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Integral tow-lifting construction technology of a tensile beam-cable dome

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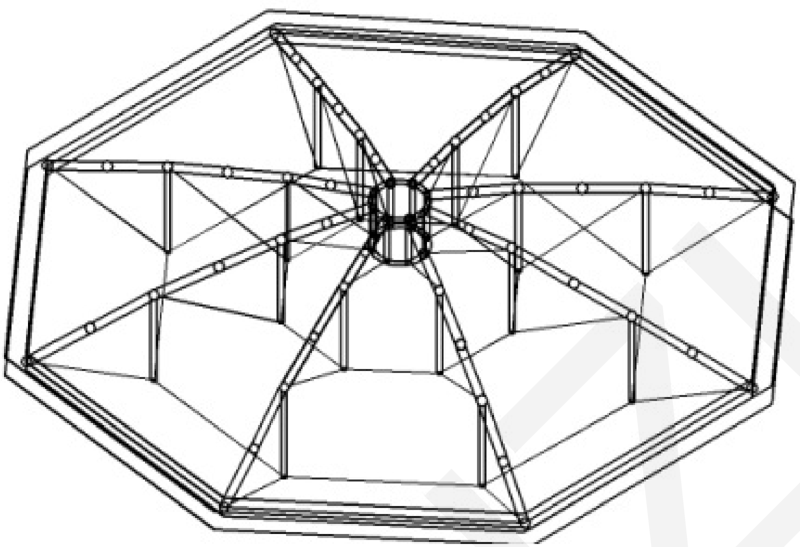
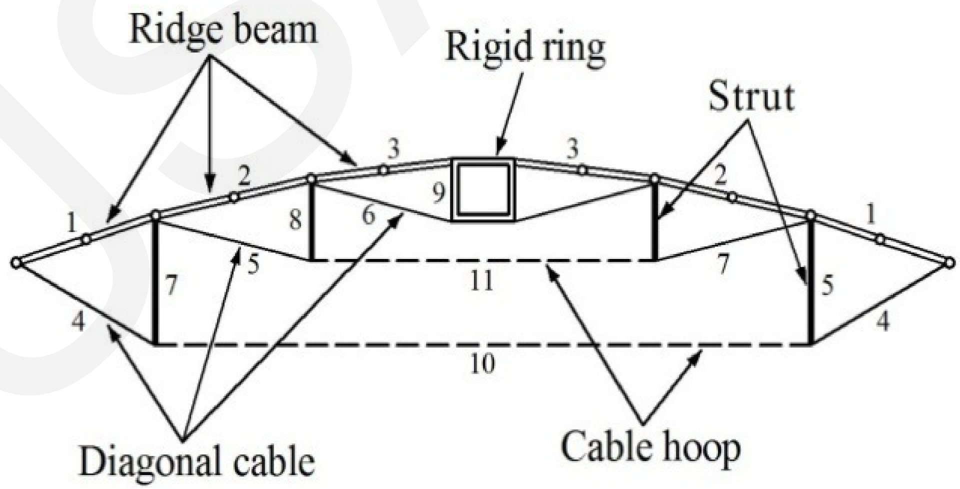
Tensile Beam-Cable Dome

A traditional cable dome is composed of ridge cables, oblique cables, ring cables and struts. If the ridge cables of the traditional cable dome are replaced by hinged beams that can bear both tensile and flexural effects, then a new structure called a Tensile Beam-Cable Dome (TBCD in short) is created.



