



European Council
of
Civil Engineers



REPUBLIC OF BULGARIA
Minister of Regional Development and Public Works



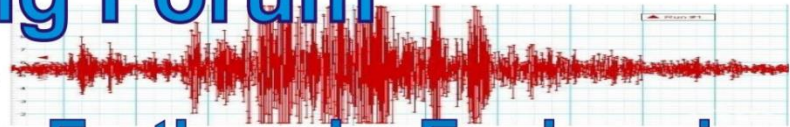
European Council
of Engineers Chambers

BEF
2021

Building Engineering Forum

20-21 October 2021, Sofia, Bulgaria

International Conference on Earthquake Engineering



INFLUENCE OF RC WALLS ON THE ENERGY EFFICIENCY OF BUILDINGS

Prof. Meri Cvetkovska

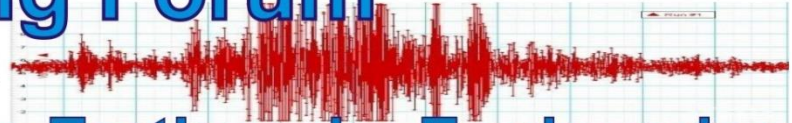
Ss. Cyril and Methodius University in Skopje, North Macedonia



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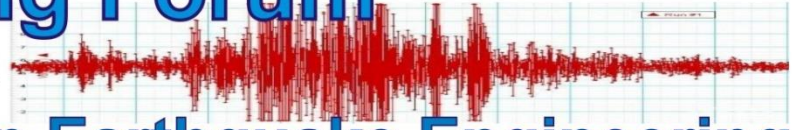


Integrated building design is a comprehensive approach which brings together all profiles of designers that have to be involved in the design process:

- ✓ architects,
- ✓ structural engineers,
- ✓ passive solar building designers,
- ✓ HVAC system engineers.

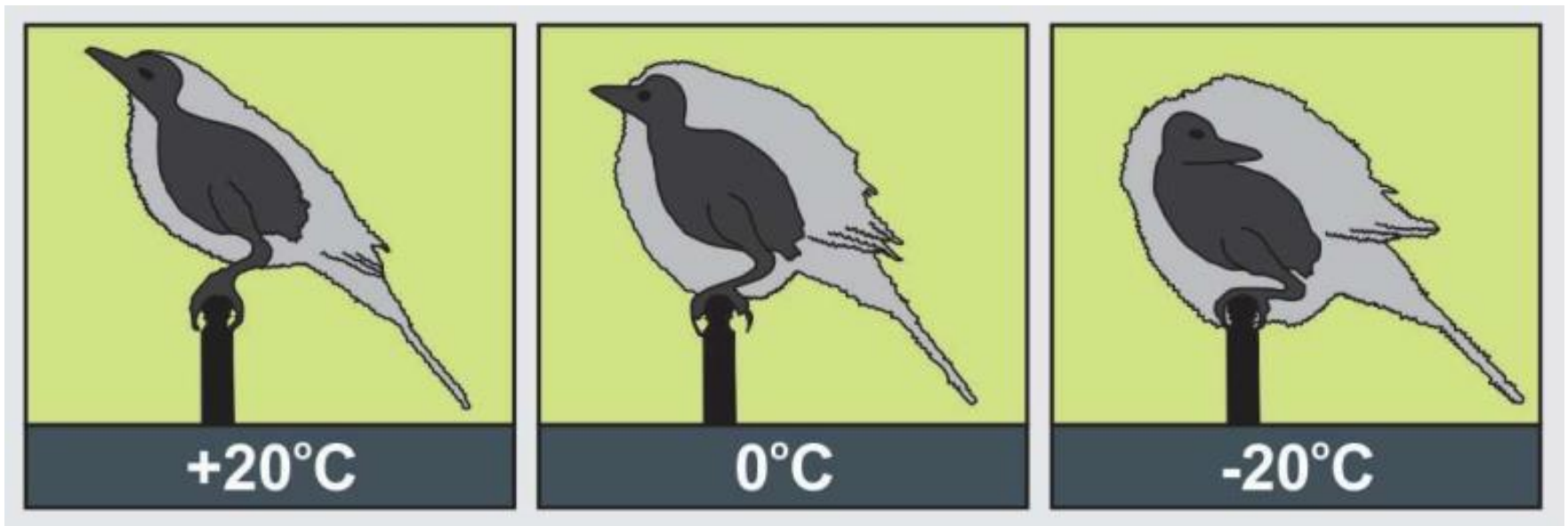
This approach develops solutions to problems by involving the **human perspective** in all steps of the problem-solving process.

The aim of the integrated building design is to produce sustainable structures

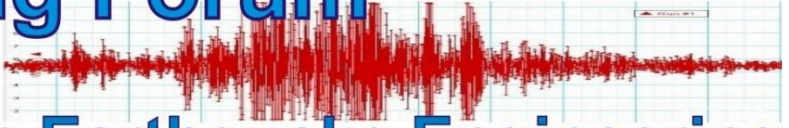


One of the aspects that has to be considered as part of the
Integrated building design is

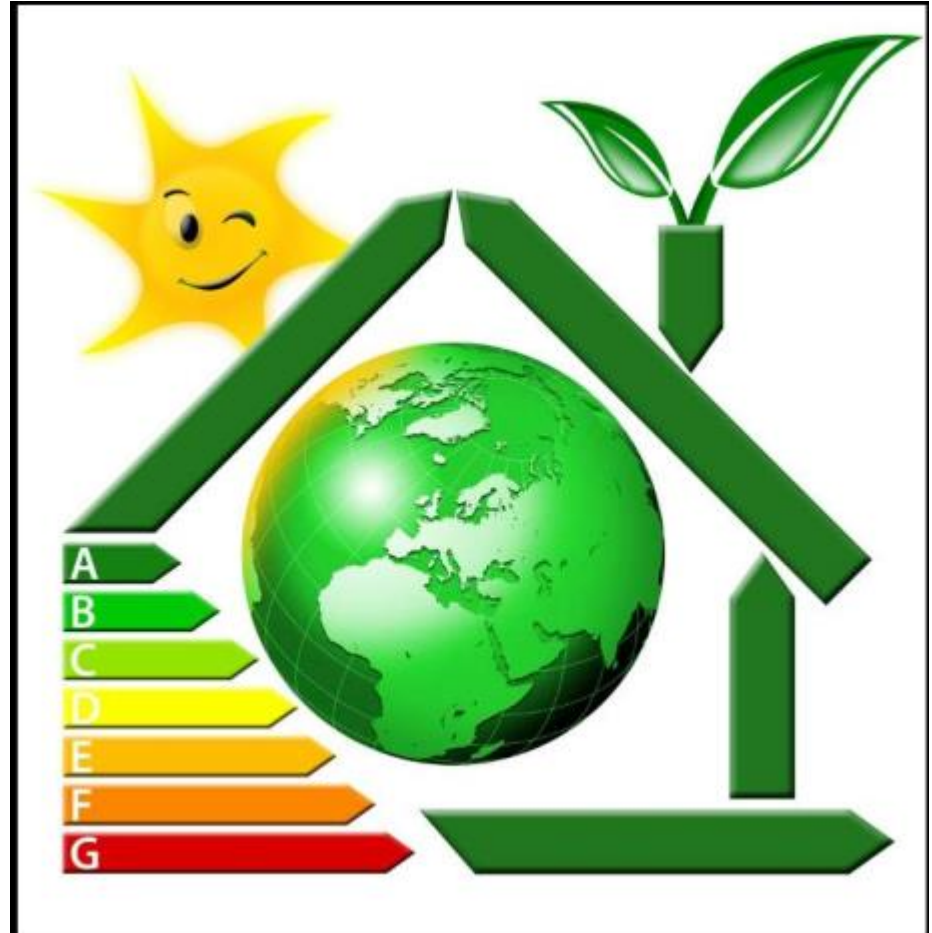
Energy efficiency of the buildings



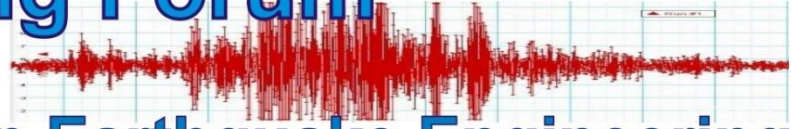
**A combination of a high level of comfort and
low energy consumption**



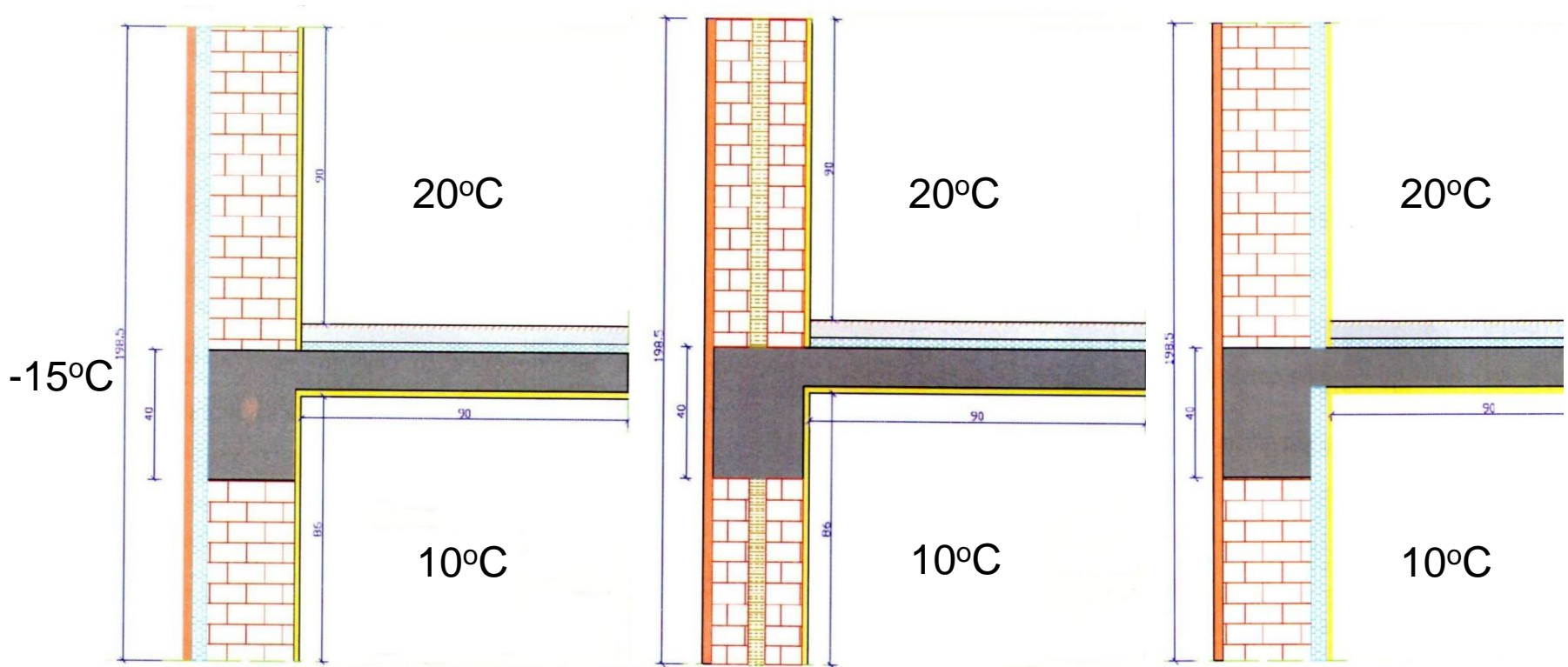
REDUCITION OF
ENERGY LOSSES
IS THE FIRST
STEP FOR
IMPROVING THE
ENERGY
EFFICIENCY OF
BUILDING



