Ultimate Strength and Collapse Process of Cable-Stayed Arch Bridges

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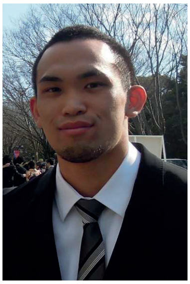

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Summary

A new type of cable-supported bridge, the cable-stayed arch bridge, is proposed. This new bridge is a combination of a cable-stayed bridge and an arch bridge, and the girder is supported by both stay cables and arch ribs. Its static behaviour, sectional forces and deflections, under the design load are compared with those of conventional cable-stayed bridges and arch bridges. Elastic-plastic large deformation analysis is then conducted to clarify the progressive collapse process and the ultimate strength. It is found that the cable-stayed arch bridge has smaller sectional forces and deformation under the design load and also has sufficient ultimate strength.

Keywords: Cable-stayed arch bridge, cable-stayed bridge, arch bridge

Main results of this study

The static behaviour of the cable-stayed arch bridge, sectional forces and deflections, under the design load are compared with those of conventional cable-stayed bridges and arch bridges. Girder compression of the cable-stayed arch bridge is about 40% of the cable-stayed bridge. Girder bending moment of the cable-stayed arch bridge is smaller than arch bridge and nearly equal to the equivalent for a cable-stayed bridge. Compression of the arch rib of the cable-stayed arch bridge is about 60% of the arch bridge. Bending moment of the arch rib of the cable-stayed arch bridge is also smaller than that of for the arch bridge. Axial forces and bending moments of the tower of the cable-stayed arch bridge are half of those of the cable-stayed bridge. Cable tension of the cable-stayed arch bridge nearly equal along the span except near the tower, and the maximum cable tension is about 50% of the one of a cable-stayed bridge. Displacement of the cable-stayed arch bridge is smaller than other bridges resulting in high bending stiffness. For the eccentric design live load the girder's torsional angle of the cable-stayed arch bridge is about 10% of the cable-stayed bridge. Girder torsional moment of the cable-stayed arch bridge is about 20% of the cable-stayed bridge's one. These superb torsional characteristics are due to the existence of the two arch ribs.

Elastic-plastic large deformation analysis is conducted to clarify the progressive collapse process and the ultimate strength. The cable-stayed arch bridge and the arch bridge collapse at an incremental live load factor k of 2.30 and 2.69, respectively, and no member is yielding until collapse. They collapse due to the global out-of-plane buckling of the arch ribs. In the cable-stayed bridge the compression yield part first appears in the upper part of the tower and finally collapse at k of 4.60 because of formation of a plastic hinge (Fig.6). The cable-stayed arch bridge is modified by inclining the arch planes 15 degrees from the vertical axis (Fig.7). This modification with the inclined arch planes can increase the ultimate factor k from 2.30 to 4.42 (Figs.8, 9, 10).

Although the total steel weight of the cable-stayed arch bridge is slightly larger than the cable-stayed bridge, the construction cost is nearly on the same level considering the material unit price. For the construction of this new bridge, the cantilever method or the cable crane method can be used. Therefore, the proposed cable-stayed arch bridge is feasible and can be economical in some cases.

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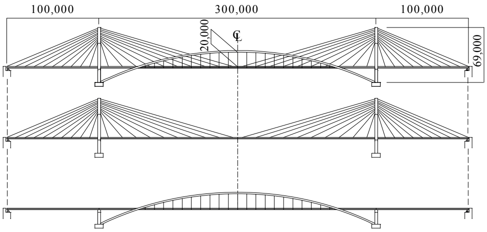

Fig.1 Side view of three bridges (unit: mm)

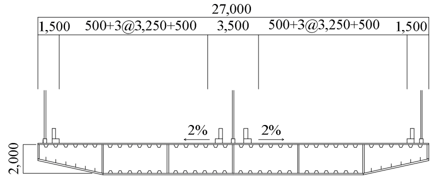

Fig.2 Cross section of girder (unit: mm)

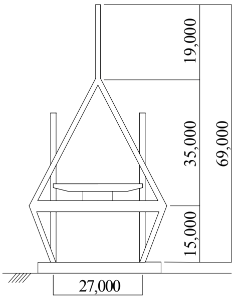

Fig.3 Tower (unit: mm)

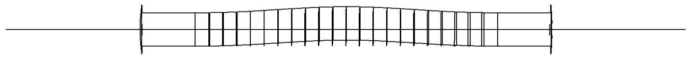

Fig.5 Top view of final deformation of cable-stayed arch bridge (k=2.30)

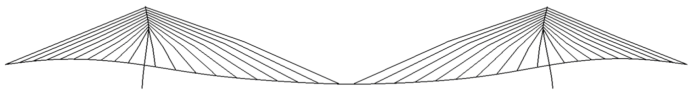

Fig.6 Side view of final deformation of cable-stayed bridge (k=4.60)

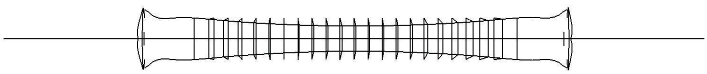

Fig.8 Top view of final deformation of improved cable-stayed arch bridge (k=4.42)

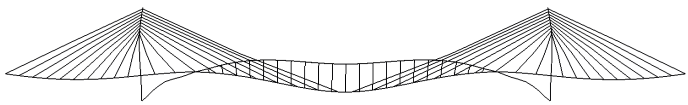

Fig.9 Side view of final deformation of improved cable-stayed arch bridge (k=4.42)

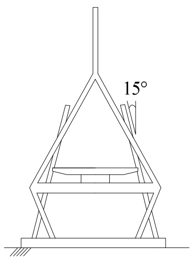

Fig.7 Arch ribs and tower

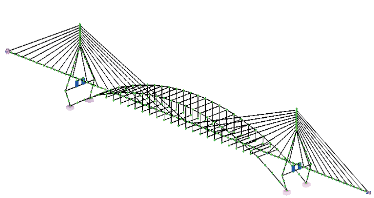

Fig.4 FEM model of cable-stayed arch bridge

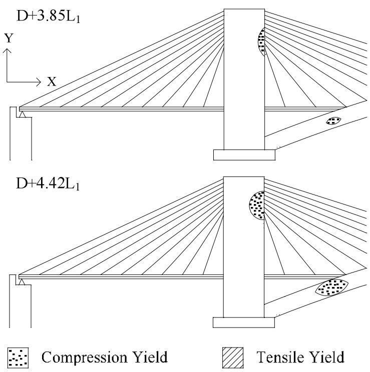

Fig.10 Collapse process of improved cable-stayed arch bridge