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WIND TUNNEL TESTS ON NATURAL VENTILATION IN THE HISTORICAL BULDING 'PALAZZO PITTI'

Lorenzo Procino*, Gianni Bartoli*, Carla Balocco, Giuseppe Grazzini**, Alessandra Borsani****

*CRIACIV Boundary Layer Wind Tunnel
c/o PIN, Piazza dell'Università 1, 59100 Prato, Italy
e-mails: lorenzo.procino@pin.unifi.it, gbartoli@dicea.unifi.it

**Dipartimento di Energetica S.Stecco
Via s. Marta 3, 50139 Firenze, Italy
e-mails: carla.balocco@unifi.it,giuseppe.grazzini@unifi.it, alessandra.borsani@pin.unifi.it

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1 INTRODUCTION

Natural ventilation techniques can provide the energy saving otherwise consumed by heating, cooling and ventilation systems in a building.

Reliable information on the existence and working conditions of natural ventilation systems inside historical buildings is a complex task. Full scale measurements can provide data on ventilation rate, air flow distribution, mean air velocity around and inside a building, but these experiments are really expensive and time consuming.

Computational fluid dynamics (CFD) modelling, even if carried out by expertise can provide quite inaccuracy due to errors on two-three dimensional geometry of modelling decisions, computational domain size, type and grid dimension and density, boundary conditions and turbulence model (RANS or LES) choice. The potential and accuracy of the CFD simulation, undoubtedly huge due to information provided on three components of velocity, vorticity and pressure and concentration at every grid point in the flow, need comparison with experimental data. Wind tunnel testing is a fundamental tool for natural ventilation systems investigation, in particular when it concerns historical buildings. Wind tunnel testing is also important for providing CFD boundary conditions and for representing and analysing the full unsteady aerodynamic interaction of the atmospheric boundary layer with building.

In the present paper wind tunnel tests, carried out both by wind and buoyancy effects with unsteady conditions, inside a scaled model of a historical building (the Pitti Palace in Florence), were performed to investigate the internal air flow induced by the present natural ventilation system.

The research has been carried out jointly by the Energy Engineering Department of the University of Florence and CRIACIV (Inter-University Research Centre on Wind Engineering and Building Aerodynamics).

2 THE PHYSICAL SCALED MODEL

During a survey inside the Pitti Palace some ducts covered by grids in the floor between the ground level and the basement were noticed; these ducts let air free to circulate between the two floors.

A research program then started aimed to investigate the internal behaviour of the air fluxes in order to verify if a natural ventilation system was possible in those spaces.

The physical model used for tests was built at the Institute of Art of Florence (ISA); a 1:200 scale was chosen, suitable both for the dimensions of the wind tunnel and for maintaining the blockage effects as limited as possible.

The global size of the model then resulted in 1.5 x 2.0 m, including the garden and the front square with surrounding buildings; these last and the part of the Palace not directly studied, were made of cork and plywood. All the doors and windows were constructed to be opened or closed. The single part of the palace that concerns the left summer apartments were made of transparent plastic and polycarbonate material so that flow visualization and PIV (Particle Image Velocimetry) measurements can be done using smoke tracer.

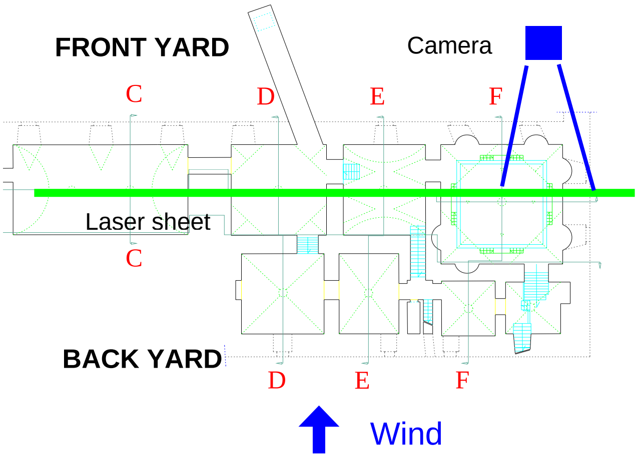

Figure 1. – Measuring set-up

3 THE BOUNDARY LAYER WIND TUNNEL TESTS

The ventilation of the internal space was evaluated in two different settings for the following conditions:

- presence of an incoming wind from the back side of the building;
- absence of forced wind, simulation of the buoyancy effect by positioning dry ice (CO_2 ice) on the Giardino di Boboli behind the building.

