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STRONG MOTION RECORD OBSERVED AT CONCEPCION DURING THE 2010 CHILE EARTHQUAKE

Saburoh Midorikawa[1] and Hiroyuki Miura[2]

1) Professor, Department of Built Environment, Tokyo Institute of Technology, Japan
2) Assistant Professor, Department of Built Environment, Tokyo Institute of Technology, Japan
smidorik@enveng.titech.ac.jp, hmiura@enveng.titech.ac.jp

Abstract: The 2010 Maule, Chile earthquake (Mw8.8) produced many strong motion records. At Concepcion where many high-rise buildings suffered severe damage, a strong motion accelerogram with long period contents was observed. In this paper, local site effects on the record are examined based on the microtremor and aftershock record. The relation between the building damage and ground motion characteristics is also discussed.

1. INTRODUCTION

A gigantic earthquake with Mw8.8 occurred in Chile on February 27, 2010. The effects of the earthquake were observed over a wide area with a length of more than 500 km. The numbers of affected people and damage houses are about 2 millions and 370,000, respectively (Elnashai et al. 2011). The monetary loss is roughly estimated at 30 billion US$. The earthquake also produced many strong motion records. Among the records, a record with large amplitude and longer period was observed at Concepcion where many high-rise buildings had severe damage. In this paper, we examine the characteristics of the record in relation to local site effect and building damage.

2. OUTLINE OF EARTHQUAKE AND STRONG MOTION RECORDS

Large earthquakes have frequently occurred along the coast of Chile due to subduction of the Nasca plate to the continental plate. The 2010 Maule, Chile earthquake occurred in the seismic gap along the coast of Chile where the last large earthquake (M8.5) occurred in 1835 (Beck et al. 1998). The magnitude of the earthquake is 8.8 in Mw and the length of the aftershock area is approximately 500km. The fault models of the earthquake have been proposed by several researchers. For example, Poiata and Koketsu (2010) estimated a reverse fault model with a strike and dip of 11° and 18°, respectively. The fault length is estimated to be 450-500 km long. Figure 1 shows the surface projection of the slip distribution. The maximum fault slip is 9 m.

Strong motion records from the Maule earthquake are obtained by two strong motion networks such as RENADIC

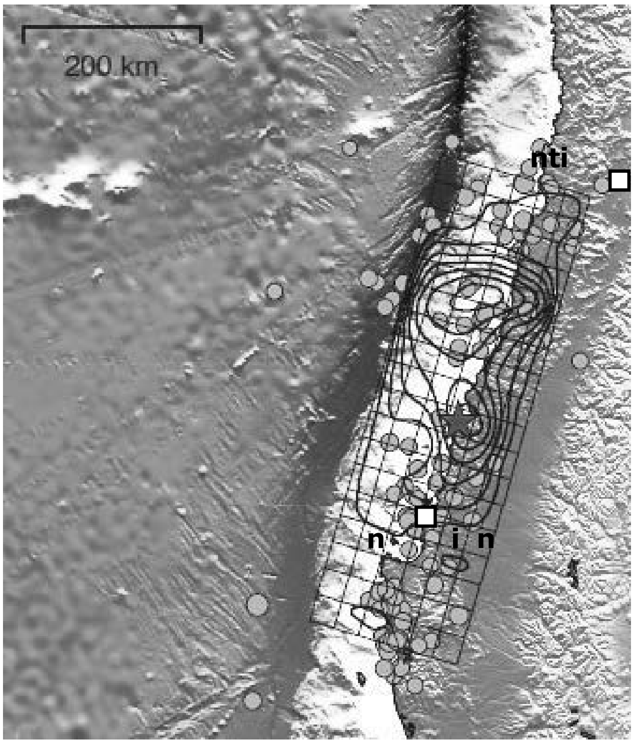


Figure 1 Fault Model (Poiata and Koketsu 2010)

[Red Nacional de Acelerógrafos del Departamento de Ingeniería Civil de la Universidad de Chile] (Boroschek et al. 2010) and RSN [Red Sismologica Nacional by Dept. Geophysics of the University of Chile] (Barrientos 2010). Figure 2 shows the distribution of the peak horizontal accelerations in the epicentral region. The peak accelerations higher than 0.3 g are observed at many sites.

