Cable supported bridge under movement of foundation due to earthquake

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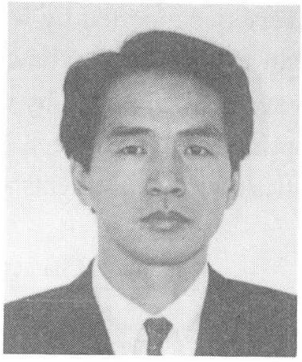

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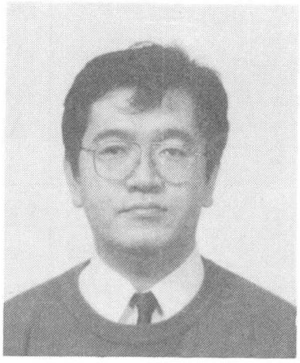

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Summary

The experience of the Akashi Kaikyo Bridge hit by the earthquake indicates that a suspension bridge is such bridge as not seriously effected by movement of foundation as compared with a cable stayed bridge. If the bridge was cable stayed bridge, much more damages would be observed. This paper describes the magnitude of stress of suspension bridge and cable stayed bridge having the same span length caused by movement of foundation due to earthquake.

1. Introduction

After the earthquake hit Kobe area including the Akashi kaikyo Bridge located very near the epicenter, where the compacting work was under way, some small damages by the shock were observed on the temporary work, but no serious influence was found on the permanent structure of the Akashi kaikyo Bridge.

This was because the earthquake had happened before the suspended truss was constructed, the magnitude of the movements were relatively small as compared with the span length and fortunately the Akashi Kaikyo Bridge was suspension bridge (not complex structure).It is easily imagined that some part of permanent structure would be damaged or overstressed if the earthquake happened after the completion and furthermore if the span length was not so long, and that another behavior of structure would be observed if the bridge was cable stayed bridge.

In this circumference, we have computed the behavior of suspension bridge and cable stayed bridge after the completion under the similar scale of movements of the foundations. The bridges for computation are suspension bridge with a main span of 1,000m having un-continuous suspended girder vertically supported by links and transversely supported by wind shoes at the towers and the anchorages, and cable stayed bridge with a main span of 1,000m having continuous suspended girder vertically supported by bearings and links, transversely supported by wind shoes at the towers and the anchorages, and longitudinally supported by spring from the towers. The general arrangements of the bridges are shown in Fig 1. and the characteristics of bridge elements are shown in Table 1.

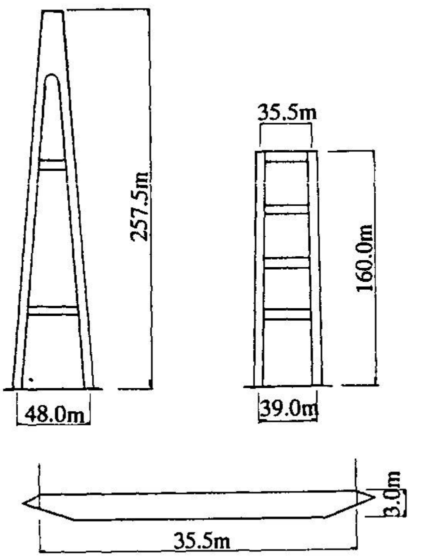


Table 1. Characteristics of bridge elements

	Suspension bridge	
Girder	A=1.378 m2	
	Iz= 2.43 m4	Iy=162.24 m4
Tower	A=2.362 m2	
	Iz= 21.97 m4	Iy=12.18 m4
Cable	A=0.195 m2	
	Cable stayed bridge	
Girder	A=1.567 m2	
	Iz=2.58 m4	Iy=172.76 m4
Tower	A=2.362 m2	
	Iz= 21.97 m4	Iy=12.18 m4
Cable	A=0.009~0.015 m2	

