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Transient Simulation of a Naturally Ventilated Façade in a Mediterranean climate

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The aim

To highlight the importance of CDF simulation to predict and study the energy performance of naturally ventilated façade systems, when experimental measurements cannot be carried out due to high costs and time needed.

To study the contribution of a naturally ventilated façade to the cooling energy savings of the building.

The system studied

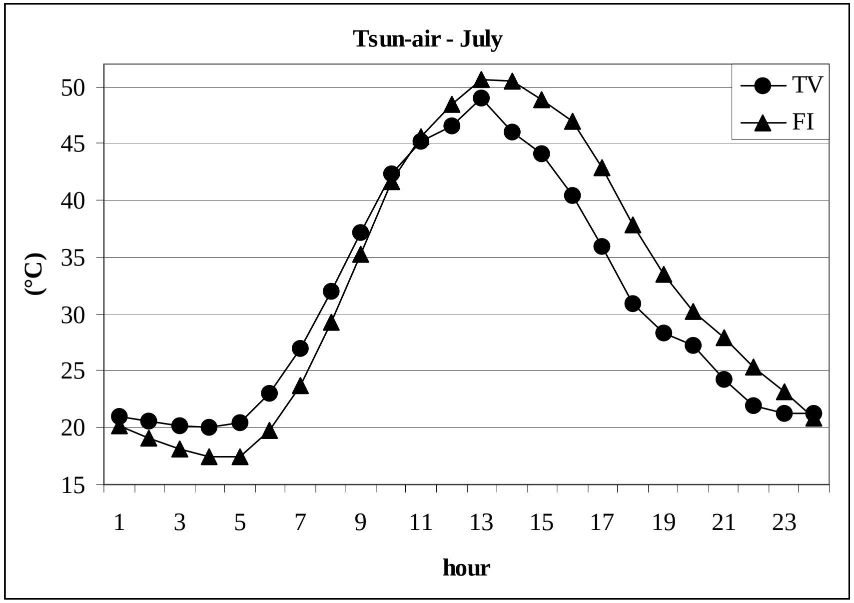
A ventilated façade made up of a brick cladding layer bonded to the perimeter walls of a building by a special "dry-mounted" fixing structure (a mechanical assembly) with an air cavity of 0.15 m thickness.

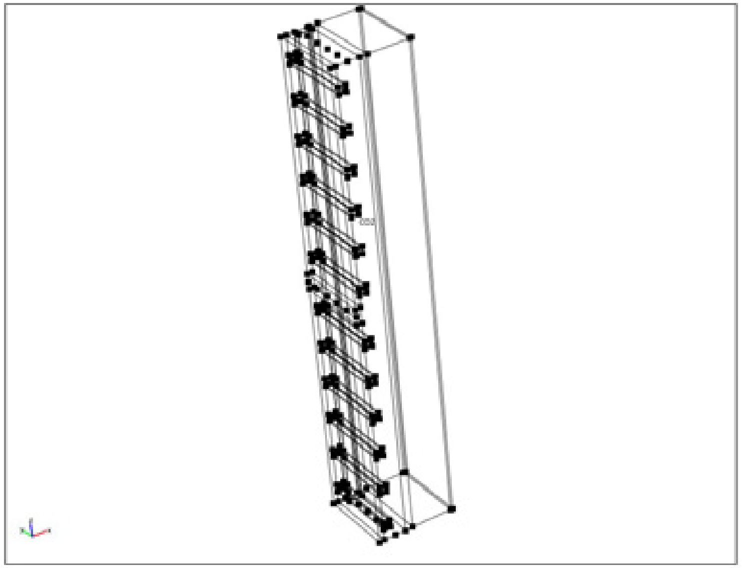
This façade was applied to the South-facing wall of an existent building considered as located in Florence and then Treviso (Italy)

Corresponding to the average latitudes: 43° for Florence and 45° for Treviso

Strata from outside to the inside ambient	s (m)	λ ($W\ m^{-1}K^{-1}$)	ρ ($kg\ m^{-3}$)	c ($J\ kg^{-1}\ K^{-1}$)
brick covering panel	0.035	0.5	1000	840
Air cavity	0.15	0.024	1.2	1000
Polistyrene	0.04	0.037	20	120
Solid brick wall	0.27	0.148	1600	850
Internal plaster	0.01	0.17	696	1089

Thermal properties of the layers of the ventilated façade studied





The simulation

Two transient simulations of the 3D models, based on **general heat transfer** and the **incompressible Navier-Stokes** on non-isothermal air flow were performed using Comsol

After many attempts, a good quality of the mesh was obtained **by 100 3172 degrees of freedom with 262604 tetrahedral elements**.