Perspective view



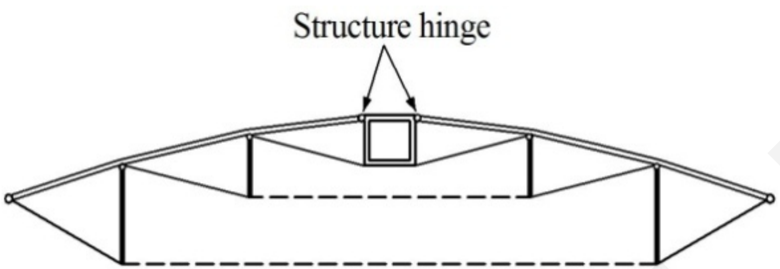
Section view

Tensile beam-cable dome

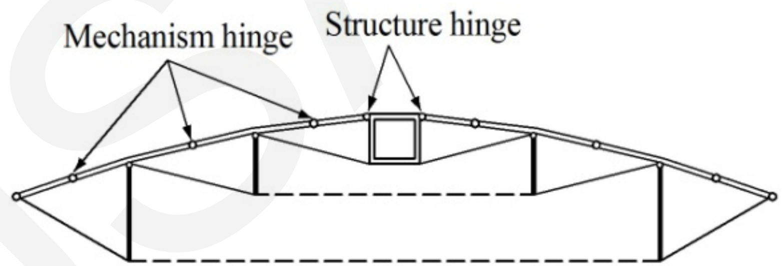
(1.outer tensile beam, 2.middle tensile beam, 3.inner tensile beam, 4.outer oblique cable, 5.outer strut, 6.inner oblique cable, 7.middle oblique cable, 8.middle strut, 9. inner tensile ring, 10. outer ring cable, 11. inner ring cable)

Tensile Beam-Cable Dome

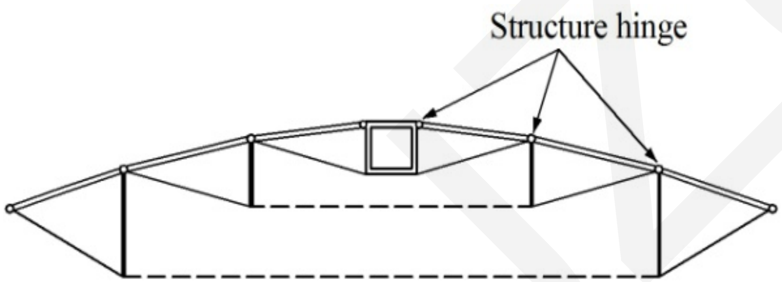
According to the location of structure hinges and mechanism hinges, TBCD can be divided into four categories: Non-hinge TBCD (NTBCD), Single-hinge TBCD (STBCD), Double-hinge TBCD (DTBCD), and Three-hinge TBCD (TTBCD).



