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Extending parameterized wind load models beyond prismatic and orthogonal cases

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SUMMARY
Wind load provisions in building design standards typically represent aerodynamic effects using simplified pressure coefficient models that do not vary with building geometry. Recent work has shown that aerodynamic loads can instead be expressed in terms of non-dimensional geometric parameters, forming the basis of the upcoming ASCE 7-28 MWFRS provisions. While this model is formulated for prismatic geometries under orthogonal wind directions, its parameterized structure is rooted in underlying aerodynamic scaling, suggesting potential applicability beyond these cases. This study investigates the extension of the ASCE 7-28 framework to irregular building geometries and oblique wind directions. Comparisons with experimental data highlight known discrepancies when applying single rectangular representations to irregular buildings, particularly underprediction of leeward wall pressures and base shear. The parameterized model allows modified rectangular approximations that better reflect governing aerodynamic behaviours while retaining a simplified design framework. The extension to oblique wind directions remains under investigation.

Keywords: building aerodynamics, parameterized models, irregular buildings

1. INTRODUCTION

Wind load provisions in building design standards commonly represent aerodynamic effects using simplified pressure coefficient models derived from experimental studies. While practical for design, these models often assign specified uniform coefficients to entire surfaces regardless of geometry, limiting their ability to represent aerodynamic scaling across building configurations.

Wang & Kopp (2021a,b) showed that existing ASCE 7 provisions cannot accurately or conservatively represent loads across prismatic configurations, and that aerodynamic loads are governed by key non-dimensional geometric parameters. Expressing pressure coefficients as functions of these parameters allows behaviour across a wide range of geometries to be represented within a unified framework. These relationships form the basis of the new ASCE 7-28 MWFRS provisions (Guo et al., 2025), where coefficients are expressed as functions of geometric ratios such as height-to-breadth (H/B), height-to-length (H/L), and breadth-to-length (B/L). By incorporating these governing parameters, the model represents the underlying aerodynamic scaling behaviour while remaining suitable for design.

This study examines whether these scaling relationships allow the parameterized framework to remain applicable across a wider range of building geometries and flow conditions than traditional fixed-coefficient approaches. Specifically, extensions to irregular plan geometries and oblique wind directions are investigated to assess whether the model can be adapted to represent these additional cases through relatively simple modifications, and to identify the limitations of such extensions.

2. METHODOLOGY

2.1. Implementation of the ASCE 7-28 MWFRS Provisions

Wind loads are calculated using the ASCE 7-28 parameterized MWFRS provisions (Guo et al., 2025), developed from wind tunnel datasets obtained at Western University (Acosta et al., 2024; Ho et al., 2005; Wang & Kopp, 2021a, 2021b). Equivalent pressure distributions corresponding to peak structural responses were obtained using the Load-Response-Correlation (LRC) method (Kasperski & Niemann, 1992).

Walls are represented using zone-averaged peak pressure coefficients $[GCp]$, with zoning varying by surface to represent relevant stagnation, separation and reattachment behaviours. Coefficients are expressed as functions of governing non-dimensional geometric ratios based on the building height H, length L, breadth B, and width W. Windward wall coefficients vary with H/B, side-wall coefficients with $min(B,H)/L$, and leeward wall coefficients with H/L or B/L depending on H/W. The collapse of the experimental data into non-dimensional parameterized relationships is shown in Fig. 1.

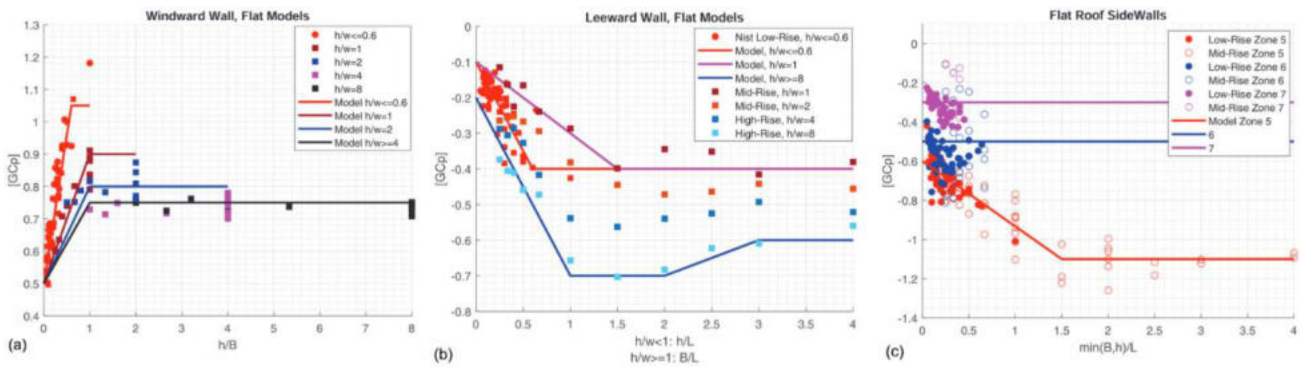

Figure 1. Non-dimensional parameterization of MWFRS pressure coefficients for (a) windward, (b) leeward, and (c) side walls. Scatter points represent experimental data, and solid lines represent the optimized relationships that define the ASCE 7-28 provisions. Reproduced from Guo et al. (2025), Fig. 9(a,b,e).

2.2. Extension to Irregular Plan Geometries

The ASCE 7-28 MWFRS provisions are defined for rectangular geometries; however, extensions to irregular shapes have been proposed by van den Heuvel et al. (2024) using modified rectangular representations that better reflect governing aerodynamic behaviour. This study evaluates whether these modifications yield notable improvements in MWFRS load predictions for irregular buildings compared with both existing design provisions and standard rectangular approximations, using wind-tunnel data from van den Heuvel & Kopp (2026).

