Integrated architectural and structural modeling for asymmetric cable dome structures

Mayur MISTRY[a], Sudarshan KRISHNAN, Ph.D [b]*

[a] Graduate Student, School of Architecture, University of Illinois at Urbana-Champaign,
611 Taft Drive, Champaign, IL 61820, USA.
mmistry2@illinois.edu

[b] Assistant Professor of Structures, School of Architecture, University of Illinois at Urbana-Champaign,
611 Taft Drive, Champaign, IL 61820, USA.
skrishnn@illinois.edu

Abstract

The fundamental and major challenge in the design of cable structures is the form-finding process and large amount of time consumed in the nonlinear analysis. This poses limitations on the exploration of many potential configurations, especially for asymmetric forms [1].

The proposed integrated procedure is developed using the commercial programs Rhino with Grasshopper plugin for architecture modelling and SAP2000 for structural modelling. Asymmetric cable domes [2] are used as examples to demonstrate the merits of the proposed integrated approach for modeling and analysis. For the shapes (circular, elliptical or special triangle) in plan, large spans, and multiple design parameters, parametric modeling allows exploration of a series of configurations, evaluations of various options, cost, time and performance optimization.

First, a model in constructed using Grasshopper based on user parameters. Then, structural calculations such as tributary areas for loads are simplified and calculated using the Voronoi function in Grasshopper. The architectural model is converted to the corresponding structural model by assigning material properties, section properties, boundary conditions, loads, etc. leading to formation of global stiffness matrix. This step eliminated the need for exporting the architectural geometry and making the structural model separately. The structural analysis is performed using an integrated plug-in called Karamba and SAP2000. Any changes in the architectural model are reflected real-time in the structural models, thus eliminating the potential for error involved when structural models need to be modified separately.

The method thus streamlines the modeling and analysis process thus leading to efficient work flow environment among architects and structural engineers. The time consumed in nonlinear analysis is also minimized further by incorporating Influence Surface Analysis [3] as part of the procedure. For architects, this procedure opens up ample opportunities to experiment with dome shapes. Hence, it leads to more flexibility with respect to spatial geometries for cable dome structures. For structural engineers, this alleviates the challenges of geometric and material non-linearity on asymmetric forms. Difficulties related to the generation of fabrication and construction drawings are also overcome by this approach.

The accompanying benefits of parametric modeling are discussed. Value engineering tasks such as cost optimization and construction feasibility can be assessed by adding optimization algorithms. This gives more flexibility to design a high-performance structure as these parameters can be optimized for daylight performance, energy simulation, and acoustic calculations depending upon the usage of the building. As such, parametric modeling leads to efficient workflow for all the disciplines associated with the project.

References

[1] Kuznetsov E.N., *Underconstrained Structural Systems*, Sringer-Verlag, New York, p. 219, pp. 152-157, 1991.

[2] Krishnan S., *Prestressed Cable Domes: Structural Behavior and Design*, Doctoral Dissertation, Department of Civil Engineering, University of Illinois at Urbana-Champaign, 2015.

[3] Krishnan S. and Abrams D., *Prestressed Cable Domes: Influence Surface Analysis*, Journal of the International Association for Shell and Spatial Structures, Spain, 2016.