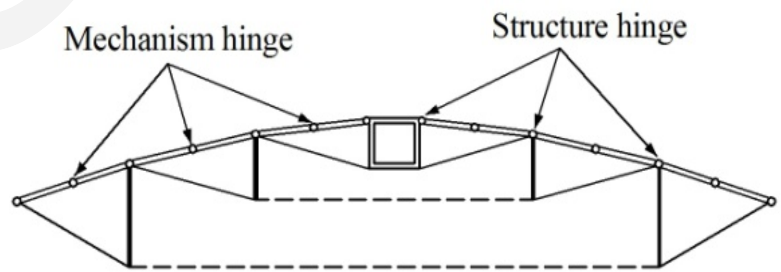
Non-hinge TBCD



Single-hinge TBCD



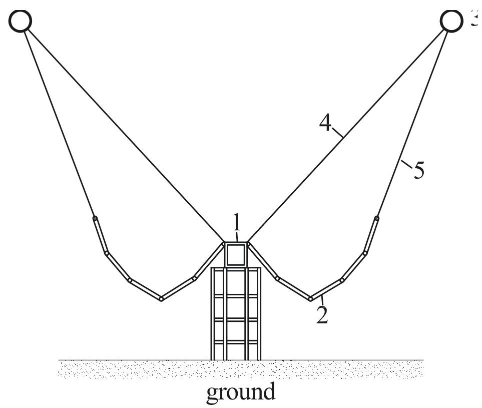
Double-hinge TBCD



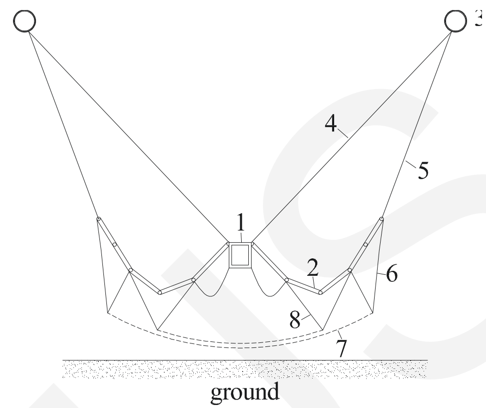
Three-hinge TBCD

Integral tow-lifting construction technology

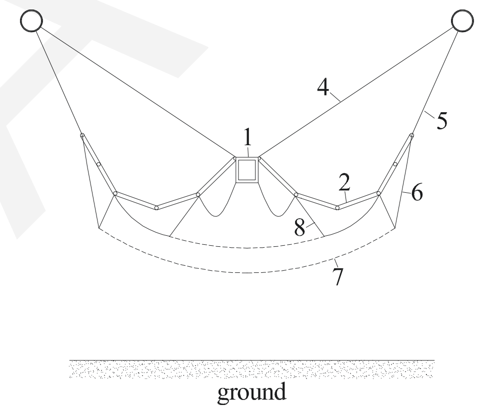
The integral tow-lifting construction method includes assembly at a low altitude, tow-lifting at a moderate altitude, and tensioning to form at a high altitude.



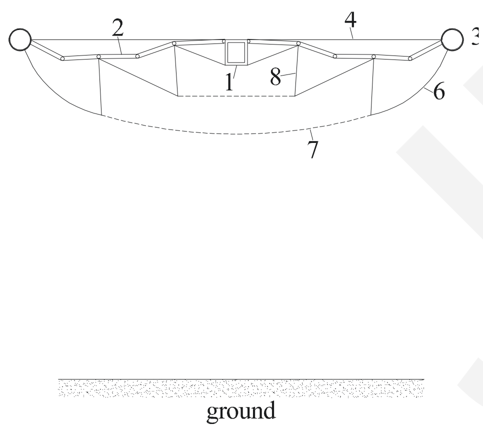
(a) Install inner tensile ring, tensile beams, and tool cables



