

Comparative Study of Structural Snow Load Predictions from Experimental and CFD Approaches Using the Finite Area Element Method

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SUMMARY

This study presents a comparative analysis of structural snow load predictions using the Finite Area Element Method (FAE) with inputs derived from experimental wind tunnel testing and Computational Fluid Dynamics (CFD) simulations. Snow loading conditions on two buildings were evaluated using FAE method, with roof surface velocity obtained from wind tunnel testing and CFD simulations. Previous research using Reynolds-Averaged Navier-Stokes (RANS) and Large Eddy Simulation (LES) on standard stepped building shapes demonstrated that LES provides improved accuracy in capturing more realistic flow separation and turbulence effects. In this work, LES-based CFD simulations were conducted. Wind velocity information from wind tunnel measurements and CFD simulations were integrated with the FAE approach to assess snow load distribution on structural surfaces. The findings highlight the influence of aerodynamic factors on snow accumulation and validate the effectiveness of LES-driven CFD as a reliable input for FAE-based snow load prediction.

Keywords: Finite Area Element Method (FAE), Structural Snow Loading, Roof Snow Drifting, Computational Fluid Dynamics (CFD), Large Eddy Simulation (LES)

1. INTRODUCTION

Snow accumulation on building roofs poses significant structural challenges, particularly in cold regions where drifting and surcharge effects can lead to uneven and unbalanced loads. Conventional building codes provide generalized and conservative estimates of snow loads, often failing to capture site-specific aerodynamic influences. To address this limitation, the FAE method was developed by RWDI engineers as a proprietary computational tool for simulating snow loading conditions on complex roof geometries (Irwin and Gamble, 1988). The FAE method integrates hourly meteorological data with wind flow field maps to model snow accumulation, drifting, and depletion over successive winter seasons, offering a more accurate representation of snow load distribution compared to prescriptive code-based approaches (Hochstenbach et al., 2004; Brooks et al., 2016).

Traditionally, wind flow fields for FAE simulations have been derived from atmospheric boundary layer wind tunnel testing. However, recent advancements in computational fluid dynamics (CFD) have introduced the potential for virtual aerodynamic modeling as an alternative or complement to physical testing (Oreskovic, et al., 2024). Previous studies (You, et al., 2025) comparing RANS and LES turbulence models demonstrated that LES provides superior accuracy in predicting flow separation and low-velocity regions near walls, which are critical areas for snow surcharge formation. In the current study, two building models were evaluated under snow and wind conditions, with CFD employing a LES approach. Building on this foundation, the present work investigates the feasibility of using LES-based CFD inputs for FAE snow load assessment through

a parametric comparison with wind tunnel data. The analysis focuses on wind tunnel tests of buildings, evaluating uniform and surcharge snow loads across the three methodologies and identifying limitations and future directions for CFD integration in snow load modeling.

2. METHODOLOGY

The Finite Area Element (FAE) method was applied to predict snow load distribution on building roofs by integrating aerodynamic flow fields and meteorological data. Two building models (Figure 1) were evaluated under snow and wind conditions: (1) an arched roof surface to assess snow load distribution under curved geometry, and (2) two adjacent rectangular buildings of different heights to study wind-induced interference effects on snow accumulation. Wind flow fields for both cases were generated using physical wind tunnel testing and computational fluid dynamics (CFD) simulations. CFD employed the LES approach to capture turbulence and low-velocity regions critical for snow surcharge formation.

As a key step in the FAE method, wind velocity distributions need to be determined near the roof surface for multiple wind directions. Traditionally obtained from atmospheric boundary layer wind tunnel tests, the roof surface velocity information was provided by LES-based CFD simulations in the current study. The roof surfaces were discretized into grids of area elements, and wind velocities at grid intersections were used to compute mass fluxes into and out of each element, representing the saltation of snow particles.

Meteorological data contain wind speed and direction, air temperature, precipitation, and solar radiation level, etc., were incorporated into the simulation in hourly time steps. Mass balance calculations at each step accounted for snowfall accumulation and melting effects, with snowfall rates derived from hourly records and adjusted using snow flags when available. Temperature and cloud cover data also informed melting computations.

