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Presentation object :

Optimization of Dynamic Embedded, Water Based Surface Heat (and Cold) Emitting System for Buildings

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Unité Surveillance de l' Environnement

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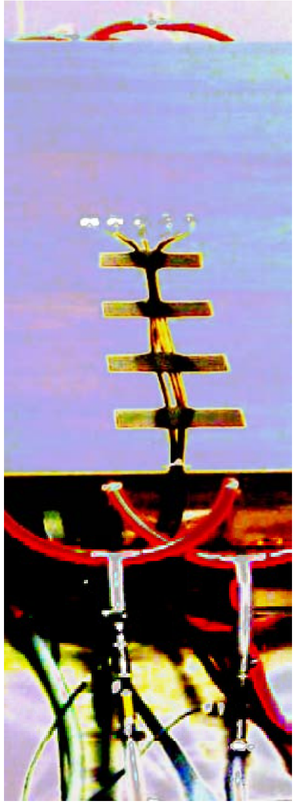
Presentation overview



- Heating device layout
- Numerical implementation
- Test bench implementation
- Results
- Further developments

Introduction

Increase building energy efficiency is crucial for reducing CO^2 emissions

Emitting system : Radiant heating/cooling

➔ best comfort for occupants

➔ more energy efficient

Classical heating floors have drawbacks

Energy point of view

➔ low reactivity (heating all the day)

➔ relatively high thermal resistance

Implementation point of view

➔ time waist during the building construction / refurbishment

➔ high weight, high height

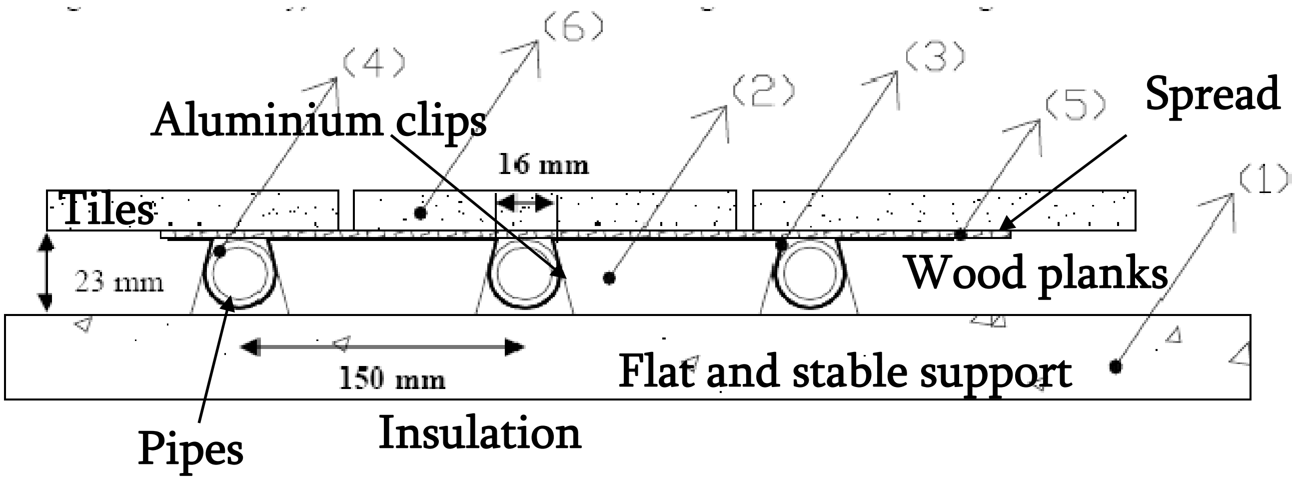
Development of a new dynamic embedded water based heating/cooling floor

Heating device layout

New heating floor has been designed (patent in progress) , it is a compromise between different aspects :

Use of COMSOL multiphysics

- **decrease thermal resistance between water and floor surface**
- simple, quick and robust implementation
- decrease thermal capacity
- ecologically friendly materials, cost effective system
- minimum height (increase possibilities in refurbishment)



Heating floor layout : Tile covering

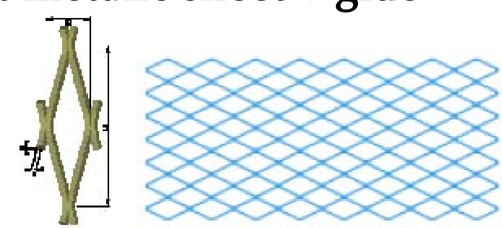


Figure 2. Grid = Spread out aluminium sheet (5).