PROPER DESIGN OF BUILDING ENVELOPE



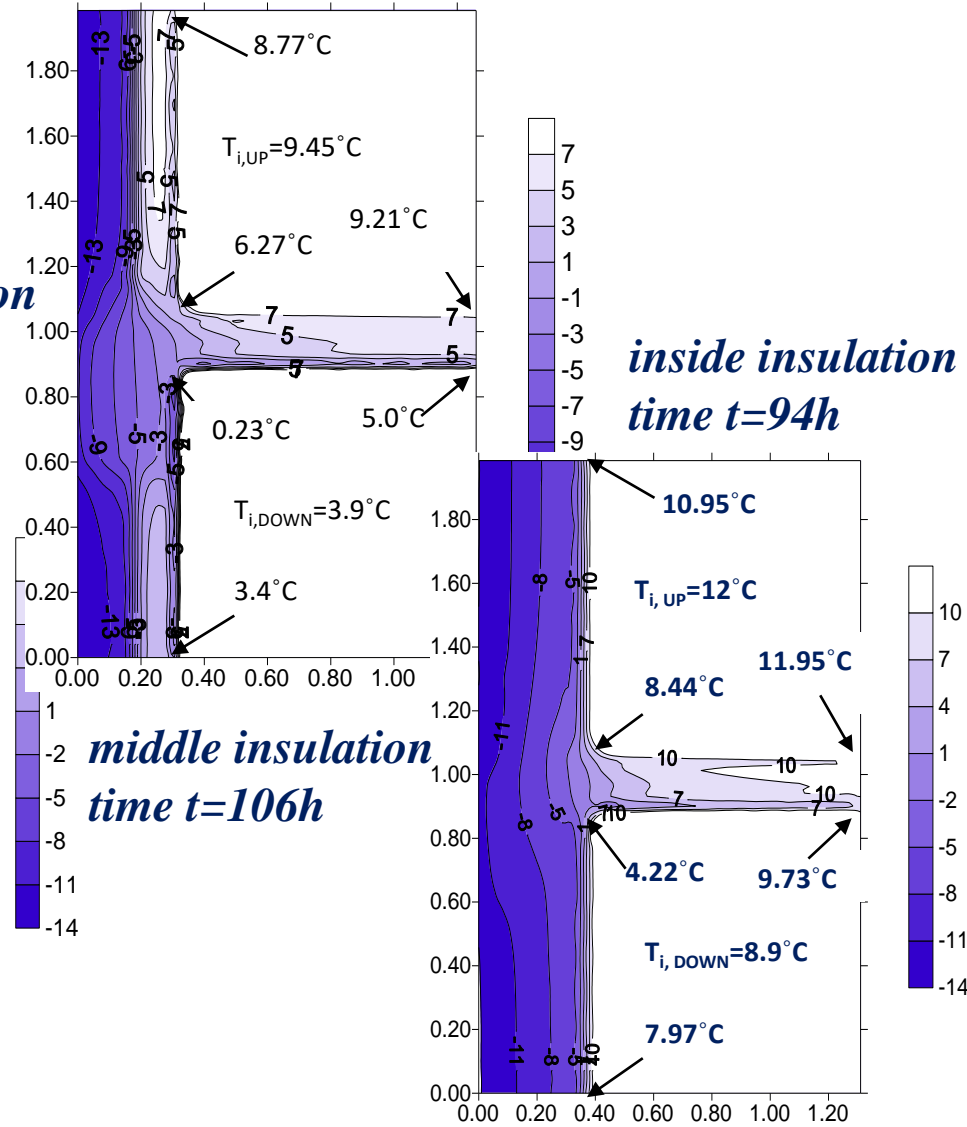
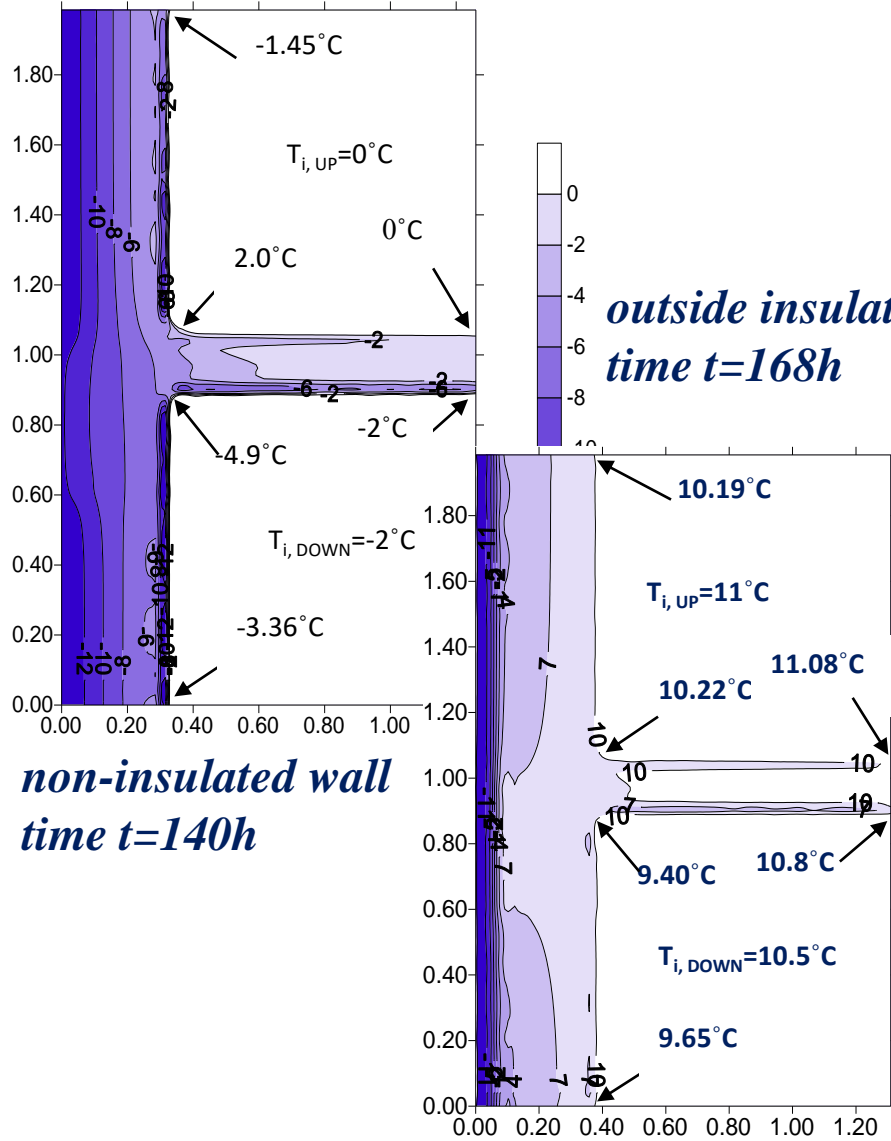
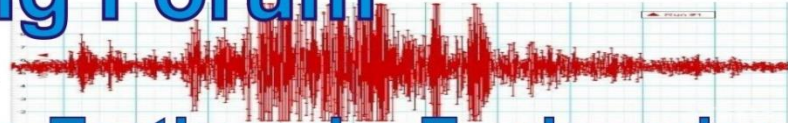
INFLUENCE OF BUILDING ENVELOPE ON ENERGY CONSUMPTION

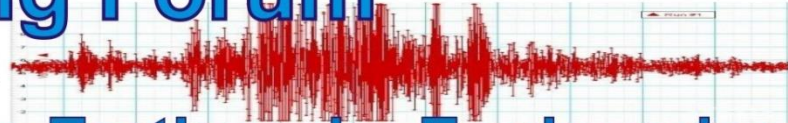


a) outside insulation

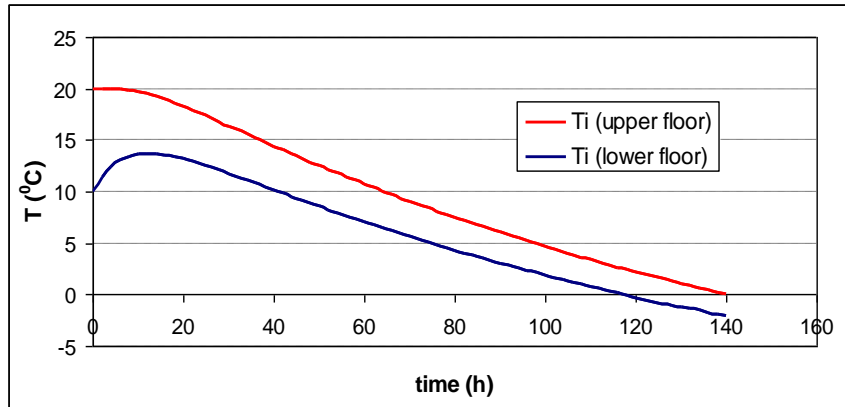
b) insulation in the middle

c) inside insulation

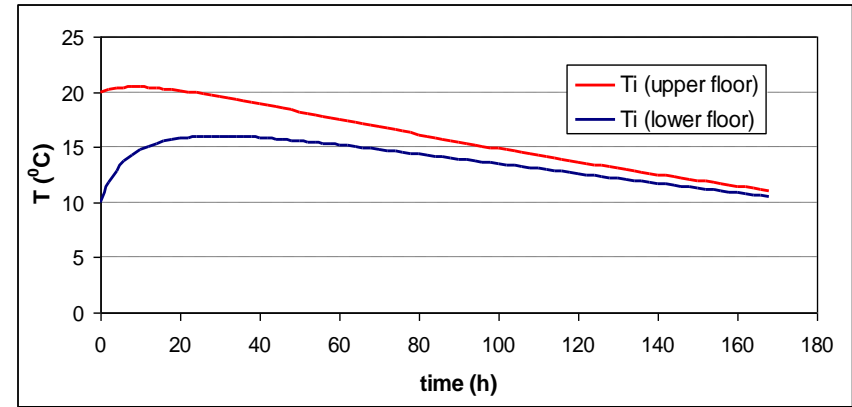




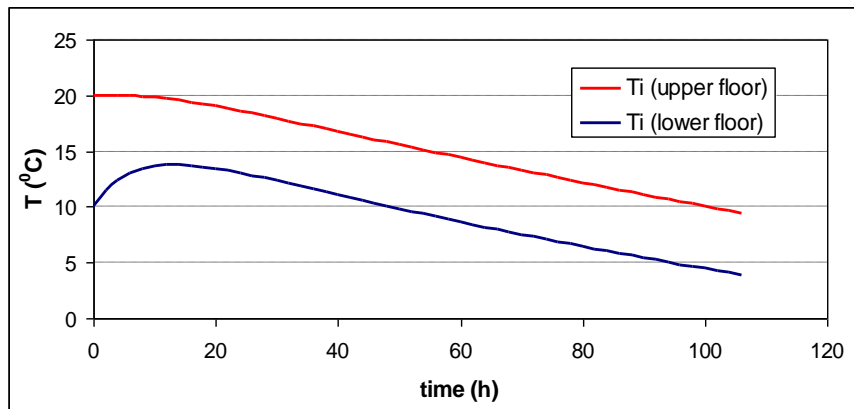
Time-temperature diagrams:



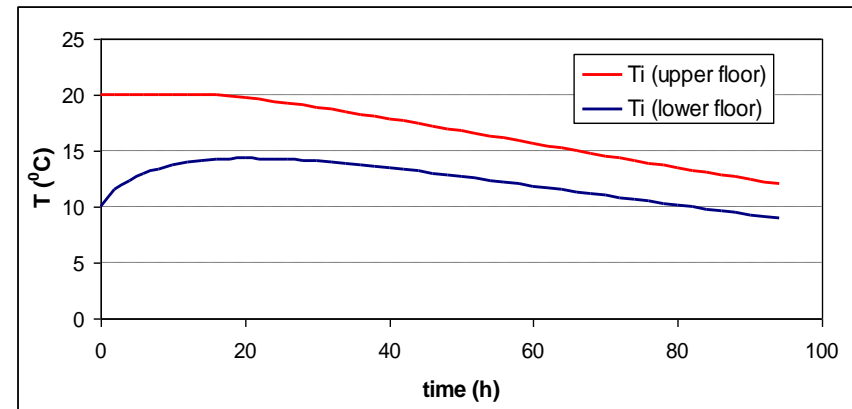
wall without insulation



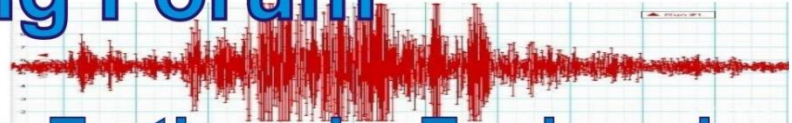
outside insulation



insulation in the middle

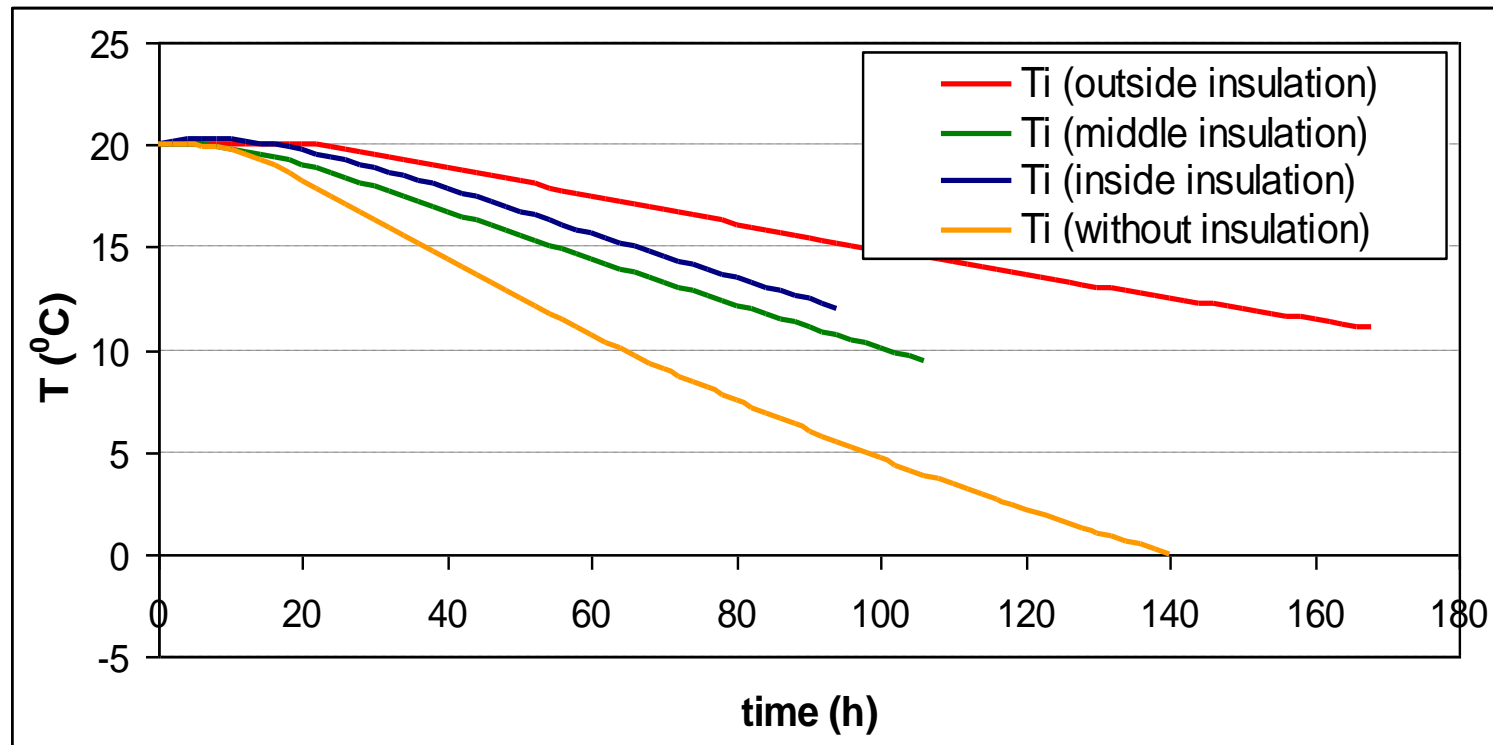


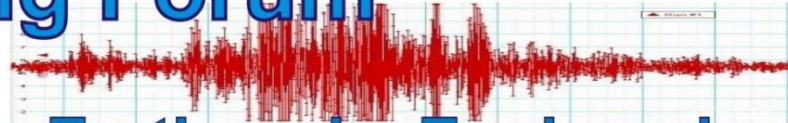
inside insulation



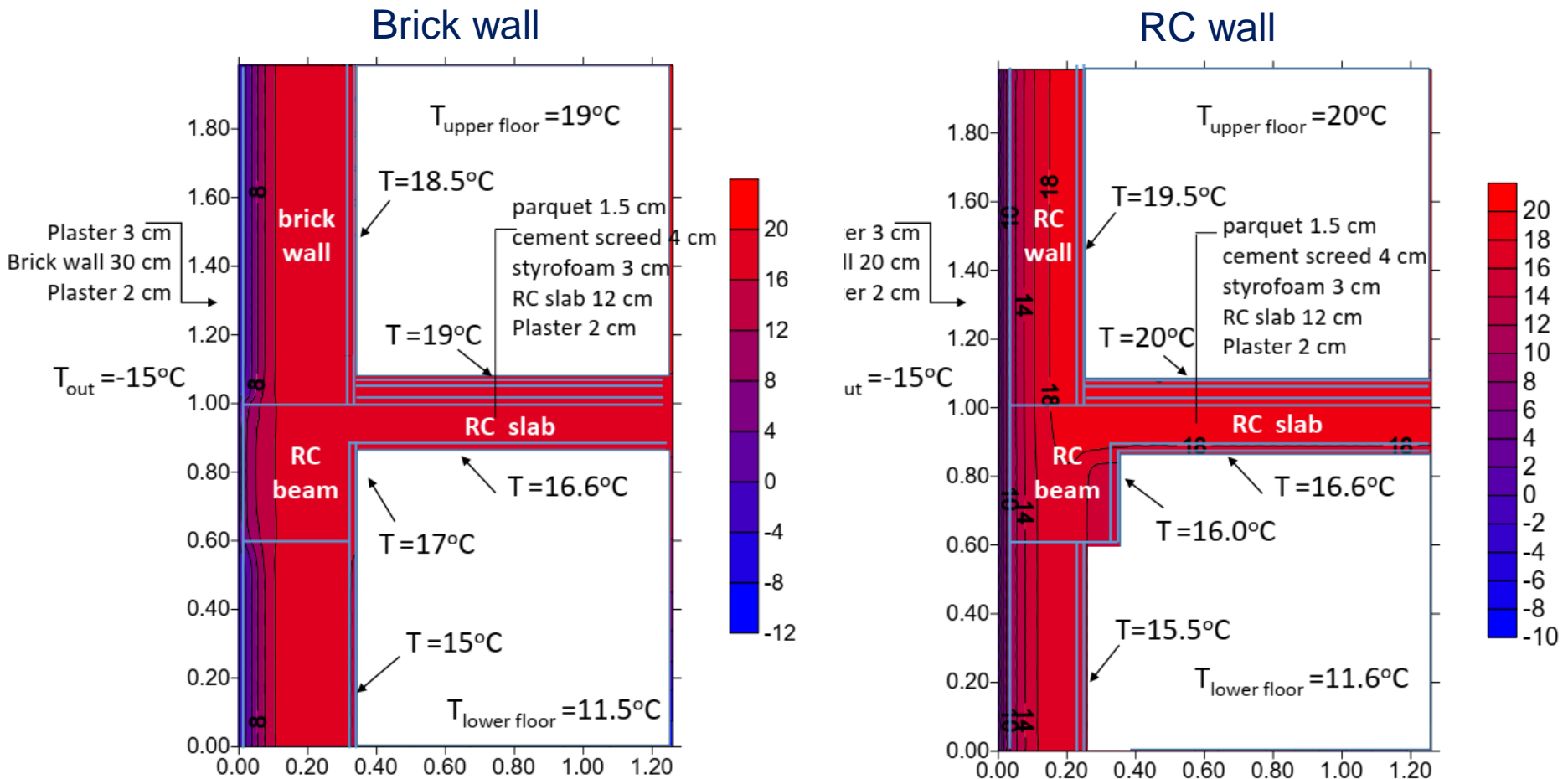
COOLING PHASE OF THE STRUCTURE

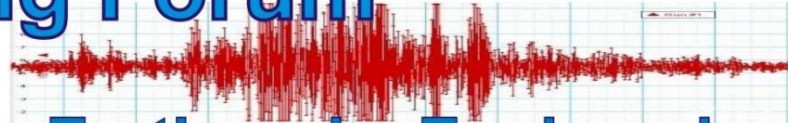
Comparison of the time for cooling of the upper room, depending on the location of the thermal insulation



