DESTRUCTIVENESS OF NEAR-FAULT GROUND MOTION FROM THE 1999 CHI-CHI, TAIWAN EARTHQUAKE

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Introduction

The 1999 Chi-chi earthquake in Taiwan (M_w=7.6) has provided some near-fault seismic records that exhibit the so-called forward rupture directivity effect. The effect occurs when the fault rupture propagates toward a site at a velocity nearly the shear wave velocity and causes a large-amplitude pulse that appears in the beginning of the velocity time-history (Somerville *et al.*, 1997). The values of peak ground velocity (*PGV*) for these records are associated with the pulse and are as large as 100-380 cm/s.

PGV is often used as a measure of the earthquake intensity, particularly in the structure fragility analysis, where it is related with the probability of structure failure (Yamazaki *et al.*, 2000; Yamazaki and Murao, 2000). The *PGV* values at the sites that are affected by the directivity effect in the 1999 Chi-chi earthquake imply high destructiveness of the ground shaking. The field evidence, however, shows no severe damages to the structures at these sites (JSCE, 2000) that makes the application of *PGV* questionable. This paper examines a way to describe more adequately the destructiveness of near-field ground motion at sites where the directivity effect took place.

Seismic motion with forward rupture directivity effect

Some examples of a seismic ground motion with rupture directivity effect from the 1999 Chi-chi earthquake are depicted on Figure 1. Strong dependence of *PGV* on the direction is also shown. The velocity time-histories correspond to the direction of maximal amplitude. The peak of the pulse is around 2 times larger than the next peaks and its period is of range 3-5 seconds. Ground velocity was obtained by integration of the ground acceleration with a Runge-Kutta scheme. The original acceleration records were adjusted by shifting last part of their zero-line. Similar waveforms are found at other sites from large crustal earthquakes that have experienced the directivity effect

Figure 2 illustrates fragility curves for wooden and RC buildings that were developed using the damage data from the 1995 Hyogo-ken Nanbu earthquake. One can see that, for instance, the peak velocity at TCU068 corresponds to 90 % heavy and moderate damages for RC and 100 % heavy damages for wooden buildings, which was not observed in the field investigations. Main reason for this discrepancy is contributed to the forward rupture directivity effect. In this case, the application of *PGV* as representative parameter that is related with the structure damages is questionable.

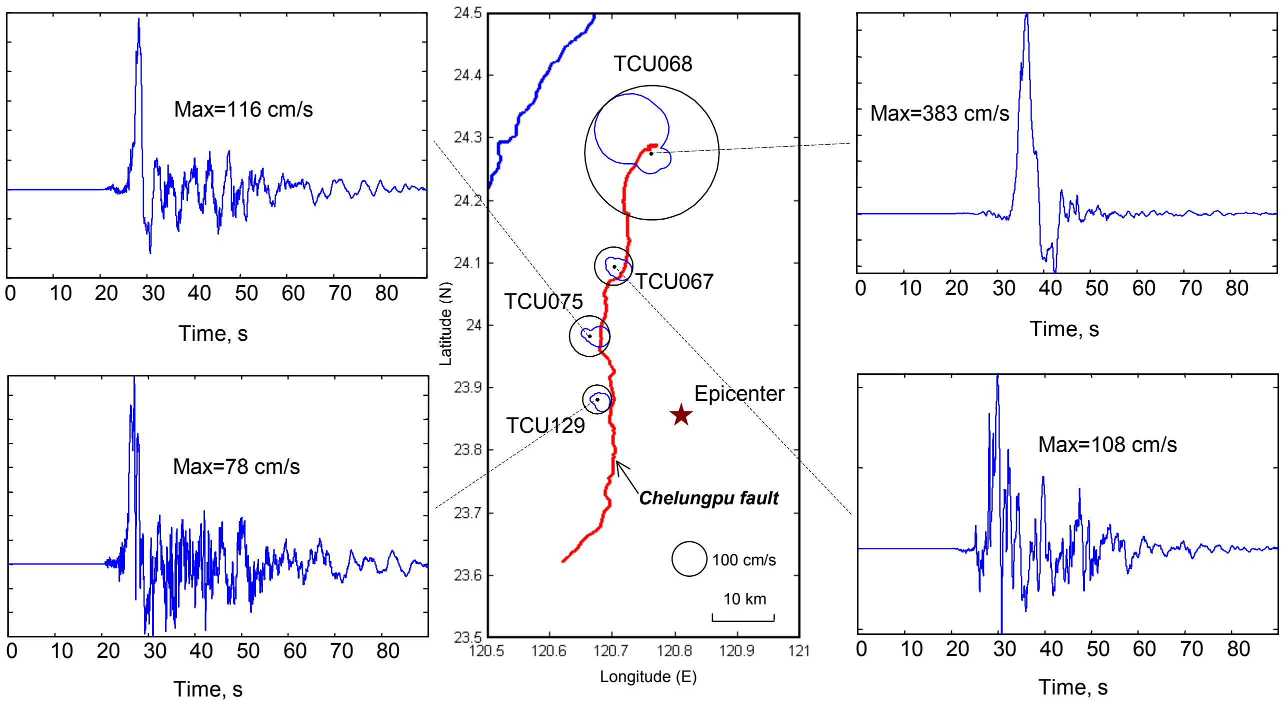

Figure 1. Location of some near-fault stations from the 1999 Chi-chi earthquake and corresponding velocity time-histories of maximal amplitude

