Comparison between different methods for urban ventilation study: the case of the city of Belo Horizonte, Brazil

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ABSTRACT: The accelerated growth of big cities has caused changes in urban climate. The density and configuration of urban areas are responsible for phenomena as heat islands and reduction of wind speed. The city of Belo Horizonte in Brazil is an example of these kinds of changes. In the city these phenomena are accentuated because of rough topography and its tropical climate. This paper presents results of a research about natural air flow in this city comparing two methods: computational interpolation of data from local weather stations and physical simulation of a scaled model in a wind tunnel. Results indicated the effects of topography in the air flow and validate the hypothesis produced by computational simulation.

KEYWORDS: urban ventilation, urban planning, environmental comfort

1 INTRODUCTION

Urban ventilation is one of the main climate variables affected by the growth of cities in tropical areas. The density and configuration of urban areas are responsible for changes in direction and wind speed, often causing situations of thermal discomfort and bad quality of air. Ventilation in urban areas contributes with evacuation of heat produced by buildings and human activities in addition to spread the air pollution.

The distribution and characteristics of the wind over a region are determined by several global and local factors as the seasonal global distribution of air pressure, the rotation of the earth, daily variations of temperature and the topography of the given region and its surroundings (Givoni, 1976). So, the winds condition study has to approach these scales to show global effects until local differences in air flow.

In local scale [1], topography is an important element that changes mainly the predominant wind paths in specific areas. In general, the major roughness of the urban area cause speed reduction and aerodynamic effects restricts to specific regions due to higher wind friction with construction surfaces. Consequently, the thermal conversion becomes prejudiced and temperatures in urban spaces can increase (Oke, 1981; silva, 1999). Most of Brazilian cities are situated in tropical latitudes where the effects of high excess temperatures in urban areas become greater due to irregular occupation and increased emission of pollutants. In the city of Belo Horizonte, high level of temperature and local wind patterns are accentuated by illegal occupation of valleys and hillsides, rivers drainage systems and poor distribution of green spaces.

In Belo Horizonte city rough relief is a feature of the landscape. Therefore a study had been made to show the topographical influence on regional mean wind conditions since the relief suffers few changes during the years and its effects can be previewed and applied in urban planning decisions. This paper presents a comparison between two different methods applied to investigate natural air flow in the city. Studies on vulnerable areas with low ventilation conditions are scarce in the city of Belo Horizonte so this research is important for planning purposes.
2 BELO HORIZONTE CITY: THE STUDY AREA

Belo Horizonte is located at 19º 55’ South latitude, 43º56’ West longitude and at a mean altitude of 875 meters (Fig. 1). The regional climate is considered as tropical of altitude however climatic classifications indicate a local changing to a warmer and drier condition (Aw, according to Köppen classification). This indicates a possible urbanization influence on the local climate (Assis, 1990). The average annual temperature is 21.1ºC and the maximum and minimum averages are 27.1ºC and 16.7ºC respectively (Brasil, 1992).

The city major altitudes are located on the Southern and Southeast of the town because of the Serra do Curral (a local mountain). The maximum altitude is approximately 1,480 meters. The Western side also presents high altitudes that reach 970 meters. The North portion of the town presents smooth topography and altitudes are between 675 and 850 meters.

3 METHODOLOGY

The methodology used in this work contains two main phases: computational interpolation of data from local meteorological stations and physical simulation of a scaled model. The first phase included database of wind speed and direction from thirteen fixed meteorological stations located in Belo Horizonte and in its surroundings – four stations are placed in the city (Fig. 2). It was important to feature surrounding areas due to physical barriers that influence winds conditions, direction and speed. These are from 1998 and 2001 and were used to calculate monthly averages of four years. The meteorological stations have different ways to register data: some of then use the hourly series and others register information by daily or monthly means. To equalize the datum collection, it was applied the treatment method used by the standard stations in Brazil, which gives the climatological data based on World Meteorological Organization (WMO) technical regulations (Brasil, 1992). They were statistically analyzed to represent an annual mean wind variation and plotted on a topographical map of the city using a surface mapping software.

The second phase was a qualitative physical simulation of a topographical city model in a wind tunnel. The model was made with a scale of 1:40,000. Topography was represented by cork blades over a plane wood support measuring 90x70x1 cm. The model was tested in a boundary layer wind tunnel using the sand erosion method representing the dominant winds condition. In different moments of the experiment were made photographic registers to analyze the effects of the wind speed variation. The results showed the influence of local topography on air flow and
indicate bad ventilated areas in the city. Physical model tests validated the computational simulation hypothesis.

4 RESULTS AND CONCLUSIONS
Results show a generic view of mean wind conditions in Belo Horizonte city and the areas with bad natural ventilation. In the first phase of study, vector map showed predominant wind direction and speed variation in the analyzed area (Fig. 3). The dominant direction expressed in the results was the East. Major speeds were sited in Northern and Central areas which had mean winds of even 2.8 m/s. In these areas, the relief is smoothness than in the Southern. this means that wind can flow easier than in mountainous regions. The Southern and Southeastern regions of the town exhibited the lowest wind speed which reach less than 1.5 m/s. Probably, the mountain range (Serra do Curral) acts mainly as a barrier to change wind speeds and direction. The direction of wind in the extreme Southern of the city was also modified to the Northeast.

Physical simulation in a boundary layer wind tunnel pointed out the air flow trends validating computational hypothesis. Besides, it showed areas which have bad natural ventilation conditions. They are on the lee side of mountainous obstructions and shows the topographical influence in wind conditions. The higher was an obstruction, the bigger was the bad ventilated wind area. Southern region was the place which had the most areas in bad ventilation conditions due to irregular relief. In the computational simulation the less wind speed occured in this area.

To translate the results acquired in physical simulation to a useful map that could be understood by urban planners and designers, a cartographic representation was done using the photo took after the end of the wind tunnel experiment (Fig. 4). First, the picture was treated in an image-editing software to make a layer of areas which gathered sand during the test. Then this image was overlayed on a map of the city neighborhoods. Based on these results, it is possible to study specific places which might be not properly ventilated.

As a conclusion, it is important to attest the study relevance. The methods used in this study are complementary. Computational simulation gives support to physical simulation since it demonstrates the dominant wind conditions which are an essential data to test the scaled model. In the other hand, physical simulation validates computational method.
In this study, the physical model had a problem with its scale in correspondence with the wind tunnel parameters. So it was not possible to extract numerical data and then wind tunnel tests were only qualitative. However the results could be applied in urban planning indicating areas which should be protected by urban legislation against a strong urban development. In the same way, computational simulation provides aid to urban planning showing the main paths and directions of wind. These results point out places which should be preserved due to their importance as wind approach in the city.

This kind of research may not only contributes to a better understanding of wind paths in the city site but mainly it may be used to improve the land use laws having in sight to preserve good ventilation conditions. Acknowledging areas well and bad ventilated in urban spaces could assist on streets orientation design, building orientation establishment and distribution of green areas, tools which contributes to a better quality of life in cities.

Figure 3: Mean wind conditions – period from 1998 to 2001. (After Ferreira, 2004)

Figure 4: Neighborhood map with bad ventilated areas. (After Ferreira, 2004)

[1] Climate scale classification defined by Monteiro (1976), according to Cailleux and Tricart.

5 REFERENCES
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