Investigation on a natural ventilation system using the structure design of a building

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ABSTRACT: The research group on "environmental postures in architecture and urbanism" linked to the school of architecture and urbanism from the Mackenzie University in São Paulo developed within the comfort laboratory, several studies focusing constructive techniques achievable to skyscrapers and adjusted to natural and social environments of a metropolis located in tropical region of altitude (+or- 800m).
The very first goal was to argue sustainable solutions that seized natural energies, embraced local geographical conditions and caused the minor impact possible to environment and neighborhood. At the same time results brought data for deliberations on new shapes and designs following new technical possibilities, thus creating soaring aesthetics to the buildings facades.
Ventilation theme was chosen as being an essential agent in comfort achievement in hot and humid zones. Measurements focused the design of a multi-functional building located close to the Ibirapuera Park, the city largest green area. From the initial design of a high building attending to a complex program, we deepened studies on a natural ventilation system that uses the building structure itself and takes advantage of its height. Looking forward to a passive system for ventilation and aeration through winds caption, we defined a conceptual model to a possible system.
This study will allow to analyze and to evaluate the performance of a ventilation system other that the traditional crossed wind through the floors, but natural and controllable.

1. INTRODUCTION

The very first idea when organizing a design workshop with emphasis in environmental comfort issues, particularly approaching natural ventilation, came from the need to promote debate concerning a most argued subject in our days concerning energy efficiency linked to building sustainability within great cities. Motivated by the subject relevance, our team aimed to stimulate discussions within the academic community, in a first moment, intending to raise fundamental questions and argue possible solutions of major problems touching contemporary architecture within great cities.

A sky scrapper was chosen for further investigation as its model became common in almost all major cities and seems to be inevitable one in western economic system. The main problem is that most of the high buildings that crowd our cities lacked of deeper studies on impacts caused in their environment, thus generating many inconveniences. But it is clear that high buildings can have qualities and positively interact with its environment when properly designed.

Copied models from other places seldom show problematic issues as they are not adjusted to the local climate, causing extra expenses in energy, that could certainly be dispensable or minimized if they had been designed in coherence with the climatic reality.

Ken Yeang´s works served as inspiration as the architect considers solutions for hot and humid climate (Malaysia) and questions the financial image of the majority of skyscrapers.

Building under the Capricorn tropic (latitude 23° 27´South), with an overstated solar incidence (when compared with other regions in higher latitudes), high temperatures and high rates of humidity due to frequent heavy rains during summer season demand special attention when aiming satisfactory achievements in comfort issues with passive solutions. Thus, inner cross ventilation becomes crucial to minimize tropical heat and humidity impact. Besides, shadings and protections from the intense sun beam must be equated for the façades, as well as thinking of the use of sun energy.
To build higher can be a solution to solve problems in a city such as São Paulo, as with height, larger wind velocity can be gained.

Figure 01: The team working at Mackenzie´s Laboratory

Teachers from the school of architecture and urbanism at the Mackenzie University in São Paulo (FAU Mackenzie) all involved in research programs on sustainability and environmental postures regarding architectural and urban designs, proposed to the students a workshop the design of high buildings willing to investigate a natural crossed ventilation system.

2. SÃO PAULO METROPOLITAN ZONE CLIMATE

The latitude of the metropolitan area of São Paulo, under the Capricorn Tropic (23° 27´South), its altitude, its rough topography and the influences of disturbed air mass systems are factors that lead to a very diversified climatology regarding temperatures. In fact, The City lies on a high plateau, 750 m above the level of the sea, explaining why mornings and nights are often cooler and for times displays the classic "paulistana" drizzle [11]. The four seasons of the year are not clearly defined, but during some days, it is possible to feel the four of them within 24 hours!

The annual average temperature varies between 20°C and 24°C, and may reach 18°C or less in the higher areas, due conjugated effects of latitude and frequency of polar air masses.

During summer, mainly in January, average temperatures around 30°C and 32°C are common, while during winter months, minimum average temperatures vary between 6°C and 20°C, with absolute minims varying from 4°C to 8°C.

Most of the rains are brought by mass air system from south, seldom come from west. The annual precipitation rate in these areas is superior to 1,500 mm. The dry period occurs in winter (June, July, and August) while the rainy period ranges from December to March.