Key Words: near-fault directivity effect, velocity pulse, spectral intensity
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Spectral intensity

Spectral intensity (*SI*) is a ground motion parameter used for evaluating the destructiveness of an earthquake with respect to building environment. Recently, *SI*-sensors have started to be installed over Tokyo area in order to grasp the range of the damages immediately after an earthquake. Spectral intensity is computed as the area under the relative-velocity response spectrum of linear SDOF system with damping ratio 0.20 between periods of 0.1 sec. and 2.5 sec., divided to that period interval. In most of the cases the *SI* value is very close to that of peak ground velocity (*PGV*) and they might be consider as interchangeable. Tong and Yamazaki (1995) suggested the following relationship between *SI* and *PGV*

$$SI = 1.18\ PGV \tag{1}$$

The change of the shape of the velocity spectrum for damping ratio 0.05 at sites from large crustal earthquakes affected by the forward rupture directivity effect was already shown. Amplitudes of spectral velocity increase considerably after period of 2 seconds and peak around period of 5 seconds. Same tendency is preserved in the relative-velocity response spectrum for damping ratio 0.20. Therefore, the *SI* value will be much less than *PGV*. This is in contrary to the usual cases where the spectrum peaks at the short periods. Figure 3 compares relative-velocity response spectra from different earthquakes. *SI* vs. *PGV* for nine near-fault stations from the 1999 Chi-chi earthquake are shown in Figure 4. The variation of *PGV* for these stations is twice larger that that of *SI*.

Discussion

The values of *PGV* at near-fault sites, which have experienced forward directivity effect and the damage observations there imply that in this case *PGV* cannot represent the destructiveness of the ground motion. The shape of the corresponding relative-velocity response spectra suggests that spectral intensity might be more consistent ground motion parameter to be related with the structural damages and used in the building fragility analysis. Alternatively, a way to remove the influence of the directivity effect in the velocity time-history might be considered.

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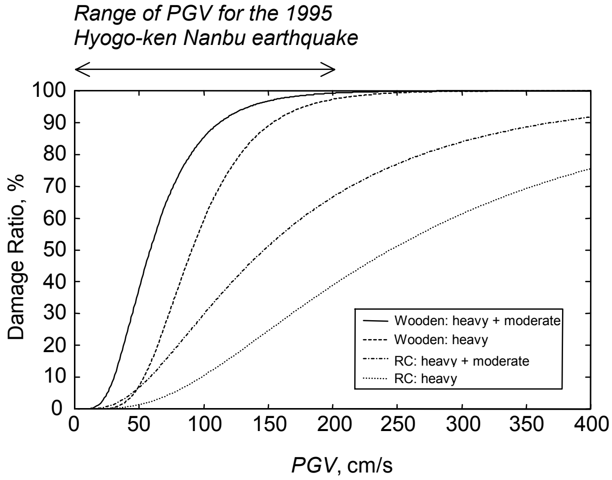

Figure 2. Fragility curves for wooden and RC buildings, developed using damage data from the 1995 Hyogo-ken Nanbu earthquake (Yamazaki and Murao, 2000)

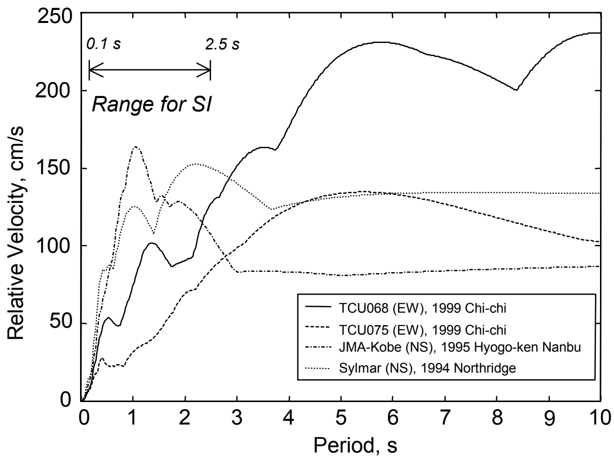

Figure 3. Comparison of relative-velocity response spectra (damping ratio 0.20) for near-fault ground motion from different earthquakes

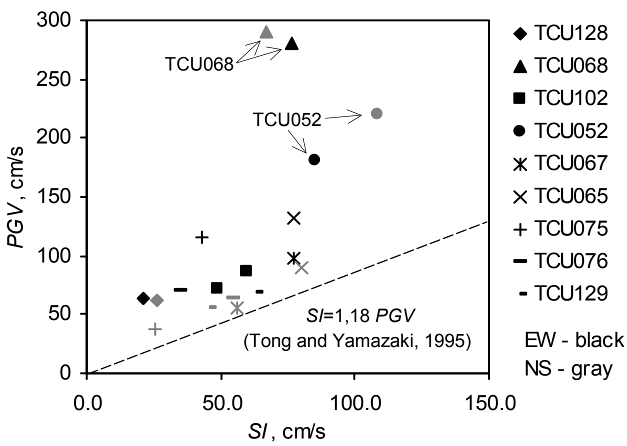

Figure 4. Spectral intensity vs. peak ground velocity for nine near-fault stations from the 1999 Chi-chi earthquake