# The effect of prestress levels and of geometric scale on the aeroelastic behaviour of double-curved membrane roofs

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## ABSTRACT

The double-curved shape of roof canopies are the result of prestressing technical membranes or cable net structures. We investigate various prestressing levels to determine ranges in which a certain aeroelastic behaviour is more likely to happen. Our work is inspired by recent observations in modelling and simulation of the Olympic Stadium Roof in Munich [1] by means of computational wind engineering, and focuses one more generic shapes, such as Frei Otto's iconic 4-point sail.

A potential strategy is to reach high prestress levels, resulting in a rigid roof. For such cases the structural membrane will predominantly exhibit a rigid body movement-like deformation pattern under wind loads. Whereas using pressure maps for load assessment might suffice for this previous scenario, the order of magnitude of the deformation needs a more systematic investigation. Moreover, having very high forces in cables or membranes can lead to overly costly construction processes, which might not be wanted. This results in the necessity of outlining appropriate levels of prestress based on what aeroelastic phenomena are deemed acceptable.

Wind loading is only marginally supported by codes and standards. Information is available in the form of pressure maps, for dome-like structures and – more recently in the Italian instructions on Eurocodes [2] – for certain types of parabolic hyperboloids. We aim to provide the sensitivity of the response to prestress levels in flexible structures in form of deviation from the mean and standard deviation of the aerodynamic pressure on a baseline rigid roof. We also intend to revise certain aspects related to geometric scaling and subsequent limitations in manufacturing models. In particular, experimental wind tunnels have been used to investigate possible aeroelastic effects on such constructions. This approach is known to be challenging, as a geometric reduction of cables and textiles required by the experimental setup requires the careful consideration of scaling laws.

Numerical methods promise to deliver complementary insights, as the geometric nonlinear structural behaviour can be captured correctly, regardless of the scale. We have precise control of prestress and the ability of knowing the actual deformation and stress state. The coupled wind-structure interaction can be modelled at full-geometric scale, with the possibility of complementary investigations at reduced-scale. For this we use a finite element method-based approach for modelling fluids and structures, and a partitioned coupling strategy for fluid-structure interaction. The project is supported by computational resources on the high-performance computing facilities at LRZ.

## REFERENCES

[1] M. Péntek, A.-K. Goldbach, K. B. Sautter, K.-U. Bletzinger, "Numerical modeling and simulation of lightweight structures – using the example of the Olympic Stadium in Munich on its 50th anniversary", Proc. 33. Forum Bauinformatik, https://mediatum.ub.tum.de/doc/1686600/, (2022).

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