Investigating wind loading for standardizing purposes on representative double-curved freestanding membrane roof canopies

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ABSTRACT

Standardized wind loading is the prescribed way of design for structures. Constructions with double-curved surfaces, typical in case of prestressed membrane roofs, are only minimally addressed by codes and standards. Our contribution set out to investigate the needs and possibilities for standardizing loads in case of representative scenarios by computational means.

We are motivated by landmark constructions, such as the German Expo Pavilion in Montreal 1967 or the shading umbrellas on the Haram Plaza in Medina 2010. These and similar works are unique, requiring specific design aspects, and the lightness of their structure makes them especially vulnerable to wind loads. Some insights on the hyperbolic paraboloid shape have been included in the Italian guidelines [1] as a result of multiple studies and various scientific contributions, such as [2].

Our aim is to cover more generic shapes, of sizes and configurations that often occur in more common use cases. Here we follow the suggested focus points outlined in the Round Robin 3 call by the Tensinet Group in 2015 [3] and [4, 5]. We present our investigation on five representative shapes – hypar, tent, barrel, upward umbrella, inverted umbrella – for roof canopies, without enclosing walls, i.e. freestanding. The chosen configurations are those commonly met when using technical membranes in public spaces, such as schoolyards, fairs, transport hubs or even leisure venues. We comment on the adequacy of the current guidelines and outline our contributions in form of wind pressure maps to better aid design. We contribute to the existing knowledge base with high-resolution pressure maps, sensitivity of local loading patterns to changes in aspect ratio of the geometry (and corresponding curvature), also exploring the effect of grouped configurations.

Recent advances in computational wind engineering support the accuracy and the efficiency of our study. The project makes use of high-performance computing on the SuperMUC-NG facilities by LRZ. This context allows us to investigate the structures at real-geometric scale and proper atmospheric boundary layer turbulence conditions. The scope is limited to studying rigid shapes, which is valid as long as the constructions are under high levels of prestress.

REFERENCES

[1] Consiglio Nazionale delle Richerche CNR-DT 207 R1/2018, "Istruzioni per la valutazione delle azioni e degli effetti del vento sulle costruzioni", (2019).

[2] F. Rizzo and C. Demartino, "Pressure modes for hyperbolic paraboloid roofs", Journal of Curved and Layered Structures, https://doi.org/10.1515/cls-2020-0019, (2020).

[3] TensiNet Working Group Specifications and the Working Group 5 of the COST Action TU1303 Novel Structural Skins. "Round Robin Exercise 3 (RRE3)", http://www.novelstructuralskins.eu/wp-content/uploads/documents/Other/151130_Round_Robin_exercise.pdf, (2015).

[4] J. Colliers, M. Mollaert, J. Vierendeels, L. De Laet, "Collating wind data for doubly-curved shapes of tensioned surface structures (RRE 3)", https://doi.org/10.1016/j.proeng.2016.08.016, (2016).

[5] A.-K. Goldbach, "The CAD-integrated design cycle for structural membranes", Dissertation, School of Engineering and Design, Technical University of Munich, https://mediatum.ub.tum.de/?id=1611497, (2021).