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Investigating the Effect of Near-Fault Earthquake Parameters on the Behavior of Horizontally Curved Bridges

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ABSTRACT: To design safe transportation systems, it is unavoidable to completely recognize the complicated behaviors of bridges under an earthquake. The past earthquakes showed that horizontally curved bridges are highly affected by earthquakes, especially near-fault earthquakes, due to irregular geometry. The previous studies indicated that magnitude; PGV and TP have been the most effective near-fault-earthquake parameters. In the present study, attempts were made to determine the effect of these parameters on such bridges using a verified software model by a field test and analyzing two horizontally curved bridges. Three suites of near-fault records were used to conduct time-history analysis with three parameters, namely magnitude, PGV, and TP. In each suite, two of these parameters are almost constant, and the third parameter is variable to observe its effect on the result. The results indicated that the change in PGV has the most significant effect on the behaviors of such bridges. Also, the effect of TP increases in longer bridges. If the difference between the lateral displacement of two ends of the deck is considered as criteria for assessing the potential of deck rotation, increasing in bridge length and being in a near

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INTRODUCTION

The number of Horizontally Curved Bridges (HCB) is rising because of geometric limitations and the need for elevated intersections in cities. The presence of a curve in the plan causes geometric irregularities in these bridges and, as a result, intensifies seismic response. Ramp bridges are a series of HCBs that one end of the deck is placed on abutment and the other end on the pier. As previous earthquakes showed, these types of bridges are vulnerable to earthquakes and especially Near-Fault Earthquakes (NFE) as the 2008 Wenchuan earthquake [1].

NFEs have pulses with long periods in their velocity time history which are important in earthquake engineering and seismology. Many types of research have been done for identifying NFEs [2-4]. One of The most complete studies on the identification of NFEs was conducted by Baker [5]. Baker introduced 3 parameters of magnitude, PGV, and T_p that are the most important and effective parameters of NFEs. In this study, time-history analysis was used for two HCBs different in terms of length and curve (Fig. 1), but similar in terms of deck type and pier characteristics, to obtain the effect of these parameters on the seismic responses.

METHODOLOGY

In this study, two HCBs (Bridge A and B with the length of 80m and 270m, respectively) were recently designed and constructed in 2012 based on Caltrans SDC and AASHTO LRFD standards were analyzed under a set of design basis earthquakes and three sets of NFEs. Three sets of NFE have been obtained from Baker's study that each earthquake has parameters of magnitude, PGV, and Tp. The selection of NFE sets was done in such a way that only one of the parameters was changed in each set so that its effect on the bridge response could be seen.

In the field of software modeling of HCBs, numerous studies have been conducted [6, 7]. These studies examined a variety of methods for modeling such bridges such as the Finite-Strip Method, Finite-Element Method, Thin-Walled Curved Beam Theory, and so on. One of the methods for modeling deck and bridge pier is using spinal elements. Research showed that using simple models will have more realistic results [8]. In the present study, OpenSees has been used for modeling and analyzing [9].

For verifying the numerical model of the deck, a field experiment was conducted. Due to the impossibility of carrying out the test on the studied bridges, a field test was performed on another HCB, which was similar to the studied bridges in terms of the type of deck and other structural components. The dominant period was obtained to be 0.346s through the test results, which is quite close to the period of 0.342s obtained by the software. For pier verification also, the experimental research carried out by Kim et al. [10] was used. The verification of the global behavior of the modeled pier indicated that the response will be similar to the actual behavior of the pier.

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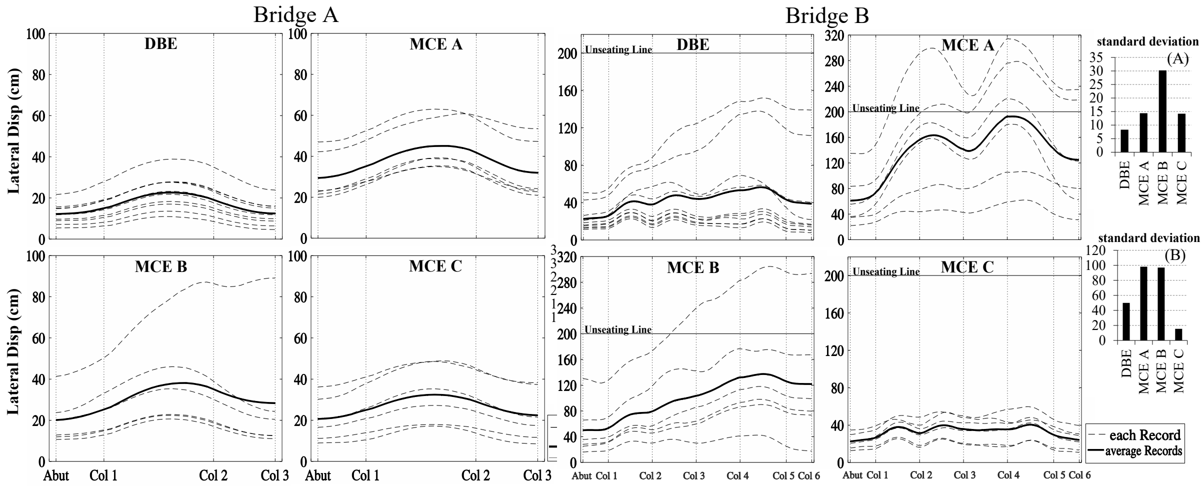

Fig. 1. The mean of maximum lateral displacement of Bridges A & B under BDE & MCE.

