3-dimensional elastic beam model for large-deformation analysis of bending-active gridshells

Yusuke SAKAI[*], **Makoto OHSAKI**[a], **Sigrid ADRIAENSSENS**[b]

[*] Department of Architecture and Architectural Engineering, Kyoto University
Kyoto-Daigaku Katsura, Nishikyo, Kyoto 615-8540, Japan
sakai.yusuke.52v@st.kyoto-u.ac.jp

[a] Department of Architecture and Architectural Engineering, Kyoto University

[b] Department of Civil & Environmental Engineering, Princeton University

Abstract

Elastic gridshells [1, 2] are composed of actively bent slender beams connected by hinge joints. The curved shape of a gridshell is generated from straight and unstressed beams on a plane, and enforcing bending and axial deformation through forced displacements at the boundary nodes. Therefore, large-deformation analysis should be carried out to numerically obtain the equilibrium shape of the gridshell. There exist several approaches to form finding of bending-active gridshells, in which dynamic relaxation method is one of the most widely applied methods [3].

This study presents a new formulation of 3-dimensional elastic beam model for large-deformation analysis of bending-active gridshells. The physically continuous long beam between supports is discretized into elements between nodes, at which two beams are connected by hinge joints, which allow relative rotations around the unit normal vector. The unit normal vector of the tangent plane of the curved surface is incorporated as variable defining the deformation. Three rotational displacement components at each node are to be determined by the direction of the normal vector. This formulation is based on the co-rotational formulation [3], and the rotation of an element excluding the rigid-body rotation is computed from the geometric relationship between the orientation of element and the directions of unit normal vectors at the two end nodes. Residual forces at nodes are formulated by axial force, shear force and bending moment.

In the numerical examples, accuracy of the proposed formulation is verified through form-finding analysis of simple gridshells using a dynamic relaxation method with kinetic damping. Equilibrium shapes are also found by optimization for minimizing the total potenrial energy, and also by using finite element analysis software Abaqus Ver. 6.14. The results by the three methods are compared to conclude that the proposed formulation is valid for form-finding of gridshell without using a finite element analysis software.

References

[1] Y. Sakai and M. Ohsaki, Discrete elastica for shape design of gridshells, *Engineering Structures* vol. 169, pp. 55-67, 2018.

[2] S. Adriaenssens and M. Barnes, Tensegrity spline beam and grid shell structures, *Engineering Structures* vol. 23, pp. 29-36, 2001.

[3] C. Lázaro, J. Bessini and S. Monleón, Mechanical models in computational form finding of bending-active structures, *International Journals of Space Structures* vol. 33(2), pp. 86-97, 2018.