SEISMIC MOTION OBSERVED IN TAIPEI BASIN BY NEW SI SENSORS AND ITS IMPLICATION TO SEISMIC ZONING

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ABSTRACT

Chi-chi earthquake occurred in the middle of Taiwan on September 21, 1999. In Taipei city, which is located 160km north of epicenter, 31 New SI sensors are installed in 80km^2 area by Great Taipei Gas Co., Ltd. and dense earthquake motion were measured and waveform were recorded in main shock and aftershock. Then after detailed analysis of these data, it is found that the site amplification factor of main shock can be estimated by the site amplification of aftershock. In other words, the seismic motion measurement in small earthquake is quite important for seismic zonation.

Introduction

At 1:47 a.m. local time on September 21, 1999, an earthquake of magnitude 7.6 occurred near Chichi, Nant'ou County (about 160 km SSE of Taipei). Even in Taipei 160km away the recorded intensity was 4. In Taipei, the Great Taipei Gas Co., Ltd., which is Taiwan's biggest gas utility, is supplying gas to some 330,000 customers over an area of about 80km^2, but records of seismic motion were obtained by 16 New SI sensors that had been installed for automatic shut-off of district regulators in order to prevent secondary disaster at the time of an earthquake. Here, we provide an introduction to records obtained from this high density seismic motion monitoring system with respect to the main shock and aftershocks. We also analyzed the data to find the distribution of the amplification factor within Taipei, and study the relationship between the amplification factor and ground structure.

Results of Observations with New SI Sensors in Taipei City

Fig. 1 shows the location of the epicenter relative to Taipei. The epicenter is near the center of Taiwan, and Taipei is near the northern end of Taiwan. The epicenter and Taipei are about 160km apart. In Taipei, the Great Taipei Gas Co., Ltd. has installed New SI sensors on all regulators in 31 locations and they were set to shutdown automatically if the SI value is 40 kine or more.

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New SI sensors are economical, highly functional, high precision seismometers developed jointly by Tokyo Gas and Yamatake Co., using micro-machining technology that use super compact acceleration pickups. Their main functions are as shown in Fig. 2 but one such function is to record acceleration waveforms and in the case of this earthquake the acceleration waveform records were observed at sixteen points. Observed values are shown in Fig. 3 and Table 1. Since the Taipei area extends about 9km in all directions, observation records were obtained on average at one point in each 5km^2. From the distribution diagram in Fig. 3, we can clearly see that both SI values and accelerations vary widely. The maximum values are at Shazoo, where the recorded SI value is 27.4 kine and acceleration is 139.6 gal. The minimum values are at Yenson, where the recorded SI value is 8.3 kine and acceleration is 38.0 gal. The ratio of maximum to minimum is 3.3:1 for SI values and 3.7:1 for accelerations. In the Taipei basin about 160km away from the hypocenter there seems to be hardly any disparity due to the effect of the hypocenter characteristics and propagation path characteristics and this variation is thought to be a reflection of site amplification characteristics.