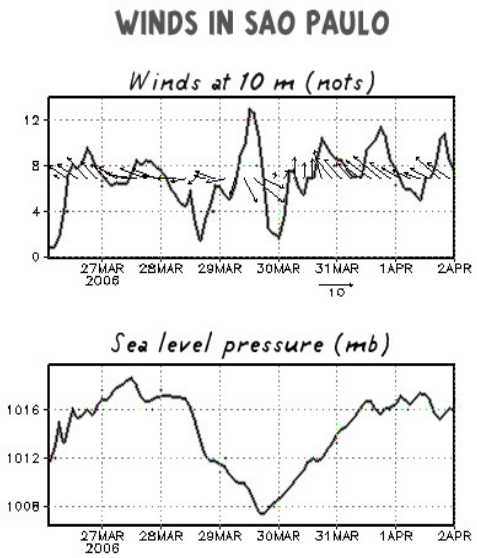

Figure 02: High resolution model for regional winds. GWT São Paulo City, SP - Font: Climatempo – WRRC

Predominant winds blow from south and southeast, however they are neither constant nor strong. Gusts of bigger force and intensity come northwest. There are many other variations in directions, when observed in a macro climatic approach, but the more intense ones occur due to irregular topography (valleys and hills) as to urbanization.

3. BUILDING DESIGN

As starting point, the design of a sky scrapper proposed in an international competition by teachers from Mackenzie University was chosen. This competition objectified the renewal of an important sportive center within the Ibirapuera Park located in the city of São Paulo who was, at the time, candidate to the 2008 Olympic Games.

The proposal considered the construction of a high building able to shelter all activities foreseen in the competition program in order to release a maximum of green area and also be an architectural landmark for the city. The fundamental issues that guided the project involved a complex and extensive program; a pre defined constructed area, the height of the building, technological possibilities, financial investments and, mainly, the whole set sustainability, including the building, the sportive courts and its neighborhood.

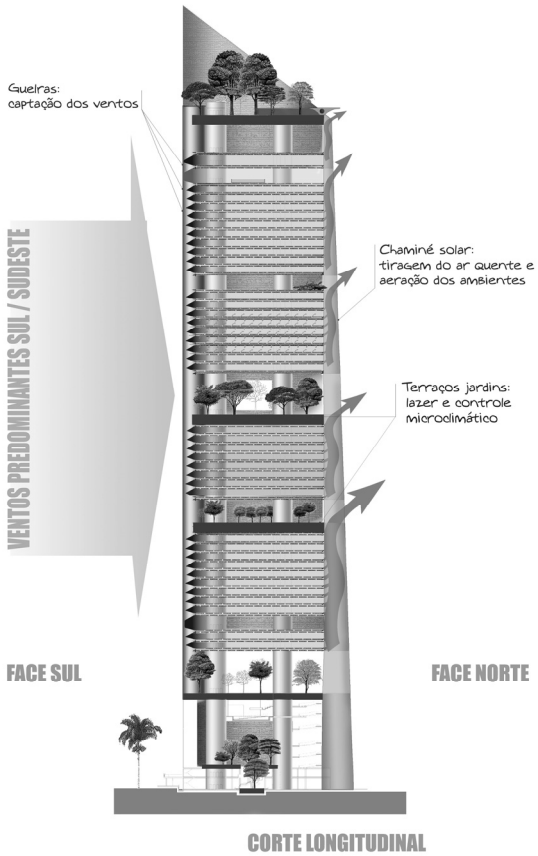

Figure 03*:* Building proposal – North/South section.

From the definition of a basic volume and the structural system to be used, some simplified models were built aiming to inquire possibilities and alternative solutions.

Concepts of ventilation, regarding internal air renewal, comfort sensation for future users and structure cooling, as well as interferences and impacts of the building in the neighborhood, were analyzed and developed from specific guide lines for build environments in hot and humid zones and were incorporated to the general conception of the building and each of its internal spaces.

The final drop shape design resulted from studies in wind tunnel, willing to minimize impacts of wind paths on the sportive courts modified by the building.

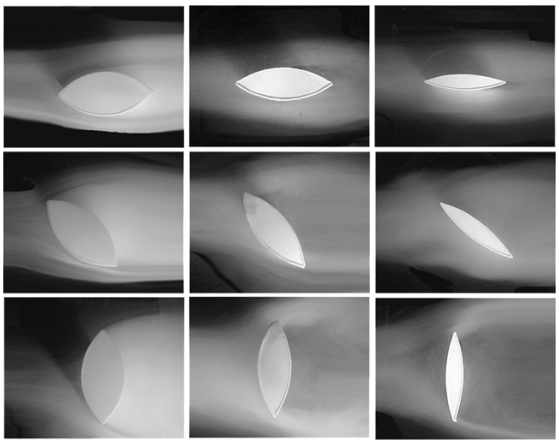

Figure 04: Studies for the shape in wind tunnel essays at Mackenzie University Laboratory. (2005)

As urban plans and of city zoning never concerned the environmental matters before the 1990, construction of high buildings thrived all through the city, privileging more realtor's speculation than life quality itself. Indeed, construction of high buildings hazards local ventilation, modifying the wind regime near to the surface and thus complicating any prediction or monitoring wind paths within the city

The proposal of a high building in a park area, as an urban and architectural landmark, must be concerned about these matters and should seize all the surrounding ambient elements, including local winds.

