Equivalent Model for Tower Design of Four-span Suspension Bridges

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

Ho-Sung NA
Senior Engineer, Ph.D.
Dept. of Civil Engineering,
Samsung Engineering,
Seoul, Korea
hosung1.na@samsung.com

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

Summary

This study proposes a simplified equivalent model for the tower design of four-span suspension bridges under static loads. The model consists of towers and equivalent springs that replace the suspension cables. The stiffness of the equivalent springs is derived based on the parabolic configuration of the cable. Finally, an example model for a four-span suspension bridge is used for verification and the resultant values of the towers are compared by using the proposed method and finite element analysis.

Keywords: Four-span suspension bridge, Tower, Equivalent cable spring.

1. Introduction

Multi-span suspension bridges with more than three main towers and two main spans can be a good solution for strait crossing bridges connecting very long distances because of their more constructability, better aesthetics and reduced construction costs, compared with typical three-span suspension bridges requiring a center anchorage [1]. For the bridges, a simpler method to analyze towers of the bridge is needed without finite element analysis requiring computationally intensive and time-consuming input preparation.

This paper proposes a simplified equivalent model for the tower design of multi-span suspension bridges, especially four spans, under static loads. The model consists of towers and equivalent springs that replace the suspension cables. An example model is used for verification and the resultant values such as horizontal displacements of the towers are compared by using the proposed method and finite element analysis.

2. Equivalent suspension bridge model

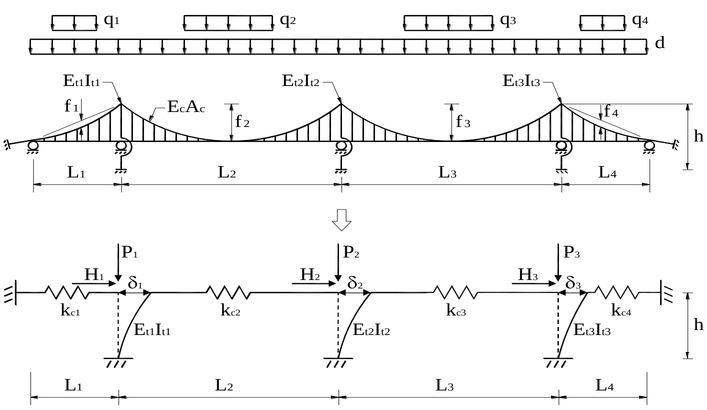


Fig. 1: Four-span suspension bridge and the equivalent suspension bridge model

Figure 1 shows an equivalent model for a typical four-span suspension bridge. In this model, the girder and main cables are replaced with equivalent springs (k_c), and the dead (d) and live (q) loads acting on each span are replaced by horizontal (H) and vertical (P) forces acting on the top of the towers. In the figure, E_tI_t is the flexural rigidity of the towers, E_cA_c is the axial stiffness of the main cable, L is the span length, h is the height of towers, f is the sag of the main cable, and δ is the horizontal deflection at the top of the towers. In the equivalent model, the stiffness of the equivalent springs is derived based on the parabolic configuration of the cable and the horizontal and vertical forces acting on the top of the towers are calculated using the deflection theory for a single span [2].

https://doi.org/10.2749/222137813808626867

3. Verification of the proposed model

To verify the proposed method, the design data based on the New Millennium Bridge with four spans under construction in Korea are used. Figure 2 shows the properties of the bridge. In addition, six cases of the live load are considered as shown in Fig. 3. The live load with intensity of 38.1 kN/m is applied on the girder for each span.

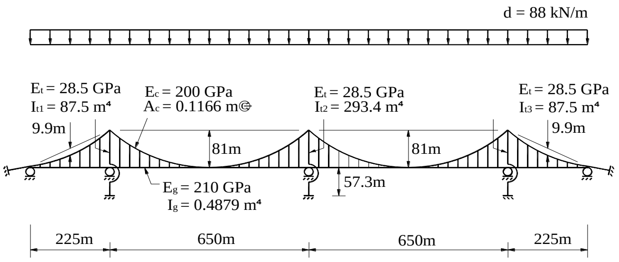


Fig. 2: Properties of the New Millennium bridge

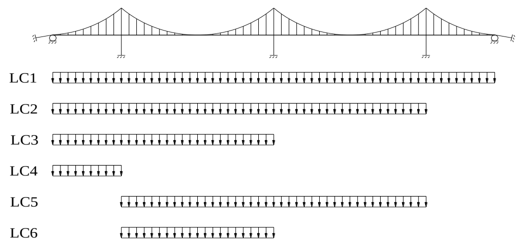
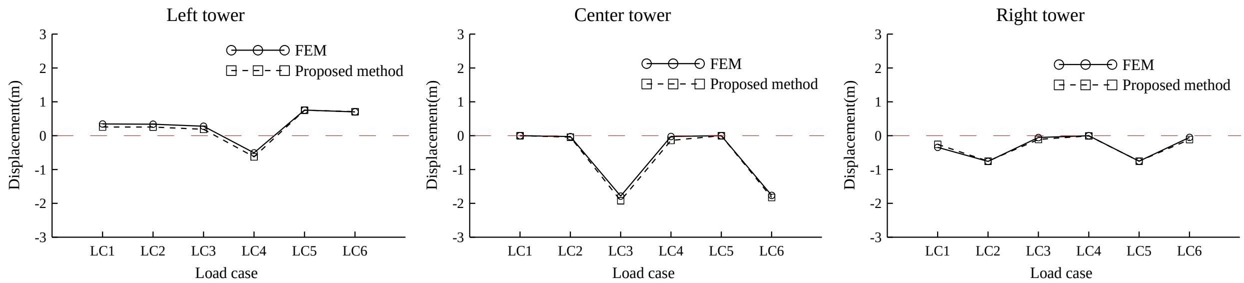


Fig. 3: Live load cases

Figure 4 shows the displacements at the top of each tower under the six load cases. In all cases, the results of the finite element analysis and the proposed method are in good agreement.



(a) Left tower *(b) Center tower* *(c) Right tower*

Fig. 4: Comparison results of horizontal displacements

4. Conclusions

This paper proposes a simplified equivalent model for four-span suspension bridges. The model consists of towers and equivalent springs that replace the suspension cables. An example model with four spans is used for verification and the resultant values such as horizontal displacements of the towers are compared by using the proposed method and finite element analysis. As the results are in good agreement in all load cases, the equivalent suspension bridge model enables simplicity of design for tower sections, foundations and piles, splay saddles, and anchorages for a suspension bridge.

5. Acknowledgements

This work is a part of a research project supported by the Korea Ministry of Land, Transport and Maritime Affairs (MLTM) through Core Research Project 1 of Super Long Span Bridge R&D Center. The authors wish to express their gratitude for the financial support. 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).

6. References

[1] Gimsing N.J., *Cable supported bridges concept and design*, 2nd Ed., Wiley, New York, 1997.

[2] Wollmann G.P., "Preliminary analysis of suspension bridges", *Journal of Bridge Engineering, ASCE*, 2001, Vol. 6, No. 4, pp. 227-233.