The initial conditions for transient computation were obtained by running the simulation for several days before, assuming, for the initial indoor climatic conditions, a uniform internal air temperature of 20°C and 50% of relative humidity, as usually suggested.

The linear system solver “PARDISO” was used

Results and discussion

Referring to the dimensional analysis based on **Buckingham Theorem** some of the **dimensionless numbers** with explicit physical meaning were defined and applied for a parametric study of the façade

$$N1 = \frac{qD_e}{\lambda_{aou}\Delta T} \qquad N2 = \frac{m}{\mu_{aou} D_e} \qquad N3 = \frac{cp\mu_{aou}}{\lambda_{aou}}$$

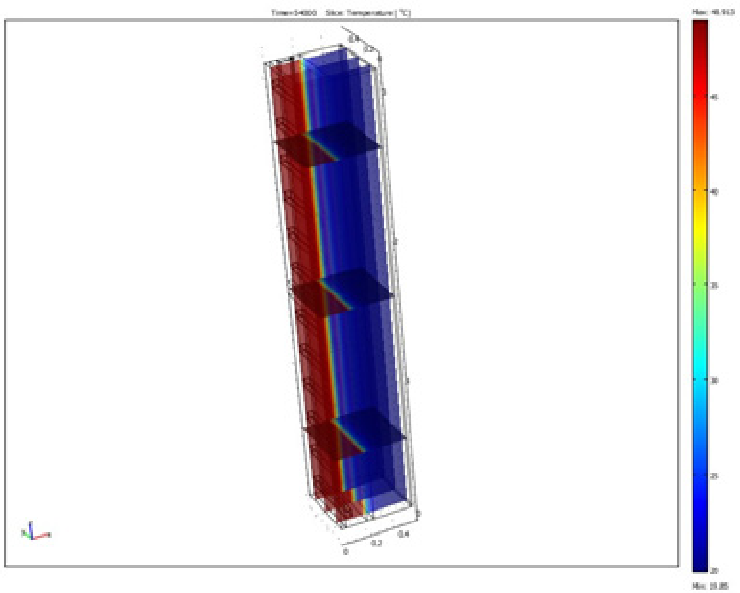
$$N4 = \frac{g\beta\Delta T D_e^3 \rho_{ach}^2}{\mu_{ach}^2}$$

$$N5 = \beta \cdot \Delta T \frac{H}{D_e}$$

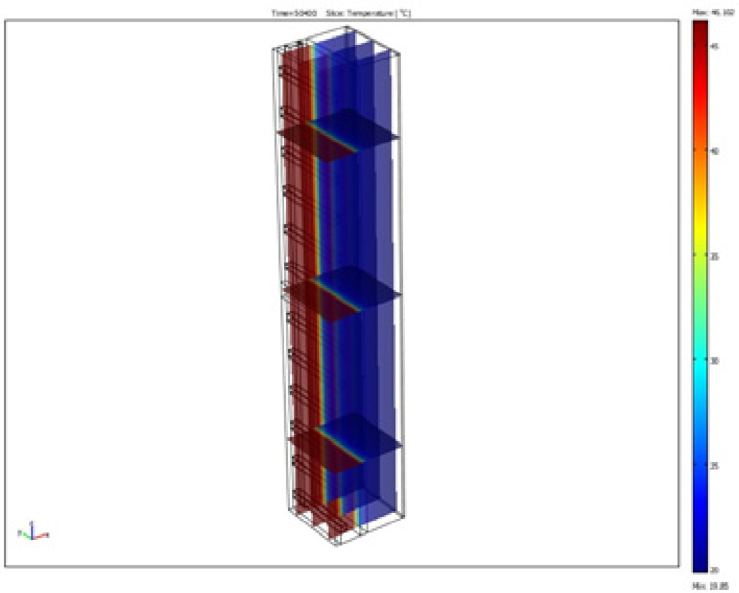
N1 expresses the average Nusselt number
N2 Reynolds number
N3 Prandt number
N4 Grashof number
N5 is connected to temperature distribution and flow regimes inside the cavity

Results and discussion

Results show that the naturally ventilated façade located in Treviso is **more efficient** than that one located in Florence.
This is mainly due to the **lower temperature differences**, between the external covering brick panel and the external air temperature, for Florence in comparison with those obtained for Treviso.

