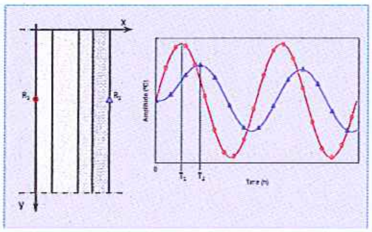
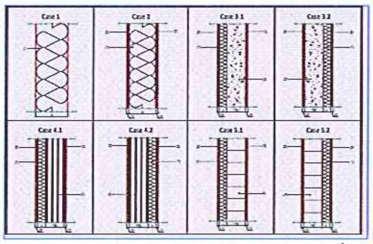
Thermal delay

▪ Thermal delay (φ)

- The thermal delay is taken to be the time difference between the instant with the thermal variation at one of the multilayer system's surfaces and the instant it appears at the opposite surface.

- Thermal delay is computed for construction walls incorporating agglomerate of expanded cork (**ICB**), mineral wood (**MW**) and extruded polystyrene panels (**XPS**).





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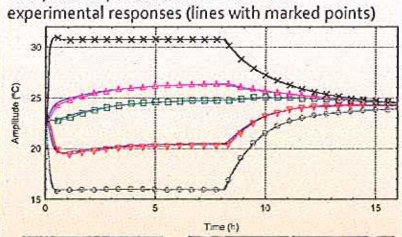
Thermal delay

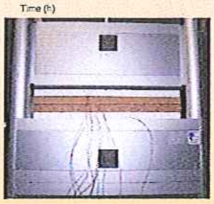
▪ Numerical formulation

- The calculation of the thermal delay uses <u>analytical solutions</u> where the time variable is catered for by using a **frequency domain approach;**

- The analytical solutions have been validated comparing the analytical results with those obtained experimentally:
  - The experiments were performed imposing an unsteady heat flow rate on both external faces of a multilayer system (using a single-specimen Lambda-meter EP-500 apparatus);
  - The temperature variation at each interface layer was measured using type T (copper) thermocouples.

Analytical responses (solid lines) *versus* experimental responses (lines with marked points)





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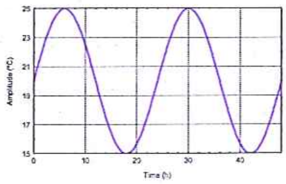
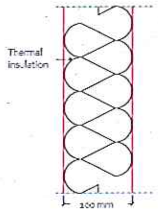
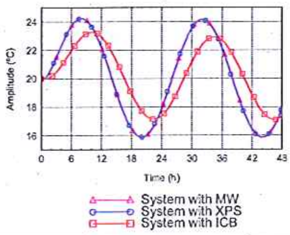
Thermal delay

- Type of results : system composed of a single thermal insulation layer (Case 1)
  - All simulations impose a sinusoidal temperature variation in the outer exposed surface, simulating the temperature variation along a set of 2 days.







Material	Conductivity, k ($W.m^{-1}.°C^{-1}$)	Mass density, ρ ($kg.m^{-3}$)	Specific heat, c ($J.kg^{-1}.°C^{-1}$)	Thermal diffusivity, K ($m^2.s^{-1}$)
Medium-Density Fiberboard (MDF)	0.120	712	1550.0	1.09e-07
Agglomerate of expanded cork (ICB)	0.038	100.0	1560.0	2.44e-07
Extruded polystyrene (XPS)	0.035	35.0	1400.0	7.14e-07
Mineral wool (MW)	0.040	70.0	837.0	6.83e-07
Traditional mortar	0.72	1860.0	780.0	4.96e-08
Concrete	1.4	2300.0	880.0	6.92e-07
Granite stone	3.0	2600.0	840.0	1.37e-06
Air	0.026	1.2928	1000.0	2.01e-05

- The system incorporating ICB evidences an higher thermal delay than the others (XPS and MW).
- Additionally, one may observe that the system with NC shows the lowest temperature on the receiving surface.

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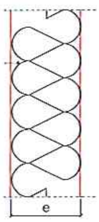
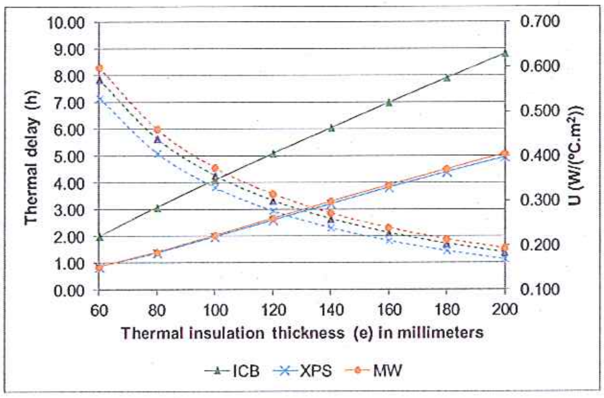
Thermal delay

- Type of results : system composed of a single thermal insulation layer (Case 1)
  - The thermal delays exhibited by the single layer systems are smaller than those for the multilayered systems, since the former allow rapid heat transfer from the exposed surface to the receiving face.





The **thermal delay** is represented by <u>continuous line</u>;
The thermal transmittance coefficient (U) is illustrated by <u>dashed lines</u>.

