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Determining the Location of Wind Turbines on Roof Building with the Help of Wind Tunnel

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Abstract: *Buildings alone the wind speed is accelerated above them in the urban environment. This fact can be utilized as an energy resource. The integration of wind turbines on buildings, is becoming a new possibility, and has begun to be studied in university research centers in wind energy, mainly in Europe. In this paper the correct location of wind turbines is assessed by wind tunnel tests on two forms of buildings that can catch the wind in the atmospheric boundary layer. The two studied buildings have different height / width ratios, the prototype A prototype B 10/80 and 45/10, located in two regions of Argentina. Two models were built in scale 1: 100 and assays were performed wind tunnel to characterize the flow pattern on the cover, and determine areas of lower turbulence intensity. Wind measurements were also performed with automatic weather stations on both ceilings for two*
Keywords: *Building Roofs, Wind Power, Wind Tunnel*

I. Introduction

The wind is a resource that exists all over the world, and that in the certain conditions of orography it can increase the potential of energy, the called ones "the effects of concentration", they can improve the average speed of wind flow. These effects not only happen in the nature, but also in urban places, which they make advisable to study them as a resource of wind power.

The integration of wind turbines into buildings, is becoming a new possibility, and has begun to be studied in schools of University Research in wind power, as the Technical University of Delft in the Netherlands and also begun to be explored on a small scale in several Dutch cities like Amsterdam, The Hague, Tilbug and Twente, and in the UK [1].

So locate a wind turbine on top of a building currently is a real possibility for electricity, using the acceleration effect on it. Wang et all [2] analyzed this possibility. Moreover Andrew Grant et all [3] studied placing of vertical and horizontal axis turbines in pipelines located on the edges of the terraces of high buildings, using the suction that occurs there. Kayan Ip Lin and Lu [4] performed simulation studies (CFD: Computational Fluid Dynamics) with different sets of buildings, and value that increased in speed between these buildings can be increased between 1.5 and 2 times the average wind speed, producing increases in power available wind from 3 to 8 times. Moreover Nalanie Mithraratne [5] evaluated the possibility of installing small wind turbines on the roofs of houses in New Zealand, and concludes that it could reduce between 26% and 81% of carbon emissions in the country

II. Methodology

All buildings cause an acceleration of free flow in certain places close to it, and as we move away from the building, the velocity approaches the speed of the free stream.

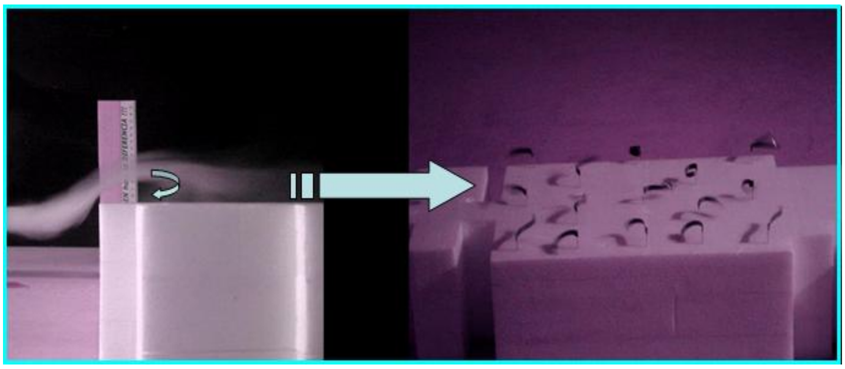


Figure 1: The trace of smoke indicates the bubble that is formed in the ceiling of the building, and the tufts show the turbulence of the zone near to the ceiling.

In a building with wind windward sharp edges, the boundary layer separates into those edges [6] and separation bubbles are formed in the sides and top of the building. The mainstream is diverted around it and forms a wake downwind. Figure 1 shows the above on the roof on the building. The results of this separation are: low-speed region, high levels of turbulence and flow recirculation in the roof and sides of the building. This recirculation region should be avoided for sitting of wind turbines. It is therefore important to know the size of the recirculation region.

To determine the best area of location of wind turbines on the roof of a building, we learn among other things: the wind characteristics in that city, the size and shape of the building, and use of analytical tools and / or experimental to solve the problem

2.1. Climatology of Wind Location

As buildings are fixed to the ground, and winds can change direction, so the choice of Wind Turbine and its location will depend on the prevailing wind direction in the locality.