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Numerical implementation

Objective : compute the thermal resistance ➔ use of Heat equation

$$\rho c_p \frac{\partial T}{\partial t} = r + \nabla \cdot (k \nabla T)$$

Double spiral pipe in a room

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Objective : compute the thermal resistance ➔ use of Heat equation

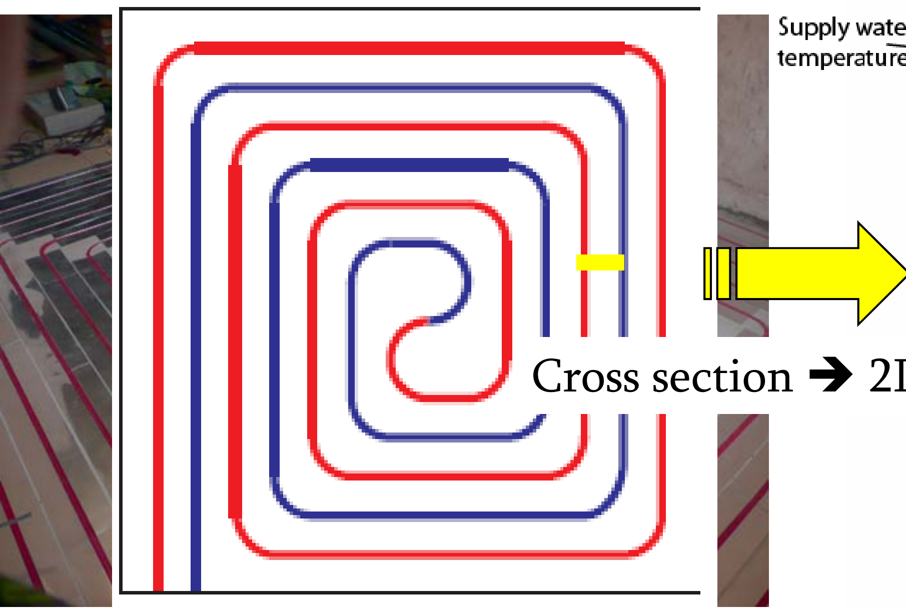
$$\rho c_p \frac{\partial T}{\partial t} = + \nabla \cdot (k \nabla T)$$

➔ k the thermal conductivity only parameter used

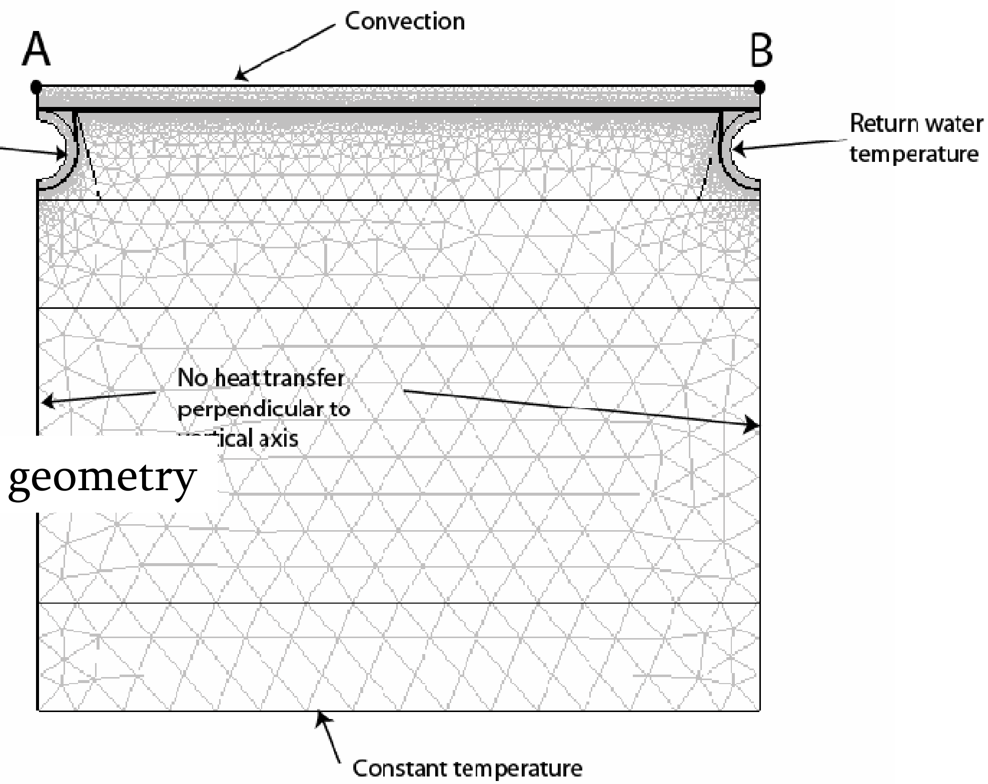
For mix aluminium spread sheet and glue : mean k value

