Static and seismic analysis of multi-span cable-stayed bridges with steel and CFT towers

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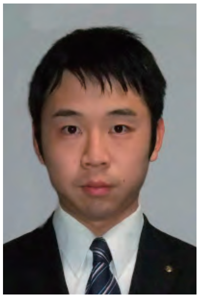

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Summary

The multi-span cable-stayed bridge is a new and attractive structure. The tower plays an important role to improve the seismic resistance. Two types of towers were studied in this paper: the steel tower and the concrete filled steel tower (CFT tower) which consists of a steel double box section filled with concrete. First, static analysis was conducted to clarify how different pattern of live load distributions affect the multi-span cable-stayed bridge. Second, seismic analysis was conducted with two different towers due to the ultra-strong earthquake. Three longitudinal support conditions of the girder at the tower positions were considered: movable supports, linear spring supports and bi-linear spring supports.

Keywords: Multi-span cable-stayed bridge, steel tower, CFT tower, seismic analysis

1. Static Analysis

Fig.1 shows the bridge model with 7 towers and 8 spans (100+6@200+100m). The girder is a steel box girder with orthotropic deck with a width of 18.8m and a web height of 2.2 m. The steel tower has a box section and the CFT tower has a double steel box section and concrete is poured inside the double steel walls. The tower has an H-shape with two cable planes. Static analysis was carried out for the dead load (D) and the design live loads (L), and sectional forces and deformations were obtained. Two live load cases were considered: L1 is the live load distributed in full spans and L2 is that distributed in the alternate spans. Fig.2 shows the deformation of the bridge model with two types of towers due to D+L2. The maximum longitudinal tower displacement and the vertical girder displacement of the steel tower are slightly larger than those of the CFT girder. On the other hand, the bending moment of the CFT tower is larger than that of the steel tower. The displacements and bending moments due to D+L2 is much larger than those due to D+L1.

2. Seismic Analysis

Seismic analysis was conducted for the ultra-strong earthquake wave, Level-2 earthquake (L2-EQ). Three support conditions of the girder on the cross beams of the tower are compared, as shown in Table 1: longitudinally movable (MOV), connected by linear springs (LS) and connected by bi-linear springs (BLS). The shear elastic modulus of LS, K1, is decided by the size of the elastic rubber bearing. The bi-linear spring follows the elastic modulus, reaches the yield displacement δy and then follows second modulus K2. This bi-linear hysteretic property produces energy absorption effect. The K1 and K2 are also decided by the sizes of energy dissipating type bearings such as Lead Rubber Bearings, High Damping Rubber Bearings and so on.

Fig.3 shows the longitudinal displacements at the top of P4 steel tower. The displacement is largest with the movable support condition (MOV), and smallest with bi-linear springs (BLS). The bending moment at the tower base with BLS is much smaller than other two support conditions. The maximum displacements and bending moments of the steel tower are also the smallest with BLS and the largest with MOV. There is not much difference between the steel tower and the CFT tower.

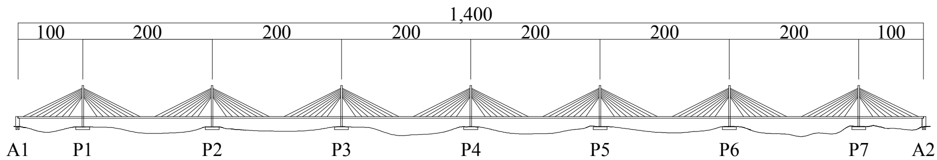


Fig.1: Side view (m)

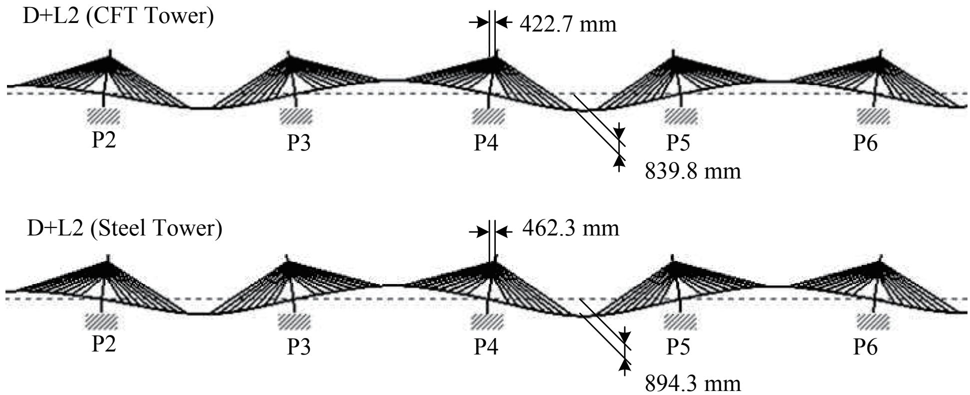
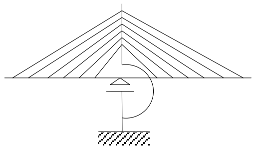
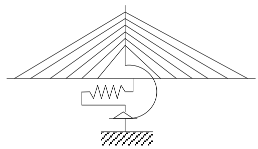
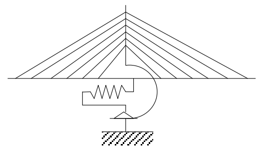
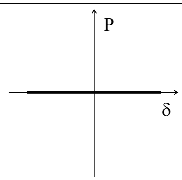
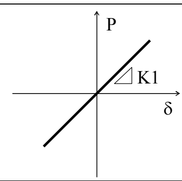
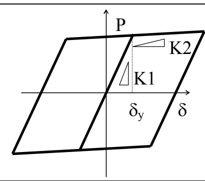


Fig.2: Deformation of towers and girder due to D+L2 (2000%)

Table 1: Girder and tower connection models

		Movable (MOV)	Linear Spring (LS)	Bi-Linear Spring (BLS)
Spring Model				
P-δ				
Spring Constant	K1	–	11,000 kN/m	33,000 kN/m
	K2	–	–	4,950 kN/m

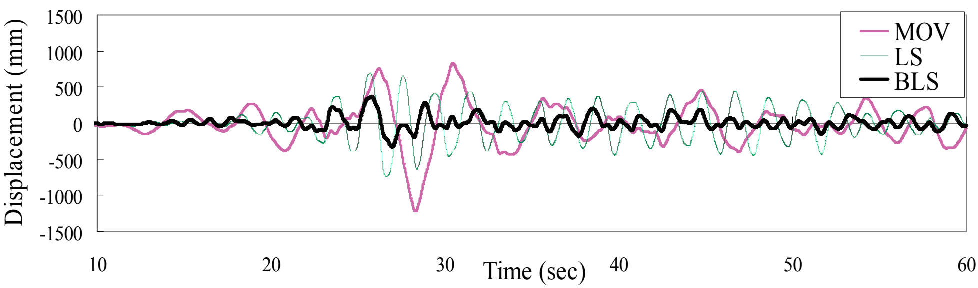


Fig.3: Displacement at the top of P4 towers (CFT tower, L2-Earthquake Type I)