特 集 世界の風工学研究の今

Brazil and Argentina Joint Program in Wind Engineering

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INTRODUCTION

Research and development on Wind Engineering in Brazil and Argentina are mainly concentrated in three institutions: (*i*) the Laboratório de Aerodinâmica das Construções of the Universidade Federal do Rio Grande do Sul (**LAC-UFRGS**), located in the city of Porto Alegre, RS, Brazil, (*ii*) the Laboratorio de Aerodinámica of the Universidad Nacional del Nordeste (**LA-UNNE**), located in the city of Resistencia, Chaco, Argentina and (*iii*) **Vento-S** Consulting, also in Porto Alegre. Since the beginning of the 1990´s, LAC-UFRGS and LA-UNNE have been increasing mutual cooperation in research, education and development. Each institution counts with a boundary layer wind tunnel as shown in Figs. 1 (Blessmann, 1982) and 2 (Wittwer and Möller, 2000). In recent years Vento-S has joined the group and is currently on the design phase of its own wind tunnel.

The labs have developed extensive research with the

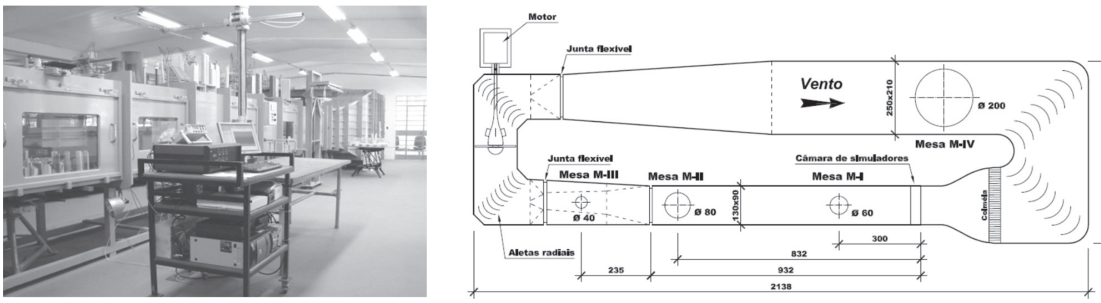

Fig. 1. Prof. Joaquim Blessmann Wind Tunnel – UFRGS [*cm*].

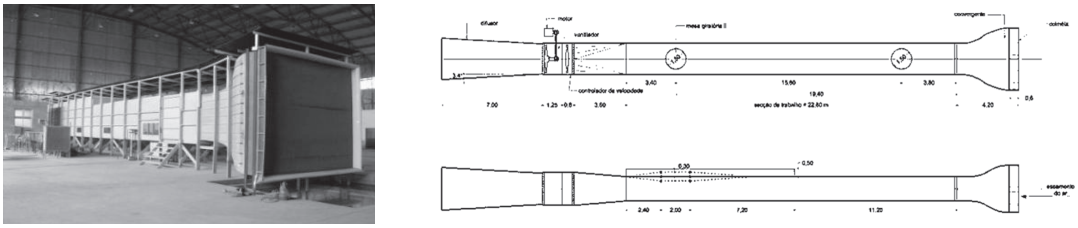

Fig. 2. Prof. Jacek Gorecki Wind Tunnel – UNNE [*m*].

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aim to form the basis of the Brazilian and Argentinian Wind Codes, but current research is more focused on extreme winds (non-synoptic), bridge behavior, vicinity effects, transmission lines and wind energy. This means that the study of the aeroelastic behaviour of structures is of paramount importance, as well as topography effects are very important. Environmental wind engineering is also being addressed, mainly through particle dispersion and wind driven rain.

NON-SYNOPTIC EXTREME WINDS

Previous studies have indicated that several regions of Brazil and Argentina are susceptible to thunderstorms, with downburst occurrences (Lima and Loredo-Souza, 2015, and Loredo-Souza, 2012). The main concern about these events remains in regard to building safety, since it is not yet fully understood in to what extent the wind characteristics generated by downbursts are different to those of the Extended Pressure Systems, or synoptic winds. A recent research in this regard may be found in Loredo-Souza et al (2016).

