IN-VENTO 2026
International Conference of the Italian Association for Wind Engineering
Bari, September 13th – 16th, 2026

BARI

Performance of cable-supported glass façades under time-depending wind action

Chiara Bedon [1], Ginevra Amendolagine [2] and Fabio Rizzo [3]

[1] *University of Trieste, Trieste, Italy, chiara.bedon@dia.units.it*
[2] *University of Bari, Bari, Italy, g.amendolagine8@phd.uniba.it*
[3] *Polytechnic University of Bari, Bari, Italy; fabio.rizzo@poliba.it*

SUMMARY
The structural vulnerability of cable-supported glass façades under wind loading is primarily due to their significant flexibility. Although standard certification procedures rely on simplified uniform pressure tests, these fail to capture the stochastic nature of wind, which fluctuates according to building morphology and atmospheric turbulence. This research employs dynamic Finite Element (FE) simulations to evaluate how factors such as building shape, wind orientation and panel location dictate the system's performance. The effects of these factors are particularly pronounced when accounting for the deformability of the glass module supports. The findings reveal that structural integrity is inextricably linked to specific wind load distribution, indicating the need for an evolution in testing standards for flexible architectural glazing.

Keywords: glass façades, wind tunnel test, numerical modelling

1. INTRODUCTION

The increasing use of glass in load-bearing applications poses a complex challenge for designers due to their sensitivity to size effects [Bedon et al. 2018]. Wind-induced stress and deflection peaks must be minimized through careful mechanical and geometric calibration. As primary physical barriers, façades are inherently vulnerable, which has led to extensive research on optimization for tall buildings [Ding and Kareem 2020], established design criteria [Brewer and Sammarco 2018] and the implementation of fragility curves for conservative design [Lima-Castillo et al. 2019]. Specialized studies have also explored cable-braced systems and smart control mechanisms to mitigate dynamic stress peaks from wind or blast events. Previous research has highlighted a significant discrepancy between wind actions and standard laboratory air pressure tests. Accurate modelling of wind-structure interaction is essential to prevent air infiltration and frame torsion. The present study utilizes experimental pressure data to analyze a specific cable-supported curtain wall typology adapted [Amadio and Bedon 2012]. Using refined ABAQUS finite element models, twelve nonlinear dynamic analyses based on distinct wind pressure time histories have been carried out. This parametric approach, supplemented by preliminary boundary condition assessments, evaluates key performance indicators for design purposes.
The primary objective of this paper is to alert to the unreliability of static laboratory tests, which do not account for the dynamic, time-dependent nature of wind [Rizzo et al. 2012]. Wind tunnel tests were employed using a structure prototype with a hyperbolic paraboloid roof to estimate pressure coefficients across various plan shapes and wind angles. A comparative analysis focused on zones near flow detachment edges versus protected areas.

2. METHODOLOGY: structural setup and wind action

2.1. Structural setup

This paper focuses on the cable-supported glass façade explored and described in [Amadio and Bedon 2012] and shown in Figure 1.

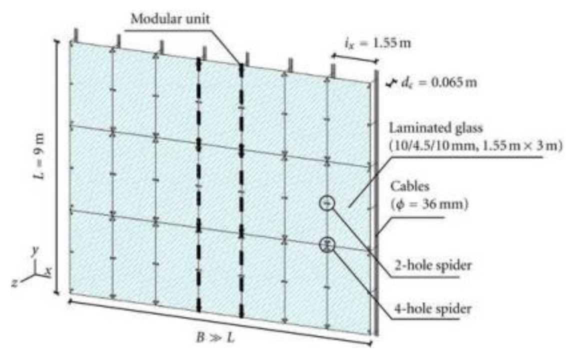

Figure 1. Schematic drawing of the examined façade system

The primary objective when designing curtain wall glass panels is to mitigate stress concentrations and deflections in flexible components, where boundary and restraint conditions significantly impact structural behavior. For laminated glass under wind pressure W, mechanical performance is estimated using quasi-static orthogonal pressure peaks to verify stress and deflection against regulatory limits defined in [CNR-DT 210/2013; EN 572–2:2004]. A preliminary comparative analysis of a B × L façade panel, assuming a monolithic section, evaluates two configurations: the CS(A) setup with linear simple supports and the 6PF(N) configuration with six ideally rigid point fixings. While the CS(A) configuration is analyzed via non-linear analytical formulations from [CNR-DT 210/2013; EN 572–2:2004] with peaks at the center, the 6PF(N) assembly requires finite element modeling as stress peaks migrate toward the supports and are adjusted by a stress intensification factor of 2.1. Comparative results for pressure up to W=30 kPa show that the 6PF(N) x K condition significantly exceeds the stress estimates of the CS(A) configuration. According to [CNR-DT 210/2013], deflection limits are established at H/60 for CS(A) and L_{min}/100 or 30 mm for 6PF(N), with values exceeding unity denoting unsafe design conditions. Ultimately, these calculations help determine global load distribution but disregard complexities such as interlayer viscoelasticity, cable flexibility, and the stochastic nature of wind.