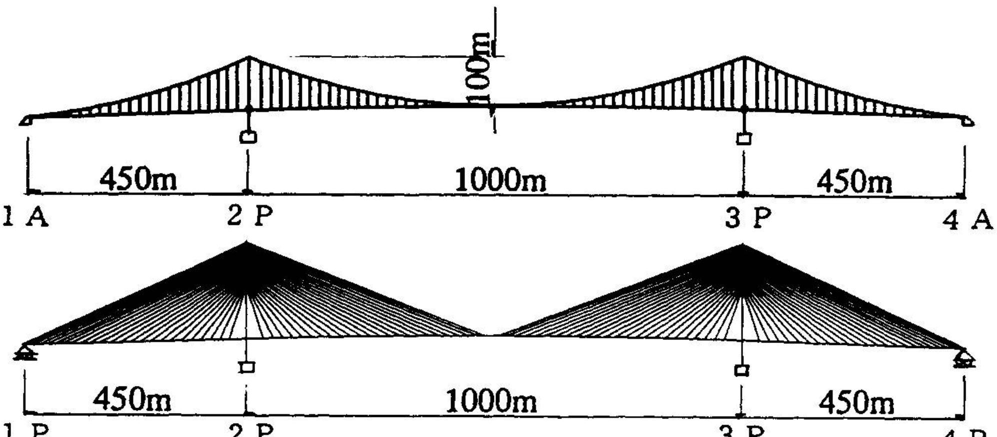
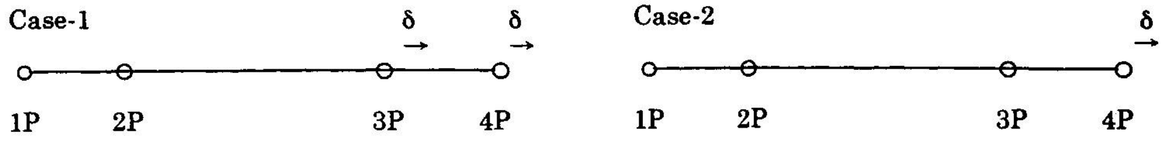


Fig 1 General arrangement

2. Longitudinal Movement

We assumed two cases. One is a tower foundation and an anchorage (or a pier) in the same side move longitudinally outward by the same distance (main span extension), which simulates that fault located in the main span slides, and the other is only an anchorage (or a pier) moves longitudinally outward (side span extension), which simulates that fault located in the side span slides, as shown in Fig 2.



Main span extension

Side span extension

Fig 2. Longitudinal movement

2.1 Main Span Extension

Fig 3. shows the deformation of two bridges for the main span extension of 1.0m, and Fig 4. & 5 show the extra stresses occur in the tower and in the cable of the two bridges by the main span extension ranging from 0.5m to 1.0m . Suspension bridge is able to absorb a extension of main span easily by a change of cable sag (1.4m for extension of 1.0m), which doesn't make tower top displacement much (0.09m each) to balance cable forces of main span and side span at tower top and increase a stress of main cable (13Mpa). By this behavior, suspension bridge is not much overstressed by main span extension. While, cable stayed bridge absorbs a extension of main span by displacement of tower tops (0.52m each for extension 1.0m) inward pulled straight by stay cables. By this behavior, cable stayed bridge is much stressed by main span extension, and the extra stress occurs at the tower base comes up to17% of its allowable stress by a extension of 1.0m.

