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

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1. INTRODUCTION

Recently, it has been reported that the probability of the M8-9 earthquakes' occurrence in Japan is 70% within the next 30 years[1]. Therefore, it is necessary to conduct the analytical study of the massive earthquakes such as the Nankai Trough earthquakes. 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 an 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

The seismic analytical software SeanFEM[3] is used in this study. One of the steel arch bridges was adopted in this study, as shown 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. The boundary conditions are shown in Table 1.

2.2 Earthquake ground motions

Two types of ground motions are used in the analyses. The first one is the design ground motions indicated in Japanese seismic design specifications, including three

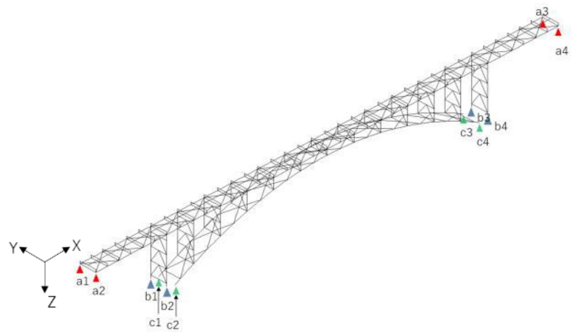

Fig.1 General view of analytical model

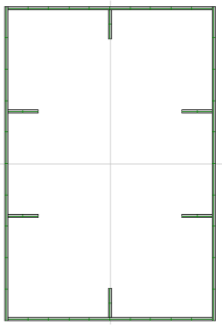

Fig.2 Cross section

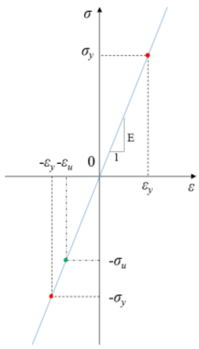

Fig.3 Steel material properties

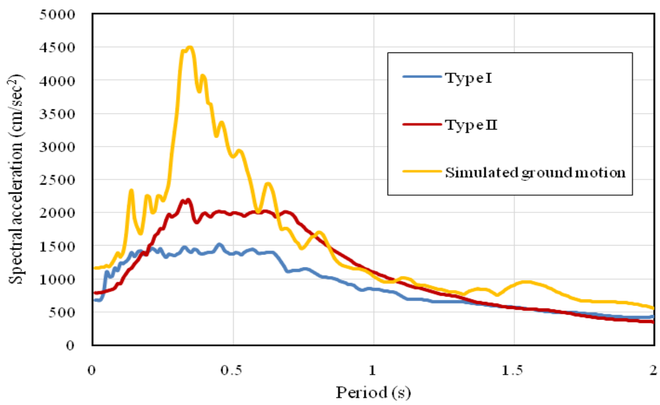

Fig.4 Acceleration response spectra

Table 1 Boundary condition of analytical model

Support	Longitudinal	Transverse	Vertical
a1, a2, a3, a4	Free	Pinned	Pinned
b1, b2, b3, b4	Fixed	Pinned	Fixed
c1, c2, c3, c4	Pinned	Pinned	Pinned

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earthquake ground motions of Type I and Type II, respectively. Ground type I was employed for the analyses. The other is the ground motion simulated from the Nankai Trough earthquakes. Fig.4 shows the acceleration response spectra of each earthquake ground motion which were input in both longitudinal direction and transverse direction. During the analysis, the self-weight of the structure was applied firstly, and the result was set as initial stage to perform the dynamic response analysis. Rayleigh damping was applied for the dynamic analyses and the damping ratio is set as 0.02 for all steel members. Details of the dominant vibration mode during the analyses are shown in Table 2.

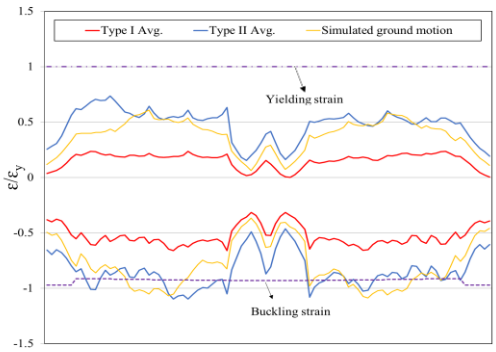
3. ANALYTICAL RESULTS

To investigate the effect of earthquake on the target bridge, results of the strain response compared with yielding strain and the buckling strain along the arch rib is shown in Fig.5. Fig.5(a) and Fig.5(b) represent the strain response when earthquake ground motions were input in longitudinal direction and transverse direction, respectively. The vertical axis indicates the maximum strain of each element divided by the yielding strain ε_y.

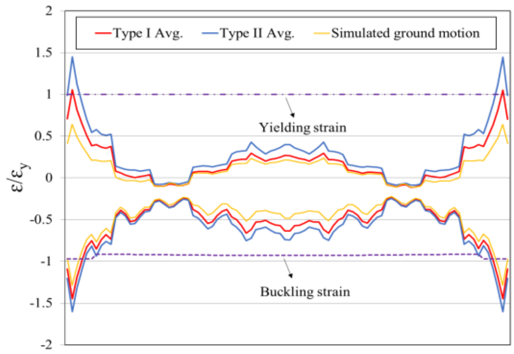
In the longitudinal direction, as shown in Fig.5(a), there is no significant difference among the shape of distributions of the maximum strain along the arch rib. The maximum strain of the design ground motion Type II has the highest value while the design ground motion Type I has the lowest value among three maximum strain results. Similar results were observed in the transverse direction; however, the maximum strain values of the simulated ground motion turn out to be the lowest values this time. For the maximum tensile strain at the locations close to the supports, the value of the design ground motion Type II is around three times larger than the simulated ground motion one. A further investigation of the reasons for current results will be examined in detail in the future.

4. CONCLUSIONS

Dynamic response analyses of the design ground motions and the simulated ground motion of the Nankai Trough earthquakes are carried out in this study. Results show that in both longitudinal direction and transverse direction, the distributions of the maximum strain along arch rib agree well with each other. For the current stage, only one simulated ground motion was used, thus more earthquake ground motions will be employed in the future and the comparison will be carried out.



(a) Strain response in longitudinal direction



(b) Strain response in transverse direction

Fig.5 Strain response along the bridge

Table 2 Details of the dominant vibration mode

Direction	Mode	Frequency f (1/s)	Period T (s)	Participation factor	Damping ratio
x	6	2.858	0.350	21.59	0.02103
	7	3.746	0.267	-26.94	0.02104
y	2	1.156	0.865	-34.83	0.02174
	8	4.022	0.249	-15.13	0.02427

REFERENCES

1) Earthquake Research Committee (2013), Evaluation of earthquakes along the Nankai Trough (2nd edition).

2) Japan Road Association (2012), Specifications for Highway Bridges: Part V Seismic Design.

3) Seismic Analysis Research Center (2005), SeanFEM (ver.1.2.3).