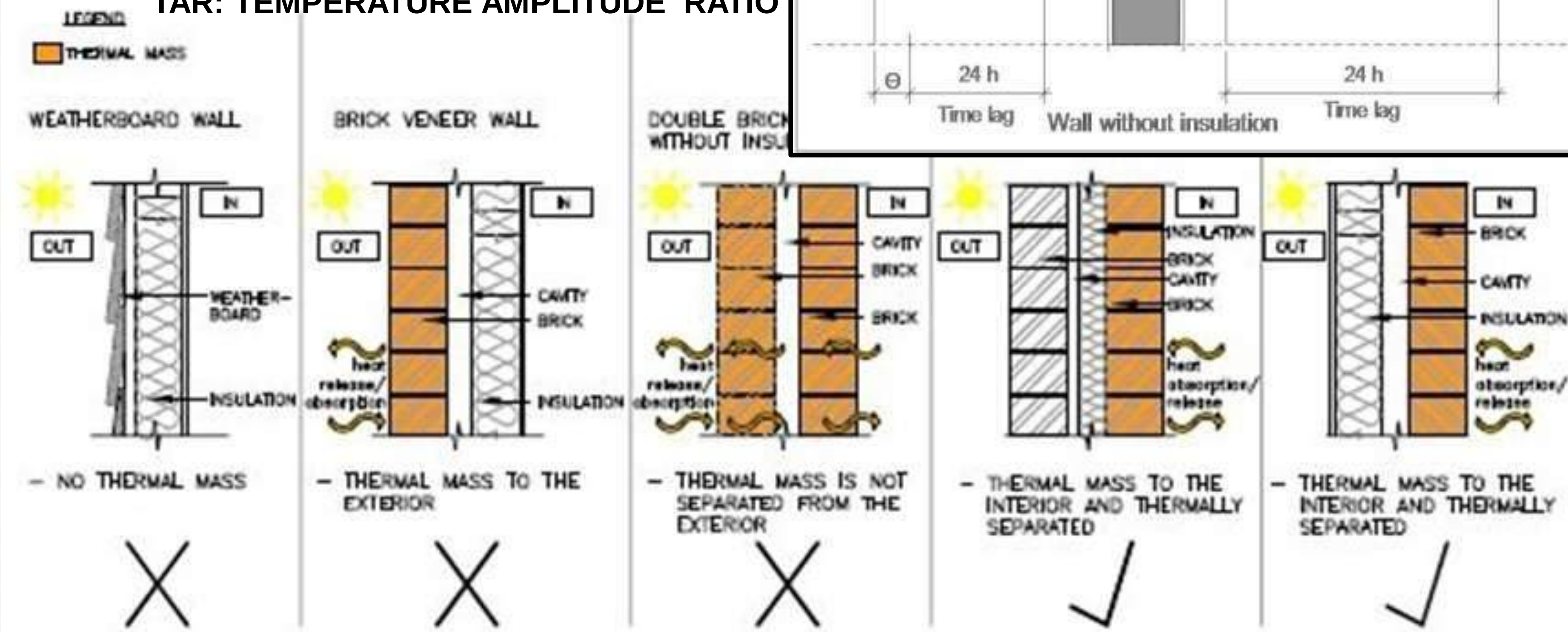
**The heat storage capacity is dependent on:**

- Material density kg/ $m^3$
- Mass per unit area kg/ $m^2$ of a component
- Specific heat storage capacity c
- Temperature difference $\Delta\theta$