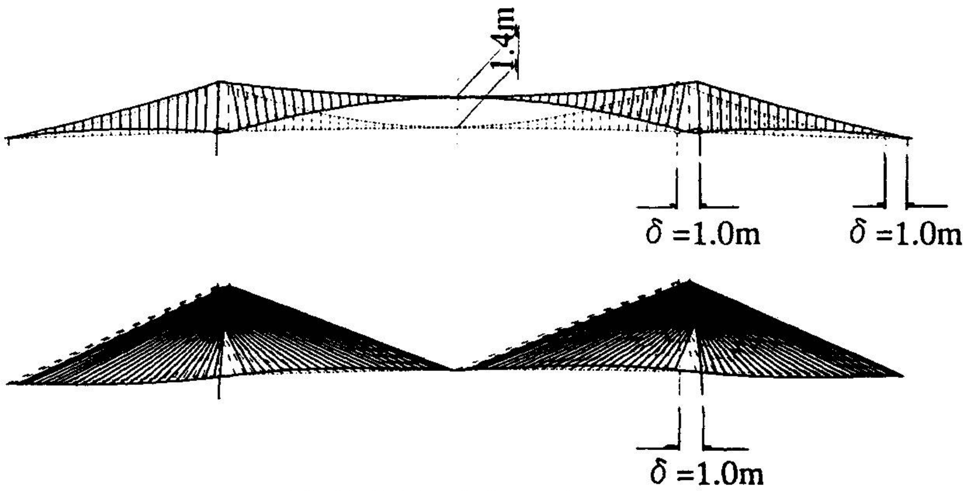


Fig 3. Bridge deformation

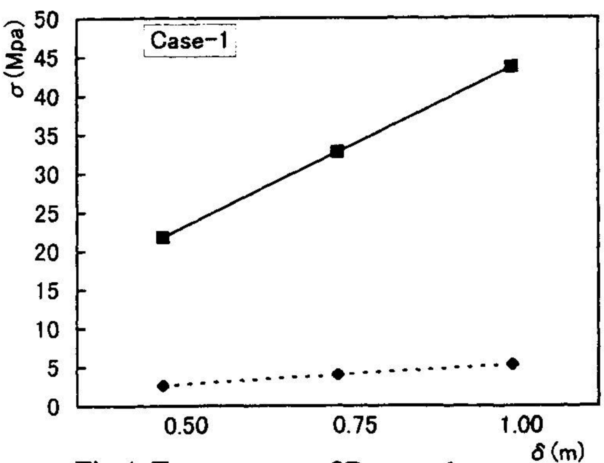


Fig 4. Extra stress at 3P tower base

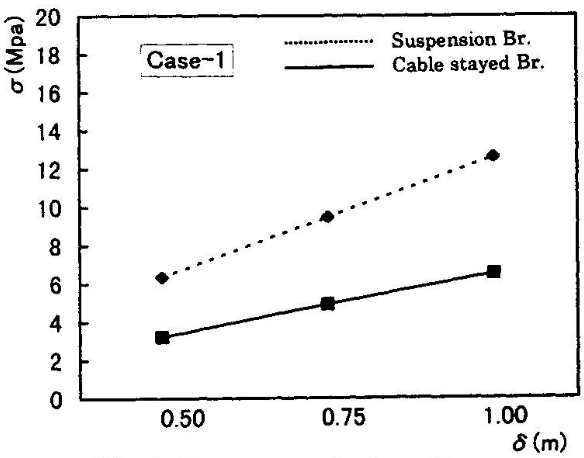


Fig 5. .Extra stress in the cable

2.2 Side Span Extension

Fig 6. and 7. show the extra stresses occur in the tower and in the cable of the suspension bridge by the side span extension ranging from 0.5m to 1.0m. Suspension bridge is much effected by a extension of side span. The tower top moves by nearly the same scale as that of the movement of anchorage (0.86m for extension of 1.0m), which doesn't produce much extra stress in main cable (16Mpa), but produces, depend on the stiffness of tower, some stress at the tower base. Cable stayed bridge is not effected by a extension of side span, because a damage of bearing at the end pier absorbs most of such extension.