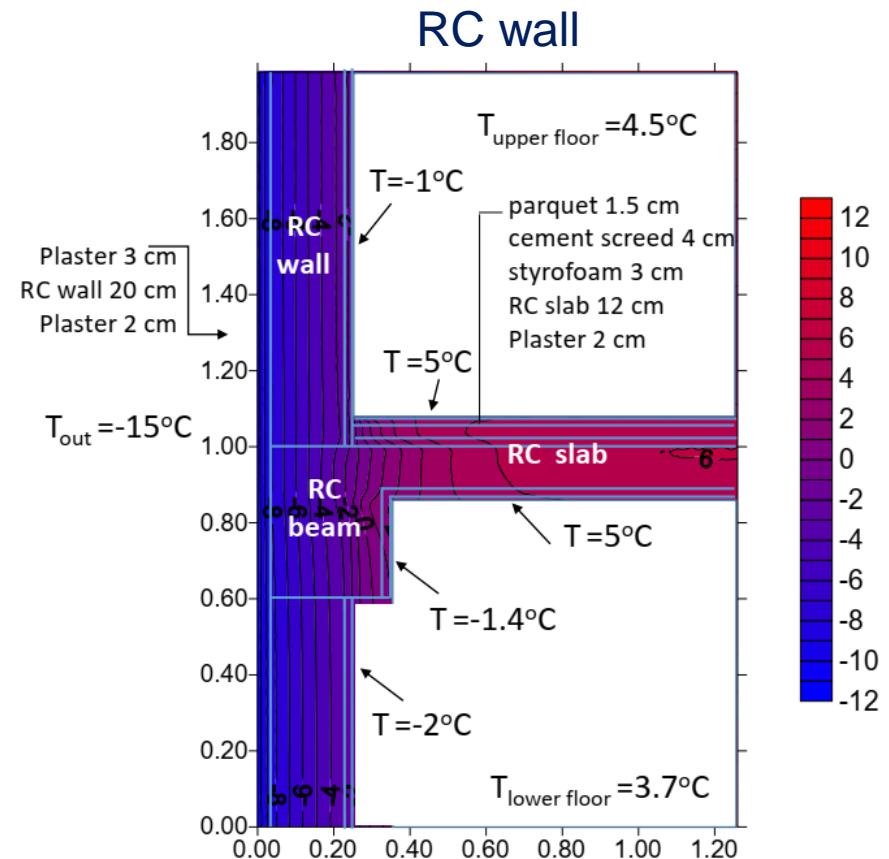
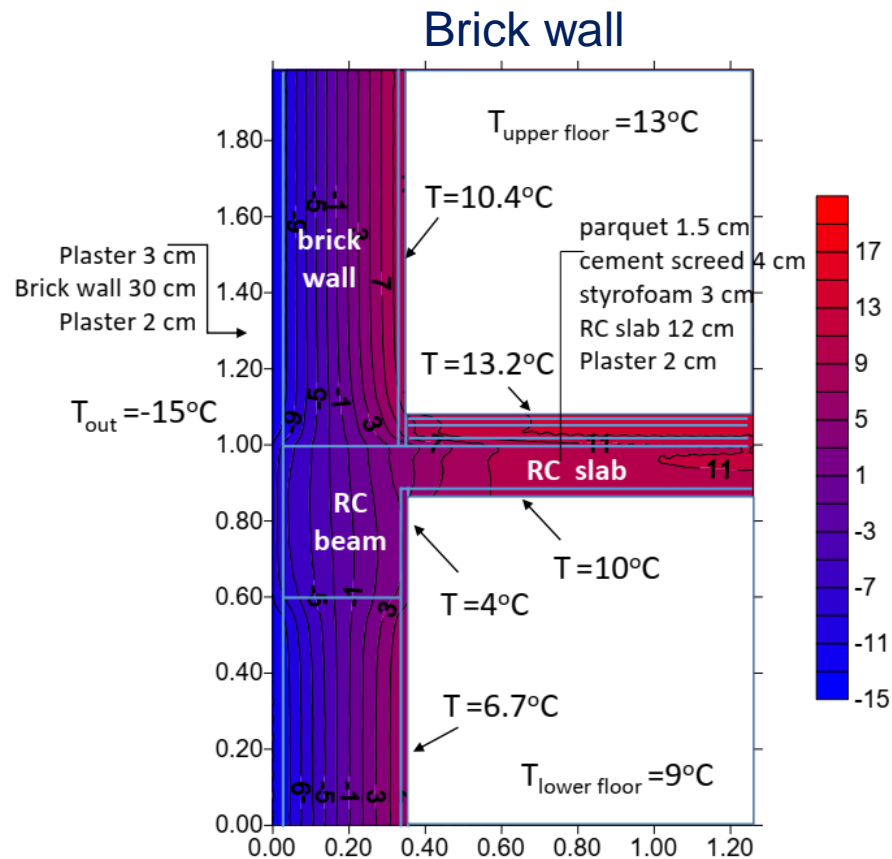


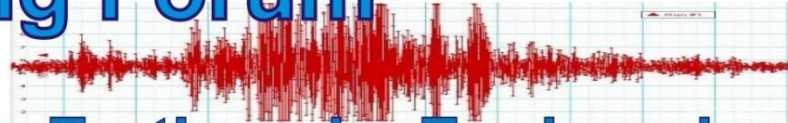
Comparison of building temperatures at moment $t=2$ hours, in case of building envelope without thermal insulation





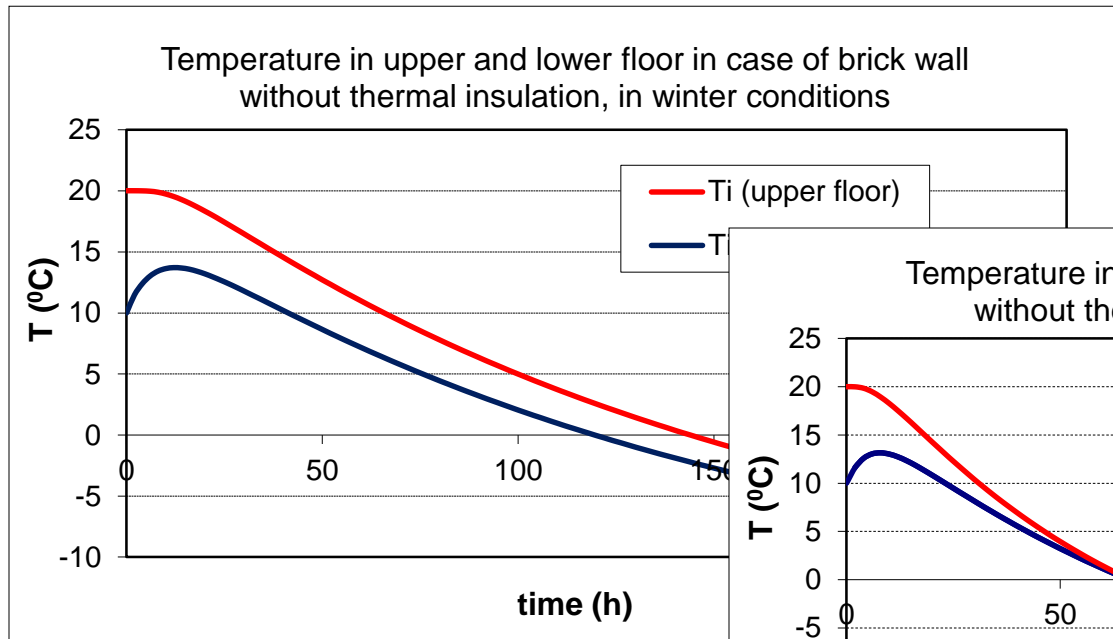
Comparison of building temperatures at moment $t=48$ hours, in case of building envelope without thermal insulation



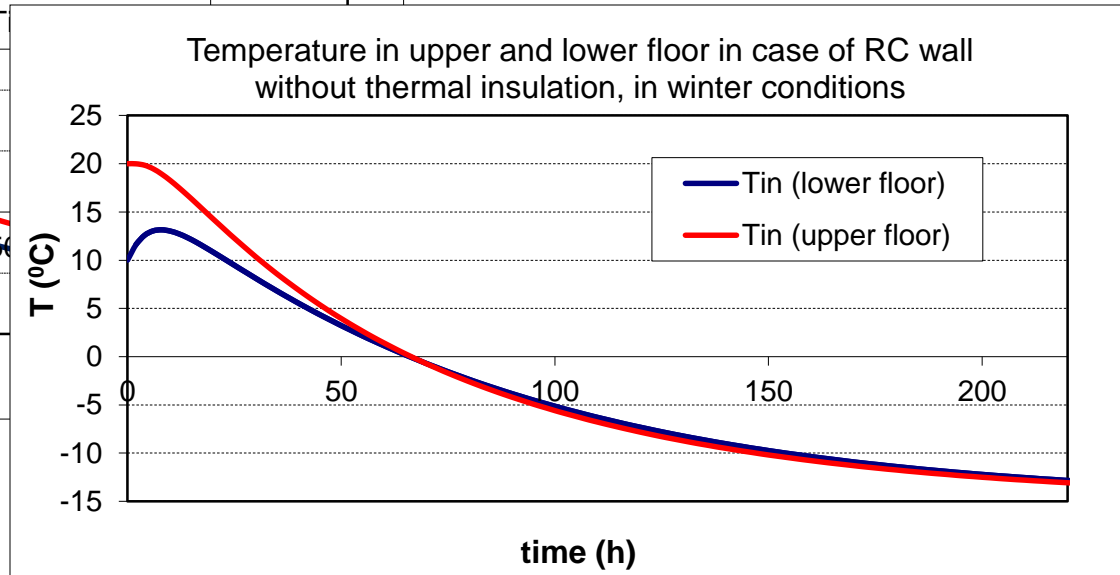


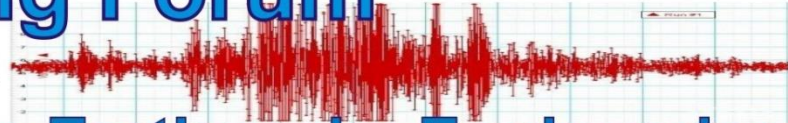
Comparison of cooling phase in case of building envelope without thermal insulation, in winter conditions

