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Effects of near-fault ground motions and equivalent pulses on multi-story structures

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ABSTRACT

The focus of this paper is the structural response of multi-story structures to near-fault ground motions, and whether structural response is dominated by the ground motion pulses present in forward-directivity ground motions. Also considered is whether simplified pulses are capable of representing the effects of these pulses on structural response. Incremental Dynamic Analysis was employed to assess the effects of forward-directivity pulses on the response of near-fault multi-story structures. Three different generic multi-story shear buildings were subjected to fifty four near-fault ground motions including ordinary and forward-directivity records. The Maximum Story Displacement Ductility Demand was selected as the Engineering Demand Parameter. Results showed that pulse-like forward-directivity ground motions impose a larger ductility demand to the structure compared to ordinary ground motions. Moreover, the response of the structures to forward-directivity motions shows higher scatter than the response to ordinary ground motions when correlated with simple intensity measures such as PGA or spectral acceleration at the first mode period. The only intensity measure that appears to be valid for both ordinary and forward-directivity ground motions is the peak ground velocity. The structural response to the forward directivity ground motions was reproduced using an equivalent pulse model based on the modified Gabor Wavelet pulse. It is shown that when the ratio of pulse period to the fundamental structural period falls in a range of 0.5–2.5, the equivalent pulse model appropriately represents the structural response to forward-directivity ground motions. The simplified pulse parameters can be predicted using existing relationships and can be incorporated into probabilistic seismic hazard analysis to develop a seismic reliability analysis. Finally, the effects of damping ratio and P-Δ were investigated for forward-directivity ground motions. The effect of variations in the damping ratio on the ductility demand was insignificant while P-Δ-effects on the ductility demand are significant.

1. Introduction

Ground motions close to a fault can be significantly influenced by directivity effects. When the rupture and slip direction relative to a site coincide, and a significant portion of the fault ruptures towards the site, the ground motion can exhibit the effects of forward-directivity. Most of the energy in forward-directivity ground motions is concentrated in a narrow frequency band and is seen as a distinct, high intensity velocity pulse at the beginning of time history records (e.g., see Fig. 1). These pulses, in turn, may result in high seismic demands for buildings. Hence, the design or retrofit of structures that are in the proximity of an active fault (within about 20 km) must account for the effects of pulse-type ground motions. Recent research has addressed the seismological aspects of fault mechanisms leading to forward-directivity, the characteristics of forward-directivity ground motions [1–3], and structural response to these motions [4–9]. However, designers still lack specific guidelines as how to account for forward-directivity effects when determining the seismic hazard for a given structure.

In the current state-of-the-practice, forward-directivity effects are introduced in seismic hazard analyses by modifying the ground motion elastic response spectra [1,2,10,11], using spectral-based intensity measures (IM) to capture the structural response [12], and with modified peak ground motion values [13]. Nevertheless, forward-directivity ground motions typically have large intensities and tend to drive structures into the nonlinear range. For these cases, a linear response spectrum, and in particular the spectral acceleration at the first-mode period of the structure, $S_a(T_1)$, no longer serves as an effective intensity measure [12]. However, forward-directivity ground motions have relatively simple time domain representations and can be characterized by the period and amplitude of the velocity pulse [14–17], and these parameters can be used as intensity measures. Moreover, the narrow band nature of the forward-directivity pulse implies that forward-directivity

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