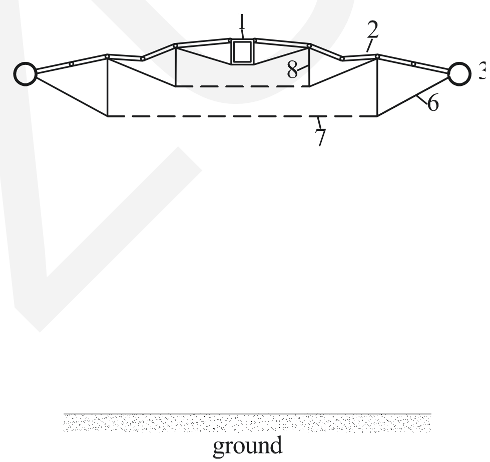
(b) Install cables and struts



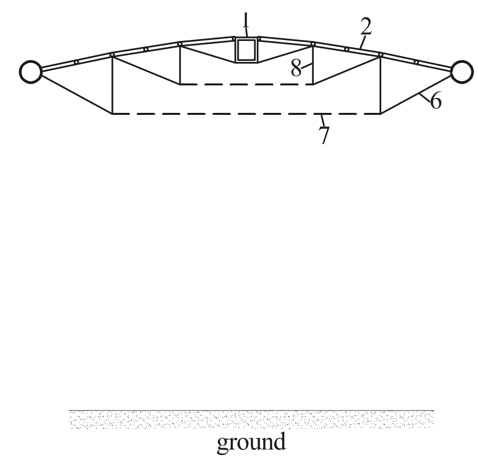
(c) Tow and lift alternately



(d) Connect tensile beams with the compressive ring



(e) Shorten the tensioning cables

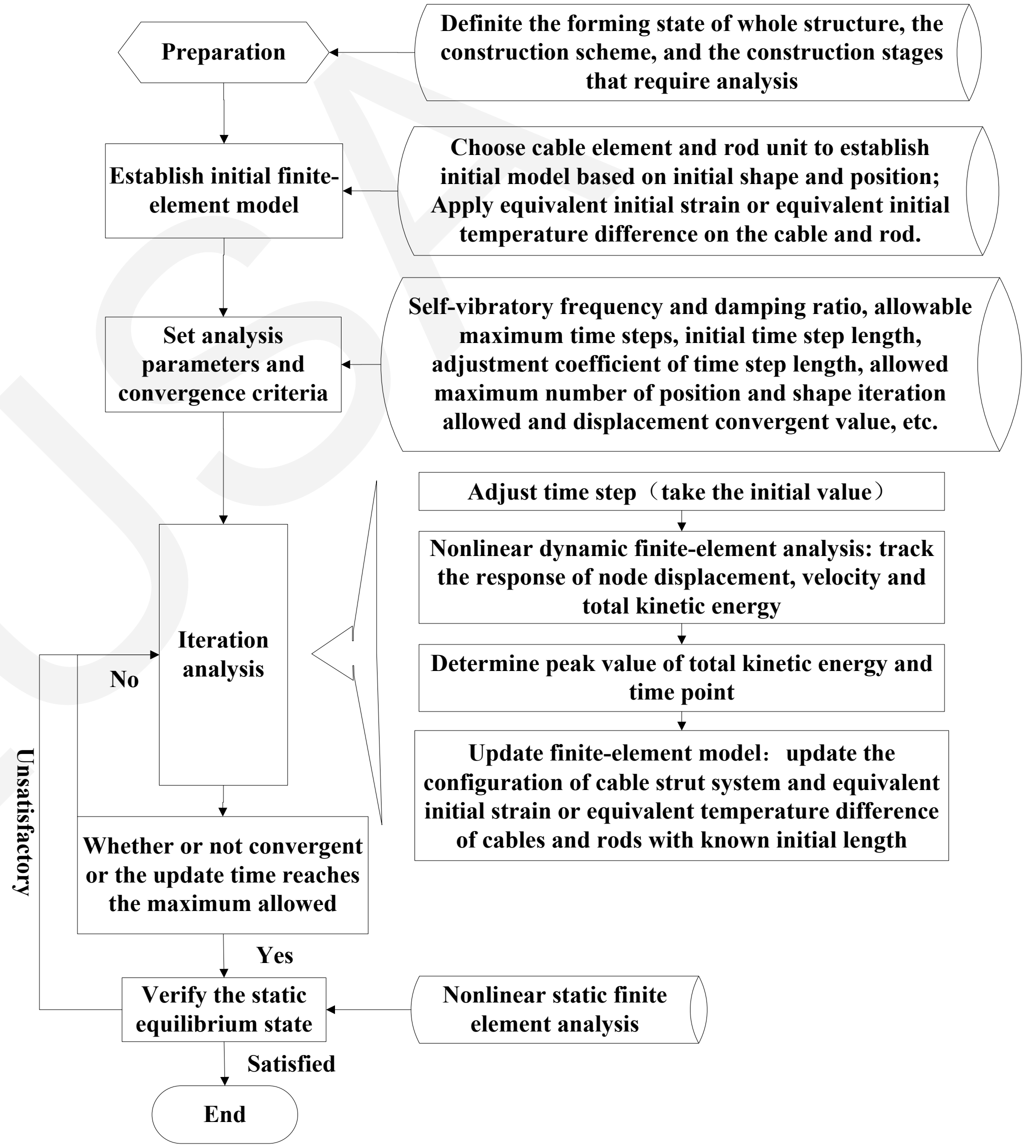


(f) Tension the outer oblique cables and form the structure

Nonlinear Dynamic Finite Element Method (NDFEM)