The purpose of this study is to verify if an internal air velocity field develops from the rooms of the basement to those at the ground level. The flow can be generated by the wind present in the garden entering through the windows at the back or by the temperature differences due to the adiabatic saturation process of the external air that flows down the Boboli Garden .

In the first testing set-up the model was positioned inside the wind tunnel where an incoming low turbulence (<1%) flow was generated at a velocity of 1.79 m/s, 2.96 m/s and 3.27 m/s.

Through PIV techniques the flow inside some rooms was measured in different configurations (opening and closing the first floor windows at the back side). The flow in the back yard was investigated to know the condition at the inlet zone.

In the second run of tests the garden was covered by a layer of dry ice in absence of forced wind; like the previous case, the flow inside the rooms and in the back yard was investigated.

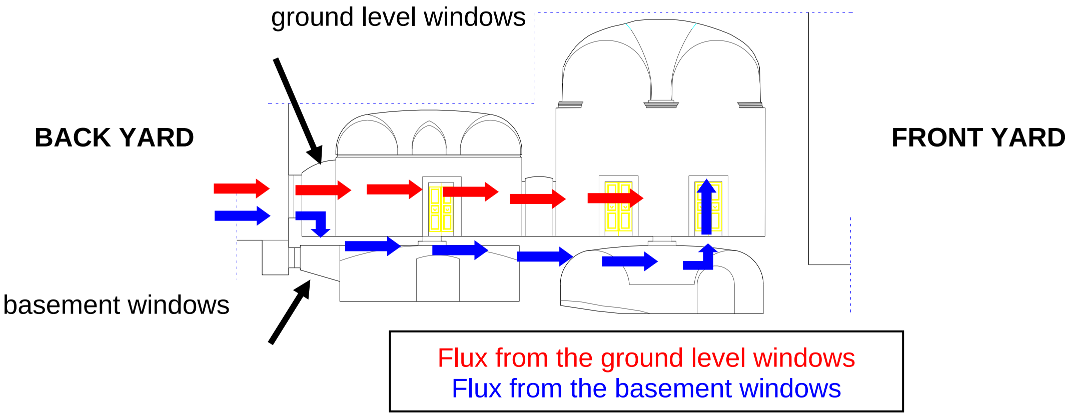

Figure 2. – Internal flows

4 RESULTS AND DISCUSSION

The important air flux is the one coming from the basement and reaching the ground level through the air duct positioned in the floor of the rooms. In following Figs. 3 and 4, the vectorial field of velocity and the isovelocity maps are shown.
The flow just before the back windows (inlet condition) was measured by highlighting a vertical plane in the back yard (between the Boboli Garden and the building).
An interesting consideration is that in the configuration with forced wind the flow in the zone of the back yard completely differs from the configuration with the flow generated by the evaporation of dry ice (the vorticity changes its direction).

