Study of an experimental methodology for thermal properties diagnostic of building envelop

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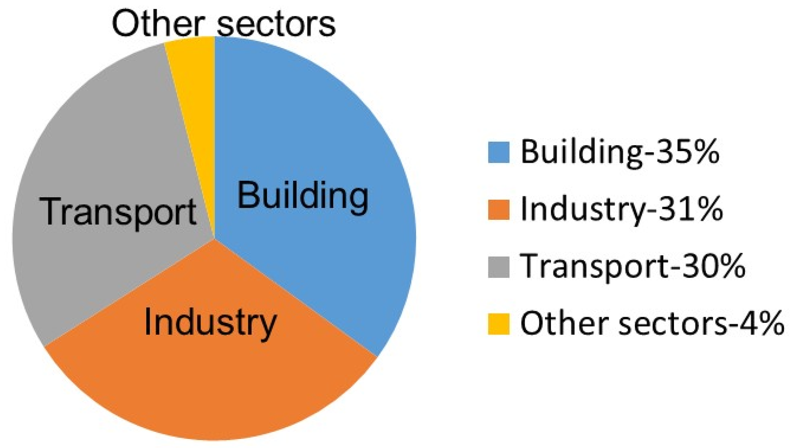
INTRODUCTION

Context:

In the energy structure(IEA),buildings represent 35% of total final energy consumption



The building envelope plays a critical role in determining levels of comfort and building efficiency. Its real thermal properties characterization is of major interest to be able to diagnose energy efficiency performance of buildings (new construction and retrofitted existing old building).

Aims:

- Develop new solutions for non-intrusive evaluation of local thermal performance of building walls.
- Investigation of sensors utilization for measuring temperatures and heat flux density of wall, providing some guidelines for the choice of sensors and measurements protocol.
- Applying inverse method to calculate thermal properties based on thermal quadrupoles modelling of wall.

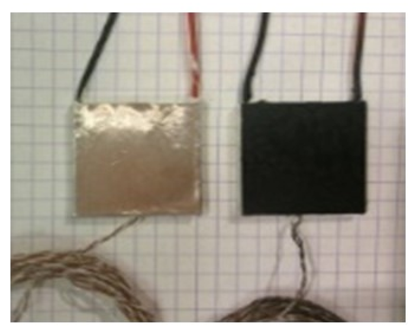
EXPERIMENTAL SETUP

Sensors:

Infrared camera FLIR A325

Peltier module (black and shiny surfaces)

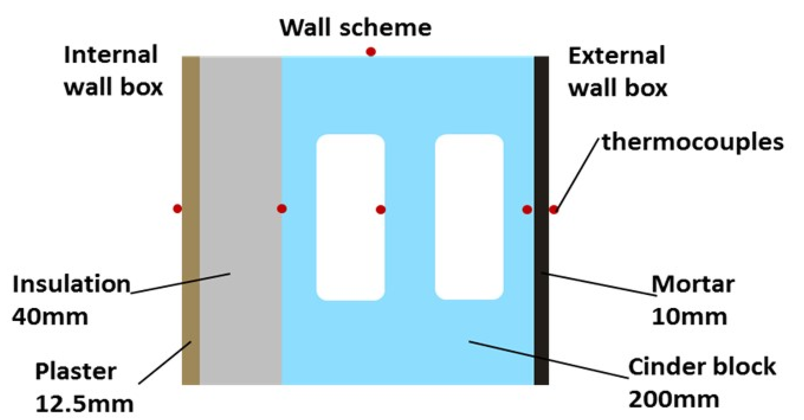
Heat flux meter (Captec)



Objective wall:

A 4-layers wall is tested.