TAR

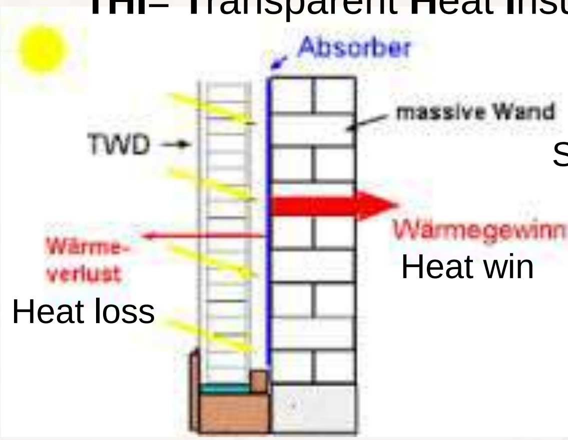


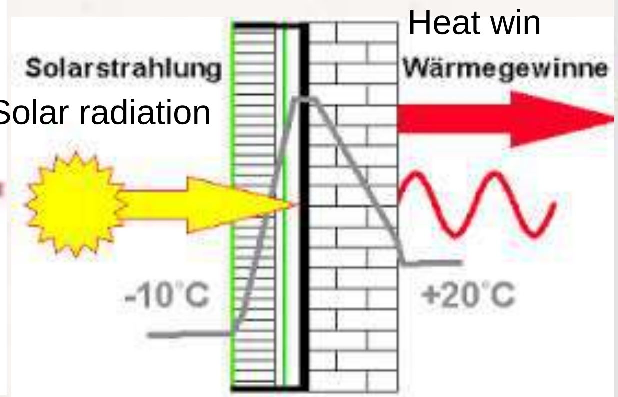

**TAR: TEMPERATURE AMPLITUDE RATIO**

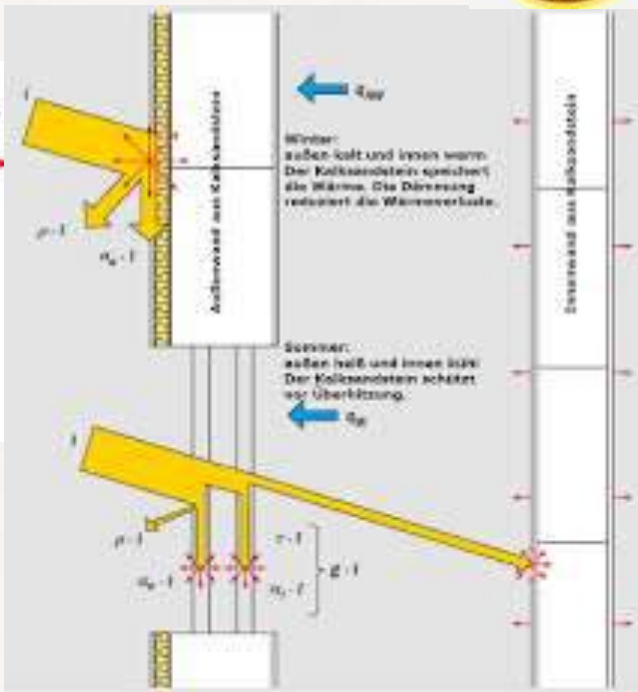


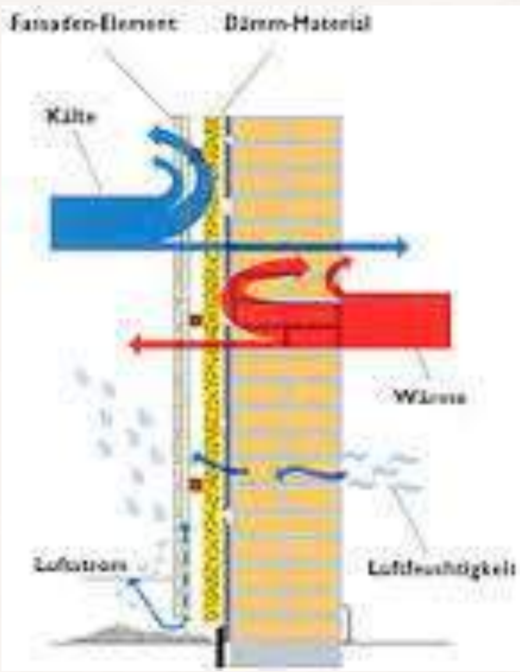
# Transparent insulation

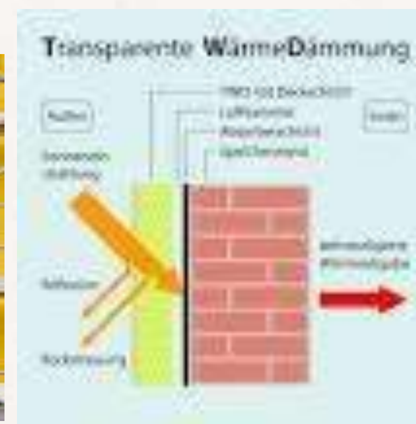
**THI**= **T**ransparent **H**eat **I**nsulation





## First method

**Θsi = θai – (Rsi x q)**

$\theta_{Si} = \theta a_i - (R_{si} \times q)$

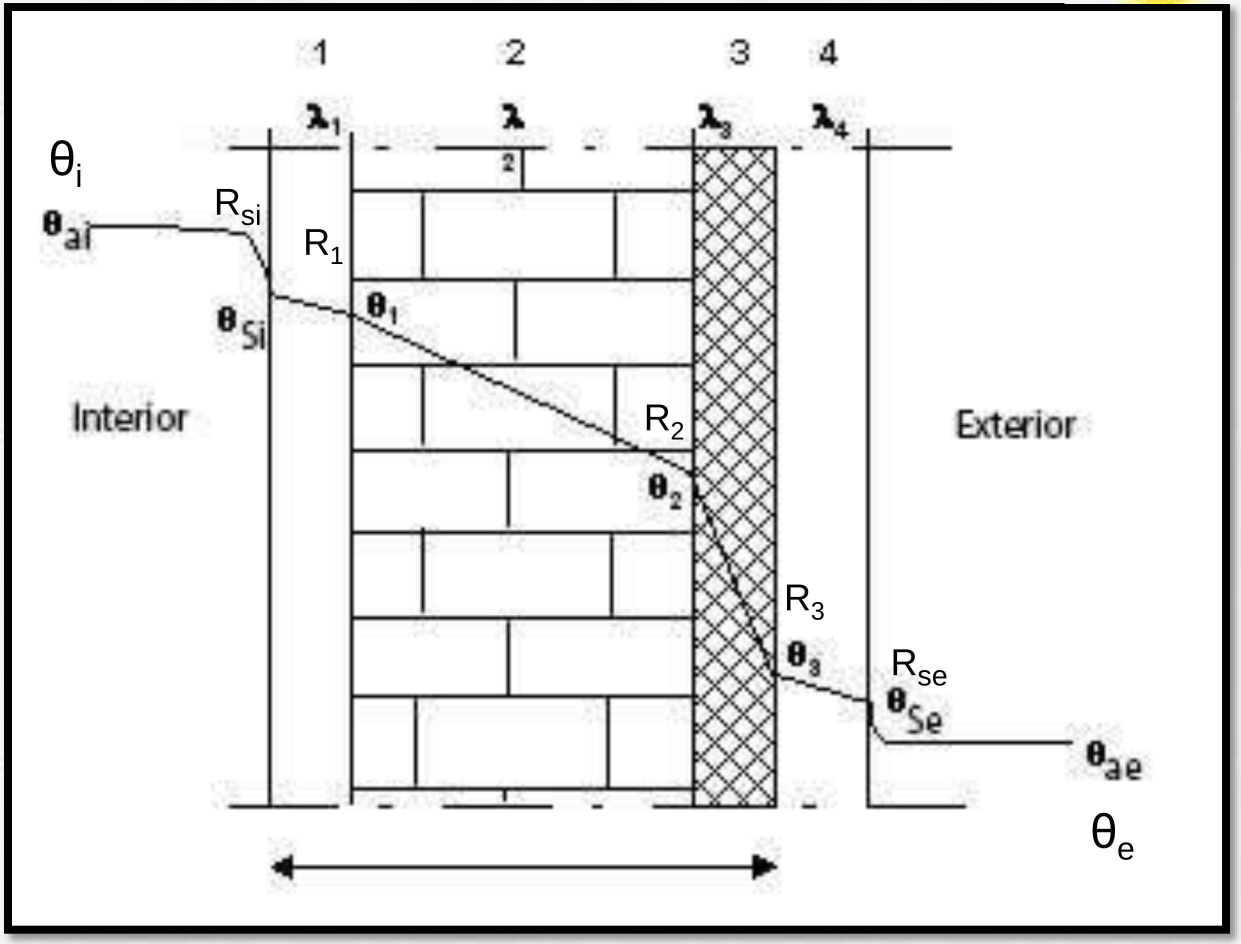
$\theta_1 = \theta_{Si} - (R_1 \times q)$

$\theta_2 = \theta_1 - (R_2 \times q)$

$\theta_3 = \theta_2 - (R_3 \times q)$

$\theta_{Se} = \theta_3 - (R_{se} \times q)$

Heat flow density $q = \Phi / A$ W/ m²




It is required for a comfortable indoor climate that the temperature difference between inside air temperature and surface temperature not more than 3 °C in winter is. But in the summer must be not more than 4 - 6 °C.

