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EFFECT OF THE NEAR-FIELD GROUND MOTION PULSE PERIOD ON THE SEISMIC RELIABILITY OF RC/MR FRAMES USING MONTE CARLO SIMULATION

Zohreh JABARI-SALMI
M.Sc. Earthquake Engineering, Daneshpajoohan Pishro, Institute of Higher Education, Isfahan, Iran
j.zohreh1992@gmail.com
Esmaeel IZADI-ZAMANABADI
Assistant Professor, Department of Civil Engineering, Islamic Azad University, Najafabad, Iran
e.izadi@pci.iaun.ac.ir

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Study of the random nature of structural parameters such as material properties, external loads and geometric dimensions, have led to the development of research on classical methods of modeling. Classical modeling methods based on the deterministic decisions do not meet the designer's functional requirements. In order to reduce the structural capacity uncertainty, new decision-making methods based on probabilities have been developed. Reliability theory is a tool that gives a probabilistic estimate of the structural design safety factors. One of the source of uncertainty is the ground motion characteristics. Near-field ground motion with directivity focusing or fling effects produces pulse-like ground motion that has characteristics different from those of far field records. Large peak ground velocity and displacement, energy concentration in one or a few pulses and also unusual response spectrum shape are the main characteristics of the near field ground motion records. These features have been recently evaluated by many researchers, while the least attention has been paid to the near-field ground motion pulse period. In this study, the effect of near-field ground motion pulse period on the seismic reliability of RC moment resisting frames has been investigated. For this purpose, multi-story RC frames were designed based on the seismic provisions provided by ASCE 7-16. Nonlinear computational model based on concentrated nonlinear springs placed at the ends of beams and columns, has been developed in OpenSees framework. For reducing computational costs, the idea of simplifying near-field ground motion record with an equivalent pulse is taken into consideration. In the past, analytical models of pulses present in the near-field ground motion have been proposed by researchers. Mavroeidis and Papageorgiou proposed a simple, yet effective, analytical model for the representation of near-field strong ground motions. In order to develop a systematic procedure for assessing near-field effects, Alavi and Krawinkler (2004) tried to relate near-field records to a small number of simple input pulses that can be fully defined by a few parameters. This pulse is fully defined by two parameters, i.e., the pulse period (Tp), which is defined as the duration of a complete velocity cycle, and the maximum ground acceleration ($a_{g,max}$) or velocity ($v_{g,max} = a_{g,max}Tp/4$). He and Agrawal (2008) proposed an analytical pulse model for velocity pulses observed in near-field ground motions for a systematic design and assessment of seismic protective systems. The proposed pulse model utilizes pulse period, decay factor, and shape parameters to model both buildup and decaying phases observed in recorded ground motions. In addition, considering structural dynamic systems subjected to digitized excitations, a technique and correspondingly a computational procedure are proposed by Soroushian (2008) for time integration with steps larger than the excitation steps. This method can considerably reduce the total computational cost. In this study Analytical simplified pulse model developed by He and Agrawal (2008) was used to reduce computational costs. He and Agrawal pulse model uses an amplitude-modulated sinusoid of the form given by Equation 1.

$$\dot{u}_p(t) = Ct^n e^{-at} \sin(\omega_p t + \nu), t \geq t_0 \qquad (1)$$

where $\omega_p = 2\pi/T_p$ = pulse frequency; T_p = pulse period; C = amplitude scaling factor; ν = phase angle of the sinusoidal component; a = decay factor; n = non-negative integer parameter controlling the skewness of the pulse envelope with respect to time; and t_0 = beginning time of the pulse.

Figure 1 shows the acceleration and velocity response spectrum of the 2015 Gorkha, Nepal, earthquake for 5% damping ratio. It is observed in Figure 1 that the response spectra corresponding to the He and Agrawal (2008) simplified pulse model correlate well with those using real recorded ground motions for structural periods close to or longer than the pulse period. Poor correlation has been resulted for the shorter structural periods because of exclusion of high frequency components in the equivalent pulse model.

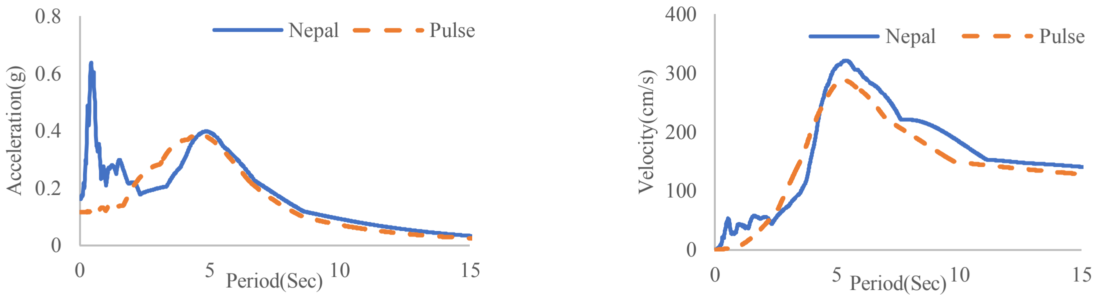

Figure 1. The acceleration and velocity response spectra of the real record and the simplified pulse model (Nepal earthquake, Gorkha, 2015).

In order to examine the significance effect of near-field ground motion pulse period characteristic on the seismic reliability of RC frames, displacement responses, probability of damage state exceedance and the average values and standard deviation of displacement responses obtained from the Monte Carlo simulation has been investigated. To determine the effect of Tp/T on the displacement responses of RC frames, the values of Tp/T (the ratio of pulse period to the period of the structure) were selected 0.4, 0.6, 0.8, 1, 1.2, 1.4, 1.6 and 1.8 and the rate of variation for different Tp/T is discussed. Probability of structural failure is investigated using the theory of reliability of structures and using the exceedance probability curve. For this purpose, Monte Carlo simulation is used that random variables are selected based on their probability density function. Average values and standard deviation of displacement responses obtained from the Monte Carlo analysis are determined in 10,000 samples for different Tp/T values. Coefficient of variation is also investigated for different Tp/T values. Then, uncertainty of the maximum displacement responses variation for different Tp/T values is discussed. In addition effect of near-field ground motion pulse period on the structural reliability index based on the limit state functions has been investigated. For this purpose, a set of earthquake records is scaled using the elastic design spectra, and the reliability index diagrams are plotted using Monte Carlo method. The slope and y-intercept of the best fit line is determined, which can help to better evaluate this parameter. Finally, it may be emphasized that uncertainty of the near-field ground motion pulse period can be combined with standard reliability methods to assess the safety of inelastic structures under near-field pulse-like ground motion.

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