Effects of Hanger Extensibility on Responses of Suspension Bridges

Dong-Ho CHOI
Professor, Ph.D.
Dept. of Civil and Environmental Eng.
Hanyang University
Seoul, Korea
samga@hanyang.ac.kr

Dong-Ho Choi, born 1963, received his Ph.D. degree from MIT in 1997. His main research includes cable-supported bridges and steel structures.

Sun-Gil GWON
Ph.D. Candidate
Dept. of Civil and Environmental Eng.
Hanyang University
Seoul, Korea
verysoon@hanyang.ac.kr

Sun-Gil Gwon, born 1985, received his Master's degree from Hanyang University in 2011.

Summary

This paper presents an improved deflection theory considering extensible hangers for the static analysis of a suspension bridge. The coupled differential equations for the deflections of the main cable and girder are presented and numerically solved by MATLAB. For verification, the two-dimensional finite-element method, the conventional deflection theory, and the improved deflection theory are used to obtain the static responses of an example model of a three-span suspension bridge. The results show that the improved theory can demonstrate accurate static behaviors of suspension bridges.

Keywords: Suspension bridge, Hanger extensibility, Deflection theory.

1. Introduction

Suspension bridges are usually analyzed by two main approaches; analytical method based on the deflection theory and numerical method based on the finite element method. Analytical methods not requiring initial equilibrium state analysis are useful in the preliminary design. However, because the conventional deflection theory assumes that the hangers are inextensible, effects of hangers on responses of the bridge cannot be observed and an improved method is thus needed. In this paper, an improved deflection theory considering extensible hangers for a suspension bridge is presented.

2. Improved deflection theory

The conventional deflection theory includes several assumptions [1]. The improved deflection theory involves the same assumptions as the conventional deflection theory except the inextensible hangers. By introducing extensible hangers and considering the equilibrium equations for each member in a single span, the differential equations for the deflections of the main cable and girder is derived as

$$\left(H_w + H_p\right)\frac{d^2 v_c}{dx^2} + k_h\left(v_g - v_c\right) = H_p \frac{w}{H_w} \qquad (1a)$$

$$E_g I_g \frac{d^4 v_g}{dx^4} + k_h\left(v_g - v_c\right) = p \qquad (1b)$$

where v_c and v_g are the deflections of the main cable and the girder, respectively; w and p are the uniform dead and live loads, respectively; H_w and H_p are the horizontal forces in the main cable caused by the dead and live loads, respectively; $E_g I_g$ is the flexural rigidity of the girder; and k_h is the distributed axial stiffness of the hangers per unit span length. Eq. (1) is converted to the six coupled first-order differential equations to be solved by using the function BVP4C in MATLAB with the compatibility equation of the cable and appropriate boundary conditions.

3. Numerical results and conclusions

An example model of a three-span suspension bridge is presented in Fig. 1. The dead and live load conditions are also shown in Fig. 1. Two types of girder conditions at the tower such as two-hinged and continuous girders are considered as well.

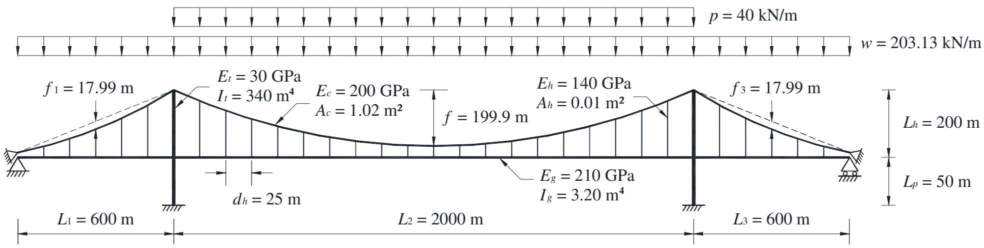

Fig. 1: Three-span suspension bridge

The two-dimensional finite-element method (FEM) by MIDAS Civil 2012, the conventional deflection theory, and the improved deflection theory are used to obtain the static responses of the bridges. The three methods give almost the same deflections of the girder. However, the conventional deflection theory gives the deviated bending moments near the tower compared with the results obtained by FEM as shown in Figs. 2 and 3. On the other hand, the improved deflection theory gives the accurate bending moments even near the tower. It was found that the hanger extensibility affects much more the bending moment of the girder than the deflection. Since the results show that the improved deflection theory can demonstrate accurate static behaviors of suspension bridges, it can be used as an analytical method for analyzing the hangers as well as the girder, main cable, and towers in the preliminary design of a suspension bridge.

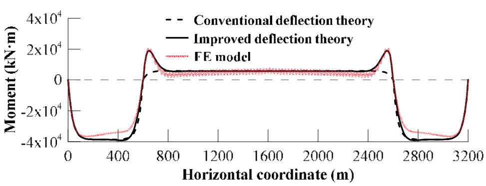

Fig. 2: Bending moments of two-hinged girder

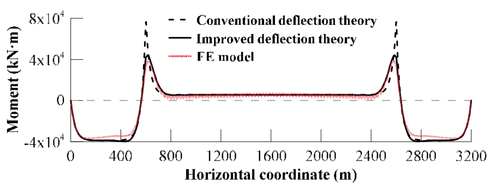

Fig. 3: Bending moment of continuous girder

4. Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2012R1A1A2007054). The authors wish to express their gratitude for the financial support.

5. References

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