The FAE method produced detailed time histories of snow mass for each area element, typically spanning 30 to 60 winters. These histories were analyzed statistically to determine design conditions, such as the 50-year return period for total roof snow load and imbalance between roof sections. Results from LES-based CFD inputs were compared against wind tunnel data predictions to assess accuracy and feasibility.

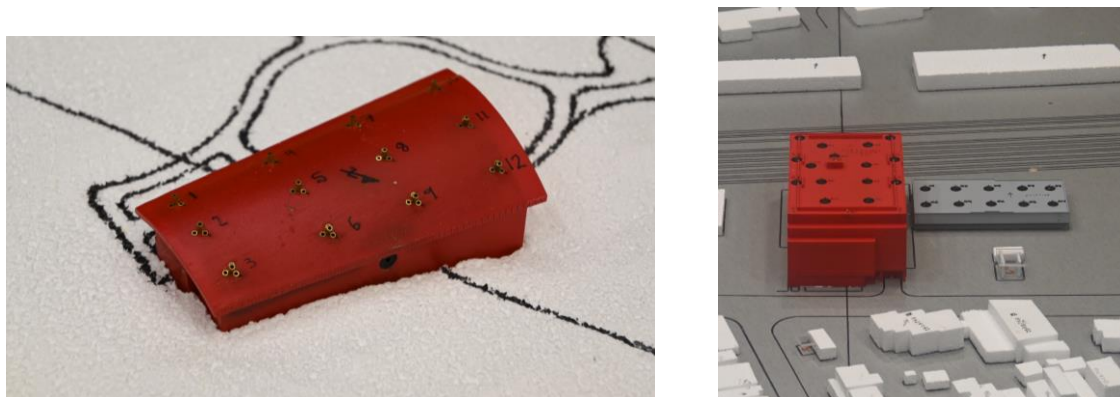


Figure 1: Studied wind tunnel models.

3. RESULTS

Preliminary results based on wind tunnel testing provide insight into snow load distribution for the two building configurations studied: (1) an arched roof surface and (2) two adjacent rectangular buildings of different heights. For the arched roof case, the FAE method predicted non-uniform snow accumulation, with higher loads concentrated near the leeward curvature and reduced deposition on the windward side. This pattern aligns with aerodynamic expectations for curved geometries, where flow separation influences drifting behavior.

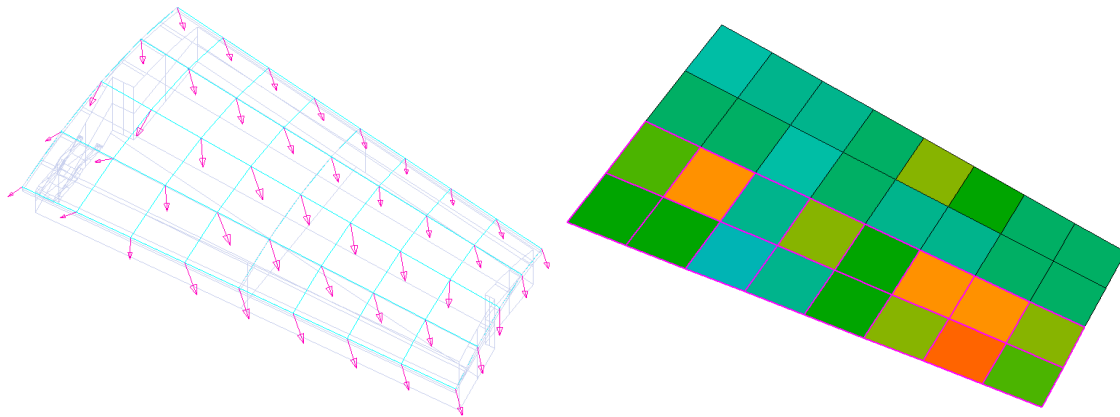


Figure 2: Wind tunnel results for the arched roof surface

In the interference case study with two buildings, wind tunnel data revealed significant variations in snow deposition caused by the addition of the taller building adjacent to an existing low-rise building. Areas of reduced wind speed between the structures exhibited increased snow accumulation, while exposed regions experienced depletion. These findings highlight the sensitivity of snow load distribution to local aerodynamic conditions and confirm the capability of the FAE method to capture these effects when supplied with accurate wind flow inputs.