## Secound method

Determine through calculation of the **temperature profile** for an **exterior wall** of normal weight concrete (20 cm thick, λ = 2.1 W/ m . K) with an outer **insulation** from wood wool light plate (5 cm thick, λ = 0.081 W/ m . K) and 2 cm **external plaster** (λ = 0.87 W/ m . K ) and 2 cm thick **interior plaster** (λ = 0.87 W/ m . K). The outside temperature (-10 ° C), and the internal temperature of 20 °

| | - 10°C | Exterior plaster | Insulation | Wall | Interior plaster | 20°C |
|---|---|---|---|---|---|---|
| S (m) | | 0.02 | 0.05 | 0.20 | 0.02 | |
| λ (W/ m . K | | 0.87 | 0.081 | 2.10 | 0.87 | |
| S/ λ ($m^2K/W$) | 0.04 | $R_1$= 0.023 | $R_2$ = 0.617 | $R_3$ = 0.095 | $R_4$ = 0.023 | 0.13 |

R = 0.758 m² . K/ W

**$R_T$ = Rsi + (R1 + R2 + R3 + R4....Rx) + Rse m² . K/ W**

$R_T$ = 0.04 + 0.758 + 0.13 = **0.928 m² . K/ W**

**Temperature deference (Δθ)/ Temperature difference (θi & θe) = Single resistance/ Total resistance**

**Temperature deference Δθ = Temperature difference (θi & θe) x Single resistance/ Total resistance**

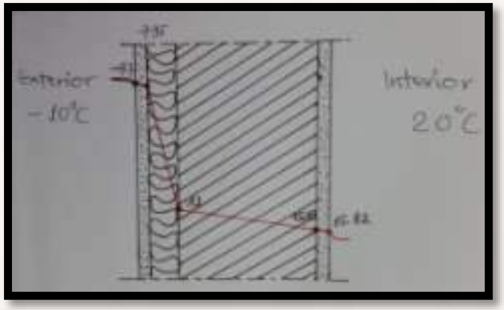
**$\Delta\theta = (\theta i - \theta e) \times R / R_T$** ⟵

**Δθ** Temperature deference in building components

**Θi – θe** Deffirence between internal & external air temperature

**Δθi** Deffirence between room temperature and wall temperature

**Δθe** Deffirence between outside temperature and wall temperature



# TEMPERATURE PROFILE IN BUILDING COMPONENTS

**$\Delta\theta = (\theta i - \theta e) \times R/ R_T$**

$\Delta\theta$ = 20 – (-10) x 0.04/ 0.928 = **1.30** **Rsi**

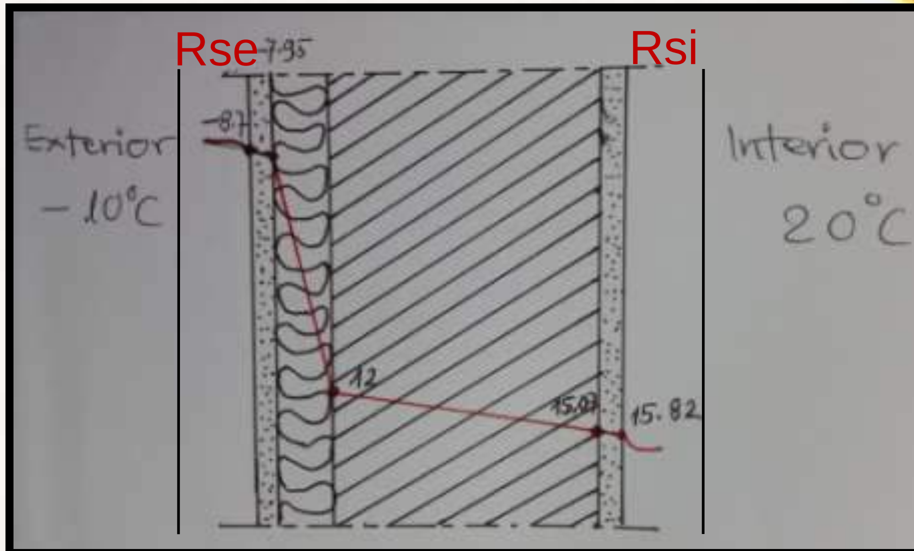
$\Delta\theta$ = 20 – (-10) x 0.023/ 0.928 = **0.75** **$R_1$**

$\Delta\theta$ = 20 – (-10) x 0.617/ 0.928 = **19.95** **$R_2$**

$\Delta\theta$ = 20 – (-10) x 0.095/ 0.928 = **3.07** **$R_3$**

$\Delta\theta$ = 20 – (-10) x 0.023/ 0.928 = **0.75** **$R_4$**

$\Delta\theta$ = 20 – (-10) x 0.13/ 0.928 = **4.20** **Rse**




| | -10 °C | External plaster | Insulation | Wall | Internal plaster | 20 °C |
|---|---|---|---|---|---|---|
| **R** | 0.04 | 0.023 | 0.617 | 0.095 | 0.023 | 0.13 |
| **Δθ °C** | 1.30 | 0.75 | 19.95 | 3.07 | 0.75 | 4.20 |
| **θ °C** | -8.7 | -7.95 | **12.00** | **15.07** | 15.82 | 20 |

The temperature on the outside of the concrete wall 15.07 ° C and on the inside of the concrete wall 12.0 ° C. The internal insulation has a good protection for the wall. The wall is quite warm and not to be cold in winter.