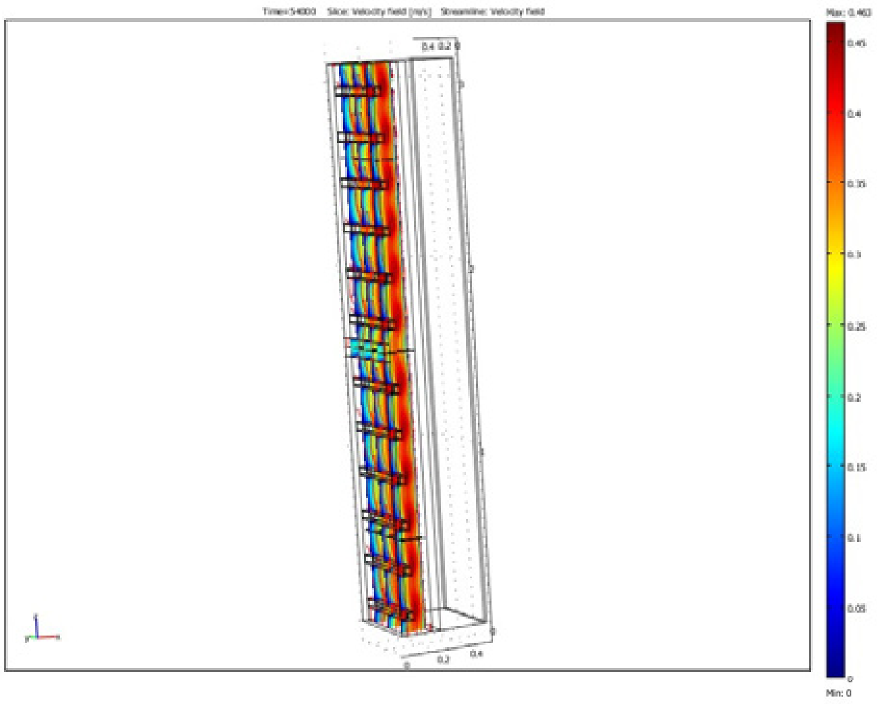


Temperature distribution – slice representation h 15, Florence

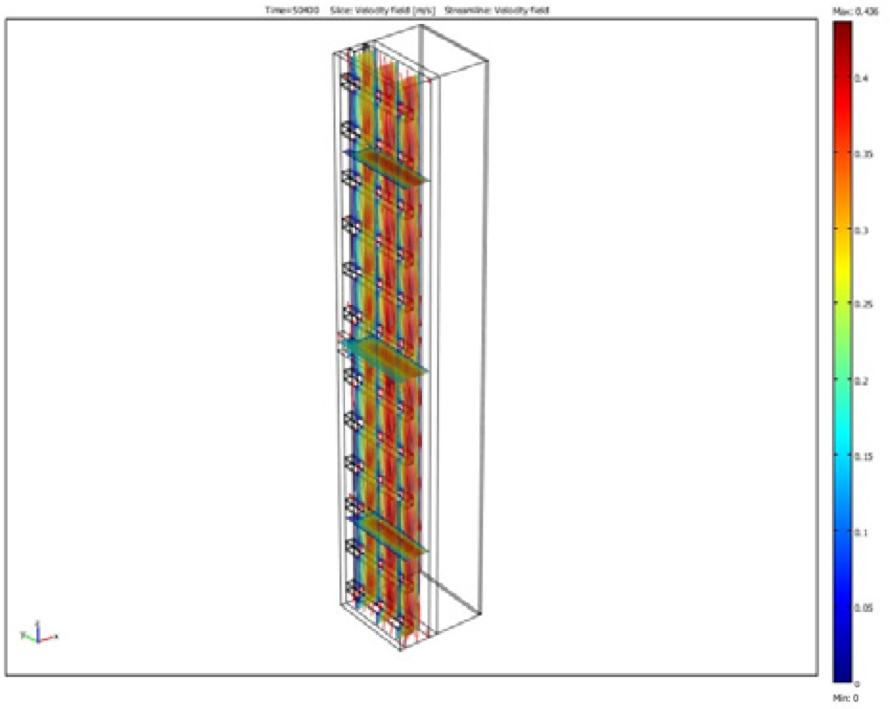


Temperature distribution – slice representation h 15, Treviso

This afflicts the average convective coefficient evaluated by the all simulation results:
for Florence location 6 W m^{-2} K^{-1}, and for Treviso 9 W m^{-2} K^{-1}