For this work two different buildings, each located in different regions of Argentina with wind climatologies were studied. One in the Patagonia region: the building of the Faculty of Engineering of the National University of Comahue (UNCo), located in the city of Neuquén, whose height is about 10 m, where the longitudinal axis thereof is aligned with the north-south direction, so there is a side face of a 80 m long looking west, coincident with the increased occurrence of winds in the region (see Figures 2).

Figure 2: Building A UNCo in the city of Neuquén

The other is located in Rosario city, a typical Argentine building 45 m high and a width of 10 m and a length of 20 m (Figure 3)

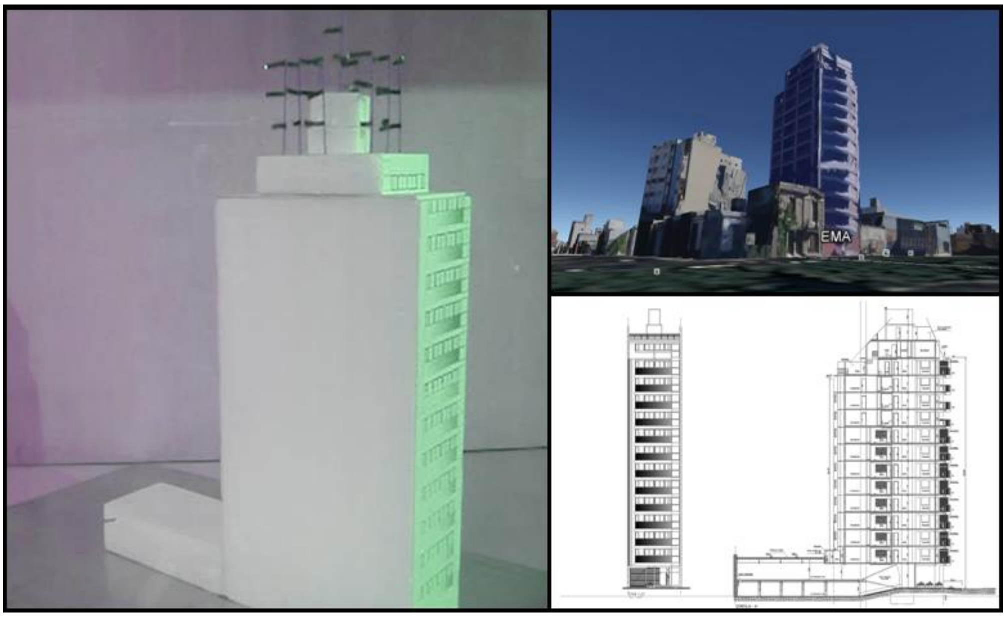


Figure 3: Building B, in Rosario city.

The figure 4 shows the wind roses for several Argentine cities, where you can see that in the Patagonia winds are very directional, and then the buildings can be aligned with them and offer you one face thereof to install wind turbines. By contrast, further north of Argentina rose are multi-directional winds.

