CERIS Civil Engineering Research and Innovation for Sustainability

Tensile membrane structures: an in-depth evaluation of themal and structural performance

Summary

The integration of membrane structures, constructed from advanced textiles or resilient foils, is reshaping urban landscapes, contributing a unique and contemporary aesthetic to city environments. The innovative lightweight tensile structures, pioneered by Frei Otto and showcased at Expo 70 in Osaka, stand out for their ability to create intricate, double-curved spatial shapes using architectural fabrics characterized by tension without compression. These structures find diverse applications, from stadium roofs to building facades and inflatable structures, revolutionizing architectural possibilities.

Despite their growing popularity, the absence of specific design codes has posed challenges for designers and engineers. The establishment of organizations like the TensiNet association reflects the industry's need to disseminate information and address ongoing developments in tensile membrane structures. On the other hand, evaluation of material properties, such as tensile strength and tear resistance, which is essential to ensure the stability and reliability of tensile fabric materials, is challenging considering their non-linear and viscoelastic nature. Furthermore, the vertical application of tensile membranes as a double-skin (DSF) solution has gained popularity for its potential to mitigate heat gain in building envelopes. However, a notable research gap exists in evaluating the thermal and mechanical performance of these structures under external loads in vertical applications.

To address these gaps, this work aims to establish a constitutive material model predicting the mechanical behavior of membrane structures during design and construction. Experimental tests on a real-world model of a vertical membrane structure are conducted to comprehensively assess its behavior under various static air loads and pretensions. The proposed numerical model, validated against these experiments, demonstrates its capability to capture the orthotropic nonlinearity of coated fabric. This practical approach is applicable to different types of PVC-coated fabrics, making it versatile for diverse applications. Subsequent development in this research involves the analysis of fluid-structure interaction when the membrane serves as a vertical building facade.

This holistic approach aims to numerically evaluate both mechanical and thermal performance, contributing to a deeper understanding of tensile membrane structures and guiding best practices in design and application to ensure enhanced structural integrity and thermal efficiency.

Keywords

Tensile membrane structure, material nonlinear analysis, coated fabric, structural analysis, wind load, numerical modelling.

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