## Example -1-

Calculate the temperature profile for the wall from the last task if the insulation is placed on the inside of the wall.

$R_T$ = 0.04 + 0.758 + 0.13 = 0.928 m² . K/ W

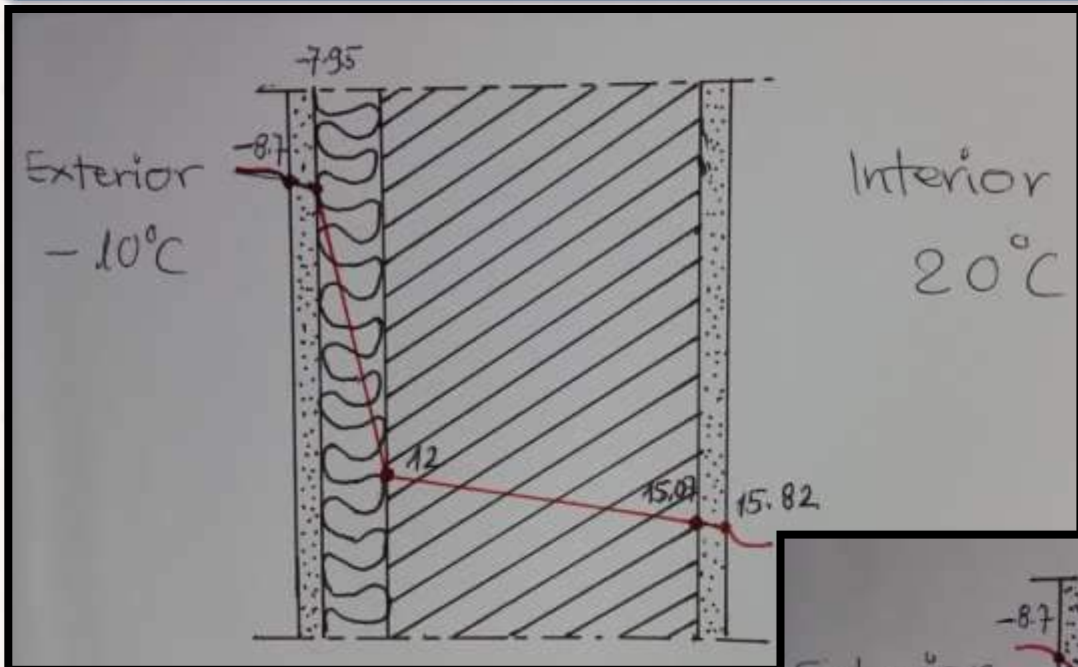
| | -10 °C | External plaster | Wall | Insulation | Internal plaster | 20 °C |
|---|---|---|---|---|---|---|
| **S** (m) | | 0.02 | 0.20 | 0.05 | 0.02 | |
| **λ** (W/ m . K | | 0.87 | 2.10 | 0.081 | 0.87 | |
| **S/ λ** (m²K/ W) | | 0.023 | 0.095 | 0.617 | 0.023 | |
| **R** (m²K/ W) | 0.04 | 0.023 | 0.095 | 0.617 | 0.023 | 0.13 |
| **Δθ °C** | 1.30 | 0.75 | 3.07 | 19.95 | 0.75 | 4.20 |
| **θ °C** | -8.7 | **-7.95** | **-4.88** | 15.07 | 15.82 | 20 |

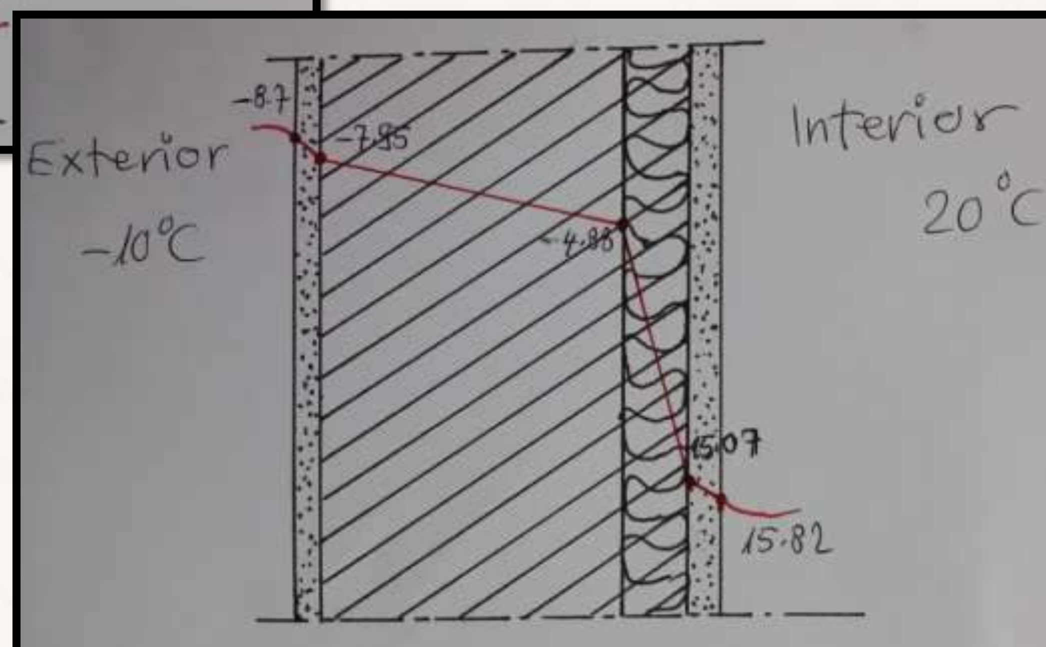
We see the temperature on the outside of the concrete wall **(-7.95)** ° C and on the inside of the concrete wall **(-4.88)** ° C. The Internal insulation has not so good protection for the wall as the exterior insulation from the last wall.