Domain & boundary conditions definition

Double spiral pipe in a room



Cross section ➔ 2D geometry



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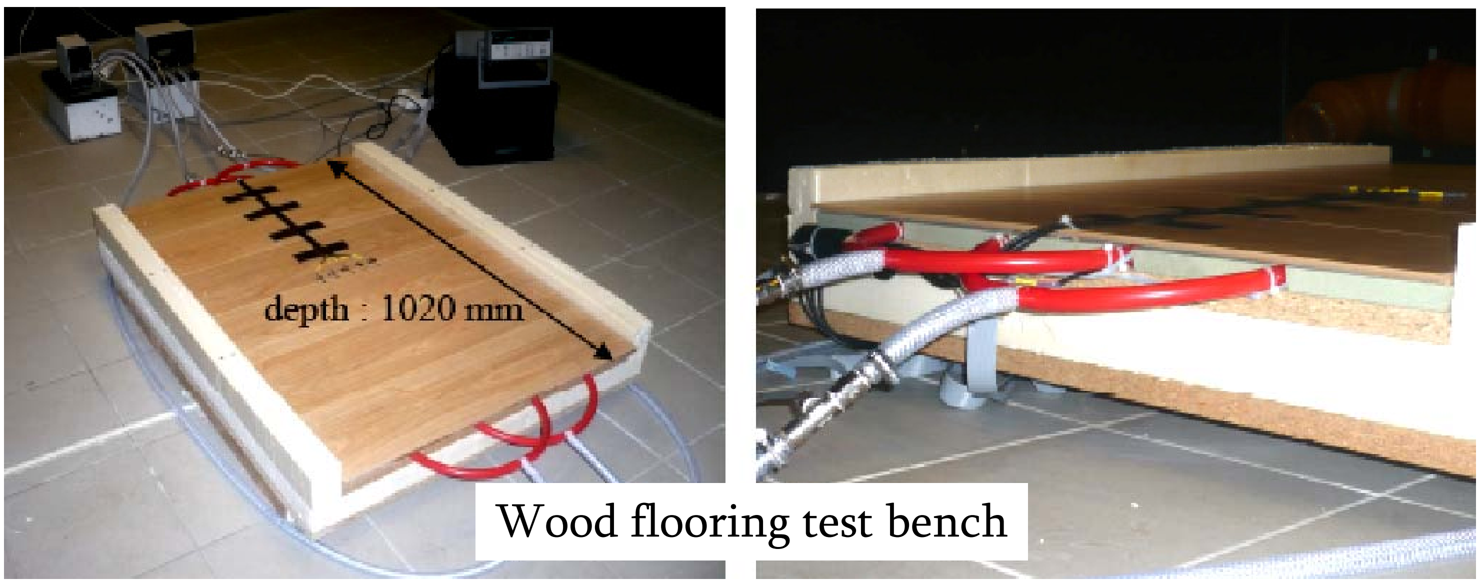
Test bench implementation 1/2

Numerical model is validated with measurements on a test bench :

Test bench is designed to meet same kind of boundary conditions as the model

- 4 pipes to avoid heat flows on the left and the right of the numerical domain
  - 2 pipes for supply hot water (eg : 38°C)
  - 2 pipes for return cold water (eg : 33°C)
- Four variables are controlled :
  - room air t°, water supply t°, water return t°, floor bottom t°



