Postprint: Configuration and Tension of Horizontal Catenary Under Out-of-Plane Normal Concentrated Force

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Abstract

Catenary theory is increasingly applied in the design of large-span spatial flexible pipelines and related fields; however, existing applications primarily consider in-plane vertical or horizontal loading conditions, while research on directly solving out-of-plane problems using catenary theory remains inadequate. To address this issue, the present study derives from two-dimensional catenary theory to establish a nonlinear system of equations for out-of-plane normal concentrated forces acting at arbitrary positions on a horizontal catenary, and obtains an analytical solution for the specific case where the out-of-plane normal concentrated force acts at the catenary's midpoint. The bisection method and Newton-Raphson iteration method are employed to solve the analytical solution and the nonlinear system of equations, respectively. The calculated results are validated through flexible cable experimental apparatus and finite element analysis. The results demonstrate that the configurations and characteristic tensions obtained from experiments and finite element calculations show good agreement with theoretical predictions, indicating that the theoretical framework can effectively solve the initial configuration form-finding and characteristic tension calculation problems for flexible pipelines subjected to combined vertical distributed forces and out-of-plane normal concentrated forces.

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