Catalogue of equilibrium forms of structures

Hiroki TAMAI*, Kenryo.TAKAHASHI[a],

Mizuki SHIGEMATSU[b], Kensuke ANDO[b], Bunji IZUMI[b]

*[b] Nikken Sekkei

Chiyota-ku Tokyo
tamai.hiroki@nikken.jp

[a] Ney & Partners

Abstract

Numeric form finding techniques have seen significant advances in the last few decades, and their application has gradually become recognized as a powerful design tool in architectural as well as structural design practice. Ever since physical hanging and soap film models were first used, the traditional motivation of form finding techniques has been to give a stable shape to structural materials that do not have their own fixed shape. These include discontinuous materials such as masonry, and tensile materials such as membranes or cables. Thin concrete shell structures have also been a major focus for form finding methods due to their thinness. For tensile materials in particular, prestressing must be introduced to stabilize and stiffen the structure. After some basic form finding techniques such as the force density method or the dynamic relaxation method became available in popular modeling software, many designers familiar with cutting-edge CAD tools but not necessarily having significant technical expertise in the area have been able to run simple form finding procedures to explore curvy roof shape options and their corresponding load paths.

What we get through form finding processes is more than just a reasonable engineering solution. From an engineering point of view, designing a structure with predominantly axial behavior helps minimize the structural material usage due to the fact that axial forces, particularly tension, are the most efficient way to transfer loads. But such forms and their corresponding load paths have something more to attract designers, including the author. This may be the aspiration for lean shapes or analogy to forms in nature.

It is actually a very exciting and delightful experience to explore various types of structural equilibrium forms. In many cases, the results from numerical form finding procedures confirm our intuitive composition of such systems. However, sometimes the output of such procedures results in very surprising geometries. Finding an analogy to rational forms in nature and finding once-unimaginable equilibrium configurations are both equally inspiring.

This paper will showcase a collection of conceptual designs of equilibrium structures created through form finding procedures. The collection will be sorted by types of material behavior, such as tensile or compressive; and types of structures, such as roofs or bridges. This will include self-stressed structures as well as tensile and compressive structures.

By showing various case studies, this paper will address a few relevant subjects in form finding which have not been thoroughly discussed besides the numerical methods. For example, form finding problems often have more than one solution. It is, in fact, still a designer's work to choose one from many possibilities. Then how do they go about choosing one?

The goals of this presentation are 1) to explore the possibility of form finding techniques used for conceptualizing unconventional structural configuration and 2) to address relevant matters needed in order to make the best use of form finding procedures.

References

[1] S. Adriaenssens, P. Block, D. Veenendaal and C. Williams (eds.), *Shell Structures for Architecture: Form Finding and Optimization*, Routledge, 2014.

[2] H.Tamai, “Form finding of cable nets for retractable membrane roofs”, The Proceedings of International Association for Shell and Spatial Structures (IASS) Conference, Tokyo, Japan 2016