2.3. Extension to Oblique Wind Directions

The ASCE 7-28 MWFRS provisions are defined for orthogonal wind directions. However, parametric relationships exist that describe surface-averaged wall pressure coefficients as functions of wind direction (Muehleisen & Patrizi, 2013; Swami & Chandra, 1988). This study assesses whether directional effects can be introduced as an external transformation applied to the orthogonal pressure distributions predicted by the parameterized framework. Modified coefficients are compared with experimental datasets to evaluate this approach's ability to reproduce directional pressure behaviour.

3. RESULTS

For irregular building geometries, predictions from the parameterized framework and its extended form are compared against the ASCE 7-22 MWFRS provisions (Chapters 27 and 28), taken as baseline representations of current design practice, using the dataset of van den Heuvel & Kopp (2026). Residual distributions are shown for both area-averaged leeward wall suction pressures and the resulting base shear (Fig. 2).

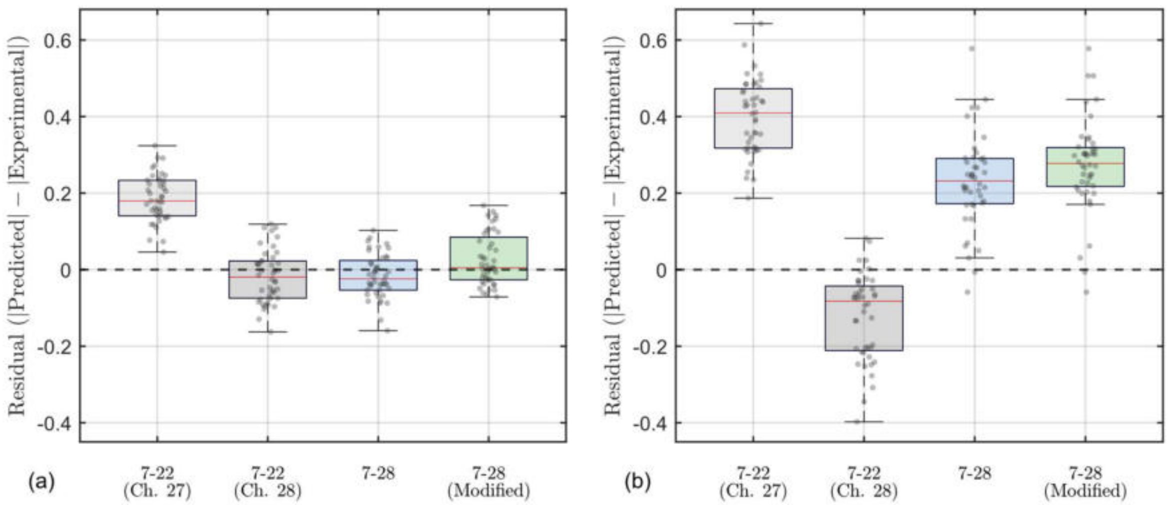

Fig. 2. Boxplot of residuals of (a) area-averaged leeward wall suction pressure coefficients and (b) base shear for ASCE 7-22 (Ch. 27 and Ch. 28), ASCE 7-28, and the irregular modification. Predictions are compared with experimental data for 16 irregular building models for non-oblique wind directions (0°, 90°, 180°, 270°) in open terrain (van den Heuvel and Kopp, 2026). ASCE 7-22 Ch. 27 Cp values are converted to [GCp] using the measured wind field from the same dataset, following the comparison methodology of Wang and Kopp (2021) and St. Pierre et al. (2005).

The baseline approaches exhibit opposing biases. Chapter 27 yields consistently positive residuals, indicating conservative predictions that are poorly calibrated to building geometry. Chapter 28 shows comparable performance for leeward wall pressures, but consistently underpredicts base shear. These trends are consistent with previous findings for rectangular buildings (Wang and Kopp, 2021) and highlight the limitations of fixed-coefficient approaches across varying geometries.

The parameterized framework demonstrates a marked improvement over both baseline approaches, with substantially narrower residual distributions for leeward wall pressures and base shear, indicating greater consistency with the experimental data.

When applied to irregular geometries using a single encompassing rectangle, the parameterized model slightly underpredicts leeward wall pressures because the governing aerodynamic length scale is not well represented by the full building footprint. The extended formulation addresses this by evaluating coefficients using modified geometric representations corresponding to the controlling leeward surfaces. This shifts leeward wall residuals toward zero and produces a more balanced distribution relative to the data. For base shear, this introduces slight conservatism, reflecting the experimentally observed relationship that irregular buildings produce higher MWFRS loads than their rectangular counterparts (van den Heuvel & Kopp, 2026), and ensuring that the model preserves this trend.

In addition to shifting the overall response, the modified approach produces consistently shorter residual distributions than all other methods, indicating improved consistency in representing the effects of building geometry. This demonstrates that the parameterized framework, when combined with physically motivated geometric modifications, can more reliably capture the governing aerodynamic behaviour of irregular buildings.

4. CONCLUSIONS

This study demonstrates that aerodynamic scaling relationships embedded in the parameterized model enable its extension beyond the rectangular cases for which it was originally developed. Within this framework, modified rectangular representations can be used to account for irregular geometries while avoiding unconservative or overly conservative predictions without requiring the complexity of more detailed methods such as Cook (1990).

The extension to oblique wind directions remains under investigation. Ongoing work is evaluating whether azimuth-based parametric relationships can similarly be used to transform orthogonal pressure coefficients to represent directional variation in surface pressures.

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