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Extended summary

Wind Exploitation for Natural Ventilation Design in Buildings

Curriculum: Analisi e progetto dell'architettura e del territorio

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Abstract. The target of the thesis is to identify a procedure able to exploit climate in order to create better living conditions. This attempt originates from the certainty that an appreciable house comfort can be more cheaply achieved through a reduction of mechanical air-conditioning. This process can be divided into four steps, where only the last step represents the architecture, which is achieved through the study of climatic variables, a biological evaluation and the study of appropriate technological solutions, therefore avoiding traditional methodologies but exploiting technological progress in order to increase the house comfort in the current massive urbanization. Climatic data to be studied for a conscious architectural design are in general temperature, relative humidity, radiation and wind effects. Moreover, microclimatic study has to be also performed since often, especially in the urban environment, it ultimately affects the climatic conditions on site, even through a change of the direction of the prevailing breezes (consider, for instance, heat islands). In this sense the natural ventilation of buildings has been taken into consideration, intended as technology supporting the building-machine.

With the objective of verifying the wind influence and interaction with the urban system and the extent to which this affects a design which could be defined traditional, a numerical approach has been followed by a practical experimentation in order to analyze the wind flows persisting at an urban microclimatic level on an area of study already affected by an architectonic design.
The results obtained point out the interaction between wind flows and built-up area, and open new study opportunities in the wind field addressed to identify a method able to better define on site conditions for an efficient and conscious design within the architectural as well as urban context.

Keywords. House Ventilative Comfort, Natural Ventilation Design, Urban Microclimate Study, Wind Exploitation, Wind Tunnel Experimentation on Complex Orography.

1 Problem statement and objectives

The aim of this dissertation was to investigate how much correct were the directions given to designers in well-orienting a building in such a way as to make it energy efficient in the case of need for natural ventilation. Starting from the notions given by Olgiay and Banham in their writings of the years 60-80 the study proceeded with the most recent literature consisting mainly of scientific articles related to research and books by Mario Grosso. The aim is to see if it is possible to give more quantitative and less qualitative parameters for the drafting of architectural design that takes advantage of natural ventilation.

2 Research planning and activities

In order to achieve the goal, the basics of climatology have been studied to define the physical parameters that directly affect the thermal parameters of the building, namely: solar radiation, atmospheric and terrestrial radiation, temperature of air and soil humidity and, finally, wind.
This is to verify that the initial assumptions were scientifically acceptable.
Then the investigation proceeded with the study of the climate and particularly the microclimate in order to verify how they vary the climatic conditions of the mesoscale site-level in relation to the microscale. Reference was made to the classification of Koppen to narrow down the area of interest and produce an area small enough to conduct experiments both theoretical and possibly practical. All aspects already seen by a physical point of view that affect the mutation of the climate at the lower levels of the atmosphere were considered, parameters that affect urban ventilation and urban liveability were defined and the characteristics of construction that mitigate these mutations were introduced with particular reference to construction materials. Then, wind profiles in urban areas were studied and the major climate changes as a result of built environment were studied from a purely qualitative point of view. As a result of this step of the research the ideal sequence to be followed in order to make a good design came out as below:
1. Overall evaluation of the intervention
2. Spatial analysis
3. Performance fluid and the thermal regime
4. Calculation of welfare
5. Calculation of equivalent mitigation.

Once decided to limit further investigation to the Mediterranean area, the architectural features typical of the basin were studied, deepening their knowledge of archaic architectural types to mitigate the summer heat with good indoor ventilation, not in order to make them play but to see how they dealt with the issue over the centuries in an area known for climatically homogeneous and empirical experience. The efficiency of archaic buildings static such as the Trulli of Alberobello, underground as the Sassi of Matera, active as wind towers in Iran was then evaluated.
In the third step of the research an area was defined that could set an example for the special allotment of experimentation by locating it in an area close to the city center of Ancona.