Brick wall



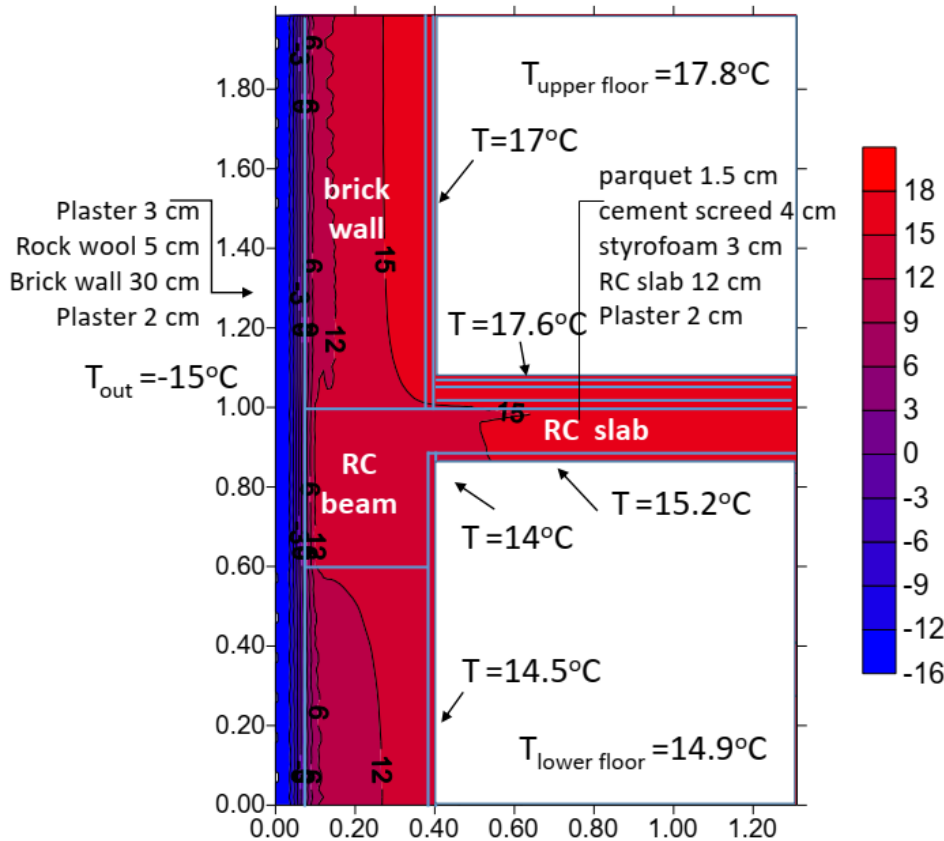
RC wall



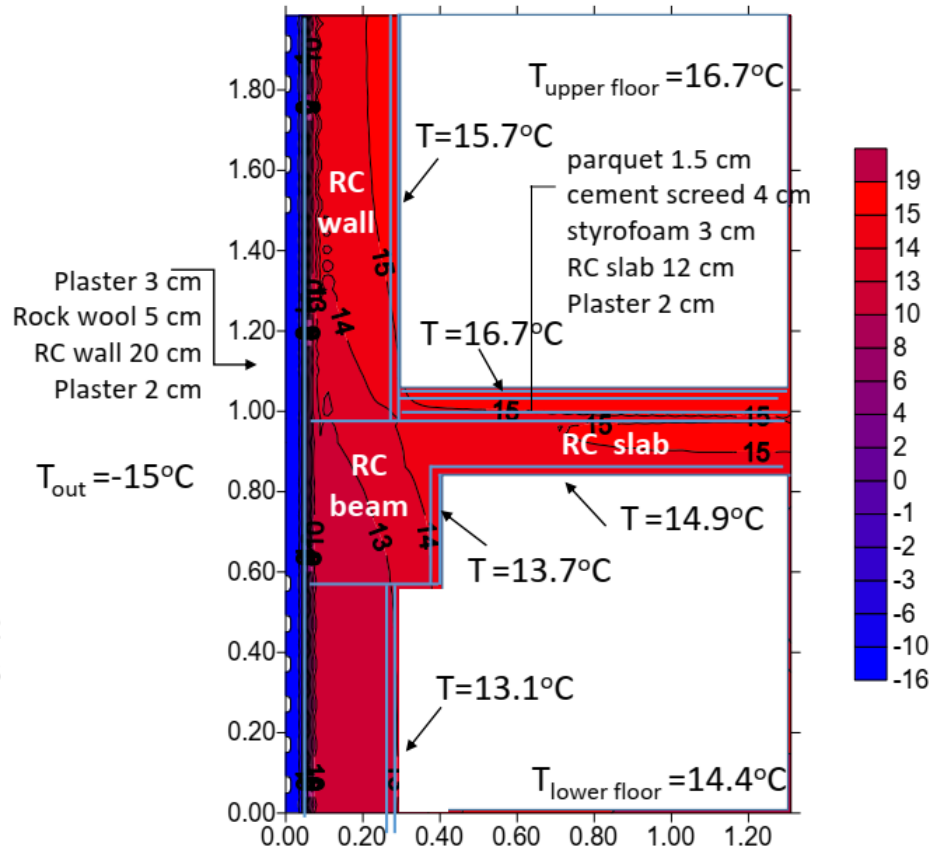


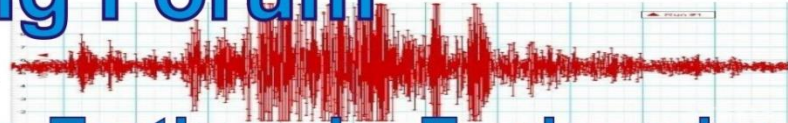
Comparison of building temperatures at moment $t=48$ hours, in case of building envelope with 5 cm thermal insulation

Brick wall



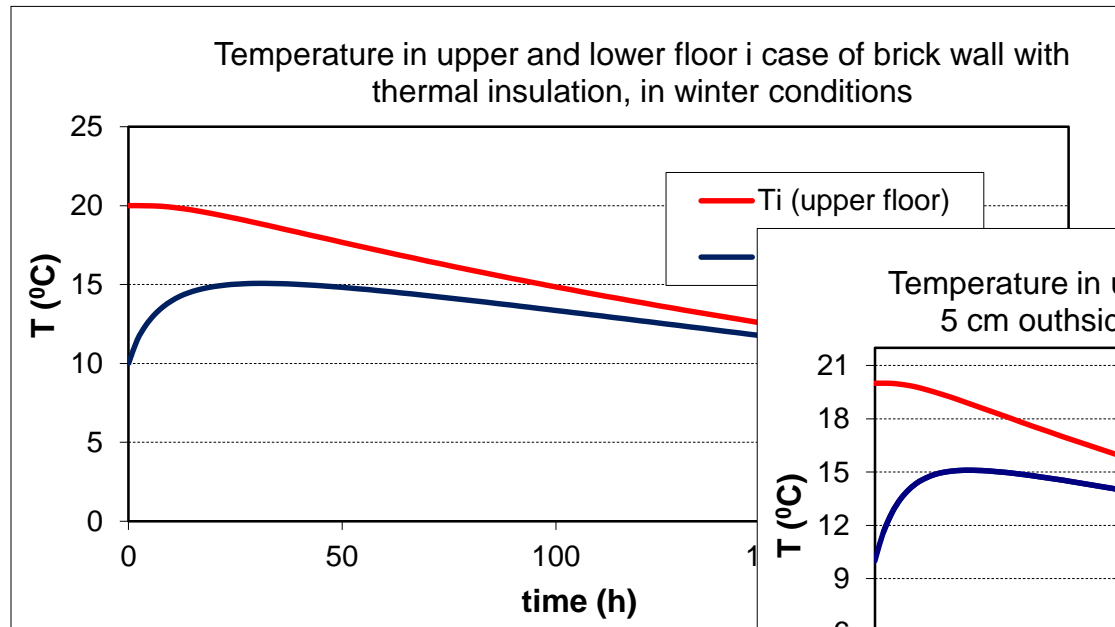
RC wall



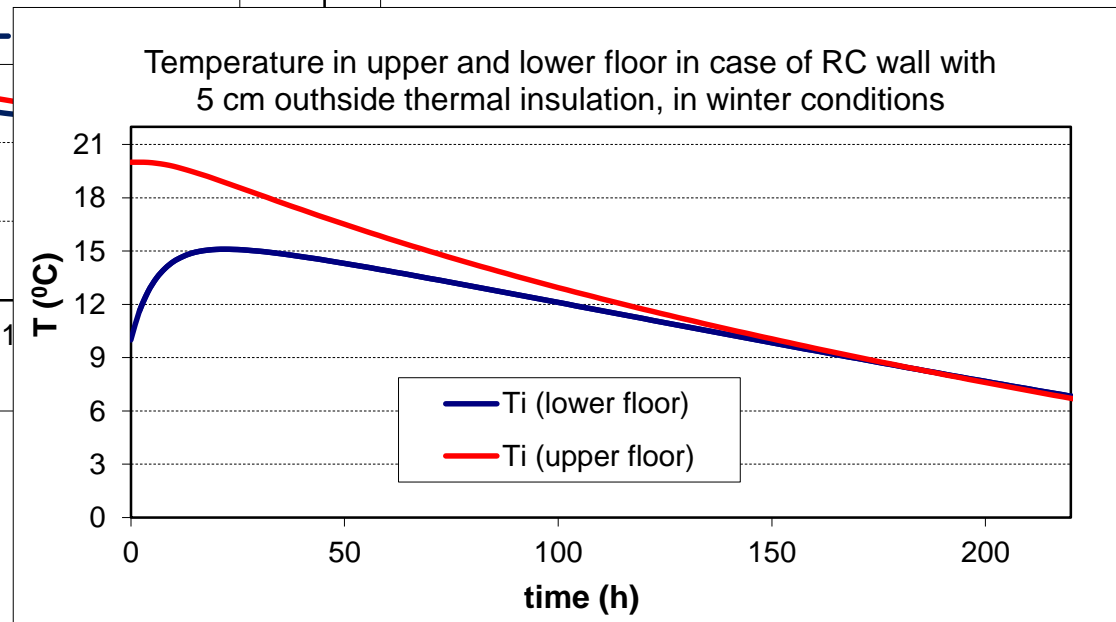


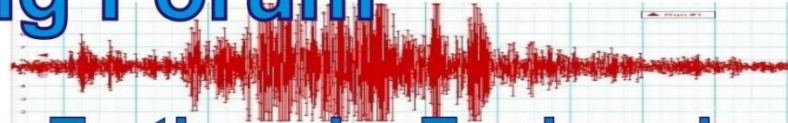
Comparison of cooling phase in case of building envelope with 5 cm thermal insulation, in winter conditions