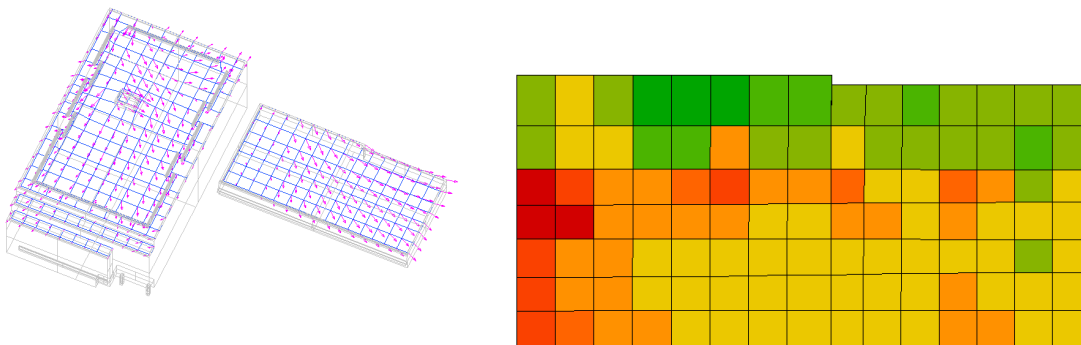


Figure 3: Wind tunnel results for the adjacent rectangular buildings

CFD simulations using LES approach will be included in this study to compare its performance against wind tunnel results. LES is expected to provide improved flow separation and reattachment regions, which are critical for predicting snow drift and surcharges. A detailed comparison of FAE predictions using wind tunnel and CFD-derived flow fields will be presented in the full paper.

4. SUMMARY

This study demonstrates the application of the Finite Area Element (FAE) method for predicting snow load distribution on real world roof geometries using aerodynamic inputs derived from CFD simulations. Two building configurations were analyzed: an arched roof and two adjacent rectangular buildings of different heights. Results highlight the sensitivity of snow accumulation patterns to local wind conditions, with curved surfaces exhibiting pronounced leeward loading and adjacent buildings showcasing interference effects that redistribute snow drifting patterns on existing roof.

The findings confirm the capability of the FAE method to capture these aerodynamic influences when supplied with accurate wind flow data. The full study will incorporate computational fluid dynamics (CFD) simulations using LES approach to evaluate their feasibility as alternatives to physical testing. LES is anticipated to provide improved the prediction of flow separation and reattachment regions critical for snow surcharge prediction. Comparative analysis of wind tunnel and CFD-driven FAE results will be presented in the full paper, along with recommendations for integrating CFD into snow load assessment workflows.

REFERENCES

- Irwin, P.A. and Gamble, S.L. Prediction of Snow Loading on the Toronto Skydome. Proceedings of the 1st International Conference on Snow Engineering. Santa Barbara, CA (1988).
- Hochstenbach, F. M., Irwin, P.A., and Gamble, S.L. Parametric Studies of Unbalanced Snow Loads on Arched Roofs. Proceedings of ASCE Structures 2004: Building on the Past, Securing the Future. Nashville, TN (2004)
- Brooks, A.J., Bond, J.V., Gamble, S.L., and Dale, J.C. Parametric Simulation of Roof Structural Snow Loads. Proceedings of CSCE Resilient Infrastructure. London, ON (2016)
- Oreskovic, C., Wiechers, T., Dale, J.C., Lal, S. Quantifying Structural Snow Loads Using the Finite Area Element Method: A Comparison between Physical Wind Tunnel and Computational Fluid Dynamics Input Data. Proceedings of the 20th International Conference on Cold Regions Engineering. Anchorage, AK (2024).
- Gamble, S.L., Kochanski, W.W., Irwin, P.A. Finite Area Element Snow Loading Prediction – Applications and Advancements. Journal of Wind Engineering and Industrial Aerodynamics, 41-44 (1992) 1537-1548.
- You, H., Dicks, M., Wiechers, T., Dale, J., & Du, X. (2025). Snow Load Assessment Using the Finite Area Element Method: A parametric study to validate the feasibility of using Large-Eddy Simulations as the wind velocity input. Structures Congress 2025, 435–445. doi:10.1061/9780784486085.039