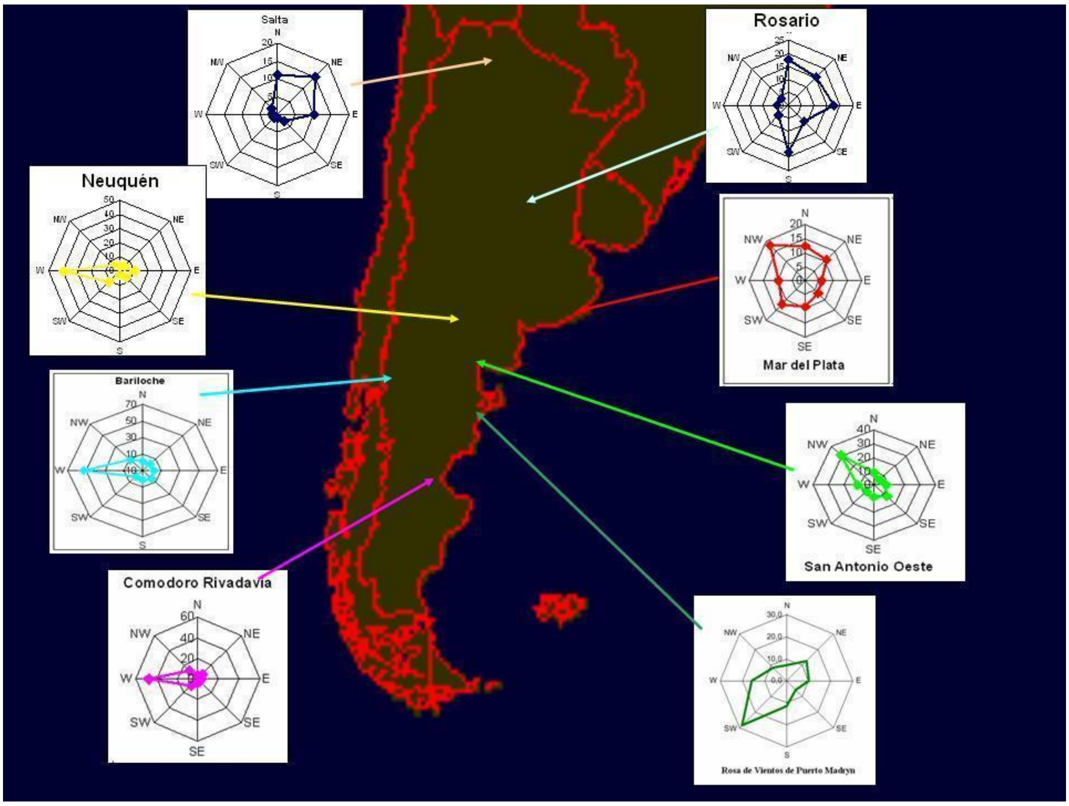


Figure 4: Rosa Winds of several locations in Argentina.

2.2. Wind Tunnel

It is important to find for a given building, the location of the maximum wind and the areas with and without turbulence, and then define where to install wind turbines. The wind tunnel is an appropriate tool for this purpose.

Therefore two models, one for each building constructed on a scale of 1: 100; and they are tested in the wind tunnel No. 2 Laboratory of Fluid Dynamics Environmental Faculty of Engineering, National University of Comahue, to find according to the preferential directions (addresses) of the wind, the best possible location of the wind turbines on the ceilings of both buildings.

The Reynolds number of tests was approximately 300,000, on the main length of the building length. The profile of wind speeds was performed with an exponent $p = 0.30$ and the turbulence level were 0.11 at the equivalent of 10 m in height.

The tests consisted, firstly in determining the height of major acceleration of the wind to windward of the building, smoke it was used as marker of the air flow path to pass over the building.

