Estimation of Inelastic Buckling Collapse Loads for Steel Cable-Stayed Bridges

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Summary

In this paper, a simple method for estimating the buckling collapse loads for steel cable-stayed bridges is proposed. An improved convergence criterion for iterative eigenvalue computations is suggested to consider the beam-column effect for girder and tower members of a cable-stayed bridge system. Then, the two example bridges representing medium and long-span models are analyzed in order to show the validity and applicability of the proposed method.

Keywords: Cable-stayed bridge; Collapse loads; Buckling; Inelastic buckling analysis.

1. Introduction

Cable-stayed bridges have been constructed frequently throughout the world because their structural system has shown itself to be an economical, efficient, aesthetically appealing, and durable solution for long span crossings. As the span length increases, the buckling instability of steel girder and tower members may be a fundamental problem. Nonlinear inelastic analysis based on the limit-point stability concept became common among many researchers for obtaining the buckling collapse loads of the bridges. However, this nonlinear inelastic approach obviously requires the preparation of adequate analysis tools and efficient computing machines as well as a wide range of understanding of the complex nonlinear theories.

This study proposes a simple alternative of complex nonlinear inelastic analysis for estimation of the buckling collapse loads for steel cable-stayed bridges. Based on the fundamental concept of the inelastic buckling analysis previously established by researchers, the range of application for the method is widened by suggesting a new criterion of beam-column members in the bridge system. Then, the two example bridges are analyzed in order to show the validity and applicability of the proposed method.

2. Proposed inelastic buckling analysis

In the inelastic buckling analysis, the criterion for a column member as Eq. (2) was applied to some cable-stayed bridge models by several researchers [1, 2].

$$E_t^i = \frac{P_{cr}^i}{\kappa^i P^0} E_t^{i-1} \quad (2)$$

where E_t is the tangent modulus, κ is the eigenvalue at the i-th iteration, and P_{cr} and P^0 are the inelastic critical load and the axial force of each member determined from a linear stress analysis, respectively. In this study, we proposed the improved criterion for consideration of the beam-column effect in each member as presented in Eq. (3).

$$E_t^i = \frac{P_{cr}^i M_{py} M_{pz}}{\kappa^i P^0 M_{py} M_{pz} + P_{cr}^i \kappa^i M_y^0 M_{pz} + P_{cr}^i M_{py} \kappa^i M_z^0} E_t^{i-1} \quad (3)$$

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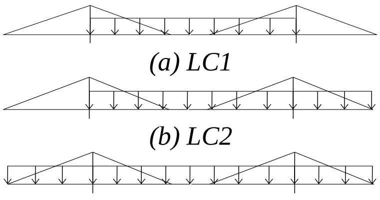
where M_p and M^0 are the full plastic moments and the moments calculated from a linear stress analysis, respectively. Then, the inelastic buckling analysis is performed with the basic equation similar to that of conventional elastic buckling analysis [1]. The converged eigenvalue indicates the inelastic critical load factor of the system and this factor may be accepted as the index of the collapse load of a cable-stayed bridge system.

3. Verification



(a) LC1

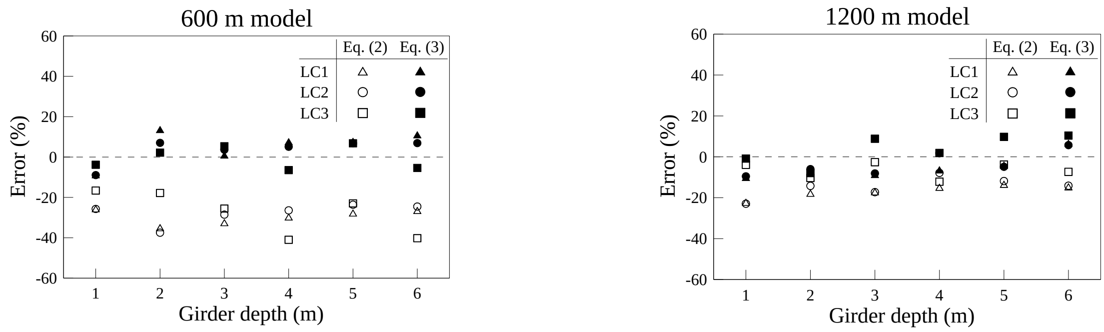
(b) LC2

(c) LC3

Fig. 2: Three live cases

The two different models with span lengths of 600m and 1,200m [1] were used to verify the proposed inelastic buckling analysis. In the models, dead loads (D) described in the reference [1] and design live loads (L) as the uniform lane load 76.2 kN/m on girder members are applied and three live load cases are considered as shown in Fig. 1. The service loads for analyses are calculated by the load combination of 1.2D+1.7L.

Figure 3 shows the errors of the critical load factor for the inelastic buckling analyses using both the column criterion (Eq. (2)) and the proposed criterion (Eq. (3)) for example models. The errors were calculated on the basis of the results of the nonlinear inelastic analysis. In the figure, the inelastic buckling analysis with Eq. (3) gives acceptable results comparing with the results by Eq. (2).



(a) 600 m-models *(b) 1200 m-model*

Fig. 3: Errors of critical load factor for inelastic buckling analyses

4. Conclusions

In this paper, a simple method for estimation of the buckling collapse loads for steel cable-stayed bridges is proposed. As the inelastic buckling analysis with the proposed criterion gives acceptable results, the proposed method for a beam-column is a good substitute for complex nonlinear inelastic analysis to approximately determine the buckling collapse loads of the bridge systems for all spans and girder depth ranges in preliminary design stages.

5. Acknowledgements

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6. References

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