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Wind tunnel study on large-building façade projections

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SUMMARY:
Wind tunnel tests were performed to design the large façade projections of the New IRCCS Galeazzi Hospital in Milan, Italy. Given the difficulties encountered by working with building details on a scale model, the experimental campaign was firstly conducted on a preliminary set-up. Thus, a portion of the façade was tested at a larger scale compared to that of the full building. This first phase was necessary to understand the ideal distribution and density of the pressure taps on the complete model. Then, pressure measurements carried out on the whole building with surrounding elements capable of influencing wind loads on the façade projections, allowed estimating design loads. It turned out that the most affected façade projections are those at the highest levels, where the suction due to flow separation from the roof can create high loads. Design of the supporting structures must also take into account the possibility that wind load sign changes depending on wind direction.

Keywords: wind tunnel, façade projections, local wind loads

1. INTRODUCTION

In recent years, the number of tall buildings aiming at iconic shapes has significantly increased. For tall and large buildings, façade projections can play a crucial role to achieve the various mandatory requirements, for instance in terms of energetic, acoustic, and aesthetic performances. The wind action is usually the design load for the structural systems of such façade components (such as sunshade louvers or solar panels). Unfortunately, the definition of the wind loads on these building elements is complicated by the many scales and parameters involved (Giachetti et al., 2019). Indeed, the relatively small distance between a sunshade louver and the building façade can be one or two orders of magnitude smaller than the building characteristic dimensions. In addition, the forces exerted by the wind on façade projections are affected by many parameters, such as size, distance from the building façade, shape, and location on the building surface (Manara, 2019). In this work, a wind tunnel study was performed on the New IRCCS Galeazzi Hospital (Fig. 1), located in Milan, Italy. The 90 m-high building is the first and unique case of vertical hospital in Italy and, therefore, the tallest one. The building has a regular shape and presents façade projections on each building side to ensure privacy for the occupants and weaken direct sunlight exposure.

Figure 1. A picture of the New IRCCS Galeazzi Hospital in Milan, Italy.

2. EXPERIMENTAL CAMPAIGN

The experimental campaign was performed on two rigid models: firstly, an exploratory study was developed considering a portion of building façade at the 1:50 scale; then, a complete model of the building and surroundings at the 1:200 scale was used for the final measurements.

2.1. Exploratory tests

Preliminary tests were conducted on a portion of the building façade (Fig. 2(b) and 2(c)) to evaluate the optimal number and position of pressure taps required in the complete model to properly reconstruct the wind loads on the projections shown in Fig. 2(a). The model was made of plexiglass and wood. About 100 pressure taps were distributed along three vertical arrays on the external and internal surfaces of sunshade elements, parapets, and on building walls. Two model boundary conditions (either laterally opened or closed) and two porosities (either $\varepsilon = 0\%$ or 100%) of the horizontal layers between façade projections and building walls were considered. The supporting system allowed changing the model inclination with respect to the horizontal plane ($\beta = -60°$, $-30°$, $0°$, $30°$, $60°$), while the wind direction ($\alpha = 0°$, $15°$, $30°$, $60°$, $90°$) could be varied by using the wind tunnel turning table. In this phase, a uniform, low turbulence, approaching flow was used.

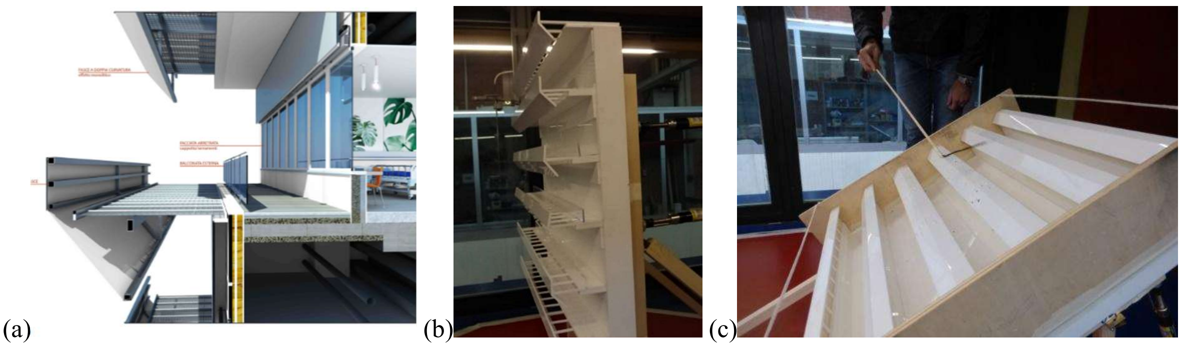

Figure 2. (*a*) Render of the considered façade components; (*b*) preliminary model during testing ($\alpha = 0°$, $\beta = 0°$, laterally opened, $\varepsilon = 100\%$); (*c*) model during flow visualizations using of wool threads ($\alpha = 0°$, $\beta = 60°$, laterally closed, $\varepsilon = 0\%$).

