Analytical Study on the Seismic Response of a Langer Arch Bridge during the Nankai Trough Earthquakes

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1. INTRODUCTION

In Japan, it was estimated that the probability of a magnitude 8 or 9 earthquake occurring in the Nankai Trough is 70 to 80 percent within 30 years[1]. Therefore, it is important to verify the safety of the structures by conducting the dynamic analyses using Nankai Trough earthquakes simulated ground motions. However, limited studies have been performed focusing on the seismic response of arch bridges subjected to the Nankai Trough earthquakes. For this reason, the dynamic analyses of a Langer arch bridge using the Nankai Trough earthquake ground motions and the design ground motions indicated in Japanese seismic design specifications[2] were carried out in this study. Based on the analytical results, the characteristic of the seismic response of the arch bridge is investigated.

2. ANALYTICAL MODEL AND CONDITIONS

2.1 Analytical model

In this study, SeanFEM[3] is used to conduct the dynamic analyses. A steel Langer arch bridges was selected as the target of the dynamic analyses. The overall view of the bridge is illustrated in Fig.1. For the analytical model, steel members of the superstructures were modeled by fiber element and the bearing model was set as linear spring. Fig.2 shows the cross section of the arch rib, which is divided into 10 pieces in width and 2 pieces in thickness. For the material properties of the steel, linear stress-strain relationship was adopted, as shown in Fig.3. Details of the boundary conditions are shown in Table 1.

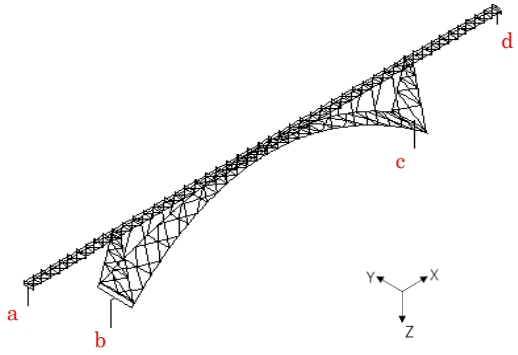

Fig.1 General view of analytical model

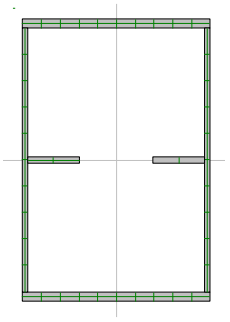

Fig.2 Cross section

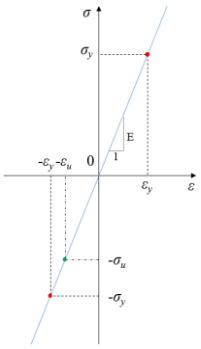

Fig.3 Steel material properties

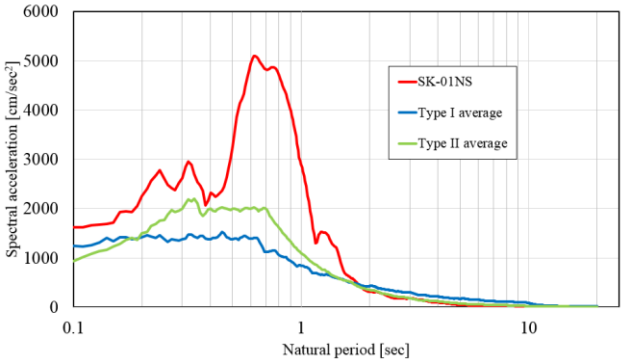

Fig.4 Acceleration response spectra

Table 1 Boundary condition of analytical model

Support	Longitudinal	Transverse	Vertical
a	Fixed	Fixed	Fixed
b	Fixed	Fixed	Fixed
c	Fixed	Fixed	Fixed
d	Fixed	Fixed	Fixed

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2.2 Earthquake ground motions

Two types of ground motions are input as the disturbance for the analyses in longitudinal and transverse direction. One of the ground motions is the design ground motions indicated in Japanese seismic design specifications for highway bridges[2], including three earthquake ground motions of Type I and Type II (Ground type I), respectively. The other is the simulated earthquake ground motions of the Nankai Trough earthquakes[1] at Shikoku area.

