Structural Countermeasures for Design of a Very Long-Span Cable-Stayed Bridge under Wind Loads

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Abstract

The purpose of this study is to present adequate structural countermeasures for reduction of the stress resultant under design wind loads, which becomes dominant in the static design due to the decreased width-to-span ratio, and for improvement of the static and dynamic aerodynamic stability in the wind-resistant design. In this paper, by using the example of a trial-design bridge with a center span of 1,500 m which is considered the critical span length, the authors clarified the usefulness of the proposed countermeasures from the viewpoint of cost efficiency and wind-resistant stability, and confirmed the realizability of very long-span cable-stayed bridges in the near future.

The development of cable-stayed bridges has been rapid, and the class of bridges with a center span of 1,000m is planned for construction in the near future. The critical span length for cable-stayed bridges is reported to be about 1,500m, mainly because the in-plane buckling stability of main girders is degraded with increasing compressive axial-forces under dead and live loads. However, with decreasing width-to-span ratios of main girders due to the increased span length, it is predicted that the stress resultant under design wind loads becomes dominant in the static design and influences the cost effectiveness, and that ensuring safety against lateral-torsional buckling instability and coupled flutter under strong winds will become very important.

The aim of this study is to present adequate structural countermeasures for reduction of the stress resultant under design wind loads in the static design, and for improvement of the static and dynamic aerodynamic stability in the wind-resistant design. For the purpose, effects of elastic out-of-plane supports for main girders (as shown in *Fig.1*) and new auxiliary cable systems for controlling the flexibility of stay cables, named "lacing cable"(*Fig.2*), were investigated using a trial-design cable-stayed bridge with a center span of 1,500m (*Fig.3*) in this paper.

As part of the analytical results, *Figs. 4*, *5* and *Table 1* are illustrated. First, *Fig.4* shows out-of-plane bending moments of main girders under design wind loads. The results in *Fig.4* indicates that the application of elastic out-of-plane supports significantly reduced the bending moments of main girders near towers. Next, *Fig.5* shows the relationship of tortional displacements at the midpoint of main girders under static aerodynamic forces to the basic wind velocity U_{10}. The results in *Fig.5* indicates that the installation of lacing cables greatly decreased the tortional displacements of main girders, and increased the critical wind velocity against buckling instability. Furthermore, *Table 1* lists critical wind velocities against coupled flutter, including natural frequencies of major vibration modes. The results in *Table 1* indicates that the critical wind velocity became higher by controlling the flexibility of stay cables.

From the all analytical results, it was confirmed that the proposed structural countermeasures for design of very long-span cable-stayed bridges could increase the cost efficiency, and secure the static and dynamic aerodynamic stability.

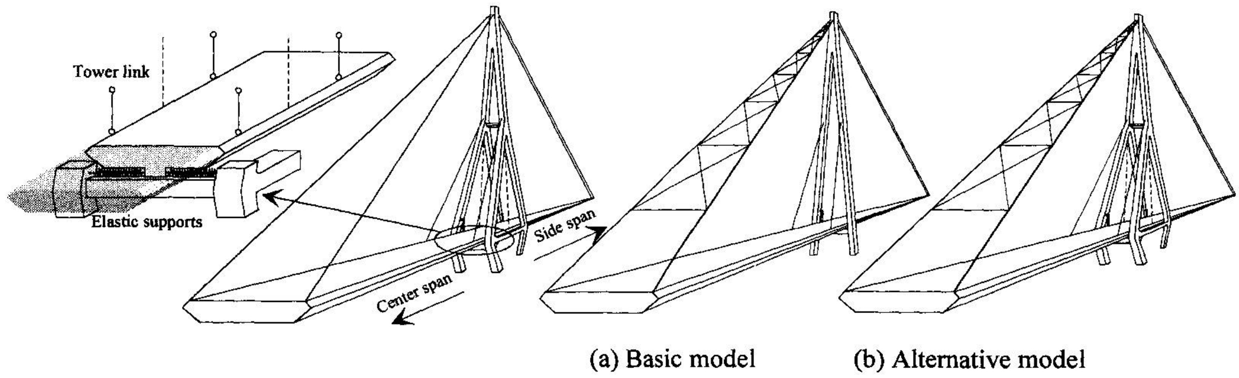

Fig.1 Concept of elastically supported girder *Fig.2 Image views of models with lacing cables*