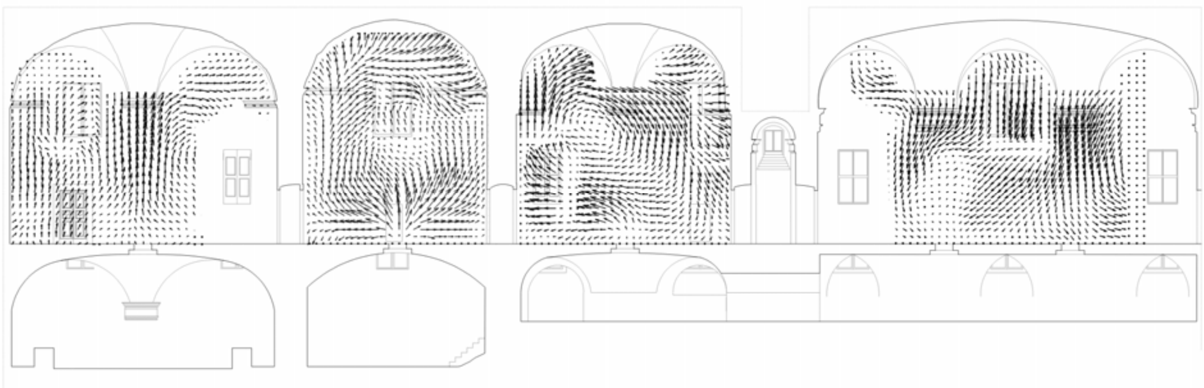

Figure 3. – Vectorial field of velocity, configuration with closed back windows

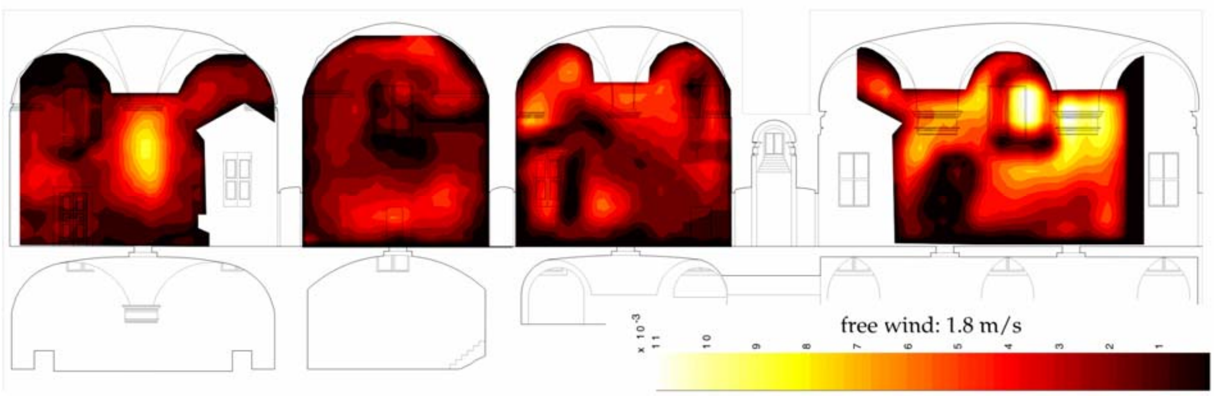

Figure 4. – Isovelocity map, configuration with closed back windows

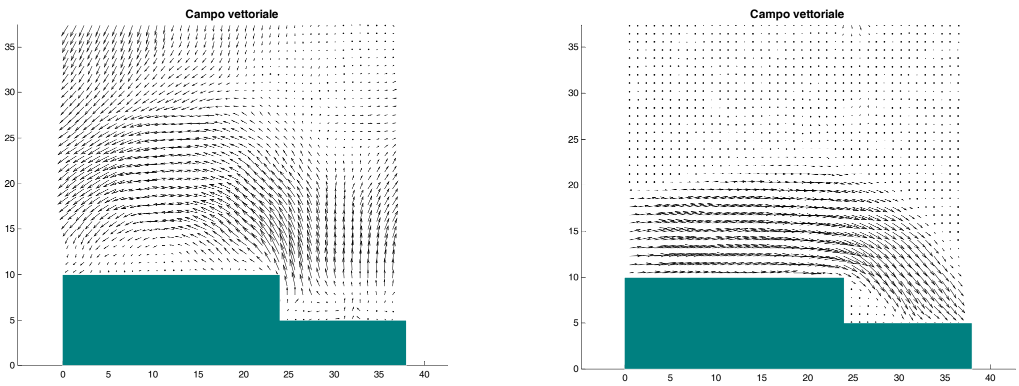

Figure 5. – Vectorial field of velocity both in the condition
of forced wind (left) and with dry ice (right), zone of the back yard

5 CONCLUSIONS

Obtained results confirm that a flux of air is generated coming from the Boboli Garden, entering in the basement rooms and then streaming towards the ground level rooms through the ducts in the floor.

The physical phenomenon involved in the process needs to be further investigated, especially from a quantitative point of view. The pressure and temperature distribution in the internal and external side of the facades should be measured in order to know the pressure gradient moving the flux; the temperature in the back (inlet) and in the frontal (outlet) windows should be investigated as well. Finally other velocity measurements can offer a better knowledge referring to the continuity equation.

The analysis inside the wind tunnel, using tracers, will allow the simulation of air flows dynamic effects through the rooms of building, taking into account shape and roughness of different surfaces and the urban morphology around the palace.

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