The current Brazilian and Argentinian codes present a wind map with the reference wind speeds where there is not a separation of the type of climatological event which generated each registered velocity. Therefore, a thunderstorm (TS), an extratropical pressure system (EPS) or even a tropical cyclone (TC) are treated the same and its resulting velocities absorbed without differentiation. There are a lot of meteorological stations and a constant work for updating the records, so a research program is on the way to separate the meteorological events that generate extreme winds, so the future codes will bring separate maps in order to optimize the wind loading, increasing reliability. Fig. 3 presents the first downburst phenomena identifications.

BRIDGE BEHAVIOUR UNDER WIND LOADING

The growth of the countries in the last years has

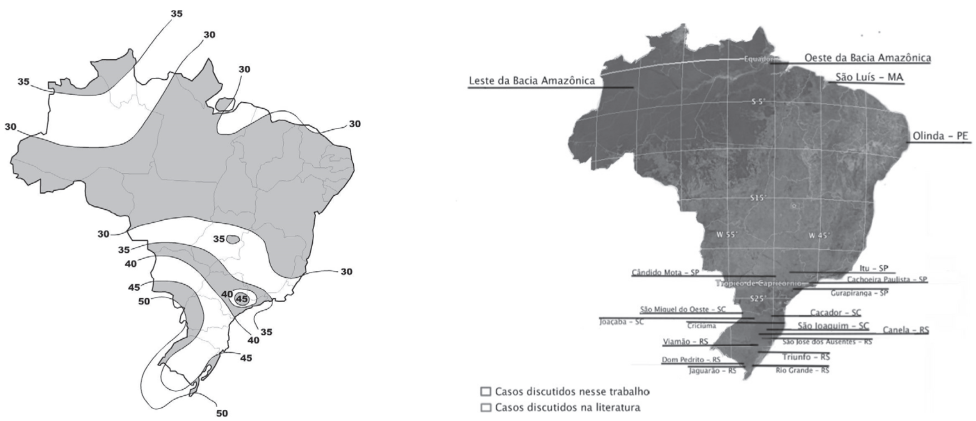

Fig. 3. Map with the reference wind speeds, in m/s, 3-s gust, at 10m height (NBR-6123, Brazilian Wind Code) and map indicating the downburst occurrences already registered from the ongoing research in non-synoptic winds.

Fig. 4. Cable stayed bridge Octávio Frias de Oliveira, São Paulo, Brazil: (a) full-aerolastic model; (b) real bridge.

brought the necessity of building more sophisticated infrastructure. Bridges with complex forms, as the one shown in Fig. 4, are being built and the wind is one of the main issues in design considerations. Therefore, bridge wind engineering is a current research and development focus.

LATTICED STRUCTURES AND TRANSMISSION LINES

An extensive wind tunnel program was commissioned for the study of transmission towers and lines. Examples of wind tunnel models are shown in Figure 5. They are representative of two typical towers from FURNAS, a Brazilian Power Company. The two main objectives of the study were (Loredo-Souza et al, 2005): (i) to verify the applicability of the criteria currently established in transmission lines codes and guidelines; (ii) to determine drag and force coefficients on latticed transmission tower models compatible with the geometries most used in real towers, as a basis for the revision of the Brazilian Wind Code NBR-6123 (1988). Several reduced models were built. Figure 5 show models for FURNAS Towers A33 (for 345 kV) and A55 (for 500 kV). The tests were performed with different wind velocities and some of the models were tested in different scales for checking eventual Re sensitivity, with the main scales being around 1:11 to 1:20. The figure also shows an example of the results for Tower A33.

