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DYNAMIC ANALYSIS OF BALANCED CANTILEVER CONCRETE BRIDGES WITH DIFFERENT PIER HEIGHTS UNDER NEAR-FIELD GROUND MOTIONS

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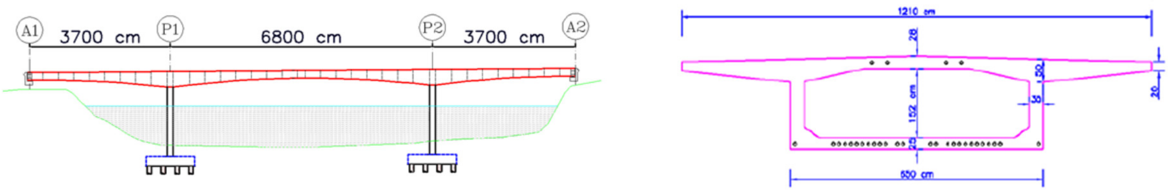
The selected bridge is a balanced cantilever concrete bridge having three spans of 37, 68 and 37 meter and is constructed using form traveller method as shown in Figure 1-a. Construction begins at each bridge pier. The deck section height varies from 4.03 m at the pier location to 2.03 m at the middle of main span in parabolic form, Figure 1-b. The deck is implemented continuously with the middle piers and seats on elastomeric bearings at each end. The height of the middle pier is 18 m. The pier section is considered wall type pier with 1.5 m thickness. The pier section width varies from the 6.5 m at the deck level to 8 m at the base linearly.



a) b)

Figure 1. a) Bridge profile, b) Deck section at middle of main span.

This paper presents seismic performance of a concrete bridge with equal pier heights (EPH) and unequal pier heights (UPH) subjected to a set of Near-Field ground motions (NFGM). Two bridges with concrete box girder (balanced cantilever construction method) having three spans (37+68+37 meter) were modeled using three-dimensional nonlinear dynamic finite element method (FEM). The first one having EPH (18 m) and the second one having UPH (18 and 21 m), which were monolithically connected to the deck. In order to evaluate the inelastic response of bridges to Near-Field and Far-Field ground motions and the effect of bridge irregularity, two types of nonlinear analysis were performed. 1) Nonlinear time series (NTS), 2) Nonlinear static analysis (Push-over). The sensitivity of time series analysis depends on selection of ground motion records. According to recommendations of FEMA P-695 report, The records were selected according to various ground motion characteristic such as the peak ground acceleration, duration, frequency content, fault type and earthquake magnitude. Suite of 28 compatible ground motion records with site soil type II ($175<V_s<375$ m/s) and fault type (strike-slip and reverse faults) of bridge site region, downloaded from PEER ground motions database website and was used in the current study. The aim of NTS is to obtain ductility demand and drift ratio of piers in the two explained cases, i.e. in the case of EPH and UPH. Static analysis (push-over analysis) also was carry out to build capacity curves and make a comparative study on global seismic behavior between bridges with EPH and UPH. The suite consisted of 14 ground motion records with pulse-like and 14 records without pulse-like occurred in the world. For preventing of results tendency to special event, just one set of records was chosen from each event. Scaling process of ground motion records was performed according to Iranian road and railway bridges seismic resistant design code. In this study, push-over analysis was done to make a comparative study between EPH and UPH effect on bridge seismic performance. Uniform acceleration in a longitudinal and transvers direction as load pattern used in the push-over analysis. EPH and UPH cases have the same behavior in X direction but a degrading response can be seen for EPH in Y direction. Table 1 presents initial Effective stiffness and effective damping of the bridge Structure.

In this paper, two groups of nonlinear time series analyses were performed for Near-Field ground motion records on bridges with equal and unequal pier heights. Figure 2 shows comparative assessment of pier head displacement in longitudinal direction of bridge layout line. As can be seen Near-Field ground motions induce nearly larger displacement in EPH case rather than UPH case.

Table 1. initial Effective stiffness and effective damping of the bridge Structure.

Bridge case-direction	K_{eff} (ton/m)	Δ_y (cm)	Δ_{ud} (cm)	$\mu_{\Delta d}$	ξ %
EPH-X direction	5178	28	33	1.67	7.2
UPH-X direction	4034	32.5	57	1.77	16
EPH-Y direction	23712	13	14	1.07	9
UPH-Y direction	14220	20	24	1.2	11

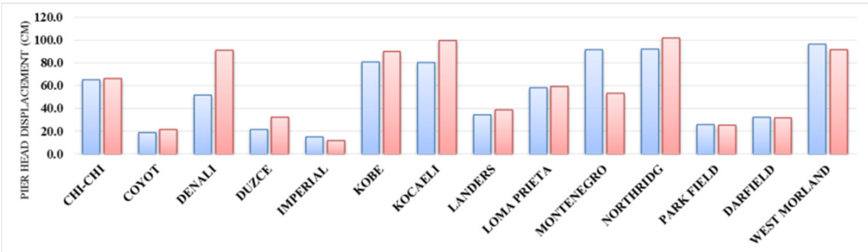


Figure 2. Pier head displacement comparison between EPH and UPH cases under near-field ground motion.

Table 2 presents the comparison between the average of near-field ground motion and the average of far-field ground motion effects on pier displacement. Near-field ground motions increase the pier displacement about 1.85 times larger than far-field ground motions. Pier hysteresis diagrams investigate the cyclic behavior of column subjected to an earthquake. Maximum rotation and energy dissipated are two important characteristics that extracted from hysteresis diagrams.

Table 2. Near-field and far-field ground motion effects on pier head displacement.

Ground Motion Type	EPH case	UPH case
Near-Field	54.5	58.1
Far-Field	29.5	31.2

Pier hysteresis diagrams investigate the cyclic behavior of column subjected to an earthquake. Maximum rotation and energy dissipated are two important characteristics that extracted from hysteresis diagrams. The moment-rotation behavior of piers depends on the pier axial force intensity. In other words, the pulse like type of motions (Near-Field) can induce axial loads more than other one. The main results of this paper are as follows:

Bridge with unequal pier heights can improve seismic behaviour of pier by asynchronous formation of plastic hinge at the base of piers.

Simultaneous forming of plastic hinges can increase the rate of degrading of Push-over curve.

The effective damping and displacement ductility of the bridge with unequal pier heights would be increased.

REFERENCES

Goel, R.K. and Chopra, A.K. (2008). Role of shear keys in seismic behavior of bridges crossing fault-rupture zone. *Structural engineering ASCE*, *13*(4), 398-408.

Shamsabadi, A. (2006). *Three-Dimensional Nonlinear Seismic Soil-Abutment-Foundation Structure Interaction Analysis of Skewed Bridges*, Ph.D. Dissertation, Department of Civil and Environmental Engineering, University of Southern California (USC), Los Angeles, CA.

Somerville, P.G. (2003). Magnitude Scaling of the Near Fault Rupture Directivity Pulse. *Physics of the Earth and Planetary Interiors*, (137), 201–212.