Wood flooring test bench

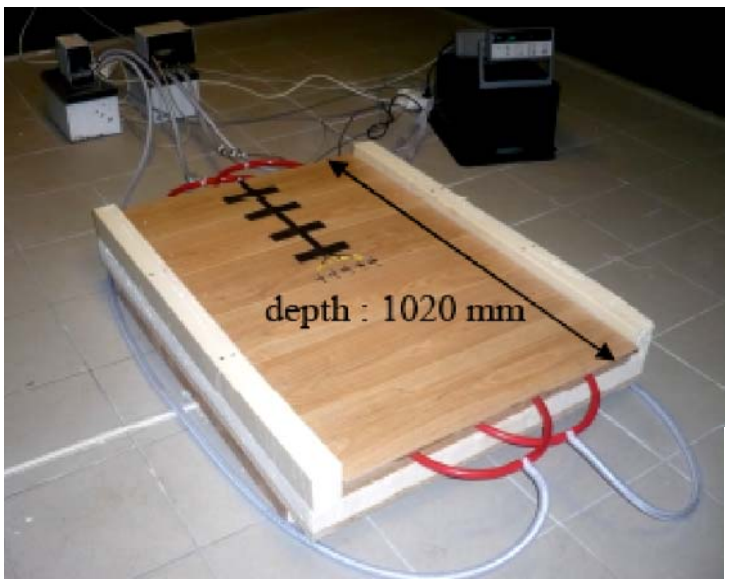
Test bench implementation 2/2

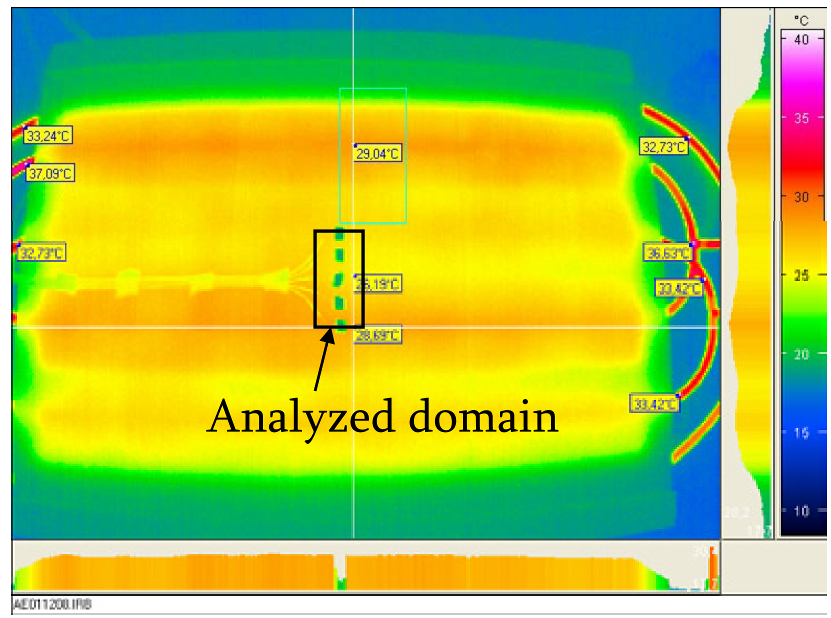
Surface temperature is computed with the numerical model, it is an image of thermal conductivity of heating floor :

low thermal conductivity → higher floor surface temperature

in the same temperature conditions

- Floor surface contains 5 t° probes, their locations rely on numerical domain
- No side effect is encountered in analyzed domain (infrared thermography)