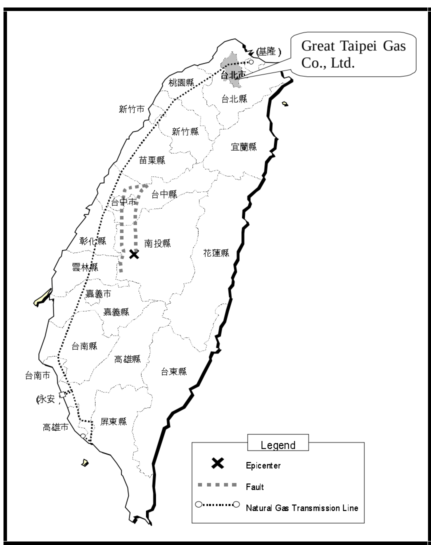

Figure 1. Location of epicenter and Taipei City

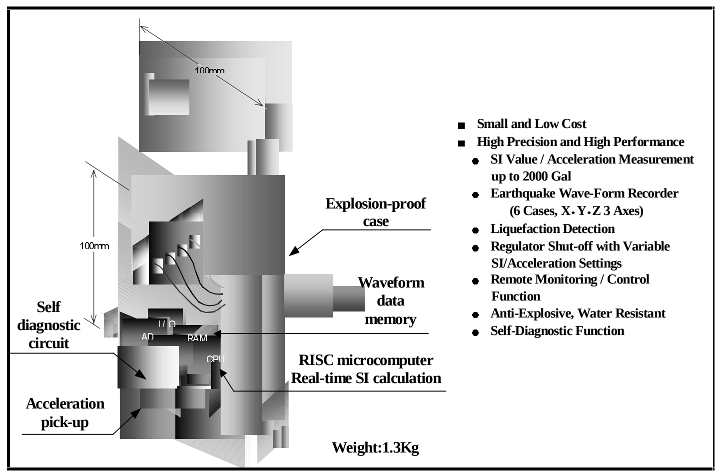

Figure 2. Outline of New SI sensors

Fig. 4 shows acceleration waveforms at Shazoo and Yenson and Figs. 5 and 6 show acceleration response spectra (5% attenuated) and soil boring data nearby. According to Fig. 4, we can see that 1 Hz waves are repeated and greatly magnified at Shazoo. Also, according to Fig. 5, where the period is 3 seconds or less they receive amplification due to the soft ground surface and large SI values were observed. According to Fig. 6, whereas Shazoo has weak offshore deposits, Yenson is located on hard rock. This ground condition is thought to be strongly correlated with the site amplification factor.

Table 1. Observations with the New SI Sensors

Code	Point	SI value	Ratio relative to Yenson	Maximum acceleration
S01	SHAZOO	27.4	3.3	139.6
G01	DAHZOO	23.6	2.8	124.4
G03	MINSEN	20.9	2.5	96.4
G05	ZONREN	21.0	2.5	103.5
G09	GIASIN	19.3	2.3	110.5
G10	DENHWA	15.4	1.9	73.0
G13	FOOPIN	17.9	2.2	105.4
G14	YINCHO	18.1	2.2	76.5
G15	KOKUAN	17.1	2.1	83.6
G16	GUELIN	16.3	2.0	94.6
G17	HWAGIA	19.3	2.3	100.0
G20	JEMKO	21.3	2.6	106.3
G23	ZONSIN	13.1	1.6	71.0
G24	CHENDE	23.4	2.8	130.9
G25	YENSON	8.3	1.0	38.0
E01	HOLE_N	12.8	1.5	66.4