Brick wall



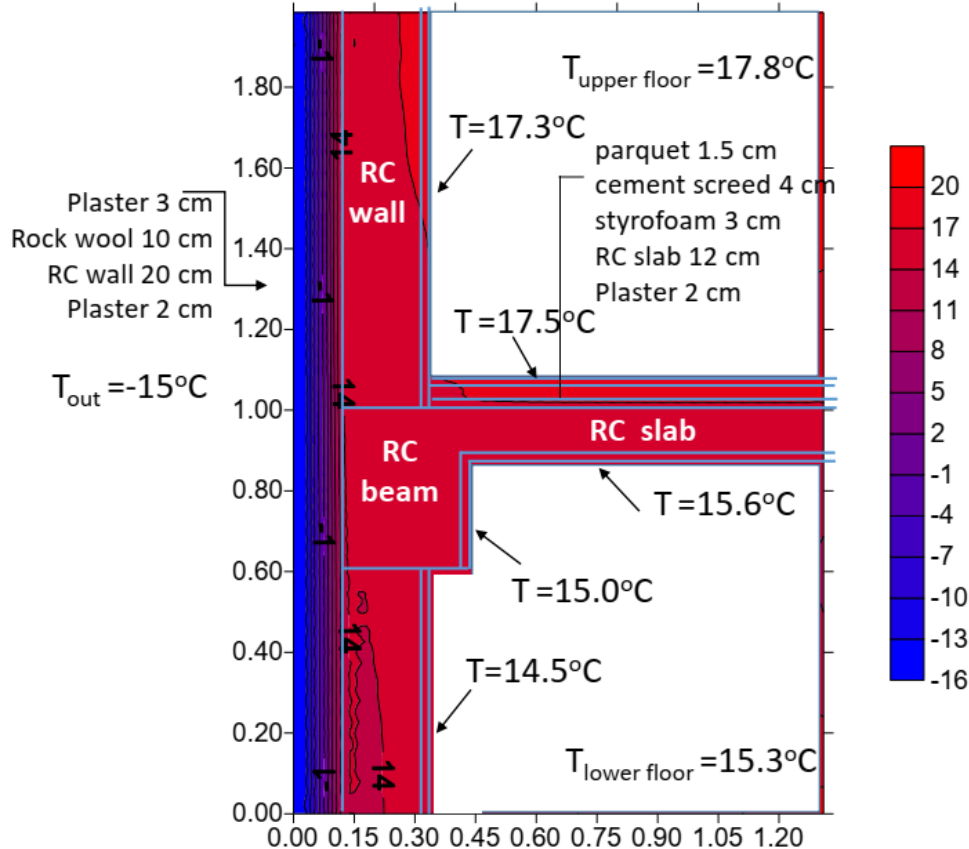
RC wall



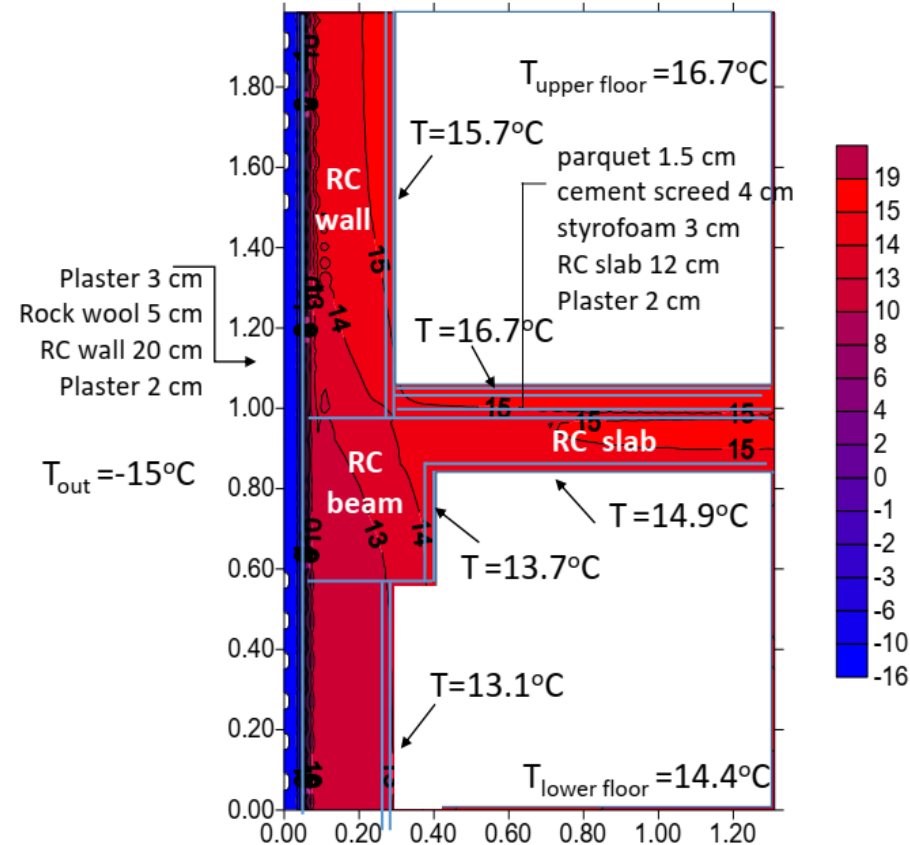


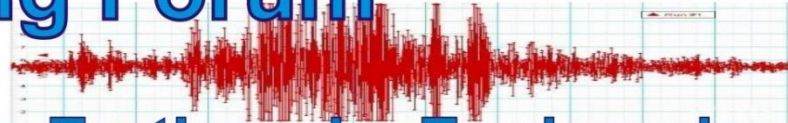
Comparison of building temperatures at moment $t=48$ hours, in case of RC wall with different thickness of thermal insulation

RC wall, 10 cm rock wool



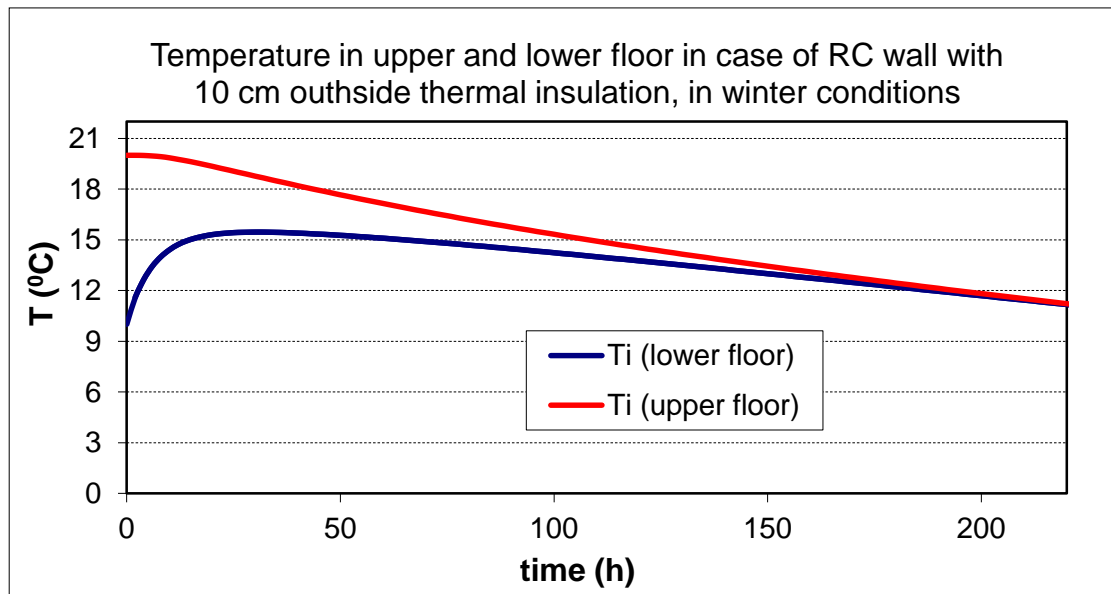
RC wall, 5 cm rock wool



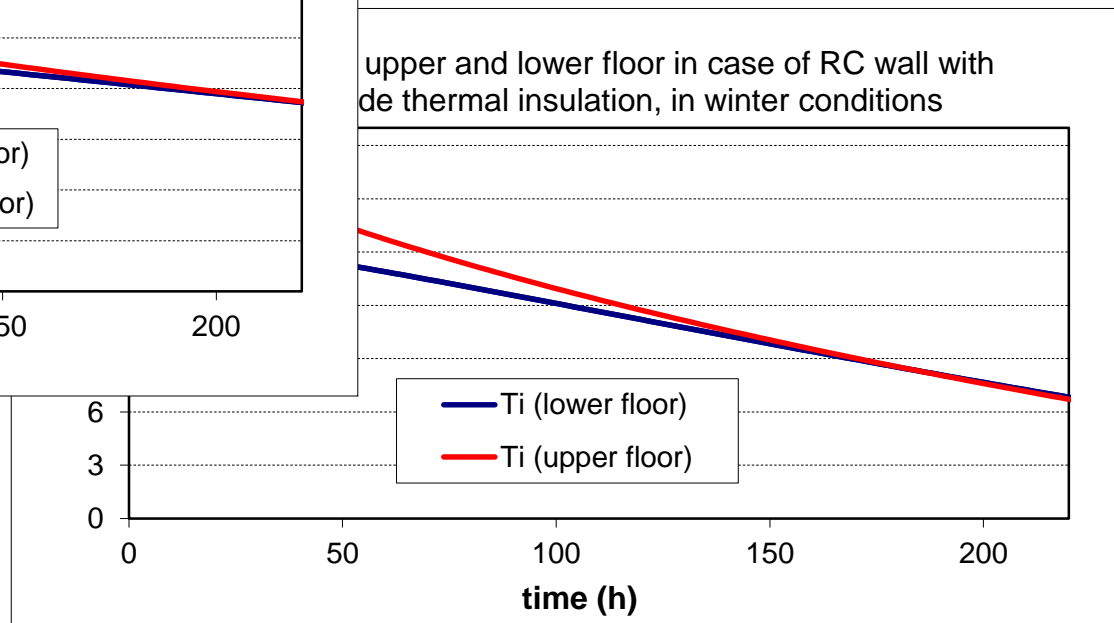


Comparison of cooling phase in case of building envelope with RC wall and different thickness of thermal insulation

RC wall, 10 cm rock wool



RC wall, 5 cm rock wool

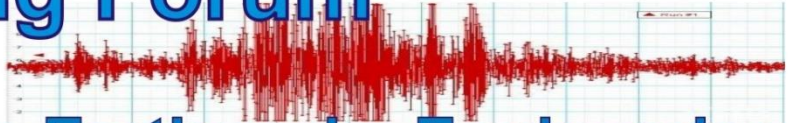




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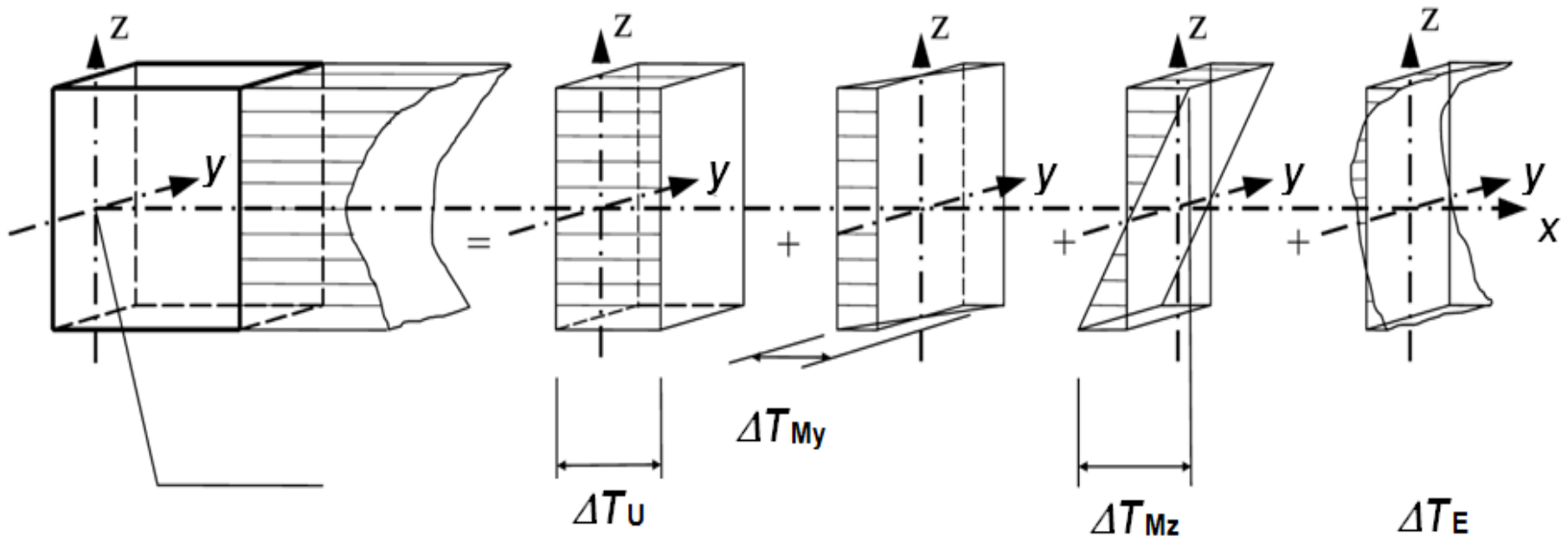
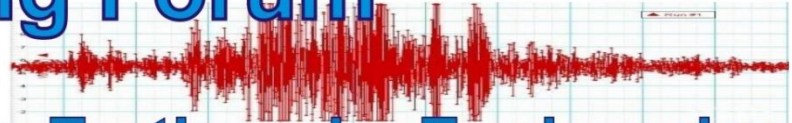
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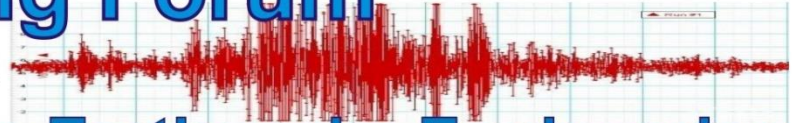


