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Optimal Measurement of Static Displacements in Managing Construction Quality of a Cable-stayed Bridge

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Abstract

When a deck segment is added to a cable-stayed bridge during its construction, cables are attached to the deck and cable tension forces are usually adjusted at a limited number of cables to fit to the target configuration. The quality of the construction is examined by measuring static displacements along the deck before and after adjusting cable tension forces. Therefore, the construction quality may be dependent on the number and locations of measurements and also on those of cables adjusted. The paper presents two algorithms of selecting an optimal number and locations of measurements of static displacements during the construction of a cable-stayed bridge. The paper applies both of the Fisher Information Matrix (FIM) formulated with the displacement sensitivities and that with the measured displacements. Simulation studies have been carried out to examine the efficiency and reliability of the proposed algorithm with respect to the number and locations of measurements. The error analysis has been carried out together with the number and locations of cables to be adjusted. The effects of measurement noise and manufacturing error in the cable length on the adjustment of cable tension forces are evaluated statistically by applying the Monte Carlo scheme.

Keywords: cable-stayed bridge, construction quality, displacement measurement, cable force, FIM

1. Introduction

A target configuration of a cable-stayed bridge is defined at each construction stage from the analysis of completed structure with the initial equilibrium condition. However, in the field of construction under various uncertainties and environmental effects, it is difficult to keep the intended target configuration even with well-prepared construction management. To correct the construction error, cable forces of some cables are adjusted in each construction sequence and the accuracy is examined by measuring static displacements at some of the cable ends attached to the bridge deck. In general, the measuring points and the cables to be adjusted are selected based on the field experience or engineer's judgment rather than any theoretical background. Depending on the field situation, the number of measuring points and the number of cables adjusted may vary. Only some of end cables are usually adjusted with the measured displacements at also around the end of constructed bridge at each construction stage.

The paper presents an algorithm of determining optimal locations for measuring displacements in each construction sequence and examines the influences of measuring locations and number of cables adjusted on the construction quality statistically. Methods to determine optimal measurement locations can be classified by two different numerical schemes of Fisher Information Matrix (FIM) and Hankel Matrix.(Kwon *et al.* 2008) FIM methods also can be divided into those using measured displacements directly and those using displacement sensitivity. (Penny *et al.* 1994, Fadale *et al.* 1995, Udwadia 1994) The paper applies both FIM methods using measured displacements and displacement sensitivity for selecting optimal measurement locations. Construction quality in each construction sequence was evaluated by the difference in the measured displacements at the selected locations and the target configuration. To examine the proposed method, a numerical study on a construction stage of a cable-stayed bridge was carried out. In the simulation study, the influence of measurement noise and error in the cable length on the cable force adjustment was evaluated statistically by applying the Monte Carlo scheme.

2. Analysis of cable-stayed bridge

Structural stiffness matrix for the analysis of a cable-stayed bridge is constructed from elastic catenary elements for the cables and frame elements for the girders. The tangent stiffness matrix of a cable element is obtained from the elastic catenary theory.(Ahn 1991) Figure 1 shows a three-dimensional cable element under deal load and tensile force. The external equilibrium of cable element e is expressed by

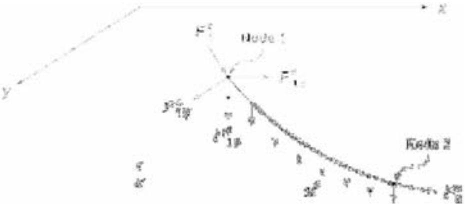

Figure 1. Free-body diagram of a cable element