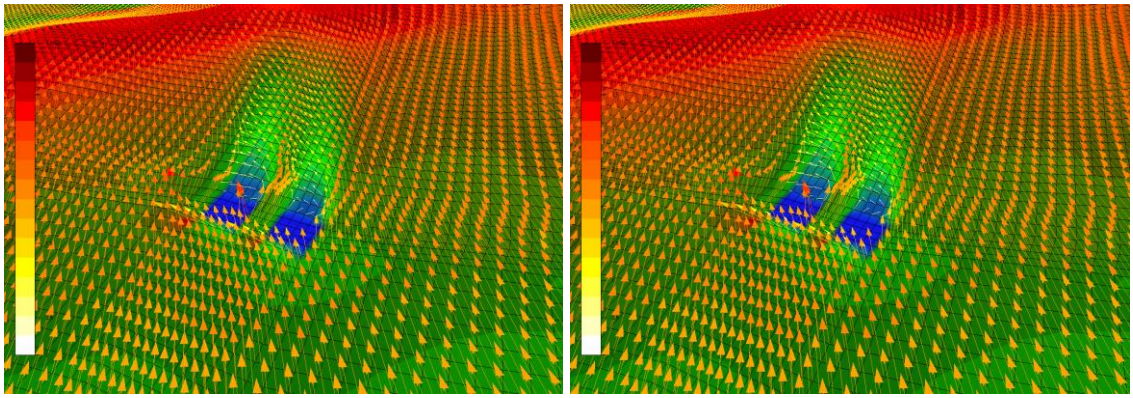
Overview of the intervention area.

Design, North is up.

After the definition of the design parameters in a conventional manner, the problem of natural ventilation was studied starting from mesoclimate prediction with numerical models utilizing a forecasting approach.
The analysis aimed at assessing the intensity of the wind and the average annual distribution of wind occurrence in the area of interest have been carried out through a series of numerical simulations. In particular, we used the computer code MM5v3, as amended by the research group in fluid dynamics of Università Politecnica delle Marche. The results of this analysis are the anemometric columns as following schematized with the relative wind roses.

Study area and related anemometric columns, with the interesting area at the center.

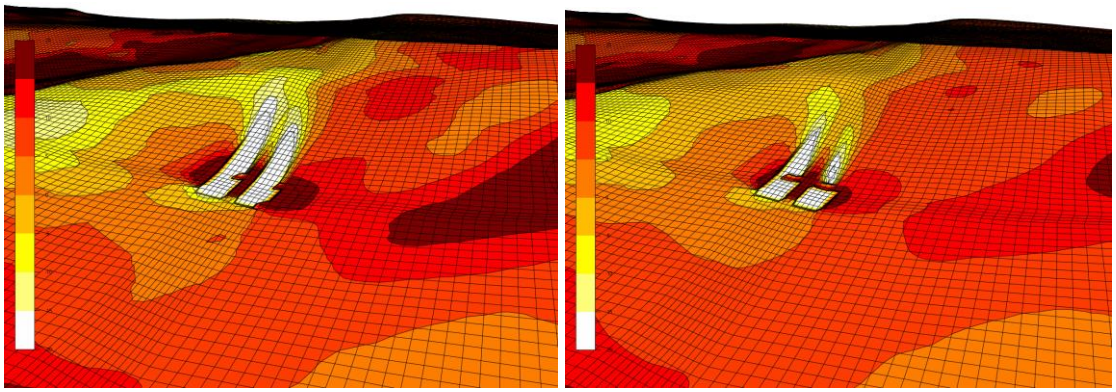
The next step is to define the flow of the wind in the immediate vicinity of the town, to better define the interaction between urban environment and wind direction at the level of microclimate. It was narrowed down to one anemometric column of the project area. Extracted from the wind roses on a monthly basis, the dominant direction to the various units of analysis were confirmed and, with regard to the lowest level, it was noted that the prevailing directions do not have a strong seasonality and occur equally in both the summer months and the winter ones, so that it cannot be deemed that the favorable winds (summer) come from a single direction. The wind direction was analyzed with the program WindSim considering in the area only buildings subject of discussion. Then the two directions 270 degrees (West) and 150 degrees (South-East), drawn from the level of mesoscale, were set deriving that, with regards to the direction South-East, the wind encountering the buildings at a height of 4 meters is channeled between the two buildings while creating a recirculation on the short side to the west. This behavior is accentuated increasing the height to 8 meters while the trend remains practically undisturbed once exceeded the height of the building at a height of 16 m.