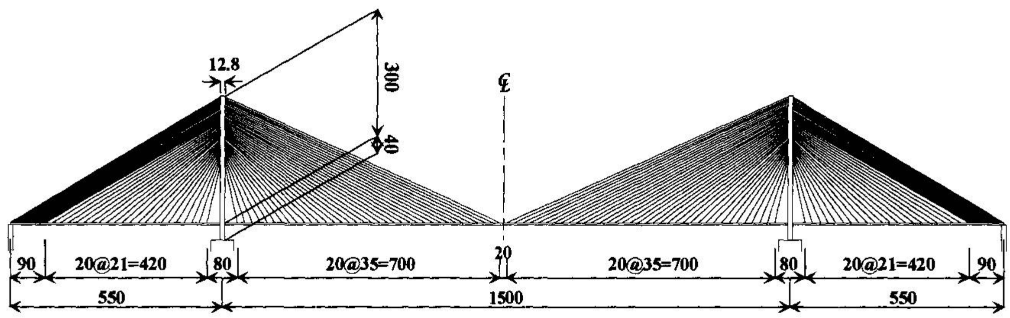

Fig.3 General diagram of the basic design model

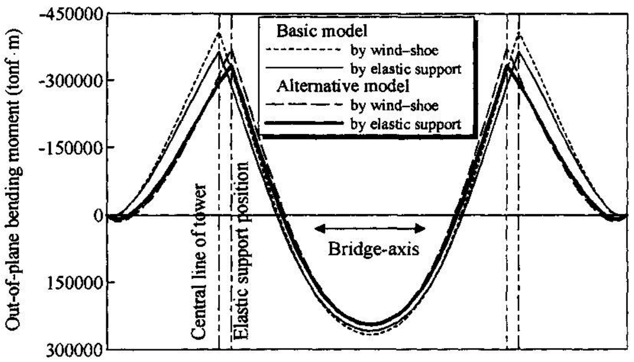

Fig.4 Out-of-plane bending moments of main girders

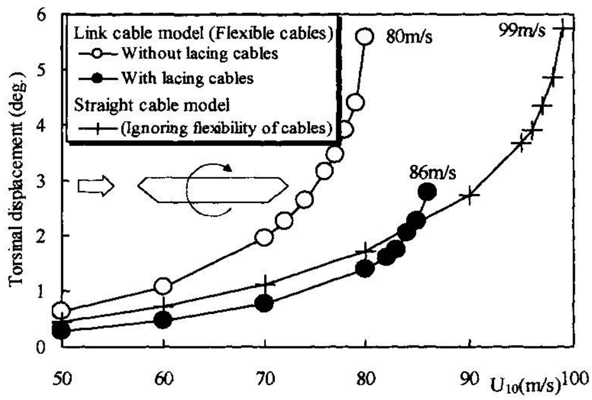

Fig.5 Torsional displacements at the midpoint of main girders

		Analytical model			
		Without lacing cables		With lacing cables	
		Basic model	Alternative model	Basic model	Alternative model
Freq. (Hz)	1-st symm. deflection mode	0.1040	0.1309	0.1034	0.1321
	1-st antisymm. deflection mode	0.1102	0.1511	0.1113	0.1522
	1-st symm. torsion mode	0.4886	0.4015	0.6321	0.5122
	1-st antisymm. torsion mode	0.8800	0.6058	0.9223	0.6702
Flutter critical wind velocity (m/s)		139.9	136.8	172.4	159.0

Table 1 Natural vibration frequencies and critical wind velocities against flutter