Influence of random loads on the optimal design of tensegrity footbridges

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Abstract

Tensegrity structures are composed of struts and tendons in such way that the compression is “floating” inside a net of tension in a stable self-equilibrated state. Although tensegrity forms have inspired artists and architects for many years, there exist very few real construction projects across the world. The main reasons are, among others, the complex construction processes and the lack of design guidelines.

When the structure is externally loaded, large displacements occur and require non-linear calculation before reaching an equilibrium. Indeed, in tensegrity structures more than in conventional ones, form and forces are intrinsically correlated. This phenomenon is due to their intern mechanism, unless appropriate pre-stressing is applied. An allowable stiffness can be possible, but at a certain material cost [1], which in turn justifies the relevance of the optimization of the weight.

While designing a tensegrity structure, optimization and form finding are often great challenges. Indeed, the large amount of parameters (span, height, shape, cross sections, materials, loads, pre-stress, etc) makes the search for the structure with the best performances cumbersome. A solution to this problem is to reduce the number of degrees of freedom to consider, by grouping them into dimensionless numbers, the morphological indicators [2].

In 2014, R.E. Skelton et al [3] were pioneers in using a similar approach for optimizing planar tensegrity bridges uniformly loaded. In 2017, P. Latteur et al [2] adapted the morphological indicators methodology, used so far to optimize mainly trusses and arches, to 3D non-linear and pre-stressed lattice structures such as tensegrity structures. In 2019, J. Feron et al [1] used this methodology to investigate the performances of different 3D forms of uniformly loaded tensegrity footbridges.

This article aims at sharing the improvements done in this optimization methodology and at comparing the best uniformly loaded versus the best randomly loaded tensegrity footbridges. New insights are provided about the impact of random loads on the optimal design and its related best form (number of modules, ratio span/height, etc) and performances (minimal weight and related stiffness). This influence may be of major concern with regards to the high sensitivity of the tensegrity forms to the external loads.

References

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