Taking advantage of the building location and orientation, with its bigger axis in the North/South direction, as well as its structural system, a system was conceived to capture predominant winds from South and South-East to ventilate each one of the floors. On the south façade, orientated toward the predominant winds, a winds capture system canalizes air through ducts incased in the structure, from one side to the other of the building.

Wind canalized, filtered using the natural force of the winds.

However, if air in movement is essential to guarantee the comfort conditions in hot and humid climates, there is a natural conflict to be managed: in a metropolis such as São Paulo, highly industrialized and with its traffic constantly congested, conditioned air becomes a necessity in internal environments, not only for thermal comfort but mainly to protect from air pollution and dust in suspension, mostly in lands next to important road axis, as in the case of the Ibirapuera Park, encircled by great avenues of very intense traffic all day long.

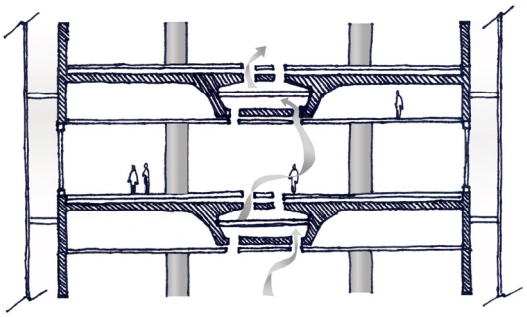

Figure 05*:* Ventilation system outline.

The basic problem was to implant an indirect ventilation system allowing to filter and control air flow through the building with a minimum energy rate for direct crossed ventilation through windows would be inconvenient and highly uncomfortable. The proposed system uses the spaces below of the flagstones and the building concrete structure itself of the, allowing the air filtering before penetrating environments and thus, controlling its flow according to needs.

Auxiliary systems, either through mechanical exhaustion or using a solar chimney system would reduce dramatically energy needs.

On the other hand, São Paulo's region of does not count on constant and trustworthy winds to guarantee its continuous exploitation. Only the highest floors would eventually have their ventilation guaranteed.

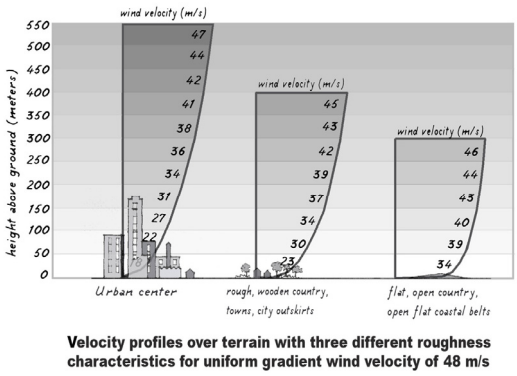

Figure 06 – Wind speed variation with height. Font: Givoni, Baruch [1] & Ken Yeang [5]

Beam radiation from the sun is much more intense and constant all year long, and therefore, a system using the sun heat for air drawing would be indicated. Aside direct winds capture (along the south façade), another air drawing system can be created by glassing the North façade (which receives the largest amount of solar radiation). It would act as a solar chimney, forcing the ventilation through the ducts during the sunny and therefore hotter days when ventilation is mostly needed for comfort purposes.

The diverse functions (theater, hotel, offices and sportive federations) were grouped in 4 major blocks separated by "empty" floors creating gardens and intermediate squares that result in positive effects regarding thermal comfort and provide areas for leisure and landscape contemplation (ref. to see Ken Yeang)

Orientation to the sun and winds was established in order to guarantee to each internal unit the best comfort conditions, as well as the possibility of use of natural energies for benefit of the building and the whole complex.

Models, tested in wind tunnel and heliodon, allowed to analyze and evaluate the air flow and structural systems, according to the internal comfort performance and to the impacts of the building on its environment.