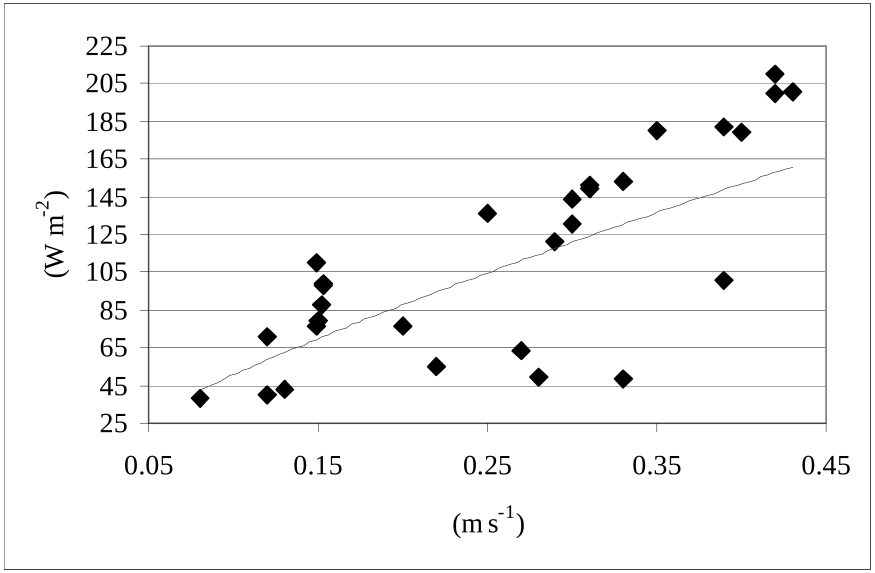
Velocity field - slice and stream lines representation h. 15 Florence



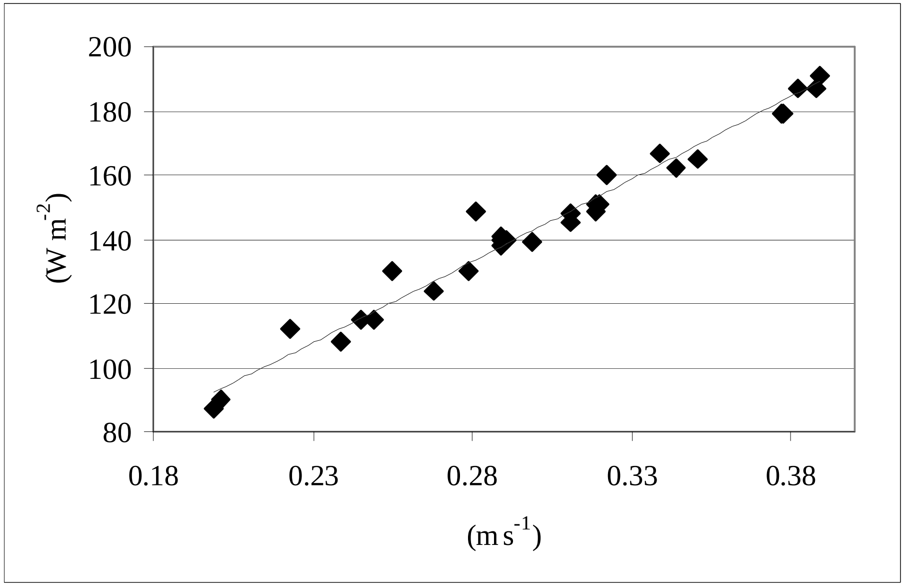
Velocity field - slice and stream lines representation h. 15 Treviso

The following figs show the **heat flux outgoing from the air channel as a function of the mean air velocity value distribution inside**: for the Florence location the values are scattered around a regression line with a lower value of the correlation coefficient R^2

The correlation coefficient obtained for Florence is 0.51 and for Treviso is 0.97



Heat flux outgoing from the air channel as a function of the mean air velocity value distribution inside – Florence



Heat flux outgoing from the air channel as a function of the mean air velocity value distribution inside – Treviso