Wind recirculation between the buildings at the heights of 4 and 8 meters. In blue the buildings footprint. Direction South-East.

In the case of wind coming from West, it applies pressure to the short side oriented to the West which is invested directly by the flow, creating a recirculation on the front facing South which continues into the space between the two buildings (note the vectors facing

South with an inflow which is directed to the West), while the side towards East appears to be in depression.
A flowchart of the relative wind flow directions (according to the two incident) confirmed what was calculated by vector analysis.



Wind relative directions at the heights of 4 and 8 meters. In white the buildings footprint. Direction South-East.

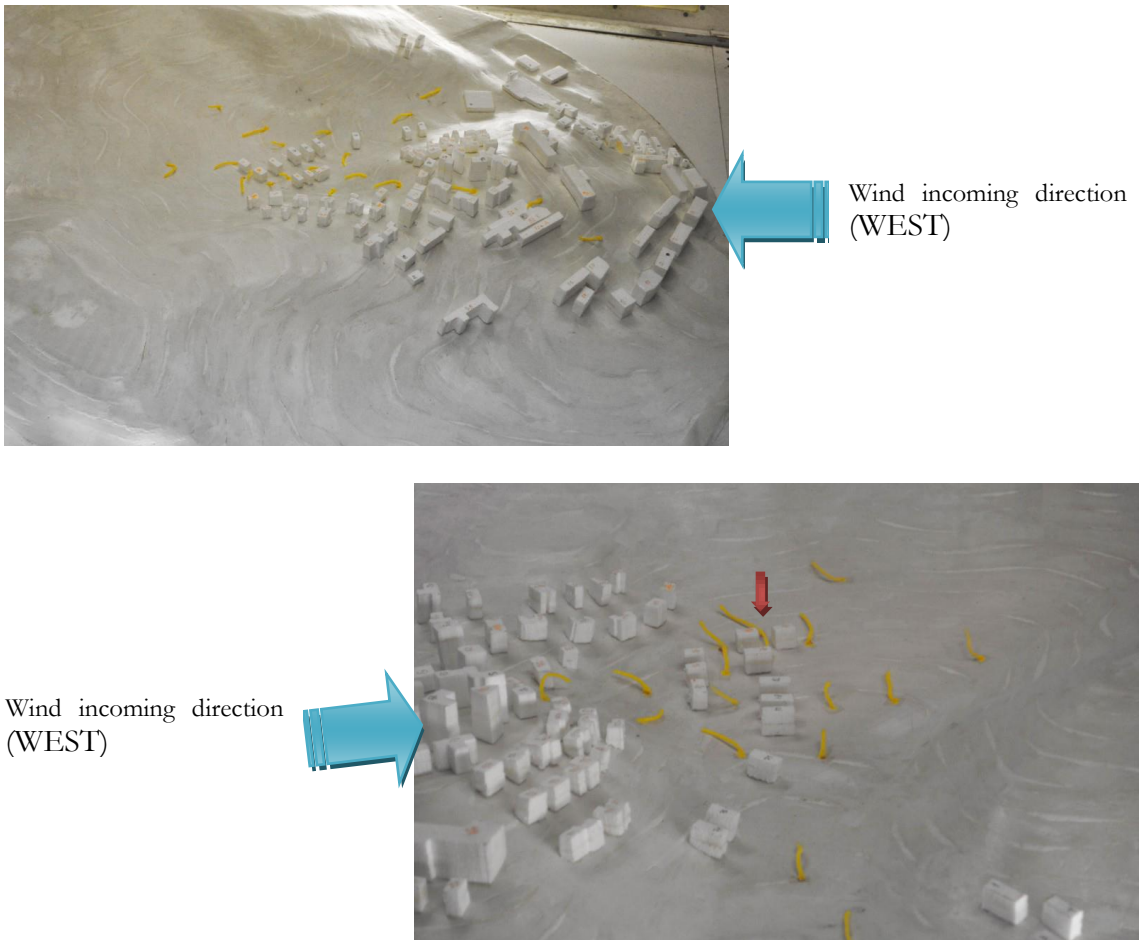
The last step to complete the test and verify the knowledge obtained so far has been an empirical testing in the wind tunnel made with the construction of a 1:500 scale model of the project area and its surroundings for a real terrain surface overall about 600 meters in diameter, including buildings of the area.
In a realistic simulation, once you set the wind profile depending on the roughness of the terrain and decide to exclude the wind direction from South-East as the area in question does not present buildings along this direction, you would then proceed in the main West direction to understand what is happening.