2.2. Complete model tests

The complete model of the building was 3D printed by using filament extrusions of Acrylonitrile Butadiene Styrene (ABS), plexiglass and wood. The surrounding buildings in a circular area with a full scale radius of 240 m were also reproduced (Fig. 3), considering both the current situation and the available masterplan. Based on preliminary phase results, the model was equipped with about 440 pressure taps. Four simultaneous recordings of a partial number of pressure taps were needed due to the limited number of pressure scanners: this was possible because of the structural independency of façade-projections supporting structures. Moreover, thanks to the symmetrical geometry of the building the pressure taps were concentrated just on one long and one short side of the building. An approaching atmospheric boundary layer flow was simulated with intermediate characteristics between terrain categories III and IV proposed by the Italian Recommendations CNR-DT 207-R1/2018 (2019) (see Fig. 4).

Figure 3. Complete model of the hospital in the wind tunnel.

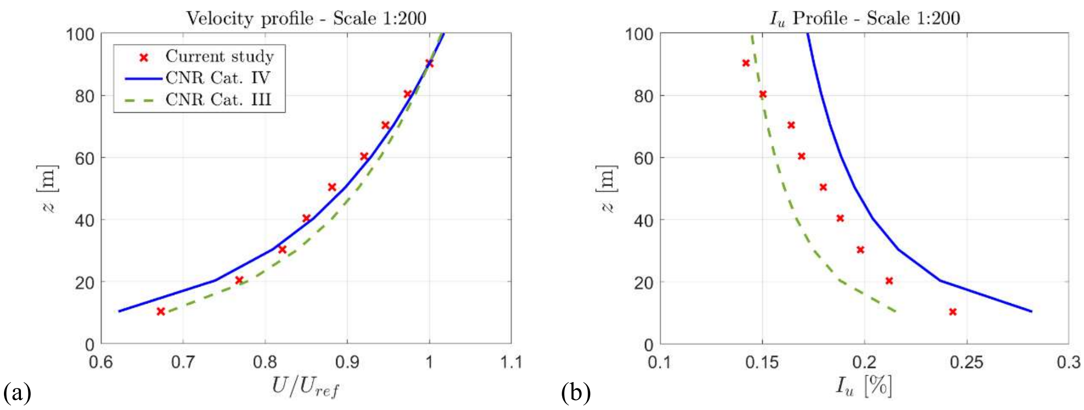

Figure 4. (*a*) Mean wind velocity and (*b*) turbulence intensity profiles.

3. RESULTS

The exploratory tests led to the following conclusions: (i) given the vertical uniformity of the pressure distribution on balcony walls, a single pressure tap is sufficient to discretize the pressure field. (ii) One pressure tap on the vertical portion and two pressure taps on the inclined portion of sunshade elements are necessary to properly discretize the external pressure distribution, while a single tap is sufficient for the internal surfaces. (iii) Generally, the results do not seem sensitive to the porosity of the horizontal layers created by the sunshade supporting structures. This is likely due to the peculiar geometry of the façade projections considered and to the weak vertical flows occurring close to the façade. Thus, the complete model was made with solid elements supporting the sunshade structures.

The tests on the complete building model showed that the top façade projection, in proximity of the rooftop, is by far the most loaded one. Indeed, for a wind perpendicular to the building face ($\alpha = 0°$) the top sunshade element is affected by a positive pressure on the windward side and a strong suction on the rear side due to the flow separation at the top of the building; consequently, the net pressures cause remarkable drag, lift and torsional loads. In contrast, for inclined wind directions (e.g., $\alpha = 225°$) net pressures can have an opposite sign, which must be considered in the design of the supporting structure. Finally, the different surroundings tested were useful to understand that future buildings indicated in the masterplan can influence the wind loads on the façade projections.

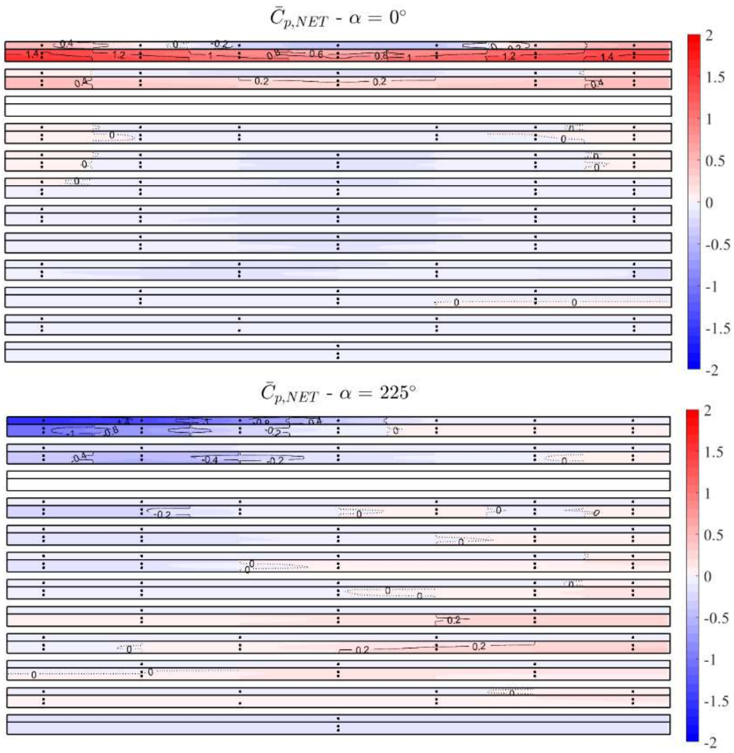

Figure 5. Mean net pressure coefficients on the façade projections of the long side of the building.

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