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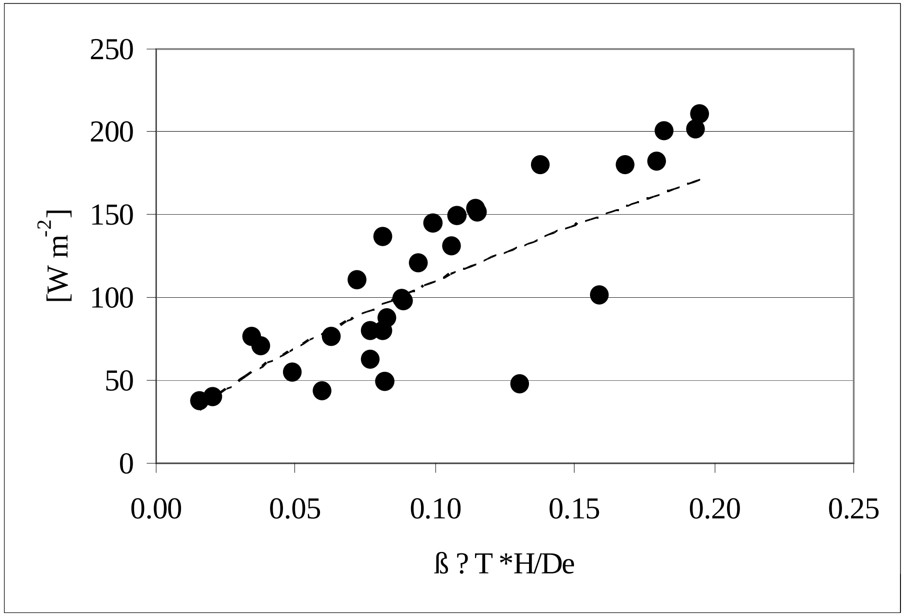
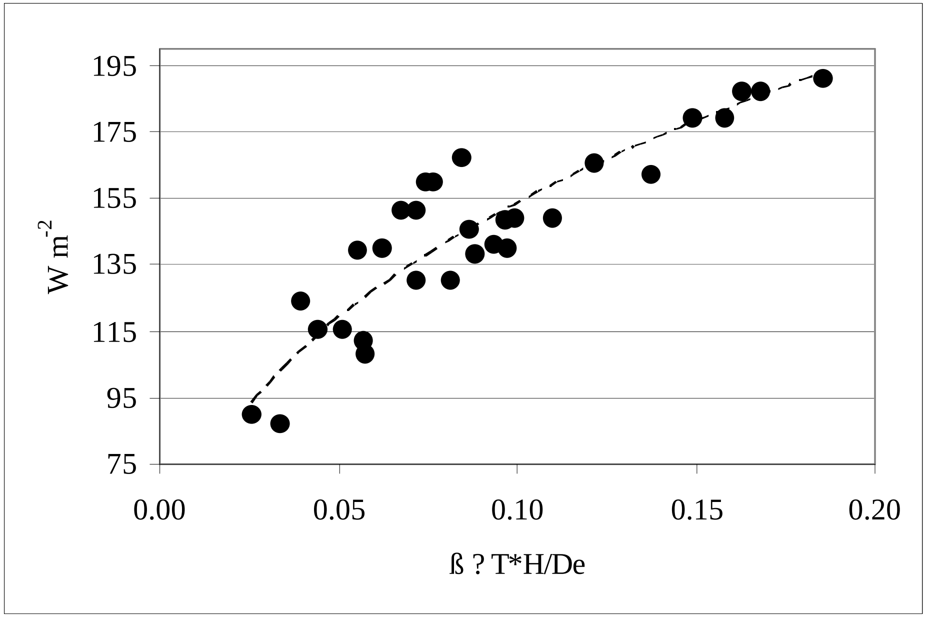
These figs show the **heat transfer throughout the ventilated façade as a function of the non-dimensional number N5**

For the Florence location the correlation coefficient is 0.62, compared to that one for Treviso which is 0.82



Heat transfer throughout the ventilated façade as a function of the non-dimensional number N5 – Florence



Heat transfer throughout the ventilated façade as a function of the non-dimensional number N5 – Treviso

Results obtained for the **average Richardson number** for the two locations show the **better performances of the façade in Treviso**

Florence: external air temperature is 19.9 < Te < 37.6
Richardson number is 0.02 < Rc < 1.20

Treviso: external air temperature is 22.7 < Te < 33.2
Richardson number is 0.49 < Rc < 1.24

The **local vertical turbulence phenomena** due to the "dry-mounted" fixing structure **are stronger in the façade located in Florence**

but at the same time for both the locations
the **dominant flow regime is low speed natural convection**

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Conclusions

The CFD-FEM transient simulation of 3D model performed by **Comsol Multhiphysics, is very efficient for simulating buoyancy driven natural ventilation**

Comparison obtained by simulating the system in two different climatic zones showed that **thermal performance of the ventilated façade cannot be generalized**

It is particularly effective **in reducing cooling loads, especially at average low latitudes, where the amount of total solar radiation striking the building walls is very important**

Results obtained by non-dimensional numbers can be used to address building sector operators in the development of new design solutions for a climate with high summer temperatures and solar radiation fluctuations

THANK YOU
FOR YOUR ATTENTION !