2.2.Wind action

The determination of the time-dependent wind action W(t) on the façade is based on calculating fluctuating pressure coefficients $cp\,(t)$ [EN-1991-1-4; CNR-DT 207/2018]. This calculation assumes a mean wind velocity V_m= 24.7 m/s. The experimental data required to characterize these coefficients for calculating average wind speed were obtained through a wind tunnel campaign involving 1:50 scale rigid wooden models. These tests were conducted at the CRIACIV open-circuit facility in Prato, Italy. Eight distinct building geometries were analyzed: four square and four rectangular, all featuring hyperbolic paraboloid roofs designed to simulate the behavior of cable-net tensile structures. The geometry is summarized in Figure 2.

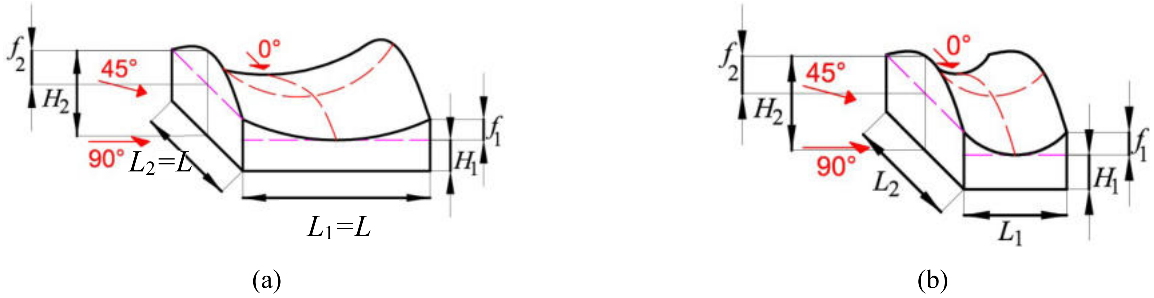

Figure 5. Building geometrical parameters and wind angles of attack during experiments: (a) square plan and (b) rectangular plan building.

The model was instrumented with 58 to 98 pressure taps connected to Teflon tubing calibrated for a flat frequency response up to 100 Hz, while data acquisition was conducted at a sampling frequency of 252 Hz with roof-level turbulence intensity maintained between 11% and 12%. Although sixteen wind angles were initially recorded, this study focuses on the 0° and 90° orientations, employing a Gumbel distribution with a 22% exceedance probability to estimate extreme pressure coefficients. To analyze airflow-structure interaction, the building's lateral surfaces were divided into specific subzones to compare flow detachment edges with distant regions, revealing significant variations between the upper façade and the section near the ground that could induce torsional effects or gasket detachment. Consequently, four primary load combinations were established to isolate the effects of proximity to detachment edges, wind orientation, roof curvature, and plan geometry. These factors informed non-linear dynamic simulations lasting 800 seconds with a 0.1-second time step, during which two distinct pressure time histories were applied simultaneously to each glass panel at specific heights to accurately represent non-uniform wind action. This methodological approach addresses a significant gap in the current scientific literature regarding the structural response of cable-supported façades to dynamic forces.

3. ANALYSIS AND RESULTS

Numerical framework was adapted to address the specific dynamic loading conditions of the façade. The finite element (FE) assembly used composite shell (S4R) elements for the glass panels and beam (B31) and truss (T3D2) elements to represent the spider connectors and bracing cable system, respectively. The resulting model consisted of approximately 3,900 degrees of freedom and 600 elements. The materials were characterized by linear elastic constitutive laws and the mechanical interaction between the components was facilitated by pinned connectors at the glass-spider and spider-cable nodes, which allowed for free relative rotations. The simulation was structured in an initial static stage to apply self-weight and a pretension force (P_0) to the cables and a subsequent non-linear dynamic stage to evaluate the effects of time-dependent wind pressures. The boundary conditions involved pinning the cables at their upper ends while imposing the initial pretension at the base via equivalent vertical displacements. To account for adjacent façade members, intermediate cable nodes were restricted to out-of-plane displacements (z) and rotations (x). A dynamic time-history approach was prioritized due to its ability to capture the nonlinear behavior of flexible cable structures. The post-processing stage focused on several key performance indicators, including tensile stress peaks in the glass, maximum out-of-plane deflections, relative panel twists and maximum stresses in the bracing cables. Preliminary modal and quasi-static analyses were also conducted to evaluate the influence of the initial prestress (P_0)