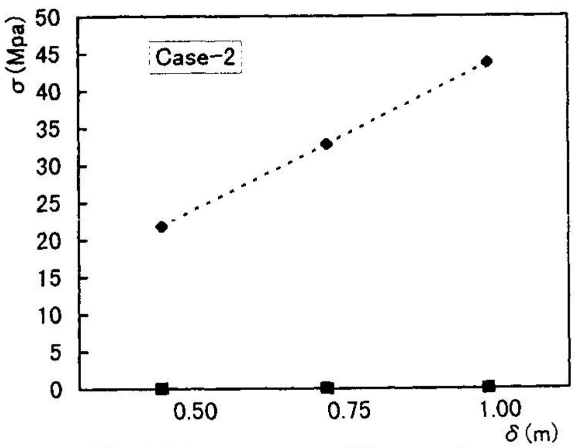


Fig 6. Extra stress at 3P tower base

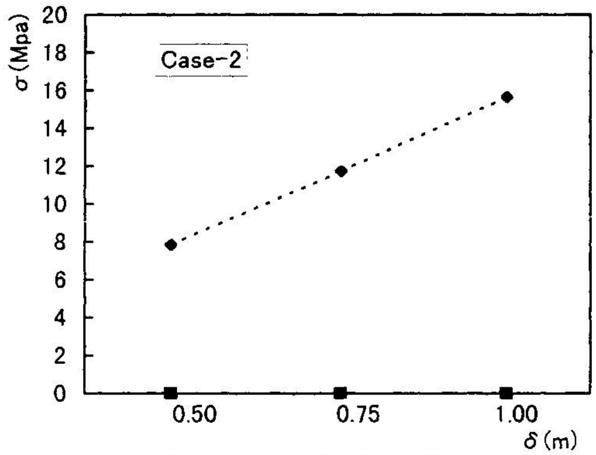


Fig 7. Extra stress in the cable

3. Transverse Movement

We assumed two cases. One is a tower foundation and an anchorage (or a pier) in the same side move transversely by the same distance (transverse shift in main span), which simulates that fault located in the main span slides, and the other is only an anchorage (or a pier) moves transversely (transverse shift in side span), which simulates that fault located in the side span slides, as shown in Fig 8.

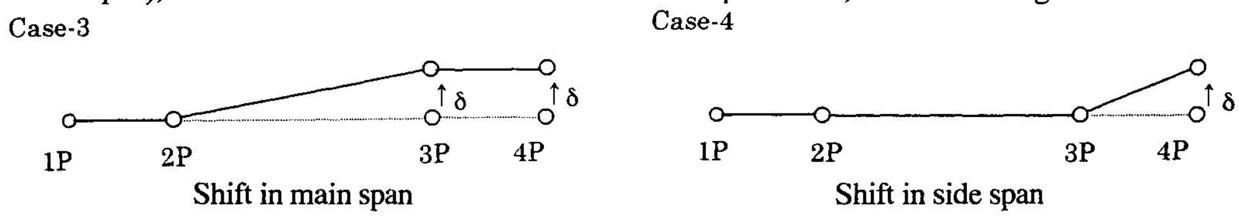


Fig 8. Transverse movement

3.1 Transverse Shift in Main Span

Fig 9. and 10. show the extra stresses occur in the suspended girder and in the tower of the two bridges for the transverse shift in main span ranging from 0.5m to 1.0m. The governing factor to produce the extra stresses in the suspended girder is a continuity of the suspended girder. Suspension bridge with un-continueus girder, which is normally applied to Japanese suspension bridges, is not effected by transverse movement of foundation. The tower tops of suspension bridge move transversely much (0.39m each for shift of 1.0m) because a big force is applied at the tower top by the main cable. While, cable stayed bridge, for which continuous girder is necessarily applied, is much effected by transverse movement of foundation, and the extra stress occurs in the suspended girder at the tower comes up to 6% of its allowable stress. The tower tops of cable stayed bridge moves transversely, but not much (0.27m for shift of 1.0m).