Wall size: height 100 cm; width 70 cm; thickness 25.5 cm



Experimental system:

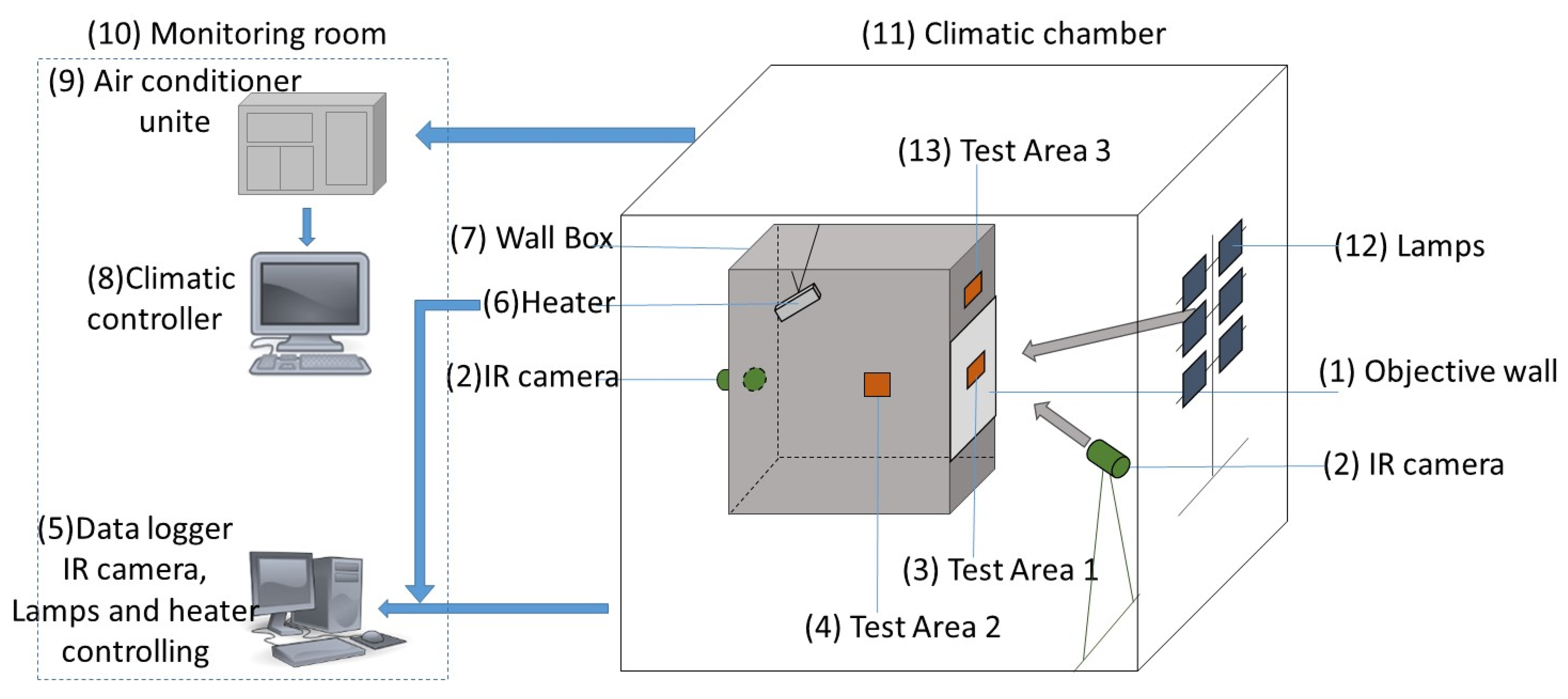


Diagram of experimental apparats and system

RESULTS AND ANALYSIS

Results of emissivity measurement

This emissivity measurement is based on the standard ISO 18434-1:2008(E). The total radiation received by the camera (W_{tot}) is :$W_{tot} = W_{obj} + W_{refl} + W_{atm}$.