EN1991-1-5: Thermal actions on structures

- EN 1991-1-5 gives principles and rules for calculating thermal actions on **buildings**, bridges and other structures including their structural elements.
- EN 1991-1-5 describes the changes in the temperature of structural elements **exposed to daily and seasonal climate changes and solar radiation.**
- The intensity of thermal actions depends on:
 - ✓ local climate conditions,
 - ✓ the orientation of the structure,
 - ✓ total mass of building elements,
 - ✓ surface treatment (for example facades on buildings),
 - ✓ the heating and ventilation regime in the building,
 - ✓ thermal insulation.



- A uniform temperature component, ΔT_u ;
- A linearly varying temperature difference component about the z-z axis, ΔT_{MY} ;
- A linearly varying temperature difference component about the y-y axis, ΔT_{MZ} ;
- A non-linear temperature difference component, ΔT_E . This results in a system of self-equilibrated stresses which produce no net load effect on the element.



Simplified procedure according to EN 1991-1-5:

- Temperature profile in structural elements **exposed to daily and seasonal climate changes and solar radiation.**

$$T_{(x)} = T_{in} - \frac{R_{(x)}}{R_{tot}(T_{in} - T_{out})}$$

T_{in} is the air temperature of the inner environment

T_{out} is the temperature of the outer environment

R_{tot} is the total thermal resistance of the element including resistance of both surfaces

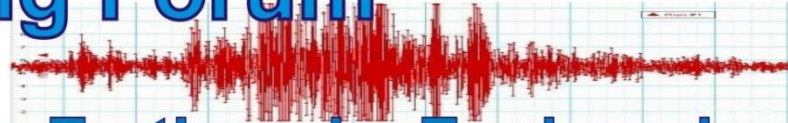
$R(x)$ is the thermal resistance at the inner surface and of the element from the inner surface up to the point x

$$R_{tot} = R_{in} + \sum \frac{h_i}{\lambda_i} + R_{out}$$

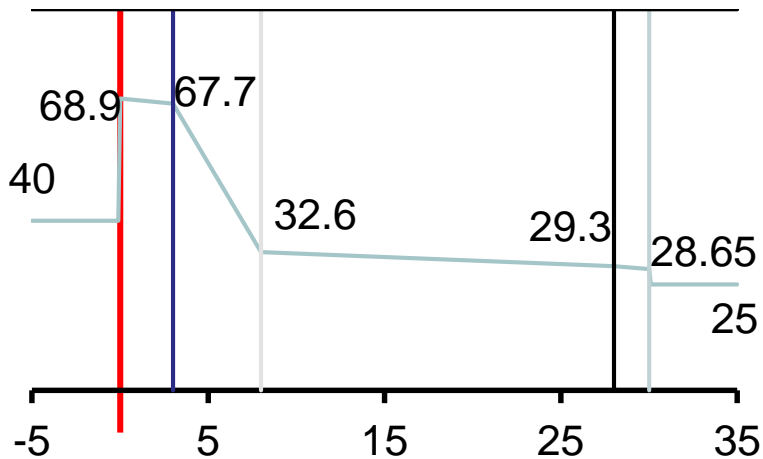
R_{in} is the thermal resistance at the inner surface [m^2K/W]

R_{out} is the thermal resistance at the outer surface [m^2K/W],

λ_i is the thermal conductivity and h_i [m] is the thickness of the layer i ,



Example: RC wall with and without thermal insulation



Thermal profile with thermal insulation

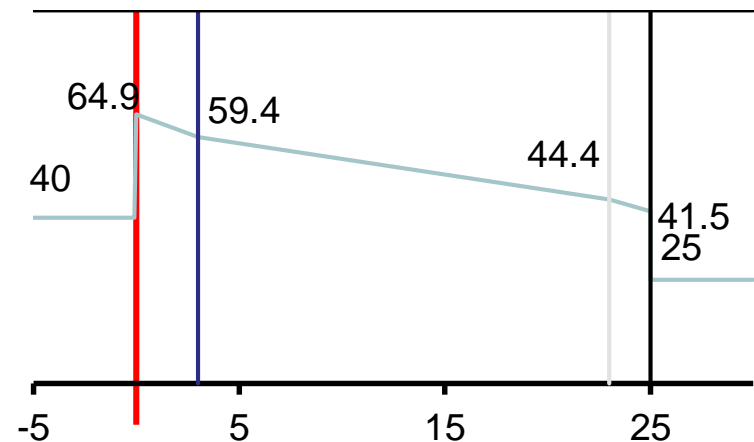
$$\Delta T_u = T - T_o = 30.95 - 20 = 10.95 \text{ } ^\circ\text{C}$$

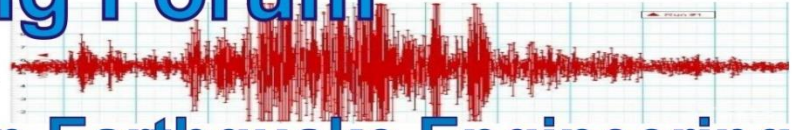
$$\Delta T_M = 3.3 \text{ } ^\circ\text{C}$$

Thermal profile without thermal insulation

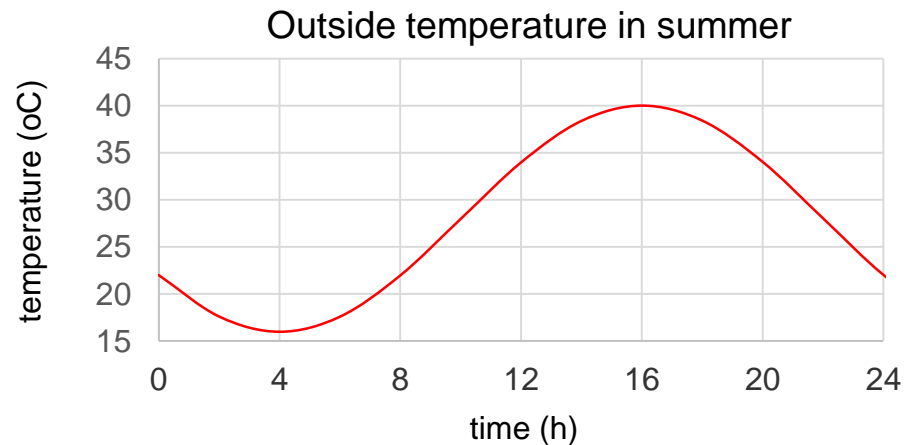
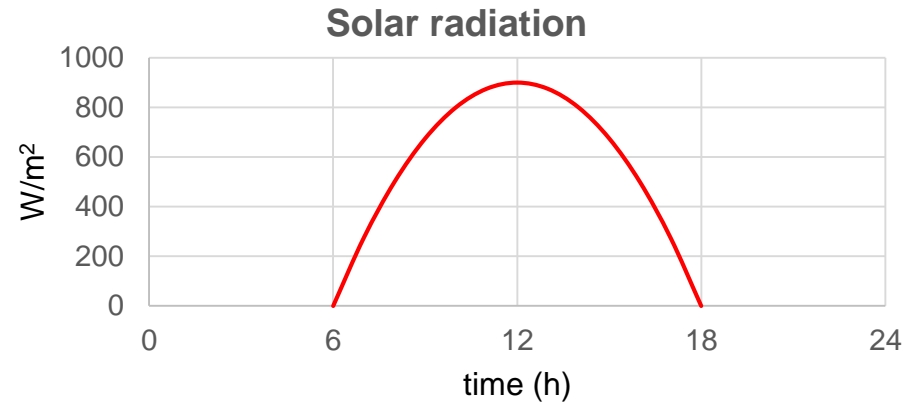
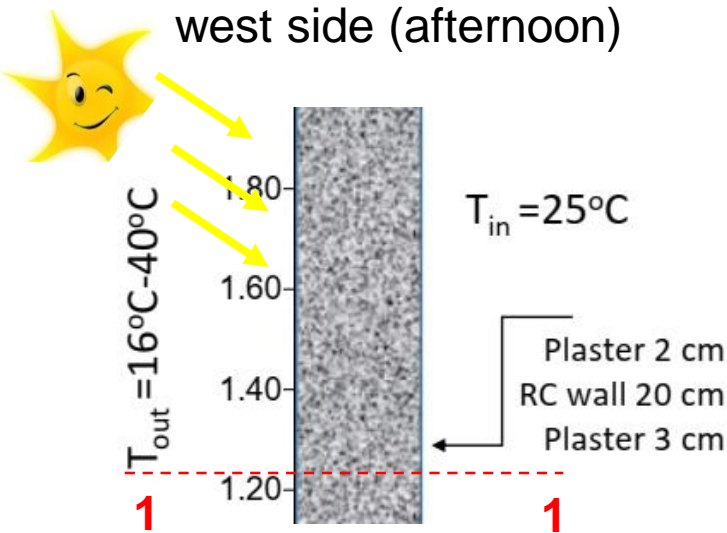
$$\Delta T_u = T - T_o = 51.9 - 20 = 31.9 \text{ } ^\circ\text{C}$$

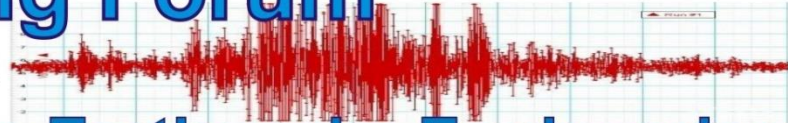
$$\Delta T_M = 15 \text{ } ^\circ\text{C}$$