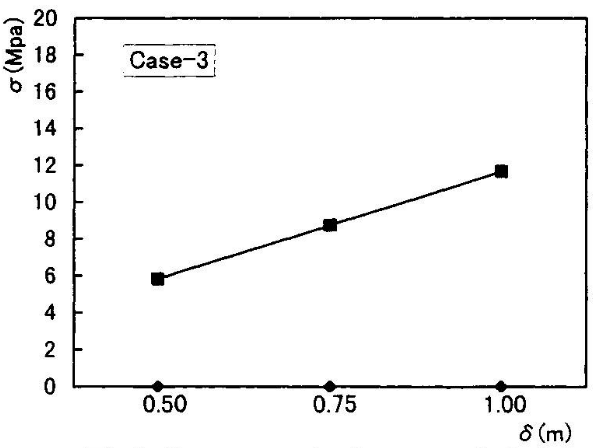


Fig 9. Extra stress in the suspended girder

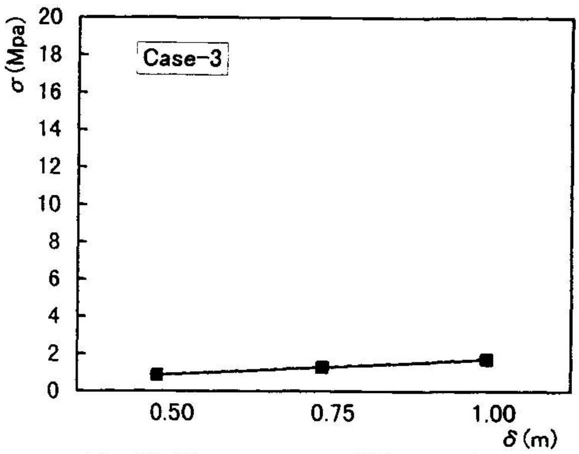


Fig 10. Extra stress at 3P tower base

3.2 Transverse Shift in Side Span

Fig 11 and 12. show the extra stresses occur in the suspended girder and in the tower of the two bridges for the transverse shift in side span ranging from 0.5m to 1.0m. Cable stayed bridge is much more stressed by the transverse shift in side span than by the transverse shift in main span. The extra stress occurs in the suspended girder at the tower is 10% of its allowable stress. The top of 3P tower moves transversely by 0.54m, but doesn't produce much extra stresses at the tower base because A-shape tower change the in-plane bending moment due to the tower top displacement to the axial forces in the tower section. Suspension bridge with un-continuous girder is not effected by transverse movement of foundation.

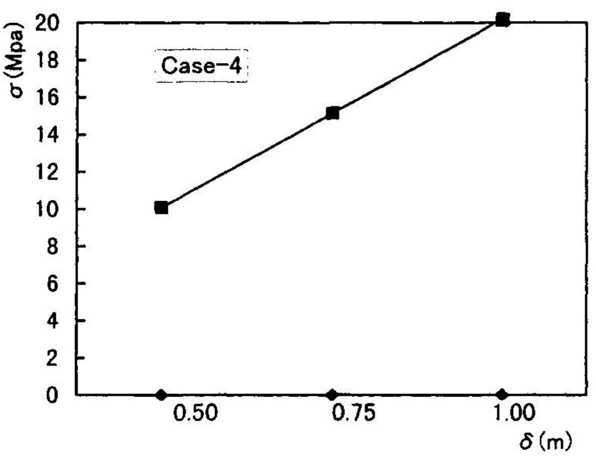


Fig 11. Extra stress in the suspended girder

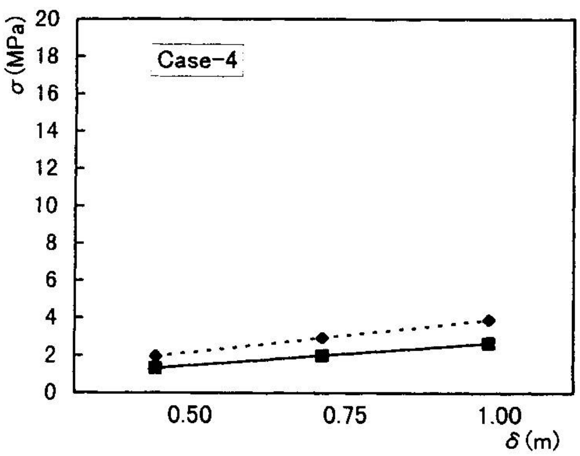


Fig 12. Extra stress at 3P tower base

4. Concluding Remarks

From the above case studies, the followings are obtained for selection of bridge type to be constructed in a seismic area.

- Suspension bridge is preferred bridge type if bridge is constructed in a seismic area, in particular near faults, and shall be constructed so that the fault is located in the main span. Un-continuous girder is to be applied not to be effected much by transverse shift.
- Cable stayed bridge requires necessarily continuous girder, which is effected much by transverse shift, and is overstressed at the tower base when the tower foundation is moved longitudinally.

It is also founded that a increase of span length doesn't reduce the extra stress of suspension bridge much. The extra stress occurs at the tower base of the suspension bridge of 900-2000-900 for the side span extension of 1.0m is 41 Mpa for 44Mpa of the suspension bridge of 450-1000-450.

Reference

K. Tada and others, "Effect of the Southern Hyogo Earthquake on the Akashi-Kaikyo Bridge", Structural Engineering International, January 1995