# TEMPERATURE PROFILE IN BUILDING COMPONENTS

DR. SALAHDEN GHAREB KADR

FOURTH LECTURE

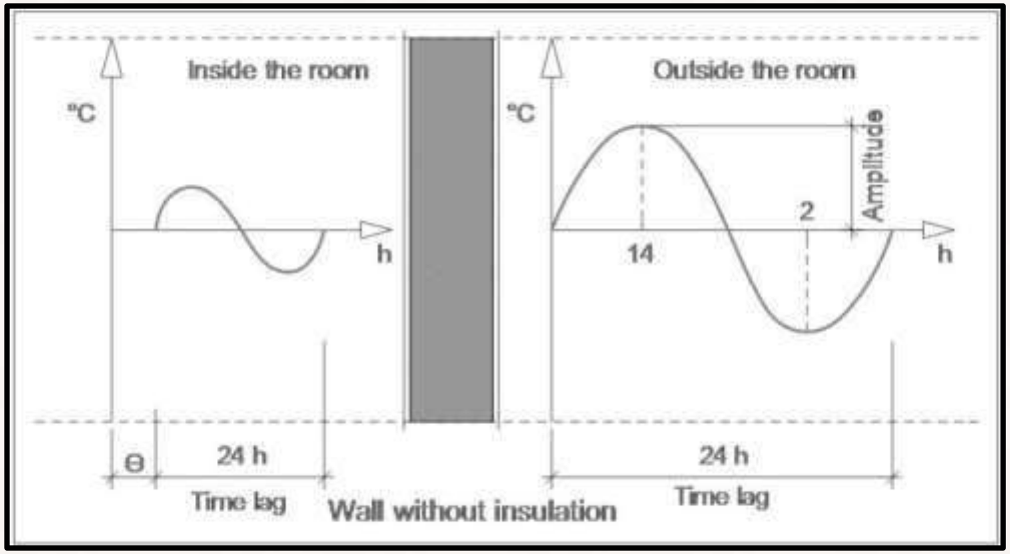


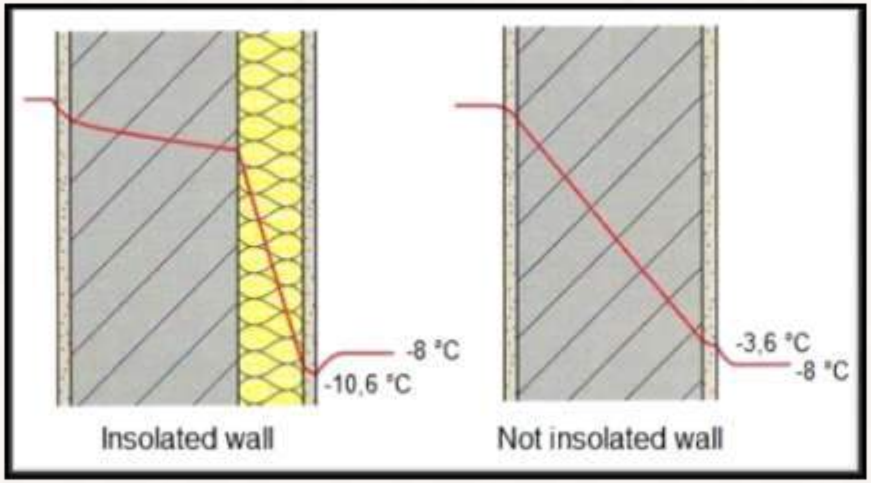
# TEMPERATURE AMPLITUDE RATIO (TAR)

The temperature profile of the outside air is not constant during a day and night phase. Naturally this outdoor temperature fluctuation affects the temperature profile in the building component and in the interior of the building during a day and night phase.

The TAR of a building component is described as good, when the room temperature fluctuation is less than the ambient temperature fluctuation of the outside air, as you see in the adjacent figure.