RESEARCH ON WIND ENERGY AND RELATED TOPICS

Wind Energy in Brazil and Argentina is under high demand. The technical and economic feasibility of wind energy projects are defined by the identification of the accurate wind behaviour on the site and by the choice of the appropriate technology and layout of wind turbines. LAC-UFRGS, LA-UNNE and Vento-S are developing wind tunnel methodologies for wind farm micrositing projects in which the wind tunnel is the research tool employed to improve the wind power assessment and the efficiency of power output in a wind power plant, as shown in Fig. 6 (Wittwer et al, 2015).

The interaction between the incident wind and wind turbines in a wind farm causes mean velocity deficit and increased levels of turbulence in the wake. The turbulent flow is characterized by the superposition of the wind turbine wakes. In this research, the technique of turbulence spectral evaluation to reduced scale models in a boundary layer wind tunnel is employed and further developed, and different measurements of velocity fluctuations are analyzed. The results allow evaluating the spectrum configuration at different frequency ranges and the differences of the spectral behaviour between the incident wind and the turbine wake flow.

Also of much interest is the knowledge of the flow behavior over complex topographies, for structural design as well as for energy generation, since it depends on incident wind velocity and turbulence intensity profiles. Fig. 7 shows some examples of complex terrains being studied in the wind tunnel (Mattuella et al, 2016; Wittwer et al, 2016).

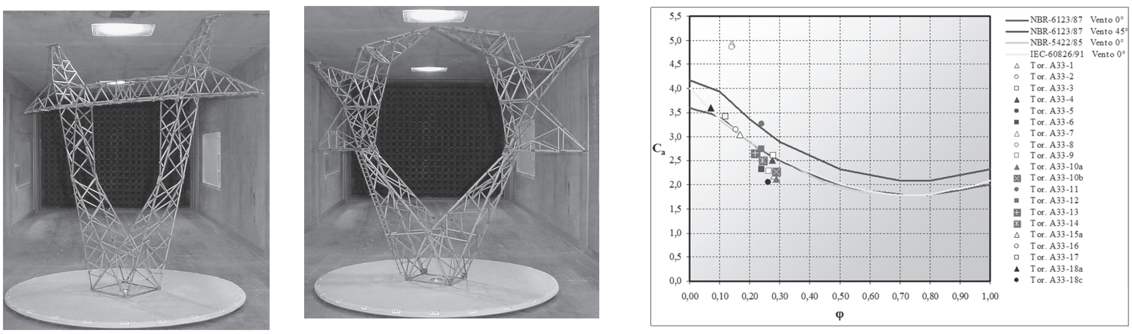

Fig.5. Latticed tower head wind tunnel models: Tower A33 (left) and Tower A55 (right), as well as Drag coefficients for latticed tower parts of Tower A33.

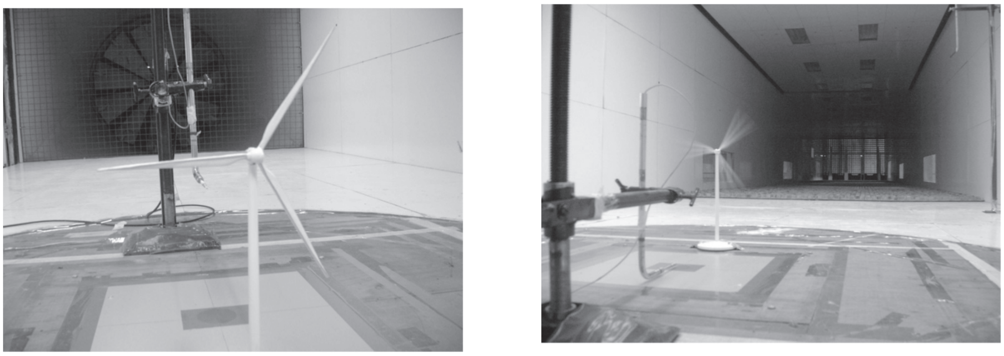

Fig.6. View of turbine model inside the wind tunnel.