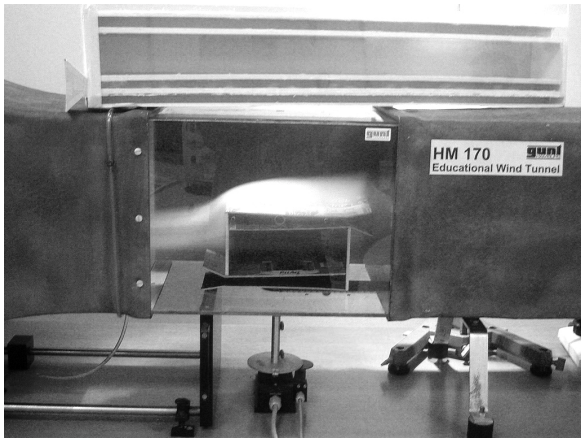

Figure 07: Wind Tunnel experiment at Mackenzie University.

4. IBIRAPUERA PARK

Enclosed in the middle of the urban grid, totalizing 1, 6 million square meters with three artificial lakes that cover 157 thousand square meters and vast areas of lawns and gardens, the Ibirapuera Park is the outcome of plastic, sculptural and expressive freedom of architect Oscar Niemeyer and landscape designer Roberto Burle Marx.

It is, with no doubt, the largest public space within the city and one of its rare leisure areas, frequented daily by more than 200,000 visitors enchanted with a rare pile of tropical plants. This main public space was inaugurated in 1954 for the 4th centenarian of the city, and became one of its most prominent symbols, a Modernist Architecture icon and is classified by the Brazilian Historical Patrimony.

An important sportive complex borders the park that already sheltered the 1963 Pan-Americans games and this is the reason why it was suggested to be the eventual headquarters for the 2008 Olympic Games.

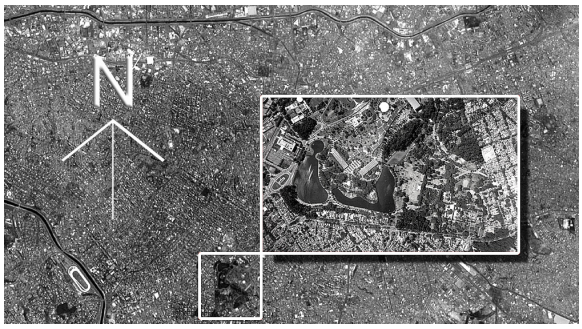

Figure 08: Ibirapuera Park location within the urban grid.

To understand the impacts that the proposed building would cause on the chosen region, series of virtual simulations were accomplished, and models were studied in a wind tunnel.

Temperatures variations and predominant winds deviations within the neighborhood were tested, taking in account existing constructions and local vegetation.

Wind deviations were simulated assuming the general Southeast and South predominant directions.

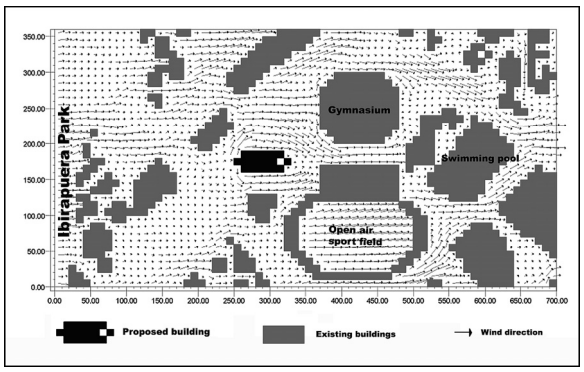

Figure 09: Wind deviation caused by edifications. Computer simulation by Joerg Spanenberg.

Once the proposed building is located along the park margins, he cooling effect in the wind blowing through the arboreous areas before reaching it could be observed, a very encouraging result regarding for the goal hunted in improving the thermal conditions and sensations inside the building.

Computer simulations were achieved at several hours of the day, during summer, winter and equinoxes, to verify temperatures variations within the area, taking in score the existing constructions as well as local vegetation. Average temperature rates from the last ten years were used attempting to recreate a climatic scenery as close as possible to the real one. INMET [9].

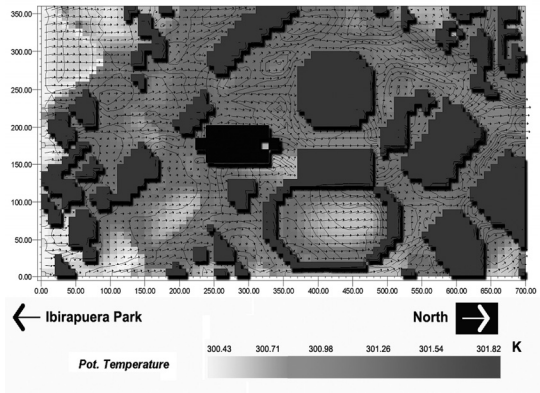

Figure 10: Temperature variance at 2:00 pm, during summer months within the chosen area.