Test bench implementation 2/2

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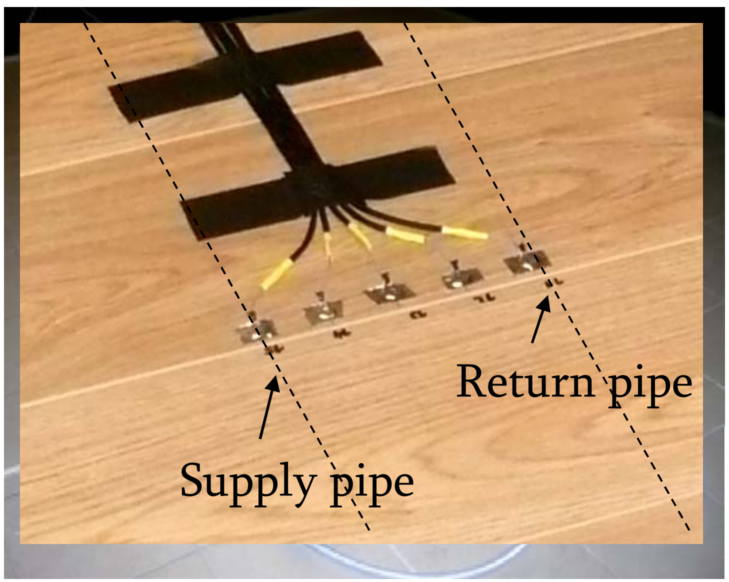
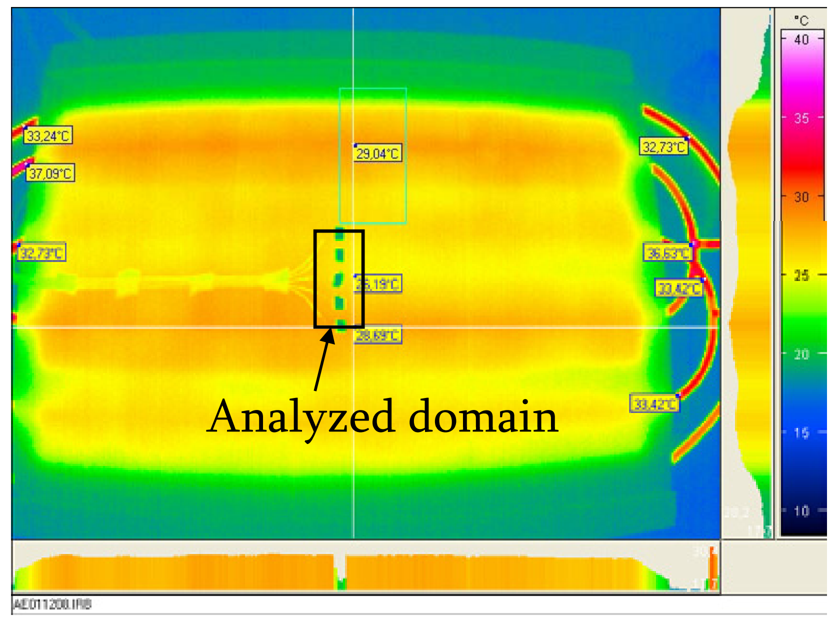