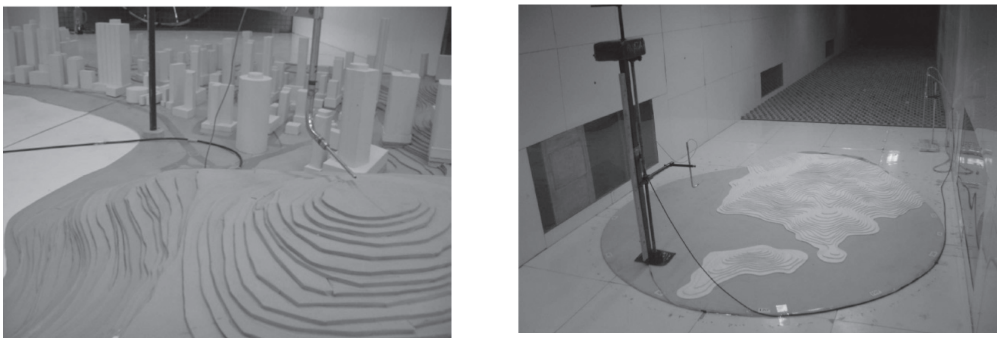

Fig.7. Complex topography models inside the wind tunnel.

WIND DRIVEN RAIN

The study is aimed at understanding the behavior of the two fluids (air and water) acting simultaneously on building model facades, and this includes the effects of neighbouring buildings. Water sprinklers are calibrated to simulate wind-driven rain in the wind tunnel. Fig. 8 shows part of the apparatus inside the wind tunnel and Fig.9 some results, which can be evaluated through a water-sensitive paper. The pictures show (one for each surrounding) the configuration before the test was carried out (the paper on the façade was still yellow) and after (with the wetting blue pattern of the façade registered on water-sensitive paper).

(a) (b) (c)

Fig.8. Rain simulation equipment (a) internal view of the wind tunnel, (b) water sprinklers used in the tests, and (c) external equipment for rain simulation, outside the wind tunnel.

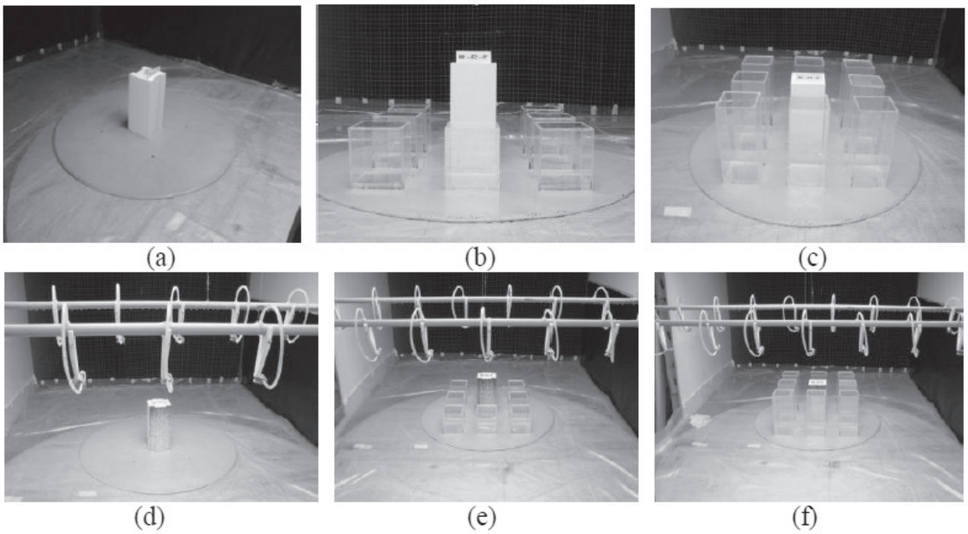

Fig.9. Configurations before (a, b, c) the tests, where the paper on the façade is still yellow, and after (d, e, f), with the wetting blue pattern of the façade registered on water-sensitive paper.

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