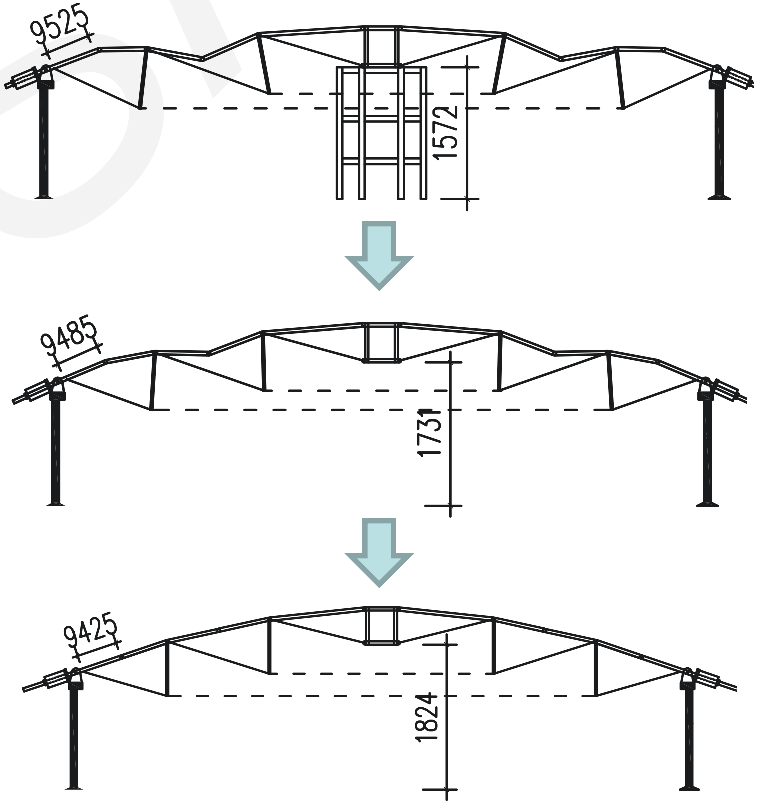
Due to the large displacement, mechanism deformation, and cable slackness during Integral tow-lifting construction, a large difference in configuration occurs between the construction stages and the formed state of TBCD. The construction process is dynamic, but the whole system is in a static equilibrium state at a certain moment.

The NDFEM method is used to determine the static equilibrium state of the tensile-beam and cable-strut systems during construction.



Nonlinear Dynamic Finite Element Method (NDFEM)

In order to test the applicability of NDFEM method in TBCD, an experiment with a three-hinge TBCD model was carried out. It was six meters in span, eight pieces in radius, and three pieces in hoop. This model was performed tensioning construction, and the errors between experiment values and theoretical values are within 12 %.

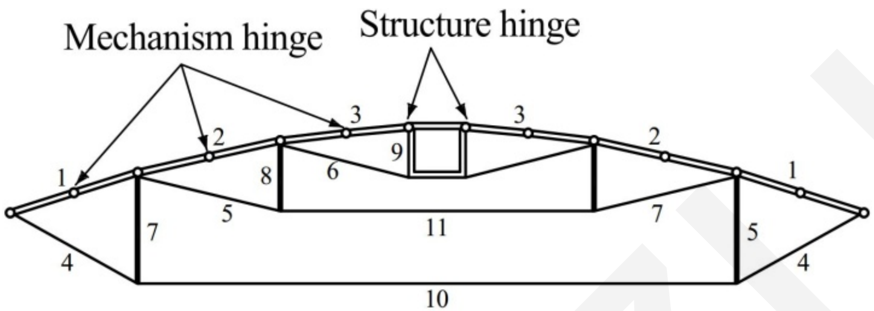


Tensioning process

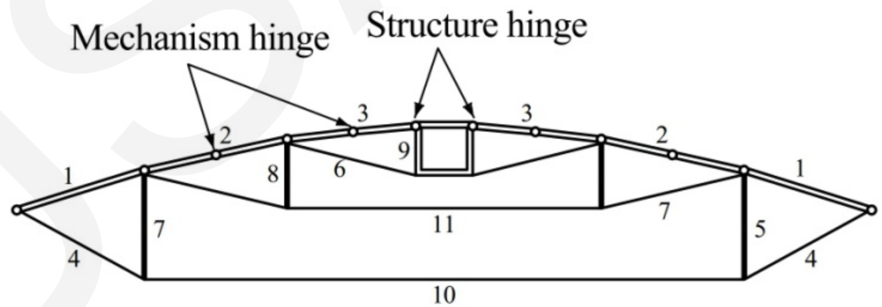
Optimal distribution mode of mechanism hinges

When integral tow-lifting construction method is adopted, the mechanism hinges should be set at the middle of the tensile beams to make the tensile beam grid a mechanism system.