on the system's fundamental vibration period and baseline structural response. The results of the parametric study showed that, although stress levels remained within the elastic range and deflections did not exceed reference limits, the non-uniform nature of time-dependent wind pressures had distinct local and global effects. A significant finding was the substantial discrepancy in performance indicators across different façade subzones. Furthermore, the analysis revealed that cable displacements, cable stresses and glass panel stresses were highly sensitive to variables such as the shape of the building plan (square vs. rectangular), roof curvature and wind angle. The study concludes that such sensitivity must be rigorously accounted for in the design of structural details and glass thickness. Given the significant variations observed, wind actions should be meticulously reproduced in testing protocols, as these effects are expected to be even more critical for façades on high-rise buildings [Rizzo et al. 2020].

4. CONCLUSIONS

The results suggest that the pressure tests carried out on the façades in the laboratory to simulate wind action do not represent real behavior, because they should consider the alternating pressure and suction caused by the building's aerodynamics and the turbulence of the wind flow. This paper aims to recommend updating the standard procedure for testing glass panels to consistently simulate the effects of wind action on glass panels, considering the effects of turbulence and aerodynamics.

REFERENCES

Amadio C, Bedon C (2012). Elastoplastic dissipative devices for the mitigation of blast resisting cable-supported glazing façades. Engineering Structures, 39: 103-115.

Amadio C, Bedon C (2012). Viscoelastic spider connectors for the mitigation of cable-supported façades subjected to air blast loading. Engineering Structures, 42: 190-200.

Bedon C, Zhang X, Santos F, Honfi D, Kozłowski M, Arrigoni M, Figuli L, Lange D (2018). Performance of structural glass facades under extreme loads – Design methods, existing research, current issues and trends. Construction and Building Materials, 163: 921-937.

Brewer TR, Sammarco EL (2018). Optimizing Glass Design: The Role of Computational Wind Engineering & Advanced Numerical Analysis. Proceedings of Challenging Glass 6 -Conference on Architectural and Structural Applications of Glass. Louter, Bos, Belis, Veer, Nijsse (Eds.), Delft University of Technology, May 2018. ISBN 978-94-6366-044-0, https://doi.org/10.7480/cgc.6.2174.

CEN (Comité Européen de Normalization), Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions, EN-1991-1-4 (2005).

Claudio Amadio, Chiara Bedon, "Dynamic Response of Cable-Supported Façades Subjected to High-Level Air Blast Loads: Numerical Simulations and Mitigation Techniques", Modelling and Simulation in Engineering, vol. 2012, Article ID 863235, 13 pages, 2012. https://doi.org/10.1155/2012/863235

CNR (National Research Council of Italy). Guide for the Assessment of Wind Actions and Effects on Structures. CNR-DT 207/2018, (2018).

CNR (National Research Council of Italy). Istruzioni per la Progettazione, l'Esecuzione ed il Controllo di Costruzioni con Elementi Strutturali di Vetro. CNR-DT 210/2013, (2013).

Ding F, Kareem A (2020). Tall Buildings with Dynamic Facade Under Winds. Engineering, 6(12): 1443-1453.

EN 572–2:2004. Glass in buildings – Basic soda lime silicate glass products. CEN, Brussels, Belgium

Lima-Castillo IF, Gómez-Martínez R, Pozos-Estrada A (2019). Methodology to Develop Fragility Curves of Glass Façades Under Wind-Induced Pressure. International Journal of Civil Engineering, 17: 347–359 .

Rizzo F., Franco A., Bonati A., Maddaloni G., Caterino N., Occhiuzzi A., (2021). Predictive analyses for aerodynamic investigation of curtain walls. Structures, 29, 1059-1077.

Rizzo F., Ricciardelli F., Maddaloni G., Bonati A., Occhiuzzi A., 2020. Experimental error analysis of dynamic properties for a reduced-scale high-rise building model and implications on full-scale behavior. Journal of Building Engineering, 28.