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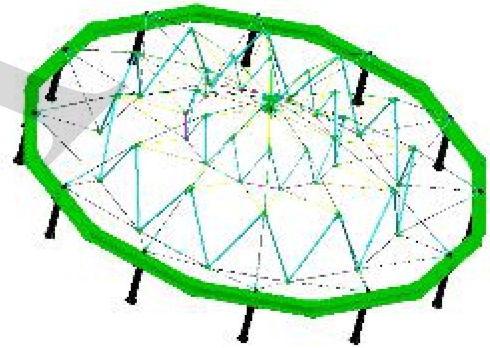
Active control experiments on a herringbone ribbed cable dome

Key words: Herringbone ribbed cable dome; Active control; Nonlinear force method; Force control; Shape control

BACKGROUND

- Active control experiments on a newly proposed herringbone ribbed cable dome are described in this study. The cables of the dome are designed to have the ability to change length in order to adjust the geometrical configuration and the force distribution of the structure.
- The cable dome was proposed and established in Seoul, Korea by Geiger et al. (1986) who were inspired by Fuller (1962)'s idea of tensegrity. Tensegrity is the conjunction of the two words tension and integrity. Thanks to its light weight and high efficiency, the cable dome is extensively employed in large-span space structures around the world.
- With the emerging conception of active structures which have the ability to change the response of the structure to its environment, an efficient method for traditional static and passive structures in civil engineering is available to help improve their ability to adapt to new challenges in extreme environments.



Herringbone ribbed cable dome model

- As the implementation of fine tuning and adjustment is easier for tensegrity structures than conventional structures, tensegrity structures are commonly chosen as the subjects of active control research.

- The experiment in this paper was to verify the adaptability of the cable dome to variable load cases by changing the length of the central strut.

METHOD

Active control experiments on a herringbone ribbed cable dome

Basic Theory

1. Active control algorithm based on force method:

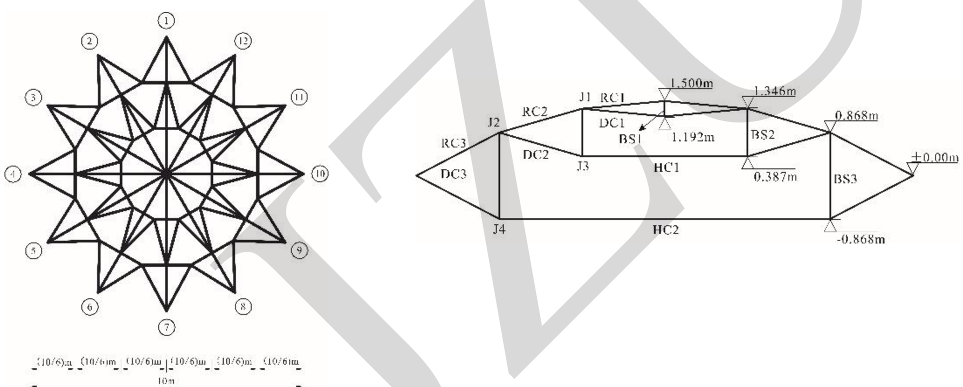
$$\begin{aligned} \boldsymbol{A}^{(k)}(\boldsymbol{d})\delta\boldsymbol{t}^{(k)} &= \delta\boldsymbol{f}^{(k)}, \\ \boldsymbol{B}^{(k)}(\boldsymbol{d})\delta\boldsymbol{d}^{(k)} &= \delta\boldsymbol{e}^{(k)}, \\ \delta\boldsymbol{e}^{(k)} &= \boldsymbol{F}^{(k)}(\boldsymbol{d})\delta\boldsymbol{t}^{(k)}, \end{aligned}$$

$$\boldsymbol{A} = \boldsymbol{USV}^{\mathrm{T}} = [\boldsymbol{U}_{\mathrm{r}} \quad \boldsymbol{U}_{\mathrm{m}}]\begin{bmatrix} \boldsymbol{S}_{\mathrm{r}} & 0 \\ 0 & 0 \end{bmatrix}[\boldsymbol{V}_{\mathrm{r}} \quad \boldsymbol{V}_{\mathrm{s}}]^{\mathrm{T}},$$

$$\begin{Bmatrix} \delta\boldsymbol{x}_{\mathrm{s}}^{\mathrm{c}} \\ \delta\boldsymbol{x}_{\mathrm{s}}^{\mathrm{u}} \end{Bmatrix} = \begin{bmatrix} \boldsymbol{S}_x^{11} & \boldsymbol{S}_x^{12} \\ \boldsymbol{S}_x^{21} & \boldsymbol{S}_x^{22} \end{bmatrix}\begin{Bmatrix} \delta\boldsymbol{e}_{\mathrm{s}}^{\mathrm{c}} \\ \delta\boldsymbol{e}_{\mathrm{s}}^{\mathrm{u}} \end{Bmatrix}.$$