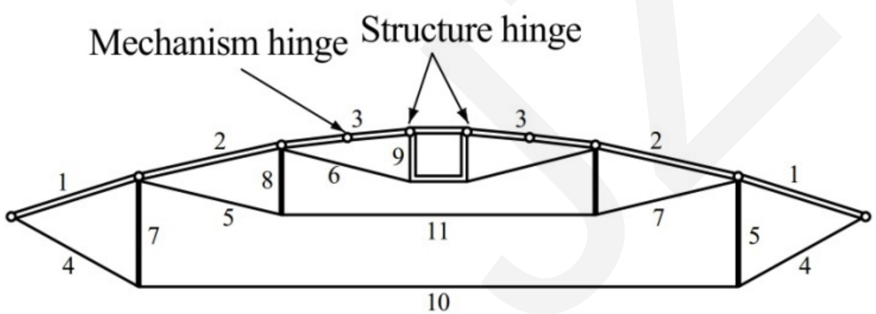
According to the locations of the mechanism hinges, seven TBCD analysis models of TBCD are built.



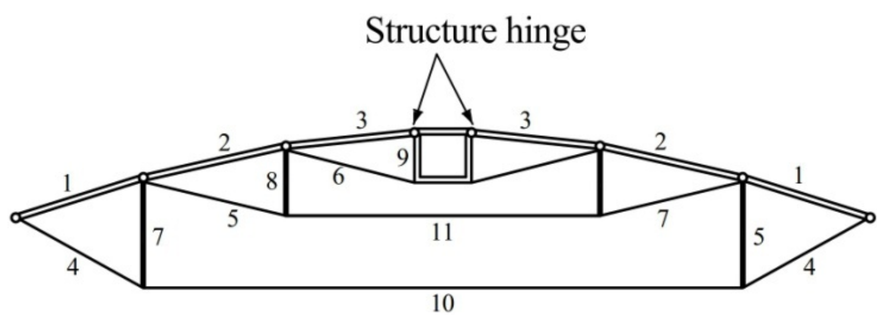
Model I



Model II

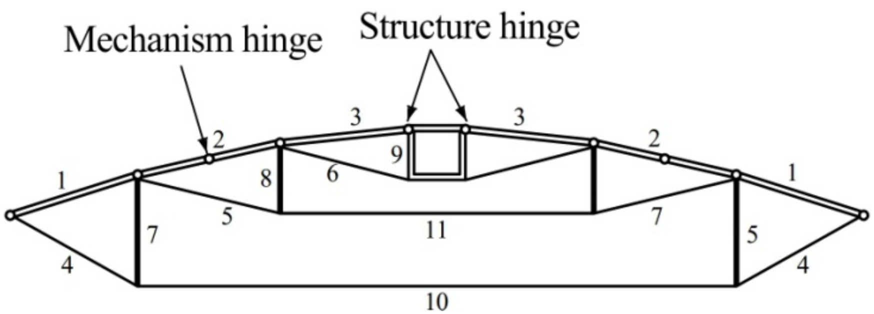


Model III

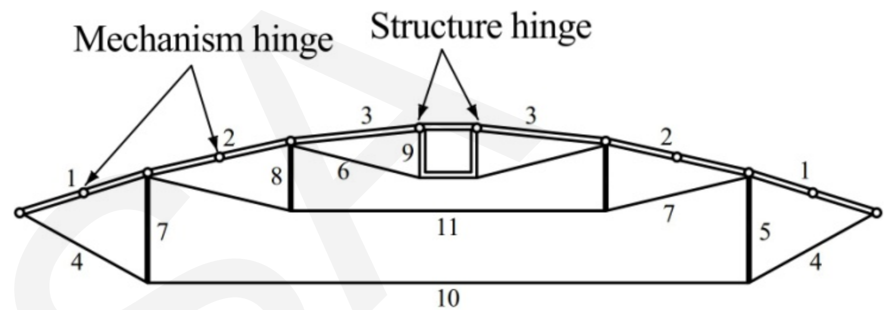


Model IV

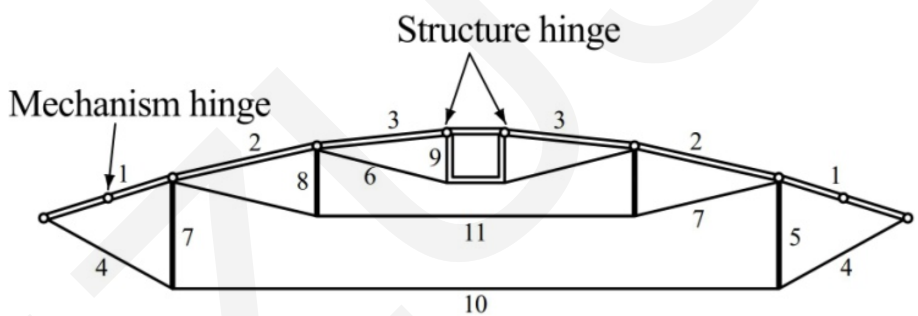
Optimal distribution mode of mechanism hinges