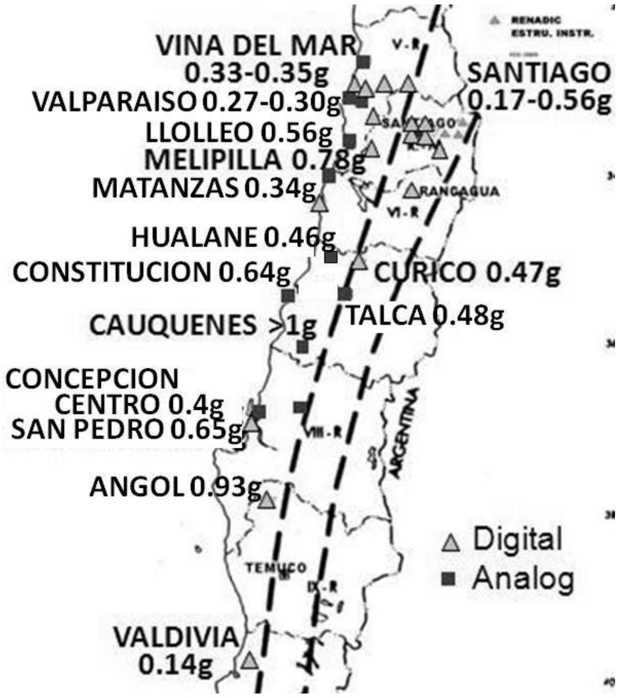


Figure 2 Distribution of Peak Horizontal Accelerations

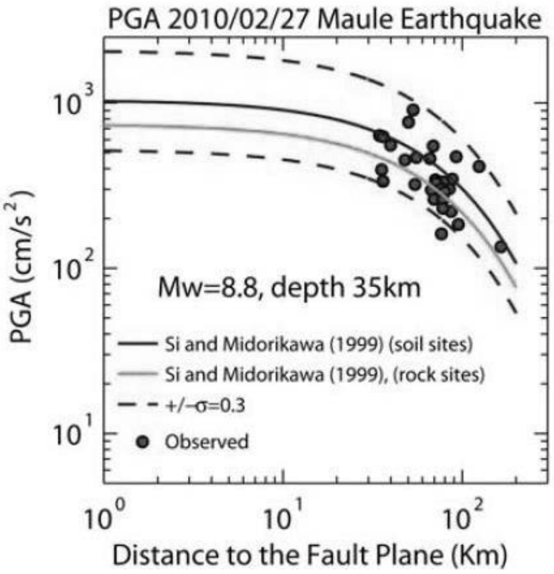


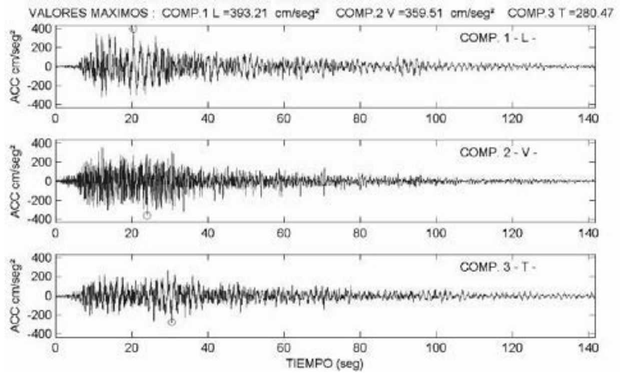
Figure 3 Attenuation of Peak Horizontal Accelerations (Pulido et al. 2011)

Figure 3 shows the attenuation of the peak horizontal acceleration (Pulido et al. 2011). In the figure, the curve from the empirical relationship by Si and Midorikawa (2000) is also plotted. The data from the earthquake is consistent with the existing relationship.

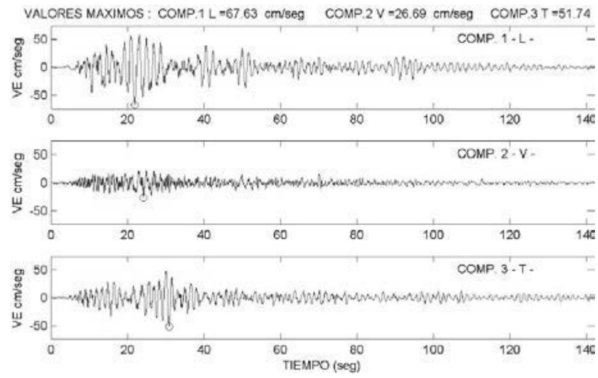
3. STRONG MOTION RECORD AT CONCEPCION

Among the strong motion records, an accelerogram observed at the downtown of Concepcion where many high-rise buildings suffered severe damage, has large amplitude and longer period contents. Figure 4 shows the acceleration and velocity time histories of the record. The peak horizontal acceleration and velocity are about 0.4g and 70 cm/s, respectively. The record was obtained at the basement floor of a three-story school building. The building suffered moderate damage.