As to air pollution within São Paulo´s metropolitan area, it has been stated by CETESB [10] that emissions from vehicles perform a highlight role in the air pollution level, once industrial emissions, mostly by sulfur dioxide and particles in suspension are already largely controlled.

The admissible daily standard for particles in suspension (240 $\mu g/m^3$) was overtaken five times during the year of 2005, although the highest levels were registered in the industrial districts. Smoke indices suffered a decrease during last years, but the daily acceptable level of 150 $\mu g/m^3$ was overflowed three times in 2005.The daily level of inhaled particles (MP_{10}), fixed in 150 $\mu g/m^3$ was overflowed only once. The microscopic inhaled particles level ($MP_{2,5}$) overtook the reference value, considered acceptable by the USA.

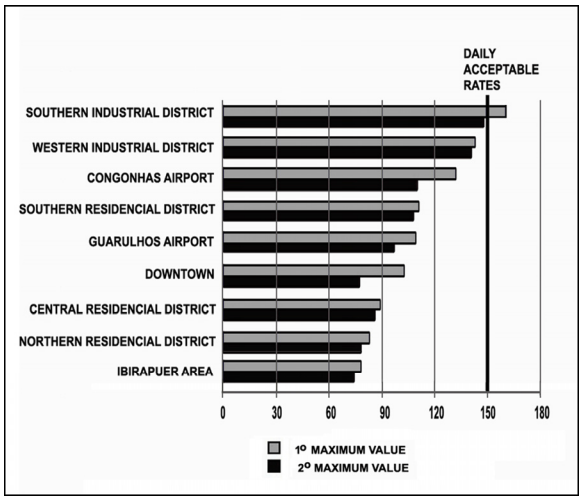

Figure 11: MP_{10}: Inhaled particles.

Daily average maximum rates in several districts of São Paulo metropolitan area. 2005 CETESB [10]

The previous figure (11) shows the privileged situation of Ibirapuera area when compared to other districts in terms of air pollution, but denounces the needs of care when planning natural ventilation in buildings.

5. CONCLUSION

Sustainability notion in architecture is recently being assimilated in Brazil and still remains connected to misguided concepts, often linked to marketing ideas or to image improvement of building companies that want to be kept *"à la page".* Air conditioning use is widely spread, because strongly entailed to a social status image and yet, unfortunately, rooted to the idea that electric power is abundant and cheap. During decades, such a mentality aroused buildings aesthetic development, frequently in harm to architecture functionality.

This work was, above all, an enquiry one, with didactic goals, proposing to explore new constructive possibilities facing a current, real and, to our understanding, serious problem.

This work was, above all, an enquiry one, with didactic goals, proposing to explore new constructive possibilities facing a current, real and, to our belief, serious problem. We willed to investigate new applicable techniques applicable to high buildings, in urban environment so as to bring up issues able to sensitize future architects and to create polemic, when showing how new aesthetics can be reached out from environmental foresights.

The submitted solution attends to picture that passive solutions can be applied in high buildings design not only improve the spaces qualities with energy efficiency and savings, but mainly to inspire the search for new aesthetics in local structures.

São Paulo is a metropolis with irregular construction density, laying out areas highly vertical buildings next to others almost empty.

Glancing over urban constructions, one can notice this tendency to verticality with a profusion of models frequently imported from rich countries. Mostly among commercial buildings, these models do not evidence the slightest concern in adapting the designs to local climatic reality, except by ineluctable air conditioning centrals systems, consuming loads of energy, especially when trying to minimize the green house effect from huge glass facade.

Although a state of mind is being brought forth and gaining strength, it is still incipient. Climatic data still are scarce, because they are so unspecific. Only recently, meteorological stations are being dispersed all through the city districts to understand and register differences at micro-climatic level, in a metropolis covering such a large area, and thus displaying striking topographical and geographical differences. For instance, there only a few systematic studies about winds close to the two main airports, fact that pictures a dramatic blank.

Available data is limited to predominant winds main directions and speeds (south-southeast and northwest), and therefore, this work also hails to alert the urgency and the essentiality of more reliable local studies, so that a city as São Paulo can face, through its architecture and its urban outlining, the challenges of a sustainable development.

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[11] " Paulistana" drizzle or "garoa" - a very light rain; stronger than mist but less than a shower- is typical during São Paulo´s cold weather.