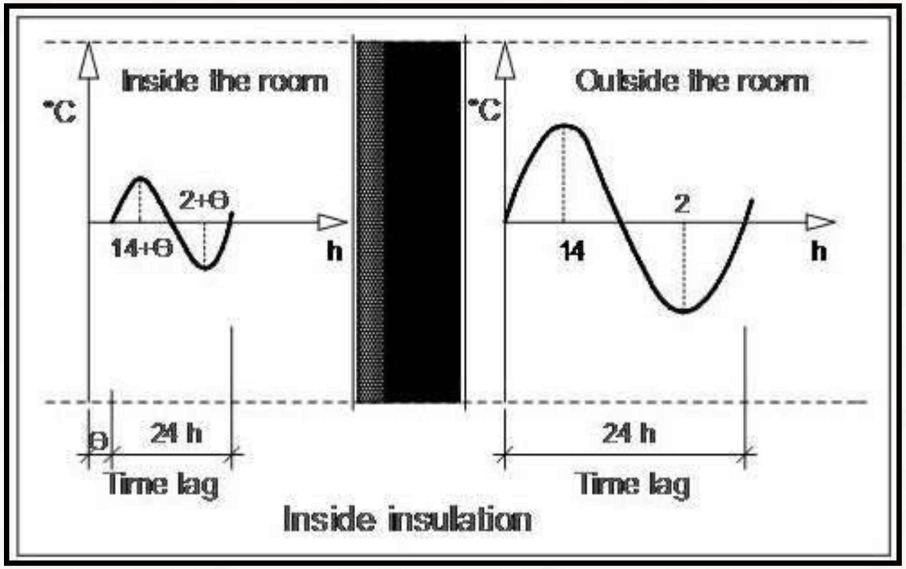


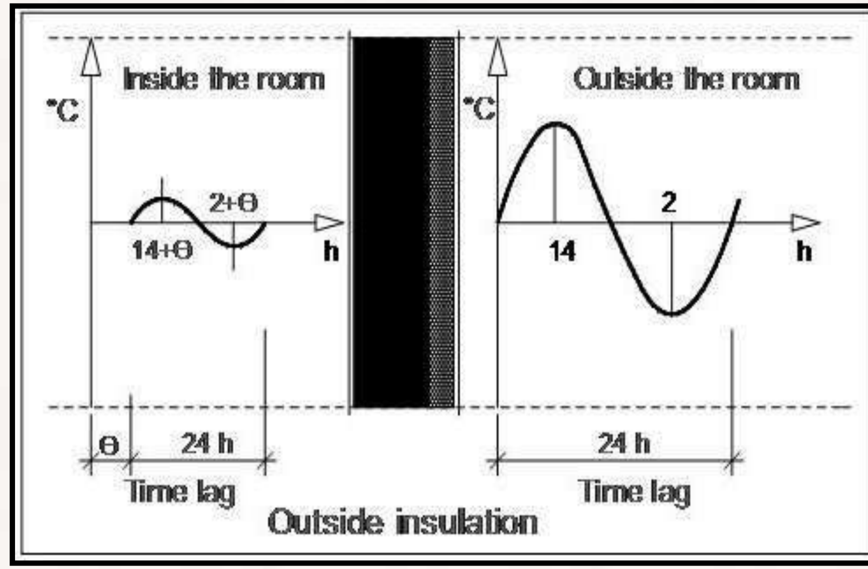

This is possible when the space-enclosing components have a good **Heat storage capacity**. It means lying outside insulation of the building components has better TAR as inside laying thermal insulation.



DR. SALAHDEN GHAREB KADR

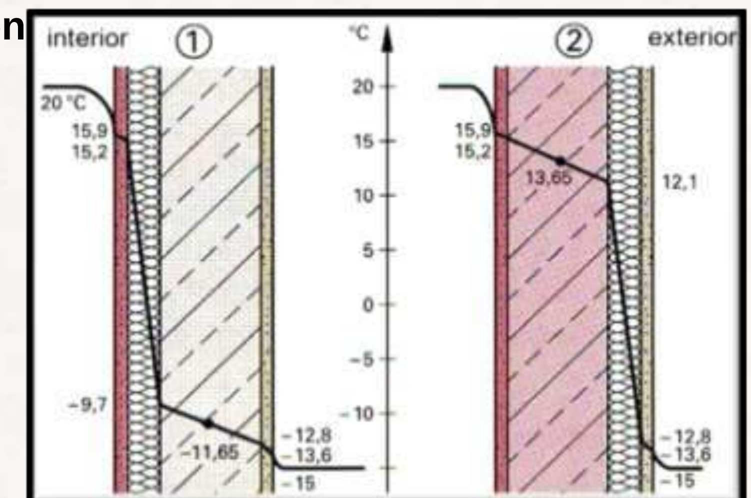





**In general, internal insulation is not good**

- The plaster is the only heat storage mass.
- Relatively high room temperature, but less TAR difference.
- Low Time lag, only 3 hours




**External insulation is good and better**

- Plaster and masonry serve as heat storage.
- Inside Temperature is essential lower than the outside temperature.
- Lounge Time lag, more than 8 hours.

## Temperature factor ($f_{Rsi}$)

The inside surface temperature in the room can be calculated with the **Temperature factor $f_{Rsi}$** as in the following equation:

$f_{Rsi}$ = θsi - θe/ θi - θe

This factor has not unit

| | | |
|---|---|---|
| Θsi : | Inside surface temperature | (Theta-Surface temperature) |
| Θe : | Outside air temperature | (Theta-External temperature) |
| Θi : | Inside air temperature | (Theta-Internal temperature) |

**Temperature factor $f_{Rsi}$ may not be less than the following value:**

$f_{Rsi} \geq 0.7$

**This corresponds to the boundary conditions given below of a room-side surface temperature of Θsi 12.6 °C.**

If this factor less than 0.7, drops the temperature on the inside surface of the room. This leads to water condensation on the surface and damage the building components.

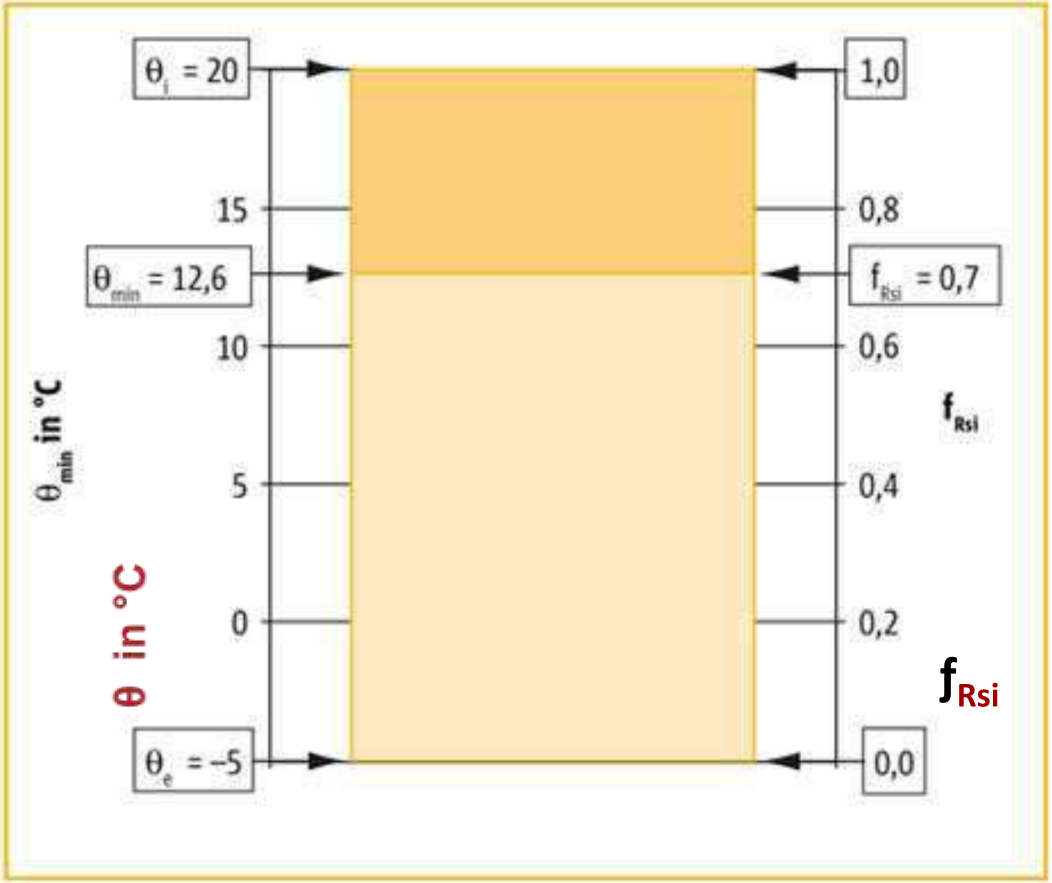
The minimum requirement of the unfavorable agency must be met in this way:

$\Theta_{si} \geq 12.6\ °C$

With due regard to the following conditions, the limit of the room-side surface temperature is maintained:

$f_{Rsi} \geq 0.70$

**Temperature factor characterize the room-side surface temperature in the buildings. It is very important for the prevention of mold formation.**




**The larger the temperature factor as 0.7, the better the thermal insulation in the room**

## Example -8-

Please calculate the temperature factor of this room:

Θsi = 12.5 °C Internal surface temperature

Θe = -5.0 °C outside air temperature

Θi = 20.0 °C Inside air temperature

The calculation of the room-side surface temperature in °C performance by switching the Temperature factor equation:

$$\Theta si = f_{Rsi} \times (\theta i - \theta e) + \theta e \quad °C$$

$$f_{Rsi} = \theta si - \theta e / \theta i - \theta e = 12.5 - (-5) / 20 - (-5)$$

$$= 0.68 < 0.70$$ ( It is unfavorable )

## Example -9-

Reinforced concrete cantilever slab with thermal separation in the area of external wall insulation.

Please calculate the **temperature factor $f_{Rsi}$** of this building components:

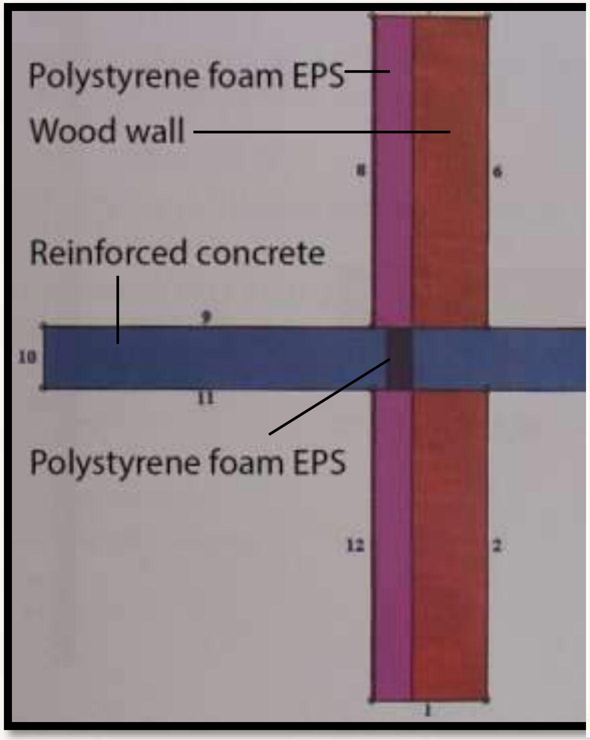
Θsi = 18.5 °C Internal surface temperature

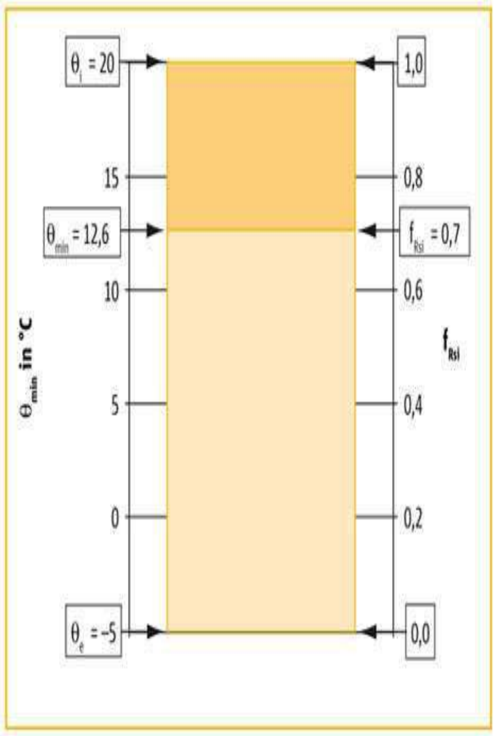
Θe = -5.0 °C outside air temperature

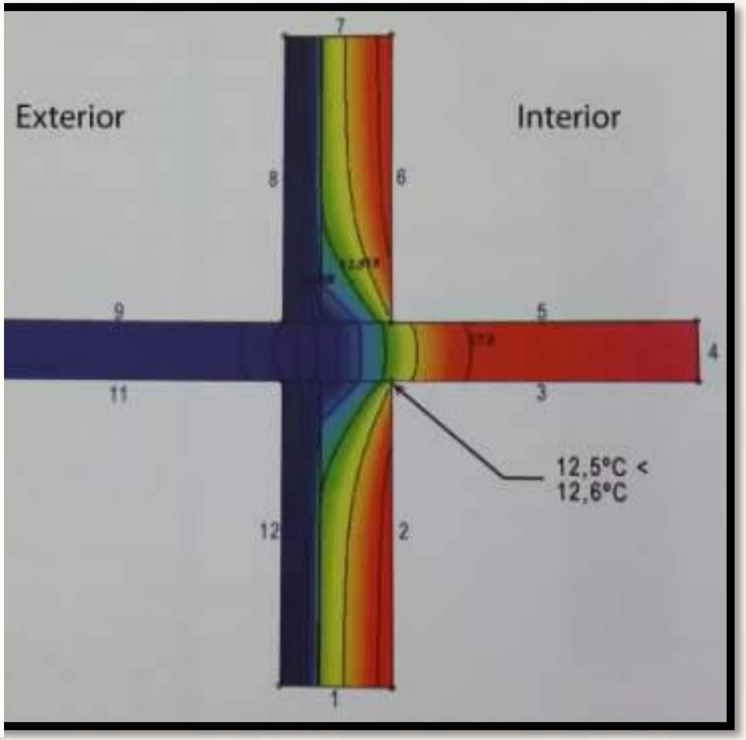
Θi = 20.0 °C Inside air temperature

$$f_{Rsi} = \theta si - \theta e / \theta i - \theta e = 18.5 - (-5) / 20 - (-5)$$

$$= 0.94 > 0.70$$ ( It is favorable )