If hypothesis that $\tau_{atm} = 1, \varepsilon_{crum\_Alu} = 0$, $T_{refe} = T_{obj}$, the emissivity of target surface can be computed as: $\varepsilon_{obj} = \varepsilon_{refe} \cdot \frac{W_{tot}^{obj} - W_{tot}^{refl}}{W_{tot}^{refe} - W_{tot}^{refl}}$

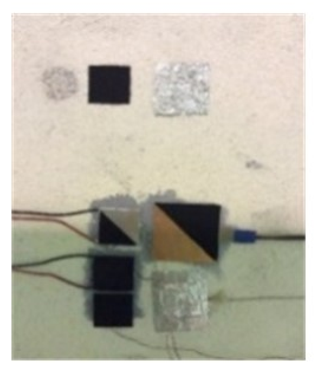
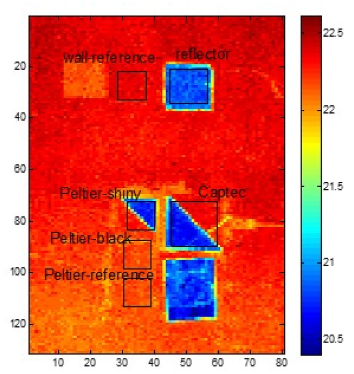
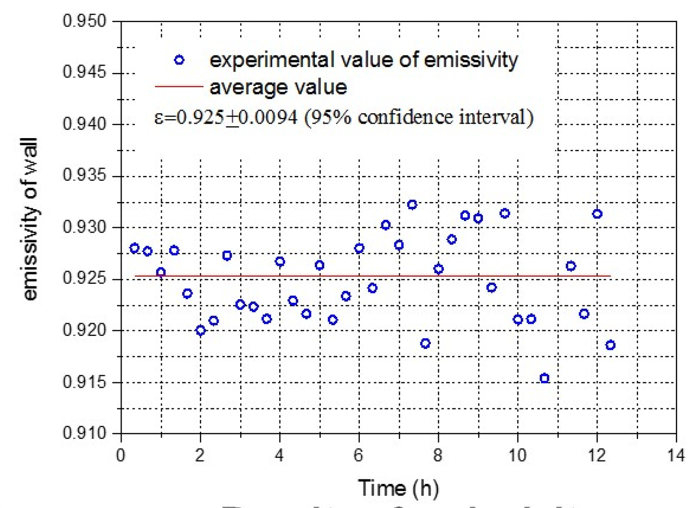


Photo of test area



Infrared image of test area



Results of emissivity

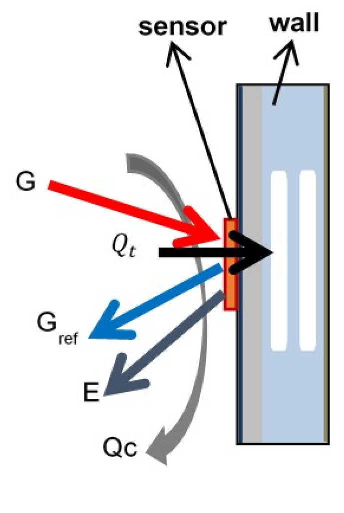
Results of heat flux

The heat flux balance of wall surface is:

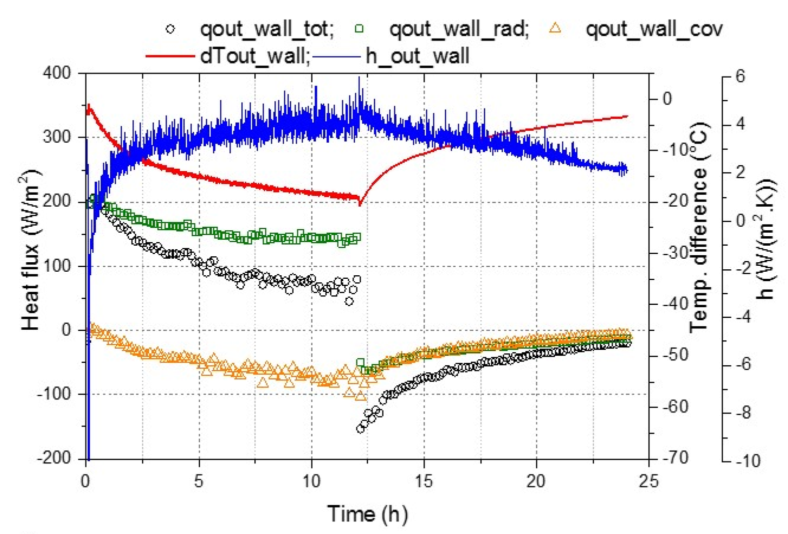
$Q_{tot} = G + Q_{cov} - E - G_{refl}$;