2.3 Real eigenvalue analyses

The results of real eigenvalue analyses characterize the basic dynamic behavior of the steel arch bridge and indicate how it will response to dynamic loading. In the longitudinal direction, mode shape 13th and 1st are characteristic while in the transverse direction, mode shape 2nd and 8th are characteristic vibration mode. Details of the vibration modes during the analysis are shown in Table 2.

3. ANALYTICAL RESULTS

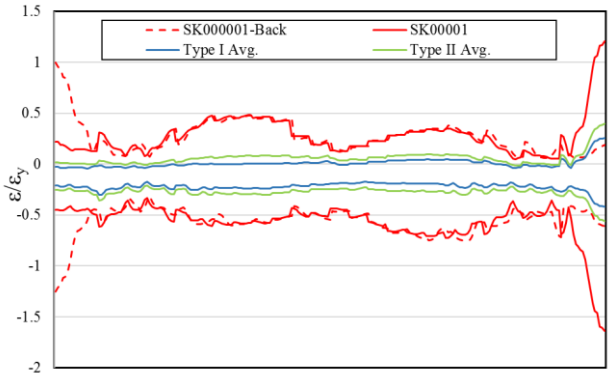
To investigate the effect of earthquake on the target bridge, results of the strain response are shown in Fig.5, whose vertical axis indicates the maximum strain of each element divided by the yielding strain ε_y. Fig.5(a) and Fig.5(b) represent the strain responses when earthquake ground motions were input in longitudinal direction and transverse direction, respectively.

In the longitudinal direction, as shown in Fig.5(a), the red lines indicate the strain responses of two arch ribs under the effect of the simulated ground motion. The maximum strain along two arch rib are symmetric to each other and it has the highest value when near the supports, which is almost the same as the value of the yielding strain.

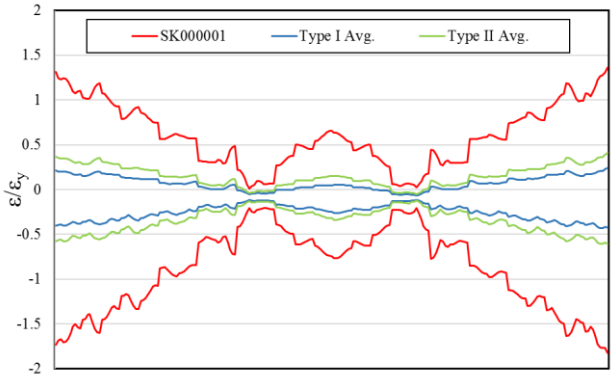
In the transverse direction, there is no difference between the maximum strain values of two arch ribs. Moreover, in both tensile and compressive parts, the values of the maximum strain of the simulated ground motion are around 1.5 times to the yielding strain when it close to the supports.

Table 2 Details of the dominant vibration mode

Direction	Mode	Frequency f (1/s)	Period T (s)	Participation factor	Damping ratio
x	1	1.202	0.832	23.15	0.01498
	13	4.116	0.243	23.75	0.01945
y	2	1.271	0.787	30.51	0.02138
	8	2.682	0.323	-20.56	0.02198



(a) Strain response in longitudinal direction



(b) Strain response in transverse direction

Fig.5 Strain response along the bridge

4. CONCLUSIONS

Dynamic response analyses of the Langer arch bridge are carried out in this study. Results show that when the measured points are close to the supports, the maximum strain values are larger than the other parts along the arch rib. To further investigate the reasons of current results, more earthquake ground motions will be employed and the comparisons will be carried out.

REFERENCES

1) Earthquake Research Committee, Evaluation of earthquakes along the Nankai Trough, 2013.
2) Japan Road Association, Specifications for Highway Bridges: Part V Seismic Design, 2019
3) Seismic Analysis Research Center, SeanFEM (ver.1.2.3), 2005.