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Ultimate Behavior and Strength of Long-Span Suspension Bridges

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Summary

This paper presents elasto-plastic finite displacement analysis of long span suspension bridges, in which inelastic behavior of main cables is taken into account. In this analysis, inelastic behavior of all the members such as girder, towers, main cables and hangers are taken into account simultaneously. A 3000-meter suspension bridge model is employed and the effect of the safety factor for the main cables on the elasto-plastic behavior of the bridge is studied.

1. Introduction

In recent years, various types of suspension bridges with main span of around 3000 meters have been studied by many researchers. The main aim of these researches is to develop economical systems that ensure the safety against flutter instability. However, static ultimate strength of long-span suspension bridges has not been made clear. In this paper, 3-D elasto-plastic large displacement analysis is carried out to investigate the ultimate strength of long-span suspension bridges. Especially, the effect of the safety factor for main cables on the ultimate behavior and strength is studied.

2. Bridge model and load case

In this study, a 3000-meter suspension bridge is dealt with. Fig.1 shows a side-view of the bridge and a front-view of the tower. Preliminary designed cross-sectional properties of the model are listed in Table 1. The area of the main cable and hangers are determined based on the criteria $\sigma_D + \sigma_L < \sigma_u/\gamma$, where σ_D, σ_L and σ_u are the stress caused by dead load, that by live load and ultimate stress, respectively. The safety factor γ of hanger is assumed to be 2.5. The safety factor of the main cable is taken as a parameter, and is varied from 1.8 to 2.0. On the other hand, we assume that the girder and the tower are made of elastic perfect-plastic material, and the cables are made of the material with bilinear constitutive relation. The yield point of the girder and the tower is 235 200KN/m^2 and 450 800KN/m^2, respectively. The yield point and ultimate stress of the main cable are 1.372×10^6KN/m^2 and 1.6464×10^6KN/m^2. Those of the hanger are 1.1662×10^6KN/m^2 and 1.421×10^6KN/m^2. In this study, the distributed load αw_G applied to the girder is considered. Where, α means the ratio of the vertical load to the dead load w_G of the girder. In the initial state, α is zero.

3. Results and discussions

Figs.2 to 5 show the horizontal displacement at the top of the tower, the bending moment at the bottom of the tower and bending moment at the girder where initial yielding in the cross-section occurred. It can been seen that, the displacement and the bending moment of the tower depends on the stiffness of the main cable. However, the behavior of the girder is nearly the same. When the stress of the hangers reaches the yield point, the deflection and the bending moment of the girder increase rapidly regardless of the safety factor. The load, which causes the initial yield in the hanger, is smaller than that in the main cable, even though the safety factor of the hanger is lager than that of the main cable. On the other hand, when the load coefficient reaches 1.95, the tension of partial hanger elements increased up to ultimate strength.

Table 1 Cross-sectional properties of the girder (Unit: m, m^2 or m^4)

Member	Cross-sectional area	In-plane moment of inertia of area	Out-of-plane moment of inertia of area	St. Venante torsion constant
Girder	1.4912	14.547	181.55	26.503
Tower	3.9360-8.2960	48.791-105.87	59.549-264.74	52.998-151.83
Main cable and Hanger	1.019-1.232 m^2/(one main cable), 0.01164 m^2/(one hanger)			

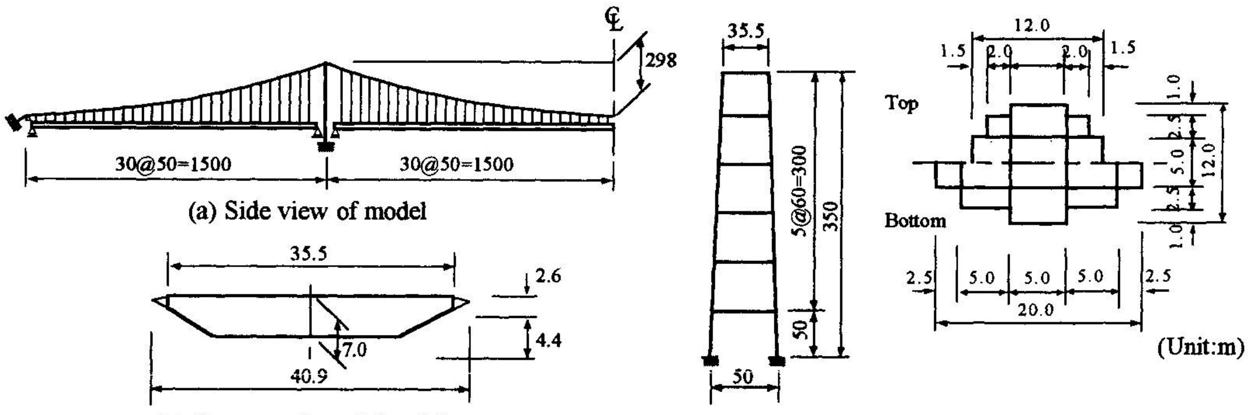

Fig. 1 Model of suspension bridge

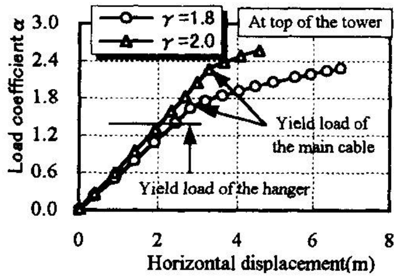

Fig. 2 Horizontal displacement of the tower

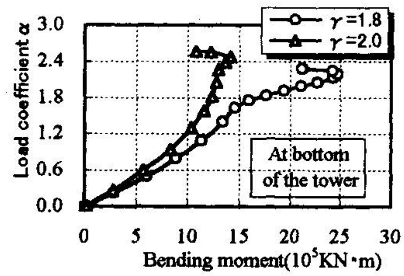

Fig. 3 Bending moment of the tower

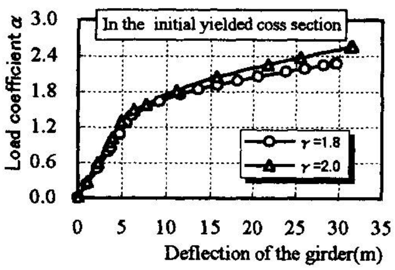

Fig. 4 Deflection of the girder

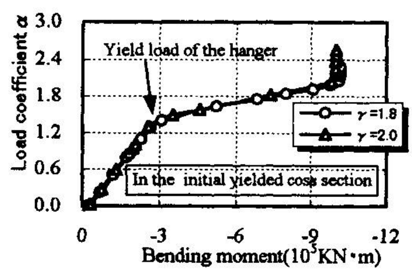

Fig. 5 Bending moment of the girder

4. Concluding remarks

In this paper, the effect of the safety factor for the main cable on ultimate behavior is investigated. The main results obtained from this study are summarized as follows.

1) The ultimate behavior of the tower depends on the factor of safety of the main cable. When the yield occurs in the main cable, the stiffness becomes to be flexible. However, the effect of the safety factor of the main cable is not remarkable for the ultimate behavior of the girder. The displacement and bending moment increase when the stress of the hanger comes into yield range.

2) In this case, even the factor of safety of the hanger is larger than that of main cables, but earlier yield phenomenon occurred in the hanger.

3) From this study, it can be seen that the effect of the main cable is important for analysis of the tower.