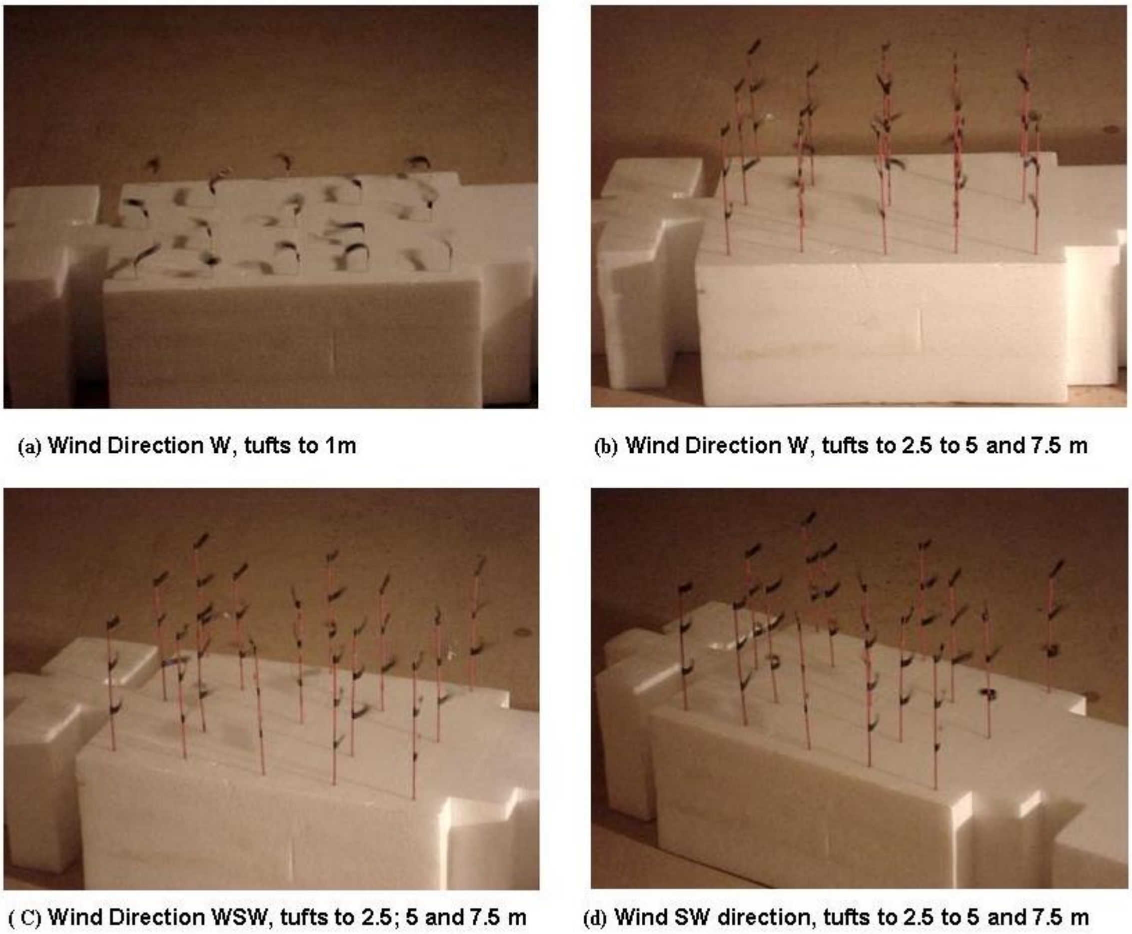
To qualify that part of this flow is more stable, and thus determine the possible location of wind turbines, we proceeded to install the roof on models tufts. The tufts were placed with prototype equivalent heights of 2.5m, 7.5m and 5m.

III. Results

3.1 Building A

For Building A, the test with tufts at higher ceiling heights, proved to be more stable in front of the building, and levels of 5 and 7.5 meters. In the center of the roof and 2.5 meters high, the markers show signs of the presence of strong vortices, see figure 5.

The most stable for the location of wind turbines on the wall area is west facing, above 2.5 meters. In the center of the building is the most stable region above 10 meters. In the center of the building and downwind flow is very turbulent and not recommended to install wind turbines there. See figure 6.



Figures 5: (a) tufts to 1m on the ceiling with wind from the West; (b) tufts to three heights on the ceiling with wind from the West; (c) tufts to three heights on the ceiling with wind from the West South West; (d) tufts to three heights on the ceiling with wind from the South West.

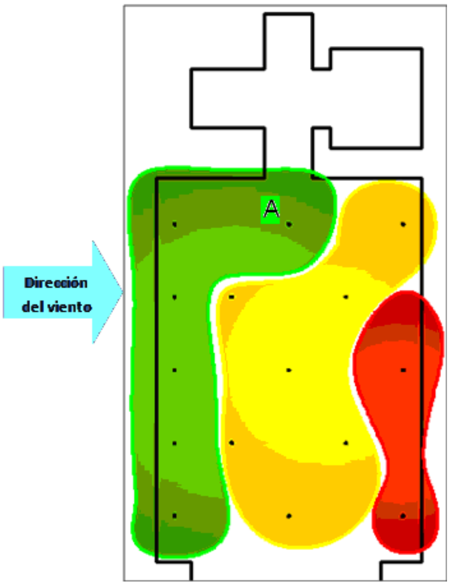


Figure 6: Zoning ceiling where it is advisable to install wind turbines. (Green) and stable maximum winds (yellow) turbulent (red) and effect of the turbulent wake.