Figure 5 shows the pseudo velocity response spectra of



(a) acceleration



(b) velocity

Figure 4 Acceleration and velocity Time Histories of Record at Concepcion (Boroschek et al. 2010)

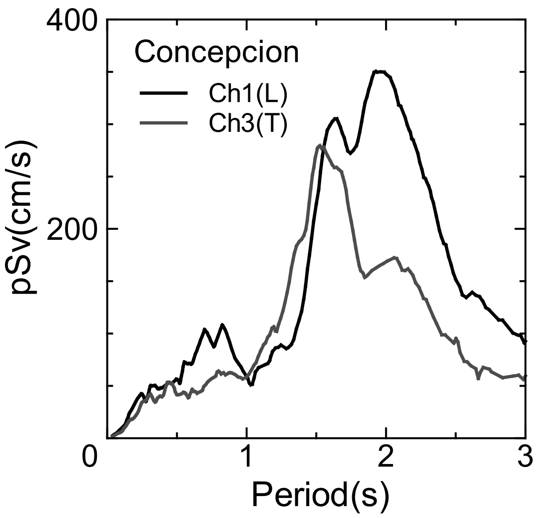


Figure 5 Pseudo Velocity Response Spectra (h=0.05)

the record (h=0.05). In the spectra, there are two strong peaks at periods of 1.5 and 2 seconds. At the peaks, the response amplitudes are very high such as about 350 cm/s at period of 2 seconds. The high response value is comparable with those of the records at Kobe in the 1995 earthquake and at Mexico City in the 1985 earthquake, where catastrophic damage was observed.

4. LOCAL SITE CONDITIONS AT CONCEPCION

To examine the local site effect, the microtremor measurement was conducted at the site. Figure 6 shows the overall response of the measurement system which is almost constant with ground velocity up to 2 seconds. As shown in Fig. 7, the H/V spectral ratio of microtremor has peaks at periods of 1 and 1.5 seconds. During the measurement, a small aftershock record was observed by chance. Figure 8 shows the aftershock record, indicating the predominant period of 1 to 1.5 seconds.

The surface soil of Concepcion consists of sand, and the estimated depth to the bedrock is 100 m or more. Table 1 shows the estimated velocity profile (Nicolau del Roure et al. 1980). The shear-wave velocity of surface soils is about 200 m/s. Figure 9 shows the computed amplification factor from the soil model, showing the predominant period of 1.5 sec.

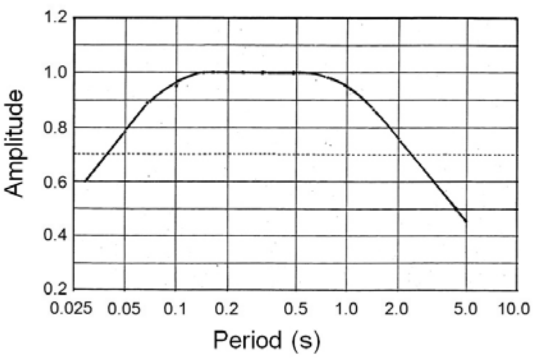


Figure 6 Overall Response of Measurement System

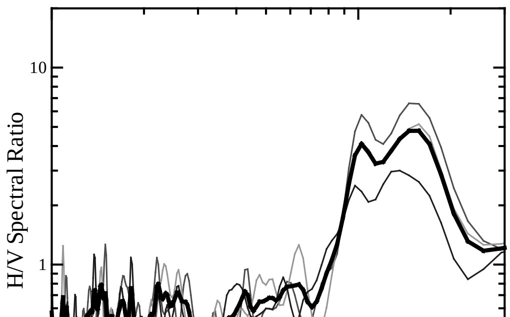
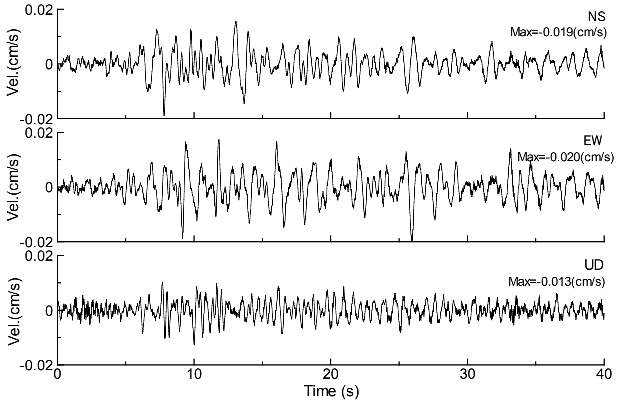
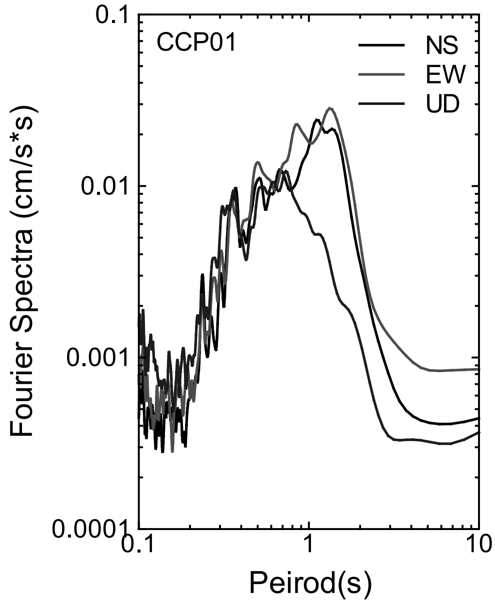


