# Step-by-Step Unbalanced Force Iteration Method for Cable-Strut Structure with Irregular Shape

Qing Ma[1, 2], b, Makoto Ohsaki[2], Zhihua Chen[1, *], Xiangyu Yan[1]

[1,*] Department of Civil Engineering, Tianjin University, Tianjin, China
zhchen@tju.edu.cn

[2] Department of Architecture and Architectural Engineering, Kyoto University, Kyoto, Japan

**Keywords**: cable-strut structure; tensegrity; prestress design; form finding

## Abstract

Cable strut structure especially cable dome is favored by engineers and architects for its high structural efficiency. A number of cable-strut structures have been built for large span roof[1]. However, most of the established ones are in the symmetric configuration. The challenges in designing asymmetric cable-strut structures are (1) solution of equilibrium equation based on initial geometry sometimes cannot satisfy the unilateral condition of members; (2) modification of geometry must comply with the architectural requirement. To overcome the difficulties, Unbalanced Force Iteration (UFI) and Step-by-step UFI are proposed in this paper.

The prestress of a cable-strut structure can be obtained according to the desired shape, if the geometry is feasible; otherwise, the geometry must be modified. Thus, the initial step for prestress calculation is to estimate the feasibility of the geometry. In the process of UFI the unbalanced forces are removed using the equilibrium and stiffness equations. Feasibility of the geometry can be judged by the convergence property of UFI. Self-stress modes can be directly obtained easily through UFI method, if initial geometry is feasible. For structures with infeasible initial geometry, the Step-by-Step UFI, which combines finite element analysis and UFI, is proposed to gradually move the nodes to feasible locations.

Three examples of structures with feasible geometry and three examples of cable domes with irregular and infeasible initial geometry are presented to verify the ability of UFI and Step-by-Step UFI for designing new irregular and asymmetric cable-strut structures.

## References

[1] Geiger, D. H., Stefaniuk, A., Chen, D., “The design and construction of two cable domes for the Korean Olympics”, in Proc., IASS Int. Symp. on Shells, Membranes and Space Frames, 1986, 265–272..