Numerical Analysis of a Curved Bridge Model

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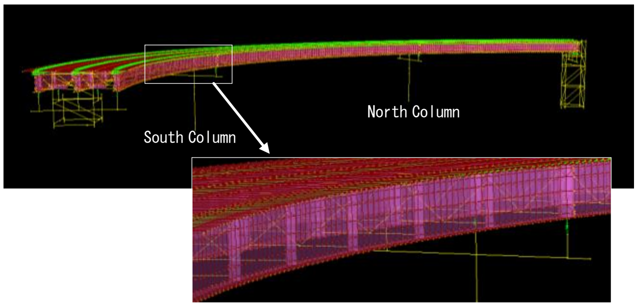
1. Introduction

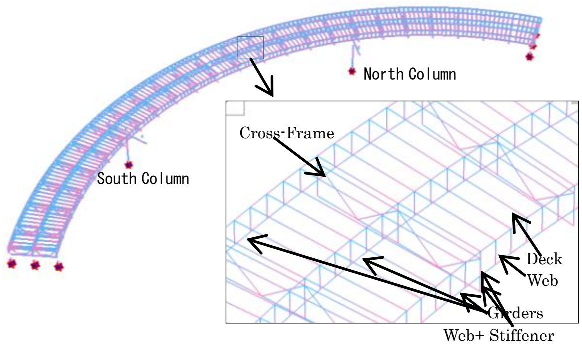
Since curved bridges have become prevalent in urban areas, their seismic behavior needs to be understood. A three-span, 0.4-scale curved bridge model was tested on the NEES Shake Table Array in the Large-Scale Structures Laboratory at University of Nevada, Reno, and seismic analysis using finite element (FE) method was conducted to validate the numerical model.

However, studies to develop modeling techniques to propose a model that can efficiently predict the seismic behavior are limited. This paper focuses on the modeling work, which used beam elements instead of shell elements for the superstructure to efficiently capture the bridge seismic behavior in the analysis.

Figure 1 Bridge Specimen



(a)



(b)

Figure 2 (a) FE model and (b) Simplified Beam model

2. Modeling of Bridge Specimen

The bridge model used in the analyses is shown in Figure 1 and the geometry of the bridge model is summarized in Table 1. This 0.4-scale bridge model has a steel plate I-girder superstructure, single-column reinforced concrete column substructure, and seat-type abutments. The superstructure is supported by pot bearings at the column locations and sliding bearings at the abutments.

Figure 2 shows two numerical models. In the FE model[1)], which was made in FE analysis software SAP2000, the superstructure is modeled as shell elements, the substructure is modeled as beam elements and fiber elements at the column plastic hinge zone. In the simplified beam model, which was made in analysis software UC-win/FRAME(3D), the superstructure is modeled as beam elements. Because the superstructure is not modeled in detail as compared to the FE model, this model reduces the computational time. In the simplified beam model, the girder beam elements are placed at the girder's center of gravity and are connected to the deck beam elements by link elements or rigid elements. But this modeling technique does not capture the web flexibility of the I-girders accurately. To take this into account, the connections are modeled with beam elements that have the properties of the web of the girder.

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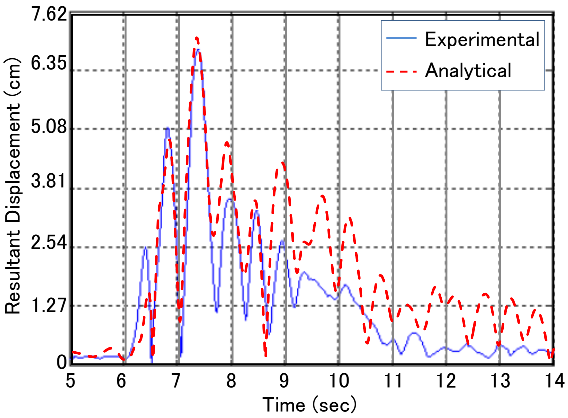
Table 1 Summary of Bridge Model Geometry

	Prototype	Model
Total Length	110.5	44.2
Span Length	32-46.5-32	12.8-18.6-12.8
Centerline Radius	61	24.4
Total Width	9.15	3.66
Girder Spacing	3.4	1.37
Column Height	6.1	2.44
Column Diameter	1.52	0.61

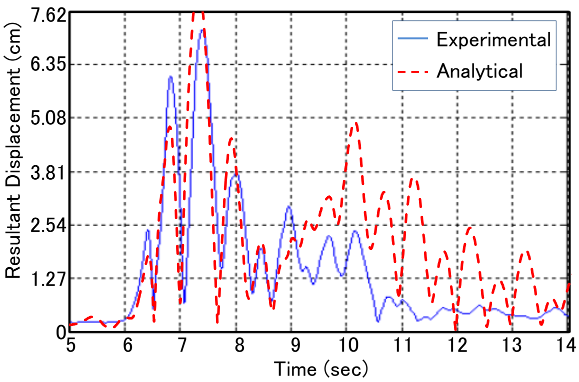
(unit: m)

Table 2 Comparison of Modal Periods

Mode No.	Direction	Period Sec		FE Model/Beam Model
		FE Model	Beam Model	
1	Lateral	0.634	0.661	0.96
2		0.486	0.503	0.97
3	Longitudinal	0.426	0.412	1.03
4	Vertical	0.325	0.386	0.84



(a)



(b)

Figure 3 Comparison of Analytical and Experimental (a) North and (b) South Column Resultant Displacement Histories under 100%DE

3. Numerical Model Validation

To determine how well the simplified beam model captures the dynamic properties of the curved bridge, modal analyses were performed using both models. The modal periods of the four modes of each model are shown in Table 2. The simplified beam model agrees well with the FE model in estimating the first three modal periods with a slight difference for the fourth modal period. These results suggest that the dynamic response provided using the simplified beam model is comparable to the results from FE model.

Earthquake response analysis results from the simplified beam model for the 100% design earthquake (DE) run are presented in Figure 3. The design earthquake selected was the Sylmar record from the 1994 Northridge Earthquake scaled to have S_1 equal to 0.41 g. Figures 3(a) and 3(b) show comparisons between the analytical and experimental results for north and south column resultant displacement histories under 100%DE. It is seen that analytical results from the simplified beam model have good agreement with the experimental results especially in the estimation of the peak values. However, it is also observed that there are differences in the post-peak values compared to the experiment results. This suggests that improvements can be made to the numerical modeling of this curved bridge.

In conclusion, the data presented in this paper suggested that the simplified beam model developed in this study can provide not only good agreement of the modal period with the FE model, but also good estimation of the peak displacement compared to the experiment results.

References

1) Wibowo, H., Sanford, D. M., Buckle, I. G., and Sanders, D. H., Analytical Investigation on the Effect of Number of Vehicles on the Seismic Response of a Horizontally Curved Bridge Model, *Tenth International Conference on Urban Earthquake Engineering*, Tokyo, Japan, CD-ROM, 2013.3.

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