Experimental model

2. Herringbone ribbed cable dome model



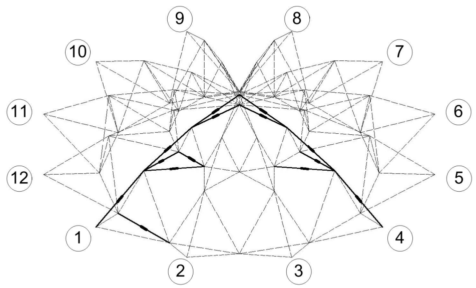
Cable dome geometry

Active unit

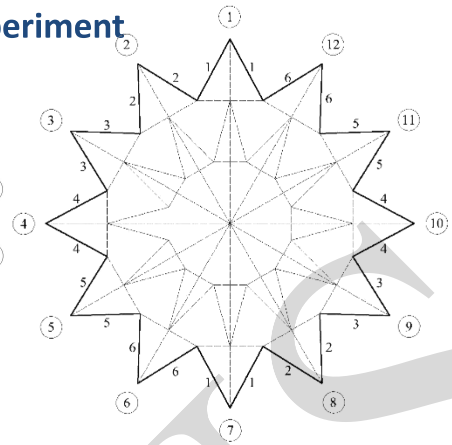
METHOD

Pre-stressing experiment

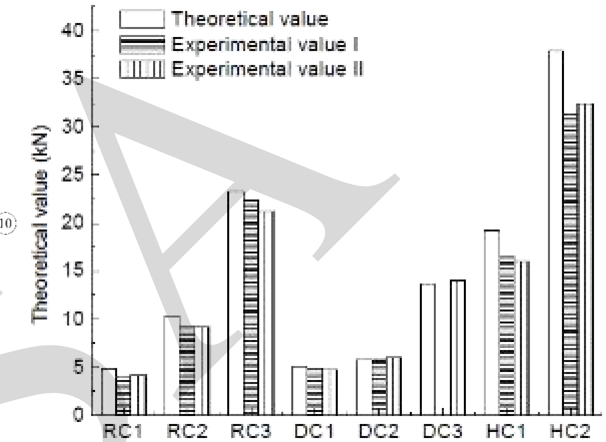
3. Assembly and pre-stressing experiment



Layout of force sensors



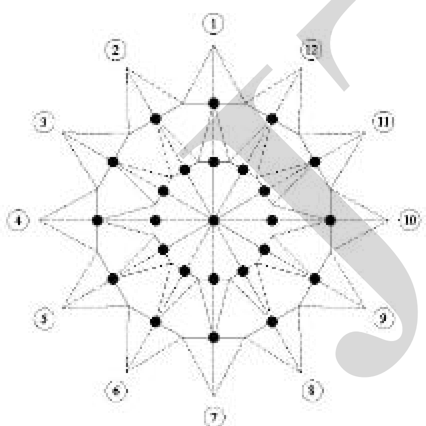
Adjustment sequence diagram



Comparison of theoretical and experimental cable internal forces

Active control test

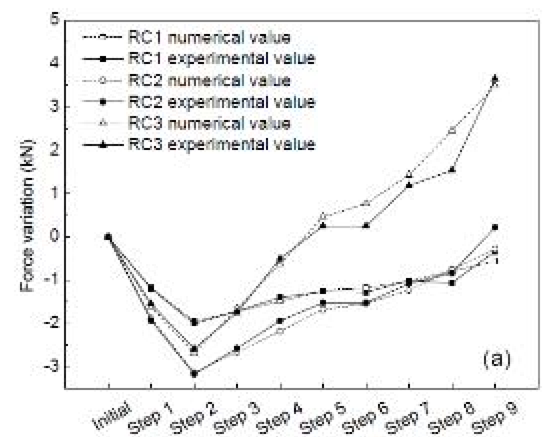
4. Active control test



Loading points layout

Procedure	Load (kg)	Adjustment amount (mm)
Initial	0	0
Step 1	60	0
Step 2	100	0
Step 3	100	−0.50
Step 4	100	−1.00
Step 5	100	−1.53
Step 6	100	−1.68
Step 7	100	−2.00
Step 8	100	−2.50
Step 9	100	−3.00

Active control test procedure



Internal force variation

RESULTS AND CONLUSIONS

- An algorithm based on the nonlinear force method is proposed for the active control of a her-ringbone ribbed cable dome. The calculation can obtain the control amount for the specified control objectives, such as maintaining the force level of the members and controlling the displacements of the free nodes. The method can be also used in different types of cable domes, for instance, the Geiger type and the Levy type and even tensegrity structures.

- By adjusting the lengths of the external diagonal cables using torque wrenches, the theoretical pre-stressing level of the dome can be attained. Based on the active adjustment test of three different types of diagonal cables, the adjustment of the cables in the external ring is more reasonable and effective for enhancing the total structural performance than the adjustment of the cables in the inner or middle rings.

- The active control experiment verifies that ad-justing the lengths of the cables can change the se-lected member force and the nodal displacement. A more reasonable stress state can be achieved by changing the member length of the structure. The active control method is able to increase the capability of the structure to withstand excessive loads.

- Since the cable dome structure is highly sensitive to the lengths of the cables, the accuracy of control relies on the precise control of a number of cables. High-precision actuators are required to enable the practical application of an adaptive cable dome. This paper focuses on active control by using symmetrically arranged actuators, and further research could be concentrated on adding a more complex case to active control where symmetry is abandoned for different kinds of cable domes.