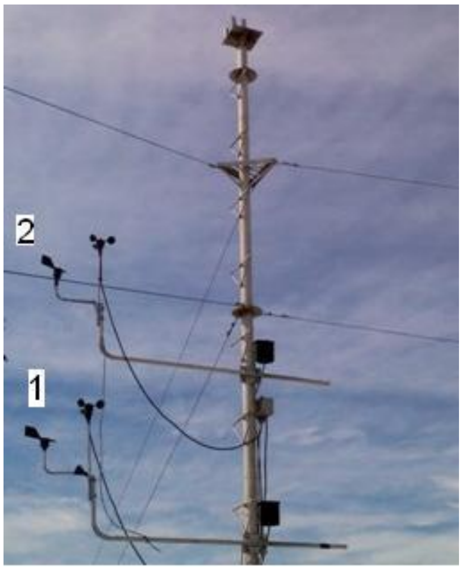


Figure 7: Automatic Weather Station.

For Building A, the most stable for the location of wind turbines on the wall area is west facing, above 2.5 meters. In the center of the building is the most stable region above 10 meters. In the center of the building and downwind flow is very turbulent and not recommended to install wind turbines there. See Figure 6.

At point A (see figure 6) a weather station was installed, in order to measure the intensity and direction of winds over the place of the roof of the building, since according to the test wind tunnel proved a suitable area to install turbines wind because in it there is less turbulence than in other parts of the roof (yellow and red zones).

The anemometer located at 1 measured at 5 m above the roof, and 2 to 7.5 m. In Table 1 the values of turbulence intensity obtained at that point and the two preferential directions of the wind in the city of Neuquén (W and SW) are indicated.

The measured values are consistent with those obtained by Carpman [7] above the roofs of the buildings, who obtained values close to It = 0.33 heights

Table 1: Turbulence Intensity (It) Measure Actual Building Ceiling (Prototype).

	Turbulence	Intensity
Wind Direction	W	SW
Location 2: to 7.5 m high	0.29	0.35
Location 1: to 5 m high	0.39	0.42

Checking the findings qualitatively in the test with the wind tunnel with tufts, where the upper tufts Site A (representing 7.5 m high) is more stable than the tufts middle (representing 5 m high), that is reflected in the measurement scale 1:1 on the true roof of the building (Table 1).

3.2 Building B

In the building B, is more difficult to determine the suitable place to install wind turbines, as the upper structure containing the water storage tank of the building, causes significant wake with consequent high level of turbulence.

Observing the three images in Figure 8, the tufts indicate that less turbulence, would be located at 7.5 m above the roof of the latter department.

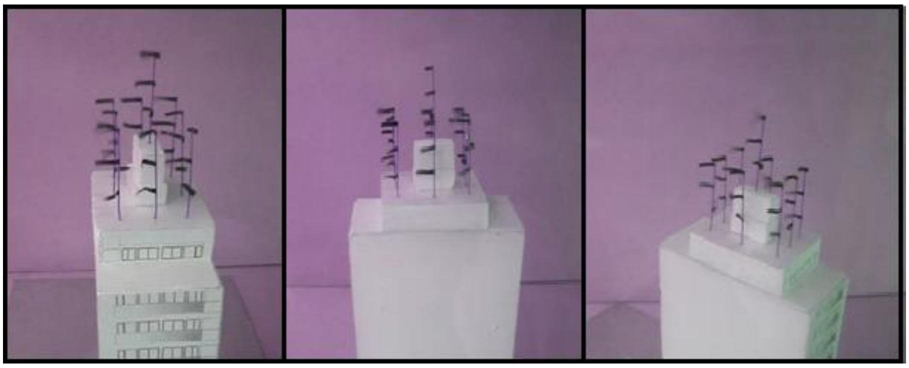


Figure 8: Tufts indicating turbulence at different heights on the roof of the building B. The wind in all pictures ran from right to left.

Lin Lu and Ka Yan Ip [4], CFD simulations on high buildings, conclude that it is advisable to locate wind turbines to 10 meter above the roof due to turbulence.

IV. Conclusion

Taking advantage of the opportunity of accelerating wind on the roofs of buildings for energy is a very real possibility, indeed in several cities in Europe there are examples. Many buildings, with many small wind turbines in a city, could provide an important percentage of energy to the grid and thus saves on infrastructure.

Has been exposed a methodology for assessing the potential wind potential on the roof of a building, consisting in a climatic analysis of the wind in the city, and use a wind tunnel to determine the most appropriate place to locate wind turbines.

In situ on the building roof measurements were performed and verified in scale 1:1 the results of wind tunnel tests.

Acknowledgements

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