$Q_{tot} = a\,G + h(T_{air} - T_{sur}) - \mathcal{E} \cdot \sigma \cdot T_{sur}{}^4$

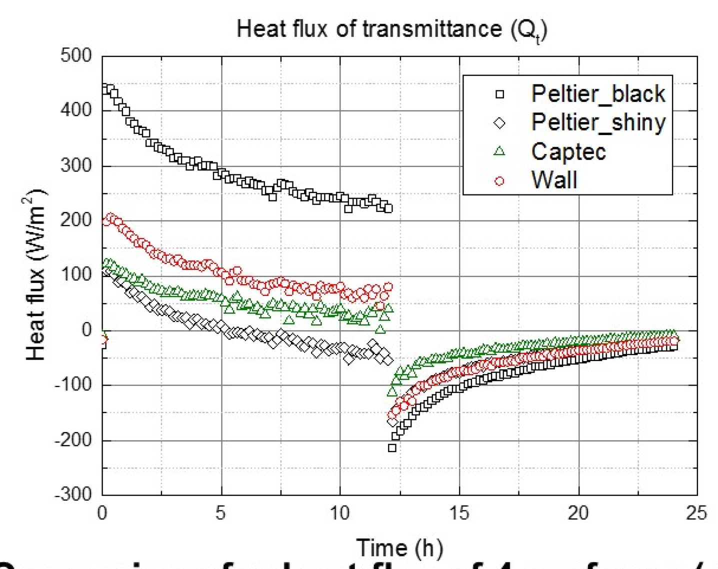
The heat flux of convection, radiation and transmittance for wall are computed out based on heat flux balance.