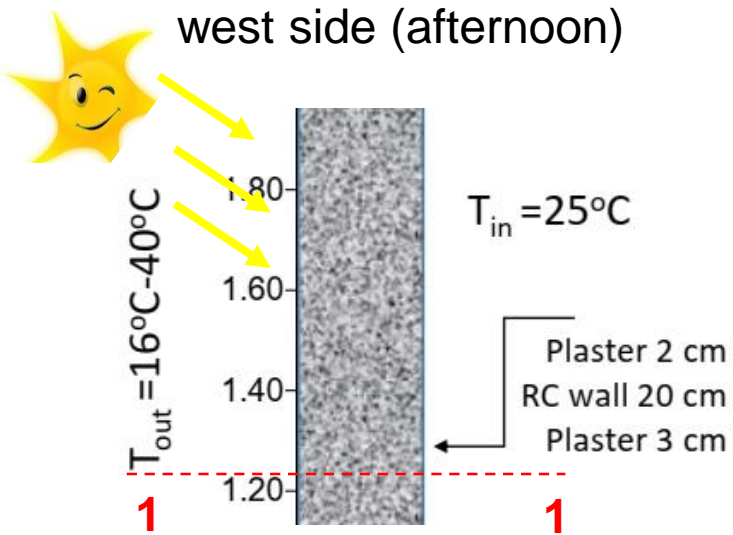


Numerical procedure for defining the temperature profile:



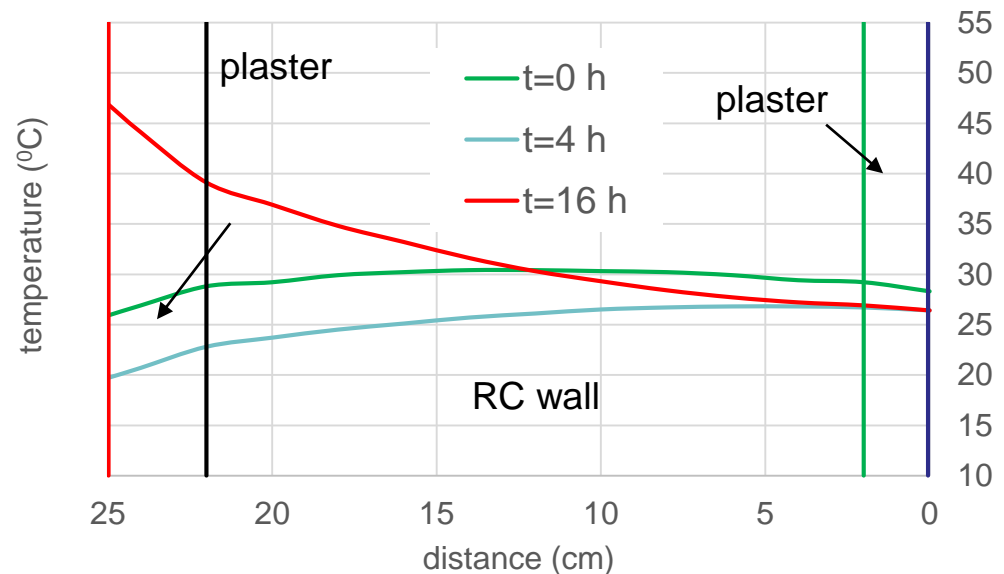


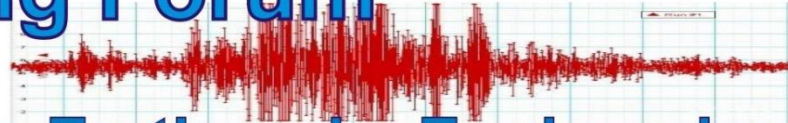
Numerical procedure for defining the temperature profile:



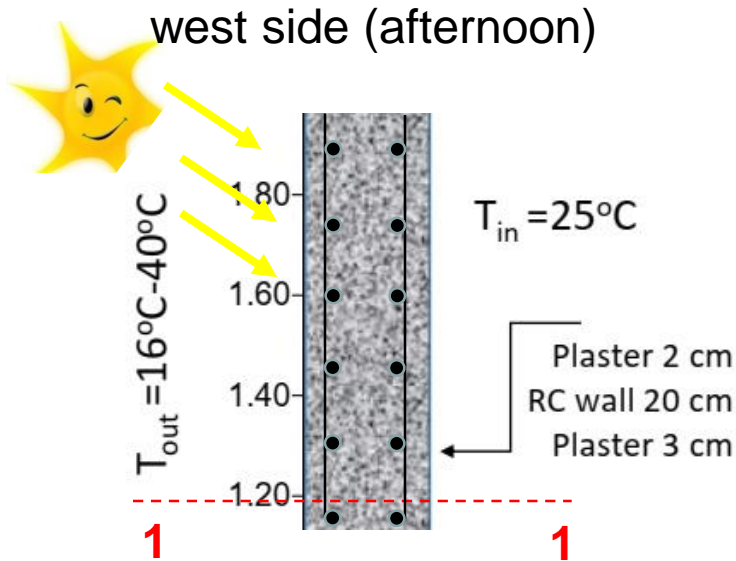
Cross section 1-1

Temperature profile in cross section of the wall





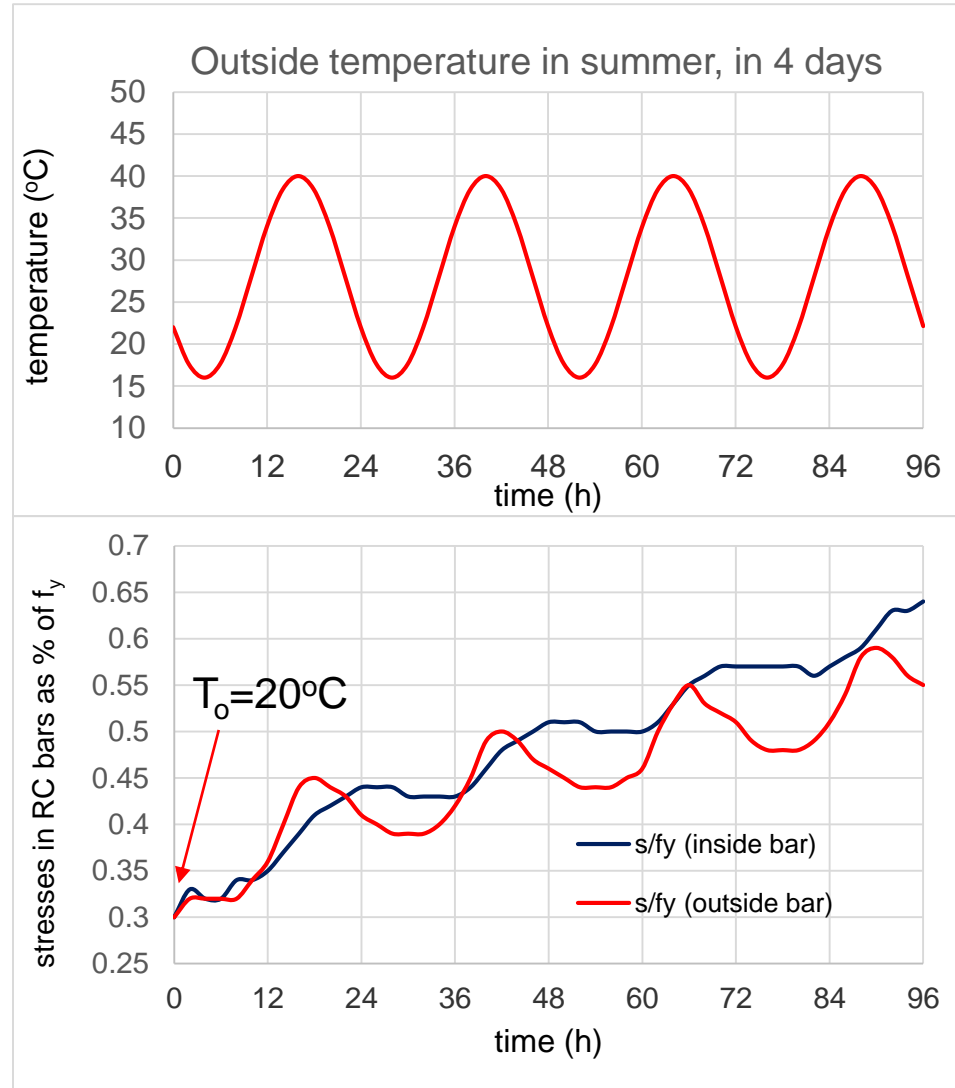
Advanced procedure for defining the temperature profile- Numerical procedure



Initial stresses: $\sigma_{max} = 0.30 f_y$

Without thermal insulation: $\sigma_{max} = 0.63 f_y$

With 10 cm thermal insulation: $\sigma_{max} = 0.37 f_y$

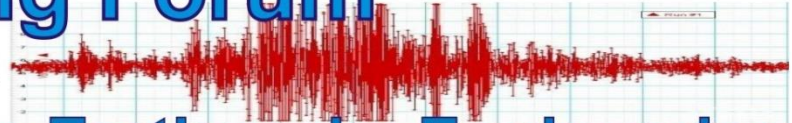




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QUESTIONS !!!

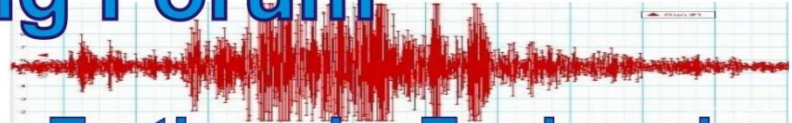
- Sustainability, Circularity, Energy-Efficiency ... and **what about (fire) safety?**
- **Are the regulations adopted to this novelties?**
- **By meeting our green goals: are we not adding new risks?**
- What is missing to avoid our buildings to burn down.
- **The best way to secure people, infrastructure and investments is to make the buildings fire safe.**



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Moskow, 2009



Skopje, 2016

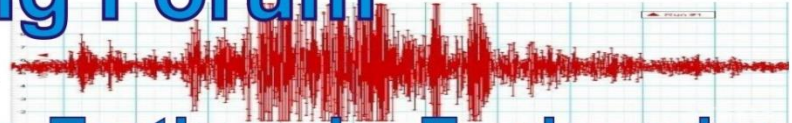




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Grenfell Tower-London , 2017

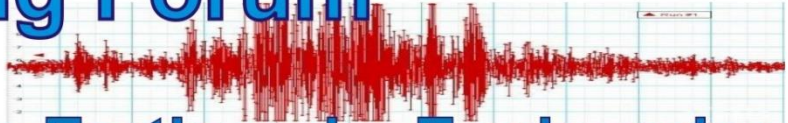




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CONCLUSIONS

Integrated design approach is of a significant importance.

Thermal insulation placed on the exterior side of the wall is absolutely the best case:

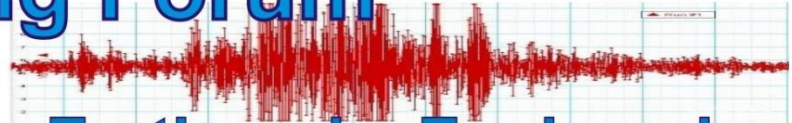
- ✓ It avoids appearance of thermal bridges;
- ✓ Provides the longest time for cooling of the building inside;
- ✓ Provides much lower values of thermal stresses caused by ambient temperature and solar radiation
- ✓ Non-combustible facades should be designed



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**THANK YOU FOR YOUR
ATTENTION**