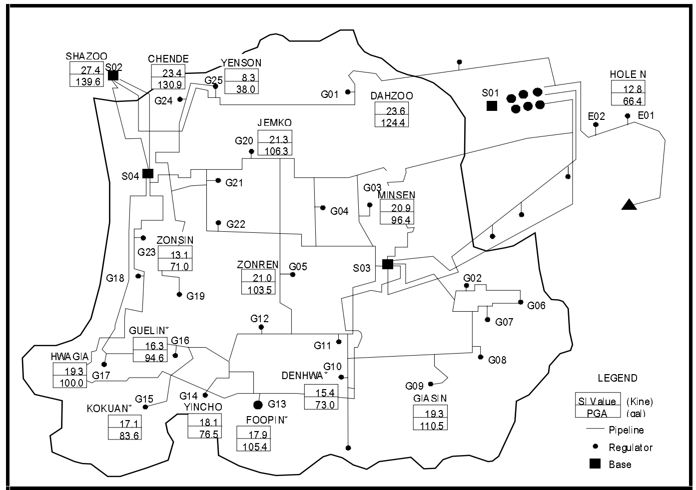

Figure 3. Distribution of SI value and PGA

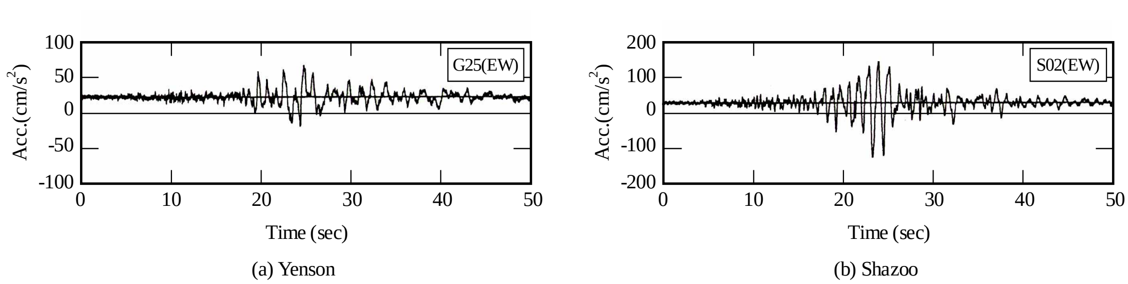

Figure 4. Acceleration waveform at Shazoo and Yenson

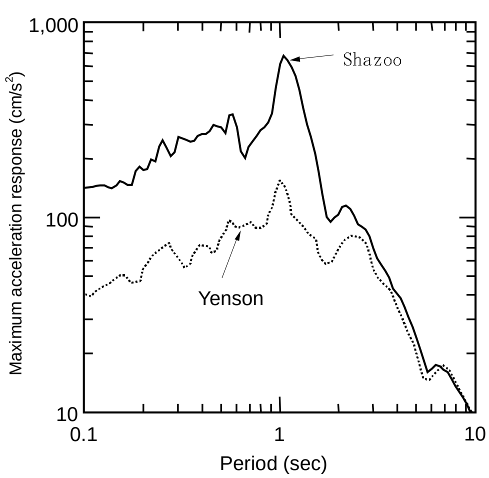

Figure 5. Acceleration response spectrum at Shazoo and Yenson

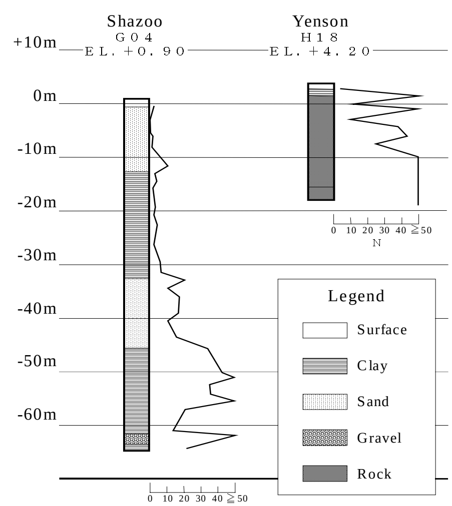

Figure 6. Soil boring data at Shazoo and Yenson

Relationship Between Main Shock and Aftershock

Following the great earthquake that occurred on September 21 many aftershocks occurred. Some of these were observed by Taipei's New SI sensors. Recordings were obtained from some points at the time of the three small aftershocks shown in Table 2. Eq.1 is the main shock. Their epicenters are shown in Fig. 7 and the SI values measured for the four earthquakes are shown in Table 3. In order to see the correlation between site amplification factor at the points where the New SI sensors were installed during the main shock and aftershocks, taking as the standard earthquake Eq. 4, for which the most numerous acceleration waveforms are available, SI values were sorted in ascending order from the point with the smallest SI value (standardized on the average values at all observation points for each earthquake) and plotted in Fig. 8. Aftershock SI values (expressed as a ratio with respect to the average of observed values) are plotted against main shock SI values (expressed as a ratio with respect to the average of observed values) in Fig. 9. It is clear that for any of the earthquakes the general trend is a rise to the right and at any point the amplification factor is generally constant and does not depend on the type of earthquake. Therefore we have learned that the amplification factor in a major earthquake can be inferred from the amplification factor in a small earthquake.

Table 2. Earthquake data

No.	Occurrence	Latitude	Longitude	Magnitude	Depth (km)	Measurement point
Eq. 1	1999.9.21 1:47:12.6	23.85	120.81	7.3 (M_w=7.6)	7	16
Eq. 2	1999.10.13 9:39:50.6	23.99	121.35	5.3	10.2	12
Eq. 3	1999.10.22 10:19:01.3	23.51	120.40	6.4	12.1	12
Eq. 4	1999.11.02 1:53:05.6	23.43	121.63	6.9	30.4	23

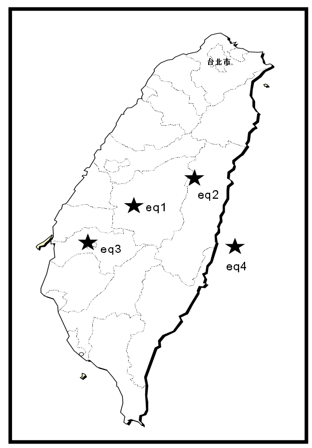

Figure 7. Location of epicenter

In Fig. 8, up to the top third observation points which have higher amplification factor in earthquake Eq. 4, each observation point is located in the southeastern edge of the Taipei Basin and no records were obtained for the main shock. We have learned from the spectral ratio with respect to the standard point and the H/V spectrum of microtremor survey, that the amplification of the 1 to 2 Hz components is large in this southeastern marginal area. Similarly, the 1 to 2 Hz amplification was also large in the northern edge where large SI values were observed in the main shock. The results of earthquake observation records and microtremor survey observations are generally coordinated and if Taipei City were to be zoned on the basis of these characteristics we believe there should be six zones: Rocky, Northern, Southeastern, Southwestern, Central and Eastern zones. From an analysis of small-to-medium earthquake observation records and microtremor survey records, Wen and Peng show that on the long period side at about 2 seconds, the amplification is large in the western part of the basin where the basement deepens, and on the short period side at about 0.5 seconds, the amplification is large at the northern, eastern and southern edges of the basin. Additionally, from a numerical analysis, they show that the magnification characteristics mentioned above corresponds with basement structure. The knowledge gained on this occasion is also in good agreement with the results of Wen and Peng and thought to be due to a mechanism caused by basement structure.