Model V



Model VI



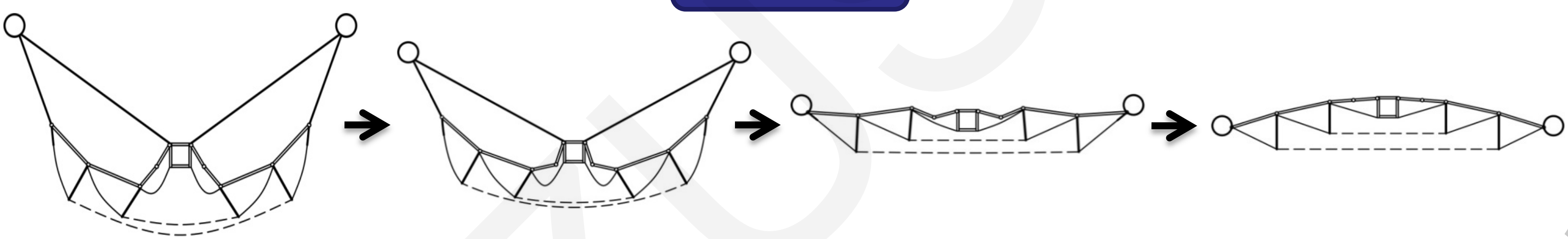
Model VII

The models are all 60 meters in span, 6 meters in height, 20 meters in altitude at the support, 3 pieces in hoop and 12 pieces in radial direction. They all have a 0.1 rise-span ratio, and the supports are clamp-hinged.

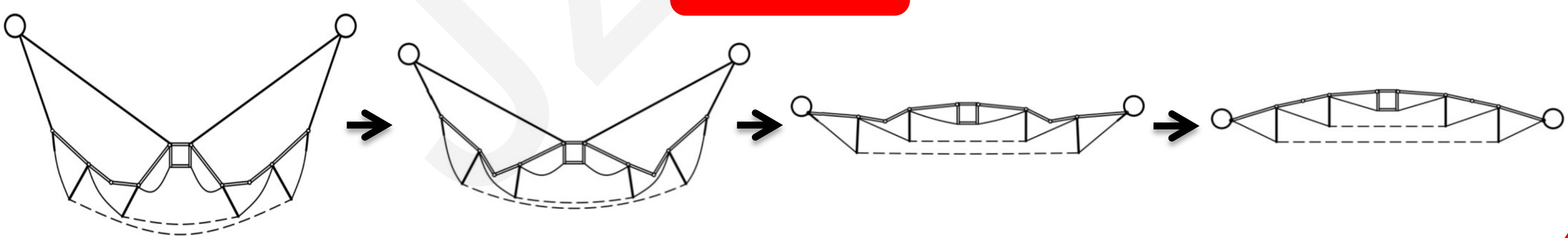
Optimal mode analysis of mechanism hinges

By considering the influence of local deformation, the number of mechanism hinges, and the bending stress of tensile beams in sequence, the mode with mechanism hinges set only on the inner tensile beams (Model III) and the one with mechanism hinges set only on the middle tensile beams (Model V) were equally optimal.

Model III



Model V



Conclusions

- Due to the bending stiffness of these tensile beams, TBCD provides enough out-of-plane stiffness and limited local deformation when compared with traditional cable domes.

- The small lifting force, limited high-level work, and high efficiency of tensioning make integral tow-lifting construction technology convenient for TBCD.

- By comparing the configurations of different numerical models during construction analysis, the feasible distribution modes of mechanism hinges were calculated and compared; the optimal modes will reduce both the complexity and the cost of the structure.