Ultra-long Span Bridge System using CFRP Cables

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Summary

Applying carbon fiber-reinforced plastic (CFRP) materials for earth anchored stay-cabled bridge (PEA bridge) has been proposed in this paper. It was shown that PEA bridge with lower tower which has less stiffness resulted in larger horizontal forces on the anchorage. The PEA bridge can avoid challenges of the application of CFRP to the main cable of the suspension bridge. The PEA bridge shows slightly higher vertical stiffness than the suspension bridge. The limit span of the PEA bridge was inferred the same as the suspension bridge.

Keywords: CFRP; PEA bridge; suspension bridge; limit span.

1. Concept of the earth anchored cable-stayed bridge using CFRP cables

The PEA bridge are composed of towers, main girders, inclined cables, anchorages, and balancing tendons in the main girders at mid-span(Figure 1). The bridge can be divided into two areas, the suspension area and the cable-stayed area. In the suspension area, the main girder bears no axial forces from the inclined cables. Instead, the horizontal components of the inclined cables are transmitted by the balancing tendons, finally to the anchorage through the towers.

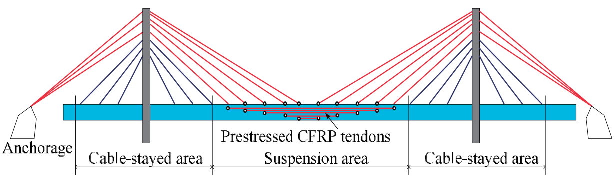

Fig. 1: Components of the PEA bridge.

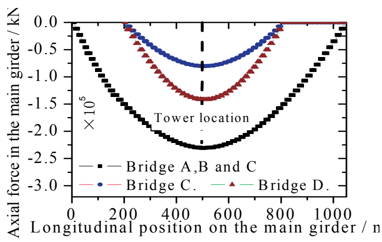

Fig. 2: Axial forces in main girders

2. Compare of PEA bridges with cable-stayed bridges and suspension bridge

The four bridge models used in this study are with the same main span (1088m). Cables in Bridge A are made of steel strands, and has a ratio of tower height to main span is 0,22. Bridge B replaces cable of bridge A to CFRP follow the principle of strength equivalence. Both bridge C and D are PEA bridges with CFRP cables, but the tower heights are different. The tower height of Bridge D is lower than that in bridge C in which the tower height to main span is only 0,12. The axial force in the main girder of the bridge C (PEA bridge with original tower height) is 1/3 of the original bridge A (Figure 2). Lowering tower height with 0,12 (bridge D) of the main span leads to the axial forces decrease to 0,6 of the original bridge A (Figure 2). The horizontal force on the anchorage increases as the height of tower decreases.

The deflections of the main girders in bridges A to D due to traffic loads are 1,459m, 2,406m, 1,830m and 2,701m respectively. The traffic load was represented by a uniform distributed load $q = 45$ kN/m and a concentrated load $P = 1015$ kN. The deflections in the bridges are mainly dependent on cable materials and tower height. Lowering the height of towers leads to dramatic increases of bridge deflections.

The maximum shear stress in suspension bridge using CFRP cables is 14,2 MPa. In contrast, the FEA bridge reduces the shear stress almost to zero ($2,8\times10^{-4}$ MPa). In addition, the normal bending stress in the FRP material of the PEA bridge is 2,2 MPa, compared at 313,7 MPa in the suspension bridge. The anchorage force in the PEA bridge is about 75% of that of the suspension bridge.

The maximum deflection of the PEA bridge and the suspension bridge under traffic load are 2,70m and and 2,83m respectively. The PEA bridge is stiffer than the suspension bridge. It can be proven that the stress in the inclined cable decreases as the length of the balancing cable increases. Thus it can be inferred that the limit span of the PEA bridge is the same as the suspension bridge.

3. Conclusions

Compared with the cable-stayed bridge, the PEA bridge with half span installed with balancing tendons can reduce 2/3 of the axial force in the main girder. The anchorage forces of PEA bridge is smaller than that in the suspension bridges. The vertical stiffness of the PEA bridges decreases dramatically as the height of tower decreases. The vertical stiffness of the PEA bridge is slightly higher than the suspension bridges with the same sag to span ratio. The shear stress and normal stress due to the bending moment in the main cable in the suspension bridges are much larger than in the PEA bridges. The limit span of PEA bridge is the same as the suspension bridge if the static capacity of the bridge is considered.

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