Analysis of Cable Supported Structure Considering Cable Sliding

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Summary

The goal of this study is to develop a 3-dimensional elastic cable finite element which considers the sliding effect and uses the geometric nonlinear cable finite element based on elastic catenary theory. In this study, two types of sliding were considered: the roller sliding condition without friction and the frictional sliding condition. These were formulated to derive the nodal force vectors and tangential stiffness matrices. To validate the proposed 3-dimensional cable sliding element, experiments were conducted for both sliding conditions, and compared to calculations of the amount of sliding and displacement at the loading point. Overall calculations using the 3-dimensional cable sliding model were in very good agreement with the measured values.

Keywords: cable finite element; elastic catenary; roller sliding; frictional sliding; cable sliding.

1. Introduction

The purpose of this study is to develop a 3-dimensional elastic cable finite element which considers the sliding effect of cables. This was achieved using the geometric nonlinear cable finite element based on elastic catenary theory. The elastic catenary cable finite element on the vertical cable plane was developed by Chang and Park [1], and is based on the well known elastic catenary cable theory [2] and employed in the spatial modeling of cable members through a simple coordinate transformation on the horizontal plane [3]. Ahn [4] and Park [5] formulated the 3-dimensional profile expressions of an elastic catenary cable element subjected to self-weight only. Until recently, continuous model updates have been performed by the Seoul National University [6,7], but the model still does not take into account the cable sliding effect.

Recently, a multi-node cable element allowing sliding without friction at its nodes has been developed by Kim et al. [8]. A two-node truss element was extended to a multi-node truss element which maintains constant tension but is connected through several nodes without friction. However, its tangential stiffness is derived under the linear elastic condition and assumes that the cable is straight before and after deformation occurs. This research was originally planned for application to the external pre-stressing method using strands based on Troitsky's theory [9].

In this paper, two types of sliding were considered: the roller sliding condition without friction and the frictional sliding condition. These were formulated to derive the nodal force vectors and tangential stiffness matrices. To validate the 3-dimensional cable sliding element developed here, experiments representing both sliding conditions were conducted and compared with calculations of the amount of sliding at the saddle and the displacement at the loading point.

This paper describes the formulation of the cable sliding problem using the elastic catenary cable element. In addition, a simplified cable-supported structural system was analyzed to investigate the characteristics of a realistic structure with cable sliding but this result can be seen in reference [10].

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2. Conclusions

A 3-dimensional, elastic catenary cable element which considers cable sliding is presented. This model is based on the theory of the geometric nonlinear cable finite element. Cable sliding is classified into two types: roller sliding without friction and frictional sliding. The element we developed was validated by comparing the measured and the calculated responses of a simple test model of a cable-supported structure. Based on our results, the following conclusions can be drawn:

The calculated sliding lengths at the saddle for both roller and frictional sliding were in good agreement with measured values. The average calculated-to-measured ratio for roller sliding was 0.99 with a standard deviation of 0.05, while for frictional sliding, the average calculated-to-measured ratio was 1.09 with a standard deviation of 0.23.

The calculated vertical displacements at the loading point for both roller and frictional sliding were also in good agreement with the measured values. The average calculated-to-measured ratio for roller sliding was 0.95 with a standard deviation of 0.02, while for frictional sliding, the average calculated-to-measured ratio was 0.97 with a standard deviation of 0.04.

In addition, a cable-supported structural system was analyzed to investigate the characteristics of a realistic structure with cable sliding. This result can be seen in reference [10]

The finite element presented here provides a useful tool for the nonlinear analysis and geometry control of cable-supported structures subjected to extreme loads such as earthquakes and strong winds.

3. References

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