Polystyrene foam EPS
Wood wall
Reinforced concrete
Polystyrene foam EPS


θi = 20
15
θmin = 12,6
10
5
0
θe = -5
θmin in °C
1,0
0,8
fRsi = 0,7
0,6
fRsi
0,4
0,2
0,0


Exterior
Interior
12,5°C <
12,6°C

## Thermal diffusivity (a) $m^2/s$

**Thermal diffusivity** measures the ability of a material to conduct thermal energy relative to its ability to store it. It means this factor describes the relation between **Heat conduction** and **Heat storage**. This means it shows the ability of a substance to conduct the heat, to insulate or to absorb. This relationship is with this equation clarified:

**Heat conduct λ (Thermal insulation) to Heat absorption (Heat storage) c . ρ**

**$a = \lambda / c \cdot \rho$ $m^2/s$ or $mm^2/s$**

| | |
|---|---|
| λ : Thermal conductivity | W/ m . K |
| c : Specific heat or thermal capacity | J/ kg . K |
| ρ : specific density | $kg/m^3$ |

The smaller the value of the **thermal diffusivity a**, the better reacts the building material in the summer heat protection in the building.

**Heat storage property of building materials is very important for the buildings not only in the hot and dry zone of the Region, but also for moderate climate**

## Heat penetrating coefficient (b)

The **Heat penetration coefficient (b)** tells how much heat in Ws per m² . K can penetrate in to a material.

We can get this factor during the following formula:

$$b = \sqrt{\lambda . c . \rho}$$

| | | |
|---|---|---|
| **λ** : | Thermal conductivity | W/ m . K |
| **c** : | Specific heat capacity | J/ kg . K |
| **ρ** : | specific Density | kg/ m³ |

**Large heat penetrating coefficient (b):**

To much heat penetrates in a unit of time in to the fabric and little is available to heat the room air. Like Steel, Aluminium and Concrete. Etc…

**Small heat penetrating coefficient (b):**

Little heat penetrates in a given unit of time in the material. In addition, more heat energy is available for heating the ambient air. For the foot warm with heating floors and walls, this factor is very importance. Like Wood, Cork and Linoleum.

**Bulk density** and **mass**, essentially determines the storage capacity of a substance. The more heavy the building components are, the longer it takes time to heat up a room and it cools slower.

**Heat storage capacity is to consider especially by heating processes in the summer**

# a- and b- value of some building materials

| Thermal diffusivity (a) | $m^2/s$ | نرخی یا فاکتەری گەیاندنی پلەی گەرمی |
|---|---|---|
| **Building materials** | **Heat penetrating coefficient (b) $J/m^2Ks^{0.5}$** | **Thermal diffusivity (a) $10^6 . m^2/s$** |
| Concrete | 2245 | 1.00 |
| Light concrete | 930 | 0.54 |
| Cement screed stone | 1670 | 0.70 |
| Gypsum | 1250 | 0.20 |
| Lime | 1017 | 7.67 |
| Wood | 300 | 0.15 |
| Glas | 1500 | 0.90 |
| **Steel** | **13000** | **14.00** |
| Calcareous sand stone CSS | 1100 | 0.60 |
| Mineral wool | 35 | 0.80 |
| Solid brick | 1100 | 0.40 |
| Extruded polystyrene foam XPS | 35 | 0.20 |

# Material density & Heat penetrating coefficient



| Materials | Density ρ Kg/ $m^3$ | Specific heat capacity c kJ/Kg. K | Thermal conductivity λ W/m. K | Thermal diffusivity a $106^{6}$ . $m^2$/ s | Heat penetraition coefficient b J/ $m^2$ $Ks^{0.5}$ |
|---|---|---|---|---|---|
| Glass | 2500 | 750 | 1.00 | 0.90 | 1500 |
| Wood | 700 | 1600 | 0.18 | 0.15 | 400 |
| Wood fibre board | 150-250 | 1400 | 0.035-0.065 | 0.16 | 92 |
| Polystyrene Foam XPS | 20-65 | 1450 | 0.025-0.040 | 0.34 | 27 |
| **Steel & other metals** | **7800** | **400** | **50.00** | **16.00** | **13735** |
| Gypsum | 1300 | 1000 | 0.58 | 0.20 | 1250 |
| Linoleum | 1200 | 1400 | 0.17 | 0.12 | 534 |
| Brick Masonry | 1400 | 1000 | 0.58 | 0.40 | 900 |
| Calcareous sandstone | 1600 | 1000 | 0.79 | 0.60 | 990 |
| Cement block | 2000 | 1000 | 2.10 | 1.05 | 2049 |
| Cement screed stone | 400 | 1000 | 1.40 | 0.70 | 1670 |
| Concrete | 2000 | 1000 | 1.35 | 1.00 | 2245 |
| Reinforced concrete | 2300 | 1000 | 2.30 | 1.07 | 2300 |
| Thermo stone | 600 | 1000 | 0.24 | 0.40 | 340 |
| Air | 1.23 | 1000 | 0.025 | 20.00 | 14.00 |
| Cork | 90-140 | 1700 | 0.041-0.056 | 0.11 | 160 |
| Water | 1000 | 4200 | 0.60 | 1.6 | 1630 |
| Marble | 2800 | 1000 | 3.50 | 1.35 | 2504 |

# FINISH

**Thank you for your attention**