Model oriented along the main direction West, fitted in the wind tunnel for profile setting.

3 Analysis and discussion of main results

What has emerged is a confirmation of the deviation of the wind due to topography and urban plan, with a dominance of southerly direction on areas affected by the intervention that is in contradiction with the data obtained from the analysis at the mesoscale.
To get further confirmation of the impact of the urban plan on wind deviation, an experi-

ment was performed in the wind tunnel with strands of wool applied at known points that would simulate wind vectors. The following image confirms what supposed.



The wool strands tilt-up revealing the South-South-East incoming direction.

4 Conclusions

In conclusion, it cannot be held definitively proven that favorable winds coming in one direction only and then it will have to opt for solutions that take into account more ventilative the thermal gradient between day and night rather than the prevalent direction of seasonal wind.
One thing immediately noticeable is the relevance of the valley that lies beneath buildings undergoing study, the wind undergoes a strong acceleration compared to the valley as soon as it is uncovered and the main component of the wind loses its importance.
Analyzing qualitative profiles of the wind in various measuring points, we note that the minimum wind up being defined undisturbed is about 50 meters above the ground.
At the end of this experiment it is evident that it is necessary to continue the investigation on the model with a speed probe that can define all three components of the wind along the coordinate axes and the form of the intensity in the entry model in order to get the precise direction of the deflection of wind at lower altitudes that are affected by a condition of microclimate strongly determined, as we have been able to show, from the urban context rather than from the orography itself.

Deepening experimental results of the analysis can come to understand how to exploit the natural ventilation of the air vents on the sides exposed and outlet nozzles on the sides placed under vacuum in order to force the process without any use of mechanical energy. Not least, it could work on the shape of the roof, making it aerodynamic, create areas of pressure and vacuum corrected accounting standards to make more efficient natural ventilation of the interior.

From an urban point of view, in the case of dense urban areas, the natural ventilation of buildings, which has as its basis the prediction of the wind, it takes a greater priority in the design where one cannot change the existing urban context.

It is seen as the traditional construction requires large spaces in the modern city cannot be found except in rare cases, a detailed study of the urban microclimate ventilation compensates at least in part the lack of space needed for the operation of the archaic type.

In the case in which it is possible to modify or decide the orientation of the built-in with a urban context, even going to affect the PRG and the various spatial plans, taking into account the urban microclimate both before and after the building work, also with experiments similar to those performed for the purpose of this thesis, leads to an undoubted advantage both economically and environmentally with a limitation of the power consumption of the built urban environment.

A further interesting aspect of the experimentation is that it can be then used to various scales of design generalizing the model studied to the city. It could also provide area-specific constraints for the design of good practice in the field of bioclimatic architecture of the Mediterranean basin.

Last but not least, are to be considered the environmental benefits that would result from this method. Indeed, in addition to the reduction in energy expenditure resulting, among other conditions for the harnessing of wind to be considered the decisive effect in the neighborhood that occupies the vegetation so it needs a reorganization of urban green spaces as much as possible for better effectiveness of the "capture" of the wind from the buildings. In this sense, one might think to specialize the skin of the building in such a way that allows the entry of summer breezes and prevents the ingress of cold wind in the winter with a definite gain in economic terms.

The last point that should be emphasized is that in this type of design, to optimize the better yield, it is essential to a careful choice of building materials, taking care to use especially for the casing material types that do not cause bubbles of heat due to their high specific heat capacity.

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