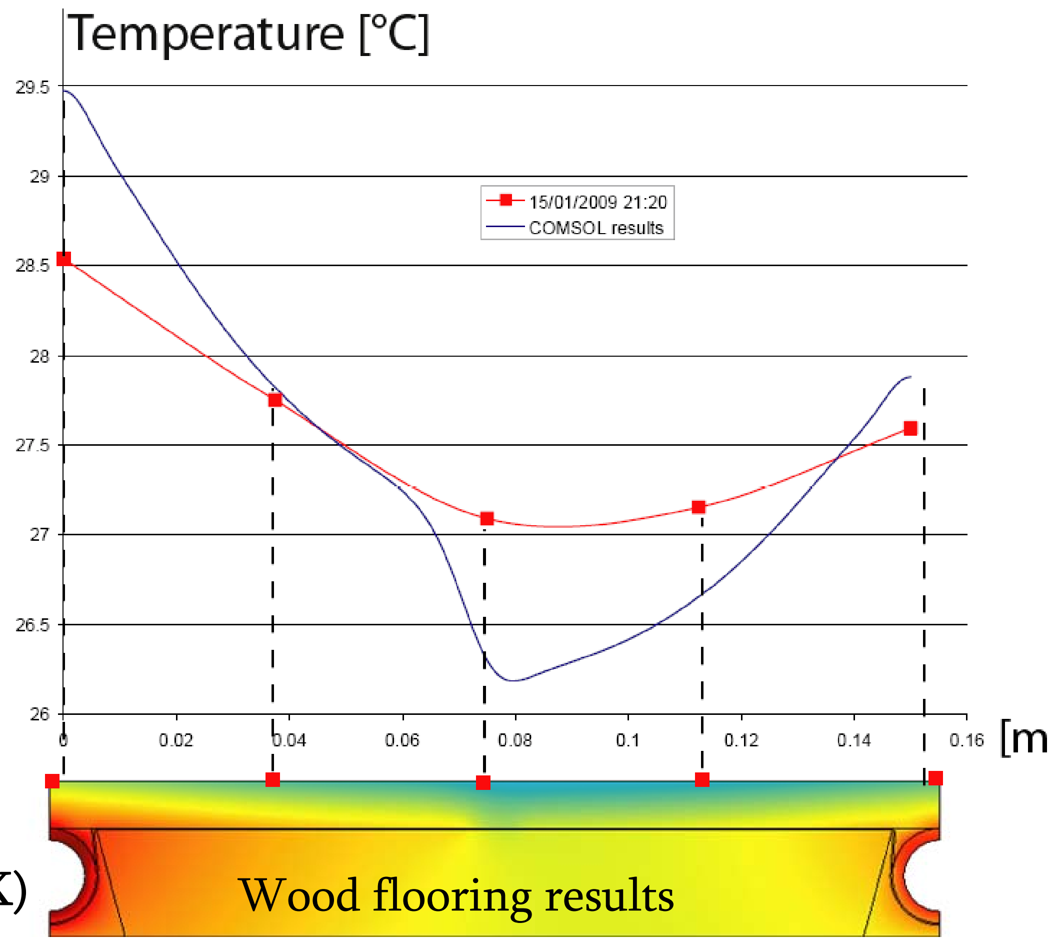


Results : comparison between test bench and COMSOL simulation 1/2

One of the test cases is presented.

Floor surface t° profile is displayed (in steady state conditions).

Key facts (wood flooring) :
- Temperature differences between model and experimentation (test bench profile smoother)
- Emitted power is the same between model and exper. (mean temperature is the same and convection coefficient is constant $h_{convection} = 11.63\ W/(m^2K)$



k water → floor surface = 8.54 W/(m²K)
standard deviation is 0.12 W/(m²K)

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Results : comparison between test bench and COMSOL simulation 2/2

Many test cases were run. Some of them are presented in the tables

Test case #	Mean surface floor temp	Supply hot temp (pipe)	Supply cold temp (pipe)	Air temp	Floor bottom temp	**Experim. Power (h = 11.63 W/m²/K) [W/m²]**	COMSOL **power result [W/m²]**	COMSOL losses bottom [W/m²]	**Variation [%]**
11	27.37	39.35	35.53	19.95	9.91	**86.30**	**86.55**	10.30	**-0.29**
12	26.91	39.31	33.52	19.97	9.87	**80.66**	**81.30**	9.98	**-0.80**
13	27.32	37.23	37.64	20.02	9.89	**84.96**	**86.16**	10.32	**-1.40**

Wood flooring results

Tile flooring results

Test case #	Mean surface floor temp	Supply hot temp (pipe)	Supply cold temp (pipe)	Air temp	Floor bottom temp	Experim. Power [W/m²]	COMSOL power result [W/m²]	COMSOL losses bottom [W/m²]	Variation [%]
6	28.06	38.00	32.71	20.00	14.79	**93.77**	**111.49**	7.32	**18.90**
7	28.00	32.58	38.11	20.06	14.80	**92.35**	**110.39**	7.29	**19.53**
8	29.71	41.24	35.95	20.00	14.91	**112.91**	**135.04**	8.30	**19.59**
9	24.46	28.25	28.43	20.03	14.74	**51.53**	**59.67**	5.06	**15.80**

Experimental result : k water → floor surface = 13.08 W/(m²K)
standard deviation is 1.26 W/(m²K)

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Further developments

Issues presented before should be investigated :

-Temperature profile smoother in experimentation than in computation.

Probe temperature diffusion ? Convection coefficient non linear?

-Variation between experimentation and computation for tile flooring.

New tile flooring test bench built ➔ verify if $k_{mix\ glue\ aluminium}$ is a good assumption

- Heat transfer between floor and air has great impact on results. A more precise value of heat transfer coefficient should be taken than normative figure.