Table 3. SI values measured by New SI sensors

Code	Point	Eq. 1	Eq. 2	Eq. 3	Eq. 4	Eq. 4 (/E01)
S01	SEIKOO	-	-	-	-	-
S02	SYAZOO	27.4	-	-	-	-
S03	KUANFU	-	-	-	-	-
S04	OOHASI	-	-	-	-	-
G01	DAHZOO	23.6	0.8	-	3.4	2.13
G02	HSINYA	-	-	-	-	-
G03	MINSEN	20.9	-	-	4.8	3.00
G04	FOOSIN	-	-	0.8	3.4	2.13
G05	ZONREN	21.0	-	-	3.4	2.13
G06	HOOLIN	-	1.0	1.1	6.4	4.00
G07	ZONSHA	-	-	-	6.4	4.00
G08	HSINYI	-	0.9	-	4.9	3.06
G09	GIASIN	19.3	-	0.8	4.3	2.69
G10	DENHWA	15.4	0.8	0.6	3.0	1.88
G11	LENAI	-	0.9	0.8	3.8	2.38
G12	SINSEN	-	-	-	-	-
G13	FOOPIN	17.9	-	-	4.8	3.00
G14	YINCHO	18.1	0.9	0.8	4.3	2.69
G15	KOKUAN	17.1	0.9	0.5	4.0	2.50
G16	GUELIN	16.3	0.8	-	3.0	1.88
G17	HWAGIA	19.3	-	-	4.0	2.50
G18	PEIMEN	-	0.6	-	3.4	2.13
G19	ZANKEN	-	0.4	-	1.8	1.13
G20	JENKO	21.3	-	0.9	4.1	2.56
G21	MICHEN	-	-	-	3.8	2.38
G22	ZACHUN	-	0.9	0.6	3.9	2.44
G23	ZONSIN	13.1	0.5	0.5	2.5	1.56
G24	CHENDE	23.4	-	-	3.5	2.19
G25	YENSON	8.3	-	-	-	-
E01	HOLE_N	12.8	-	0.4	1.6	1.00
E02	HOLE_S	-	-	-	-	-

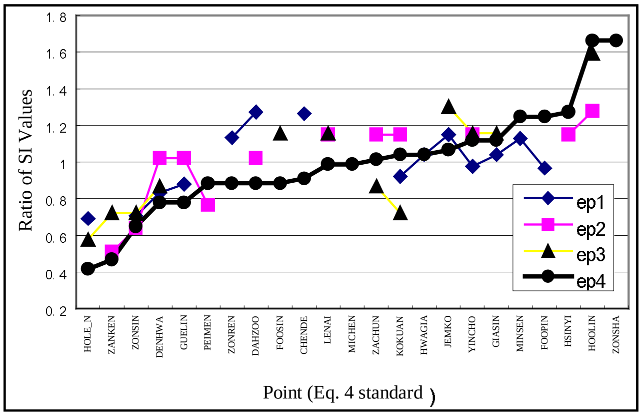

Figure 8. Site amplification for main shock and after shock

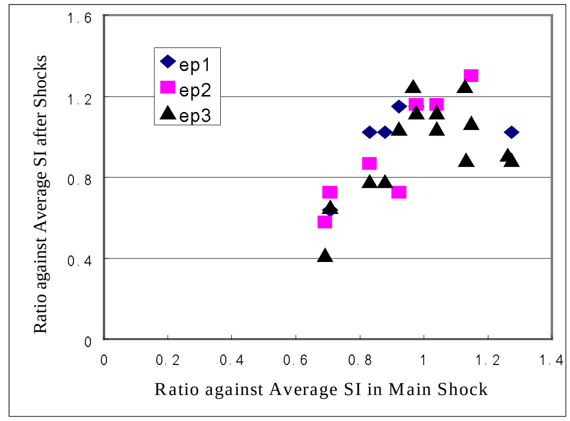

Figure 9. Ratio against average SI in main shock

Conclusion

As a result of studying Taipei City Basin, site amplification characteristics from records of observation of the Chichi earthquake using New SI sensors in Taipei, it has become clear that ground structures have a major effect on the site amplification and those characteristics are generally uniform in the main shock and aftershocks. We will also analyze Taiwan Central Meteorological Bureau data and study the relationship between the magnitude of seismic motion and basement structure to gain site amplification factor from earthquake waveforms.

Acknowledgements

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Reference

Wen, K. H. and H. Y. Peng: Strong motion observations in the Taipei Basin, Proceedings of the Second International Symposium of the Effect of Surface Geology on Seismic Motion, Yokohama, pp. 263-270, 1998.