RESULTS AND DISCUSSION

The previous studies have shown that after shear keys are broken, deck unseating and piers failure are the two most important damage mechanisms to HCB [11, 12]. Therefore, the lateral displacement response of the deck and the torsion force of piers were obtained as the representative of the bridge response to examine unseating and piers failure. The width of the pier head is 400 cm, accordingly, the 200 cm displacement of the deck is considered as deck collapse (unseating).

According to the results of Fig. 1 for bridge A, the responses of the two ends of the deck were similar under DBE, and most of the displacement occurs in the middle of the deck. While under NFE, the responses of the two ends are different. It can be illustrated deck tendency to rotate around the abutment. The highest standard deviation values were obtained under MCE B. Thus, the PGV changes have the greatest effect on the response of HCBs. In other words, we have the most changes in the responses by changing PGV which indicates the effect of this parameter on the response variation compared to other parameters.

For Bridge B, the peak of the deck lateral displacement of Bridge B compared with Bridge A under DBE, MCE A, MCE B, and MCE C obtained 2.4, 4.3, 3.6, and 1.25 times, respectively. Another point is that the standard deviation of the results under MCE A was approximately 7 times, while it was 3.2 and 1.3 times under MCE B and MCE C, respectively. Hence, more length of the bridge leads to increasing the TP effect on HCBs.

Evaluation of torsion force on piers showed the piers of Bridge A were designed conservatively. In general, the torsion force response of piers also confirmed previous findings.

CONCLUSIONS

The results obtained in this study as representative of the response of HCBs showed that:

- The results showed that the increase in the bridge length makes the deck rotation potential enlarge around the abutment, and when the length of the bridge reached from 80 to 270 meters, this potential under DBE and NFE increases by 78% and 137%, respectively.
- Investigating the effects of three parameters of NFEs on HCBs has shown that changing the PGV has the greatest effect on the response of this type of bridge in the near-fault zone. Therefore, among the three major parameters of NFEs, the PGV value plays the most important role in the response of this type of bridge.
- The influence of T_P on the response of HCBs increased significantly when the bridge length was enhanced. In fact, by increasing the length of HCBs, the periods also increase and reach the predominant frequency of earthquakes. Therefore, the effect of TP on the response has a direct relationship with the bridge length.
- Previous earthquakes have shown that the greatest damage to HCBs has been due to rotational demand intensification of deck around the vertical axis which led to shear key failure and deck unseating. Thus, according to the low response values obtained under DBE, can be concluded that designing this type of bridge based on existing codes is somewhat un-economic.

REFERENCES

[1] Kawashima, K., Takahashi, Y., Ge, H., Wu, Z. and Zhang, J., 2009. "Reconnaissance report on damage of bridges in 2008 Wenchuan, China, earthquake". *Journal of Earthquake Engineering*, *13*(7), pp.965-996.

[2] Somerville, P.G., 2003. "Magnitude scaling of the near fault rupture directivity pulse". *Physics of the earth and planetary interiors*, *137*(1-4), pp.201-212.

[3] Somerville, P.G., Smith, N.F., Graves, R.W. and Abrahamson, N.A., 1997. "Modification of empirical strong ground motion attenuation relations to include the amplitude and duration effects of rupture directivity". *Seismological Research Letters*, *68*(1), pp.199-222.

[4] Spudich, P., Chiou, B.S., Graves, R., Collins, N. and Somerville, P., 2004. "A formulation of directivity for earthquake sources using isochrone theory". *US Geol. Surv. Open-File Rept*, *1268*, p.54.

[5] Baker, J.W., 2007. "Quantitative classification of near-fault ground motions using wavelet analysis". *Bulletin of the Seismological*

Society of America, *97*(5), pp.1486-1501.

[6] Begum, Z., 2010. *Analysis and behavior investigations of box girder bridges* (Doctoral dissertation).

[7] Gupta, T. and Kumar, M., 2018. "Flexural response of skew-curved concrete box-girder bridges". *Engineering Structures*, *163*, pp.358-372.

[8] Evans, H.R., 1984. "Simplified methods for the analysis and design of bridges of cellular cross-section". In *Analysis and Design of Bridges* (pp. 95-115). Springer, Dordrecht.

[9] McKenna, F., Fenves, G.L. and Scott, M.H., 2000. "Open system for earthquake engineering simulation". *University of California, Berkeley, CA*.

[10] Kim, J.K., Kim, I.H., Lim, H.W., Lee, J.H. and Lee, J.H., 2001. "Cyclic loading test of bridge pier models without seismic detailing".

[11] Amjadian, M. and Agrawal, A.K., 2016. "Rigid-body motion of horizontally curved bridges subjected to earthquake-induced pounding". *Journal of Bridge Engineering*, *21*(12), p.04016090.

[12] Zuo, Y., Sun, G. and Li, H., 2018, "January. Response analysis of curved bridge with unseating failure control system under near-fault ground motions". In *IOP Conference Series: Earth and Environmental Science* (Vol. 108, No. 2, p. 022065). IOP Publishing.

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