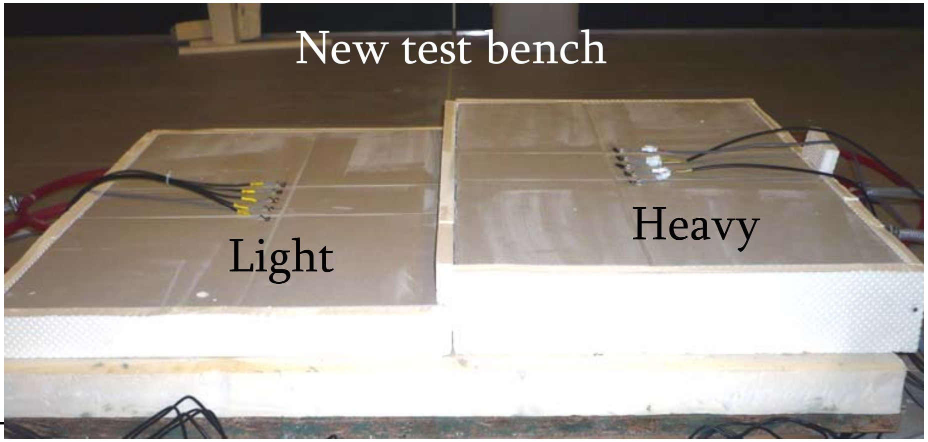
Semi empirical correlations have lead to lower heat transfer value

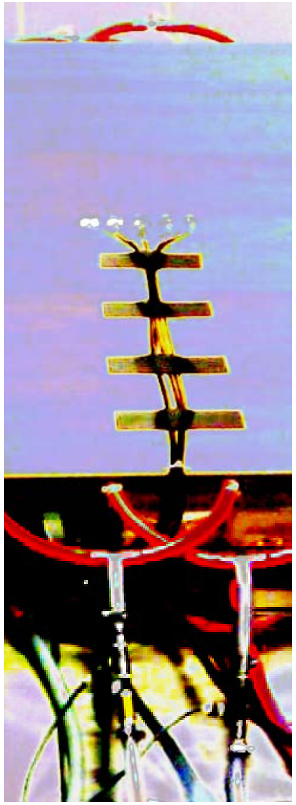
New test bench allows measurement of heat transferred by fluid to floor.

Verify high reactivity of the heating floor :

- COMSOL transient simulations will be run (same numerical domain)

- New test bench allows to compare light an heavy floor





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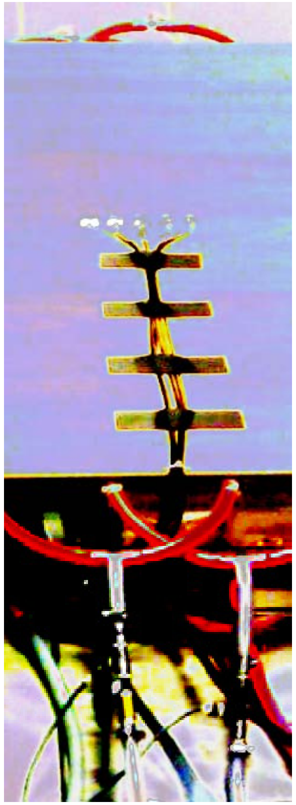
Conclusion

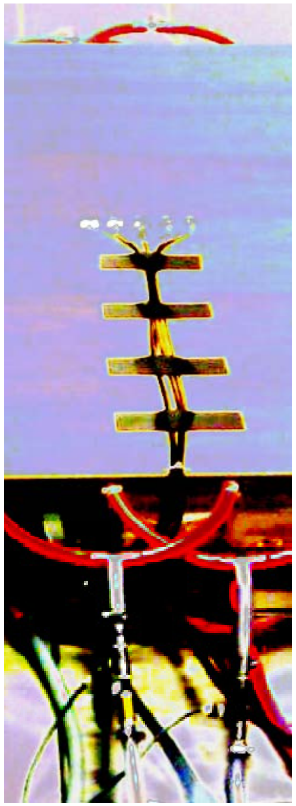


> Development of new heating/cooling floor with the help of **numerical simulations** and **test bench experimentations** was presented.

> Comparison between simulations and experimentations is done but not persuasive in each case.

> High conductivity of heating floor has been revealed, **energy savings** on a whole year should be investigated (with help of a new TRNSYS® model based on this work).

> This heating floor is a promising technology, it is now already sold on the market by **OPAL SYSTEMS spin-off company**. Numerous applications have been built yet.



Any questions ?