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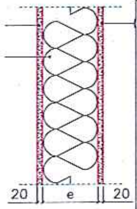
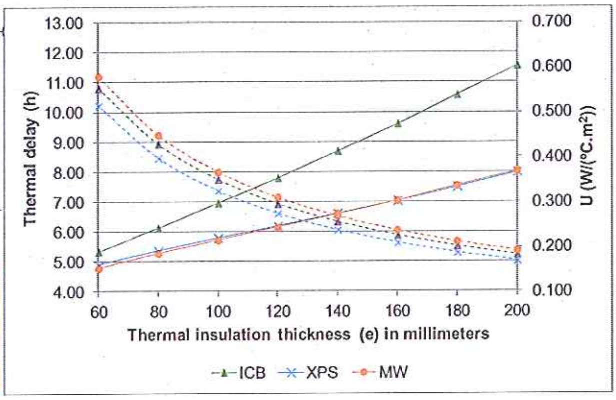
Thermal delay

- Type of results : system with a thermal insulation material and traditional mortar (Case 2)
  - Increasing the thermal insulation thickness, it is observable an increase of the thermal delay and a reduction of the thermal transmittance coefficient.





The thermal delay is represented by <u>continuous line</u>;
The thermal transmittance coefficient (U) is illustrated by <u>dashed lines</u>.

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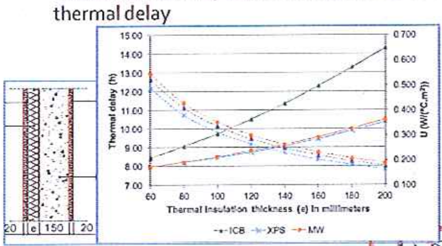
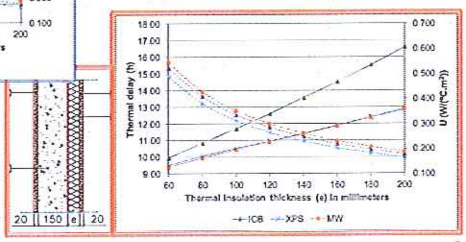
Thermal delay

- Type of results : multilayer system with a concrete layer (Case 3)
  - Systems with same thermal transmittance coefficient have different thermal delay;
  - Comparing the various constructive solutions with similar thermal transmittance coefficients we may conclude that a lower coefficient is not necessarily a sign of a greater thermal delay



The thermal delay is represented by <u>continuous line</u>;
The thermal transmittance coefficient (U) is illustrated by <u>dashed lines</u>.



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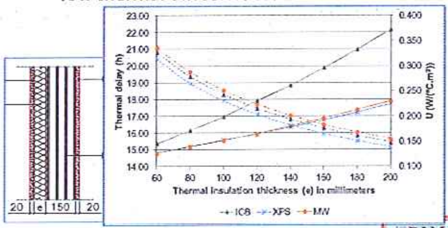
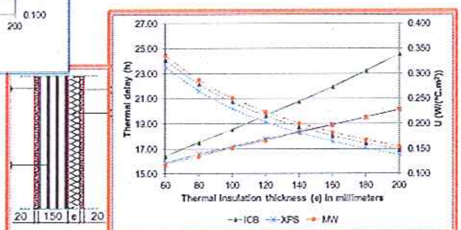
Thermal delay

- **Type of results : multilayer system with a MDF layer (Case 4)**
  - The thermal delay increases with the number of layers;
  - Comparing systems with the same number of layers and with the same thickness of insulation, it is noticeable that **greater thermal delays** are provided by the **solutions with low thermal diffusivities.**



The **thermal delay** is represented by <u>continuous line</u>;
The thermal transmittance coefficient (U) is illustrated by <u>dashed lines</u>.



Thermal diffusivity: $K = \dfrac{\lambda}{\rho c}$

A <u>slight larger thermal delay</u> when the insulating material is placed <u>close to the receiving surface</u>.

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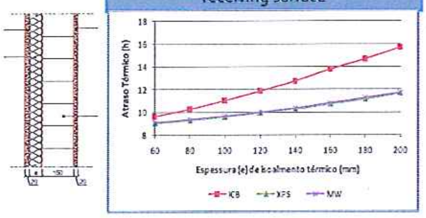
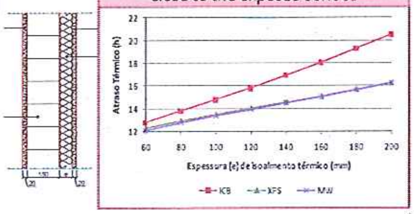
Thermal delay

- **Type of results : multilayer system with stone layer (Case 5)**
  - Multilayer systems :
    - when the insulating material is placed close to the receiving surface, the thermal delay achieved by a solution with only 60 mm thickness ICB is equivalant to that achieved by systems with 100 mm of XPS / MW.
    - when the insulating material is placed close to the exposed surface , the thermal delay achieved by a solution with 60 mm thickness ICB is only surpassed by systems with 80 mm of XPS/MW.

Case 5.1: system with stone and thermal insulation material placed close to the receiving surface



Case 5.2: system with stone and thermal insulation material placed close to the exposed surface



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