Heat flux balance of surface

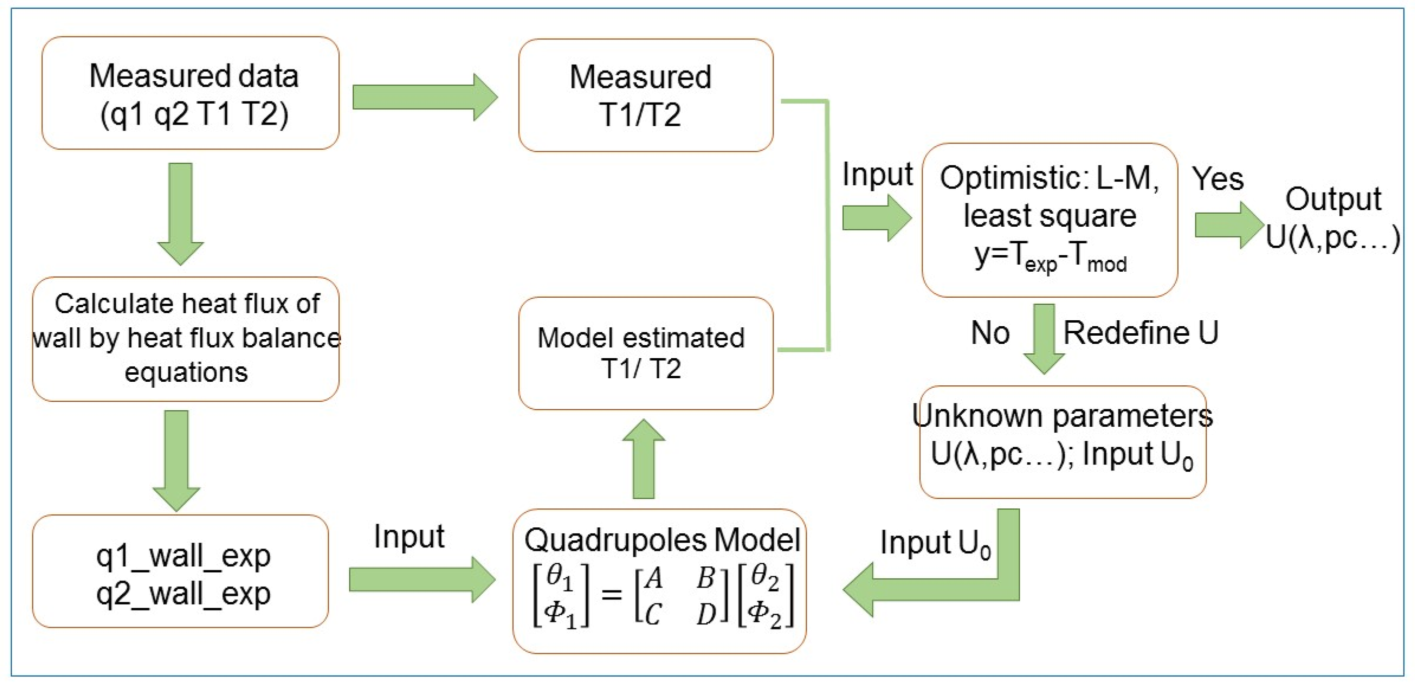


Heat flux of convection, radiation and transmittance of wall

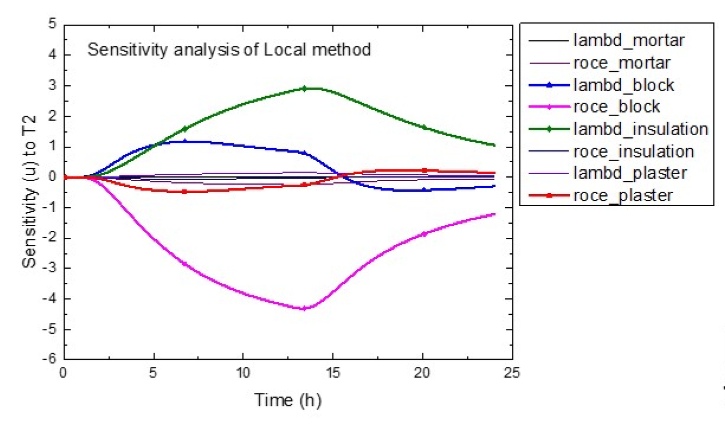


Comparison for heat flux of 4 surfaces (wall, Captec fluxmeter, shiny Peltier, black Peltier)

Inverse method



Sensitivity analysis



Sensitivity of rear face temperature

For the optimization of front face temperature T1, U=(λ_{mortar} ρc_{mortar} λ_{block} ρc_{block}). The optimization time is between 1-5 hours.

For the optimization of rear face temperature T2, U=(λ_{block} ρc_{block} $\lambda_{insulation}$ $\rho c_{plaster}$). The optimization time is between 5-10 hours.

Optimization results

Based on the sensitivity analysis, 6 thermal parameters were optimizated by inverse method with the measured heat flux and temperature of wall

	λ_{mortar} (W/mK)	ρc_{mortar} (10^6 J/m^{3}K)	λ_{block} (W/mK)	ρc_{block} (10^6 J/m^{3}K)	$\lambda_{insulation}$ (W/mK)	$\rho c_{plaster}$ (10^6 J/m^{3}K)
Test 1	1.17	2.36	0.84	0.92	0.045	0.53
Test 2	1.70	2.27	0.86	1.02	0.051	0.64
Test 3	1.45	2.45	0.84	0.99	0.056	0.69
Test 4	1.47	2.64	0.80	0.99	0.046	0.69
Advantage values	1.45	2.43	0.83	0.98	0.050	0.64
Reference values	1.15	1.70	0.87	0.90	0.038	0.90

CONCLUSIONS

- Emissivity of wall is measured with an infrared camera through an improved reduced data process.
- Peltier sensors are applied and analyzed for the measurement of heat flux in this test.
- Heat flux of radiation, convection and transmittance for wall is obtained by heat flux balance equation.
- The thermal properties of wall is characterized by an inverse method based on the thermal quadrupoles modelling.