Figure 7 H/V Spectral Ratio of Microtremor



(a) velocity time history



(b) Fourier spectra

Figure 8 Aftershock Record on March 31, 2010

Table 1 Soil Profile Model (Nicolau del Roure et al. 1980)

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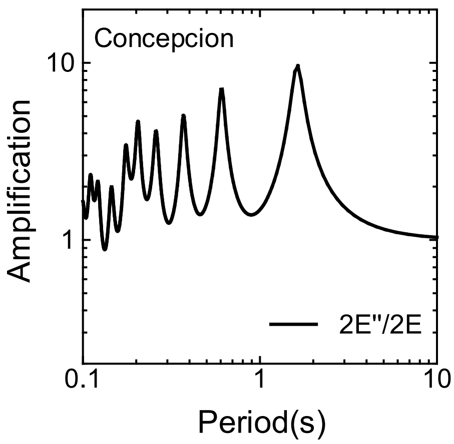

Figure 9 Computed Amplification Factor

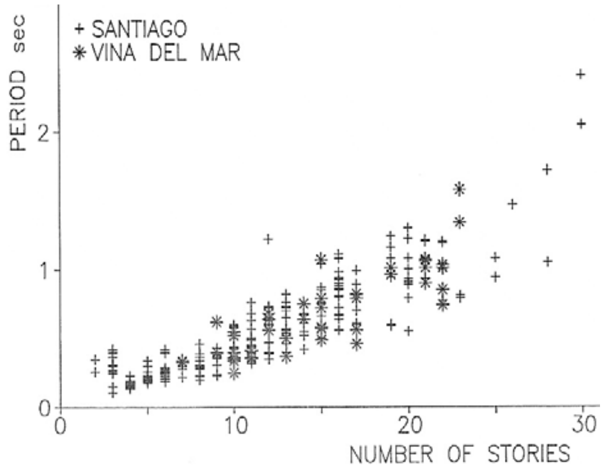

Figure 10 Number of Story vs. Period of Buildings from Ambient Vibration Test (Midorikawa 1990)

The results of the microtremor, the aftershock record and the computed amplification factor show strong local site effects at the site. In the results, the strong peaks are commonly found at periods of 1 and 1.5 seconds. The periods are 40 to 50 percents shorter than those in the strong motion records. As the period during strong shaking will be longer due to nonlinear soil response, the predominant periods of the strong motion record can be explained by local site effects.

In the city, more than seventy buildings suffered severe damage (Municipality of Concepcion 2010). High-rise buildings with 15 to 20 stories seem to be prominent in the damaged buildings. Figure 10 shows the relationship between the story number and vibration period of RC buildings from the ambient vibration test in Chile (Midorikawa 1990).

The period of the 15 to 20 story building which is prominent in the damage building seems 0.5 to 1 sec. at the ambient motion level. At the strong motion level, the period becomes longer due to nonlinear building response, suggesting that resonance of the building response with ground motion may have occurred during the earthquake. Importance of seismic microzoning studies is reconfirmed to evaluate local site effects for damage assessment in urban areas.

5. CONCLUSIONS

The 2010 Maule, Chile earthquake (Mw8.8) produced many strong motion records. Among them, an accelerogram observed at the downtown of Concepcion where many high-rise buildings suffered severe damage, has large amplitude and longer period contents. The pseudo velocity response spectrum has peaks at periods of 1.5 and 2 seconds, and the amplitudes are very high such as about 350 cm/s at period of 2 seconds. The predominant periods of the strong motion record correspond to those of the microtermor, the aftershock record and the computed amplification factor, suggesting strong local site effects. The periods also coincide with the vibration periods of high-rise buildings which suffered severe damage. This suggests that resonance of the building response with ground motion may have occurred during the earthquake. Importance of seismic microzoning studies in urban areas is reconfirmed.

Acknowledgements:

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