Nonlinear static and dynamic analysis of mixed cable elements

Miquel Crusells-Girona*, Filip C. Filippou* and Robert L. Taylor*

* Department of Civil and Environmental Engineering
University of California, Berkeley
731 Davis Hall, 94720 Berkeley, CA, USA
e-mail: miquel.crusells@berkeley.edu

ABSTRACT

This paper presents a mixed variational formulation in general curvilinear coordinates and finite deformations for the nonlinear static and dynamic analysis of cable structures that constitutes a generalization of forms found in the current literature [1, 2, 3]. The formulation identifies stress measures, in the form of axial forces, and conjugate deformation measures for the catenary problem, and thus allows an independent interpolation of displacements and axial forces that can readily account for nonlinear material behaviour and the consistent mass of the cable. Two possible solution strategies for the problem, defining two cable elements, arise since no continuity requirements exist for the axial forces in the variational formulation: a continuous and a discontinuous axial force distribution.

The proposed mixed formulation, under both solution strategies, is assessed with standard problems from the literature. Both solutions give accurate response for axial forces and displacements, even with few elements, and converge to the same result. Two nonlinear elastic material models, St Venant – Kirchhoff and compressible neo-Hookean, are tested in the simulations, with accurate and robust numerical results for both materials. In one example, both cable elements are used to analyze the stability of the transport pulley system in Fig. 1, and determine its multiple stable (solid) and unstable (dashed) equilibrium configurations in Fig. 2.

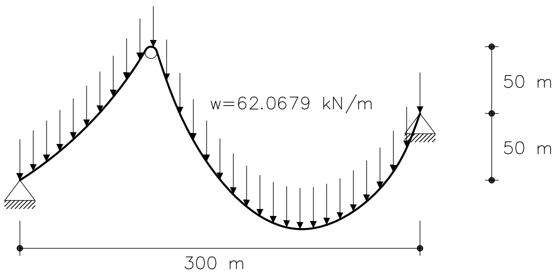

Fig 1. Transport pulley system

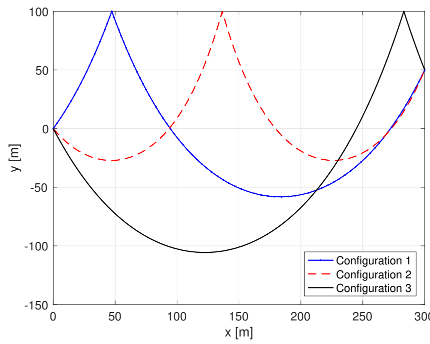

Fig 2. Stable and unstable configurations.

The paper also discusses the dynamic response of cables under cyclic imposed displacements. It shows that harmonic oscillations result for light cables, while heavier cables do not exhibit such oscillations for the same displacement magnitude.

The numerical simulations show that the proposed mixed cable elements and their numerical implementation constitute a generalization of existing elements for the nonlinear analysis of cable structures under general loading, providing consistency, accuracy and numerical robustness.

REFERENCES

[1] M. Ahmadizadeh, "Three-dimensional geometrically nonlinear analysis of slack cable structures", *Computers & Structures*, **128**, 160-169 (2013).

[2] W. Lacarbonara, *Nonlinear structural mechanics*, Springer (2013).

[3] O.C. Zienkiewicz, R.L. Taylor and D.D. Fox, *The finite element method for Solid and Structural Mechanics*, 7th edition, Elsevier, Ltd. (2014).