Paper No. 2032. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

SEISMIC RESPONSE ANALYSIS OF TAIPEI BASIN

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ABSTRACT

Local site amplification of sedimentary deposit during earthquake is an important issues in strong ground motion analysis. From the Taipei basin strong motion observation network program, the ground motion characteristics of the basin effects are studied which include the following analyses: (a) the horizontal peak ground acceleration and spectral ratio contours in low frequency band; (b) correlation of strong motion duration with site amplification; (c) the seismic source, path and local site effect between different seismic events; (d) analysis of principal direction of seismic waves in the basin.

KEYWORDS

Site amplification, Strong ground motion, Response spectrum.

INTRODUCTION

The possibility that the local site conditions influence the amplitudes of recorded seismic waves have been investigated by many researchers (Ref. 1, 1988; Rosenblueth, 1992; Wang, 1994; Wen, 1995). The results show that local soil conditions can significantly affect the characteristics of ground motion during earthquakes giving rise to large amplifications. These effects can not be ignored in the assessment of seismic risk, in studies of microzonation, and in the seismic design of important facilities. A recent case history was offered by the September 19, 1995 Michoacan, Mexico earthquake which cause unprecedented destruction in Mexico City. In addition to important source and path effects, the lacustrine formation of the valley originated observed spectral amplifications of ten to 50 times compared with that observed on nearby firm ground in the frequency band of 0.2 to 1.0 Hz. This shows that at some site the site amplification during strong earthquake excitation is quite significant to the safety of structures.

Taipei basin, similar to the Mexico City, is on top of an alluvium basin. It is filled with unconsolidated sediments. The aim of this work is to review the problem of evaluating the seismic response of alluvial basin. From the recorded earthquake responses of the Taipei basin, the characteristics of the basin effects on ground motions both in time and frequency domains

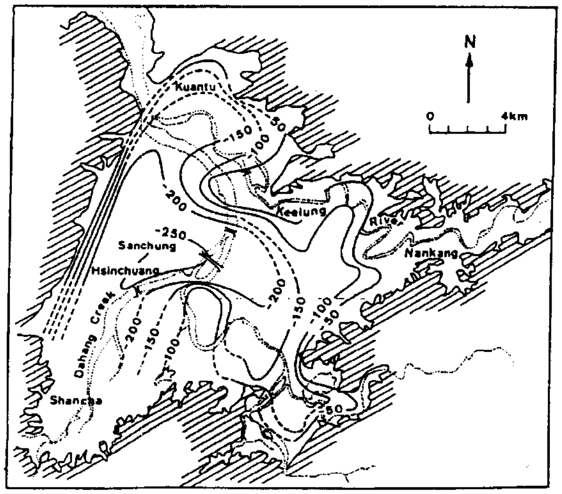

Fig. 1: Map of the Taipei Basin. The contours indicate the depth to the base rock surface (in meters).

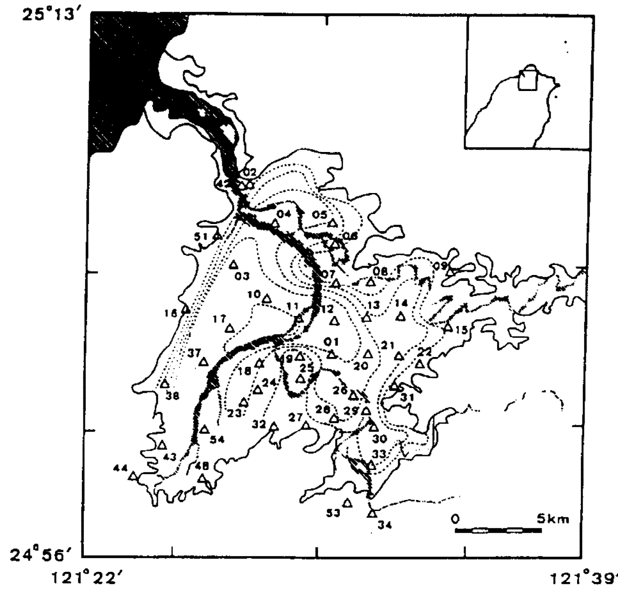

Fig. 2: Locations of the Taipei strong motion observation network.

are examined. Comparison on the ground motion characteristics between different seismic event is also made which include the horizontal peak ground acceleration and spectral ratio contours in the low-frequency band.

GEOLOGY AND THE STRONG MOTION OBSERVATION NETWORK

The area of the Taipei basin with an altitude below 20 meter is about 240 km^2. The basin is filled with unconsolidated sediments. The contour line of the depth of the base rock surface is shown in Fig. 1. The deepest place of the base rock surface, about 250 m in depth, is located on west side of the basin. The geological structure inside the basin consist of the quaternary layers above the tertiary base rock. Table 1 shows the P-wave velocity structure. The stratigraphic formations of the quaternary layers are, in descending order, surface soil, the Sungshan formation, the Chingmei formation and the Hsinchuang formation. The Sungshan formation is composed of alternating beds of silty clay and silty sand and covers almost the whole Taipei basin. The Chingmei formation is a fan-shaped body of conglomeratic deposits. The Hsinchuang formation consists of bluish grey, clayey sand with conglomerate beds.

Under the Taiwan Strong Instrumentation Program, begin executed by the Seismological Observation Center of the Central Weather Bureau, Taiwan, ROC, a total of forty-three stations are already in operation in the free-field of the Taipei basin area. The distribution of stations is also shown in Fig. 2, and stations are indicated by triangle symbols. In this figure, the dotted lines show the contours of the same base rock. The instrument is a force-balanced

Table 1: P-wave velocity structure of Taipei basin

Depth (m)	Layer velocity (m/sec)	Refractor velocity* (m/sec)	Formation
0–10	400	350	Alluvium
10–60	1550	1500	Sungshan
60–120	2050	1260	Chingmei
120–180	2400	2410	Upper Hsinchuang
180–240	3100		Lower Hsinchuang
> 240	3800	3640	Base Rock

Table 2: Earthquake parameters by the strong motion observation network

Event	Time	Epicenter	Depth	ML
1	1994.06 05	121.84E 24.46N	5.3km	6.57
2	1995.06.25		39.9km	6.50

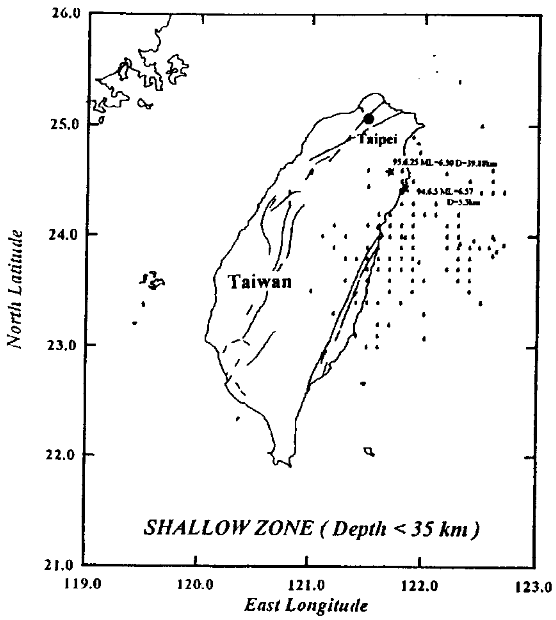

Fig.3: Epicenters of magnitude greater than 6.0 for shallow zone. The epicenters of two events in this analysis were also indicated.

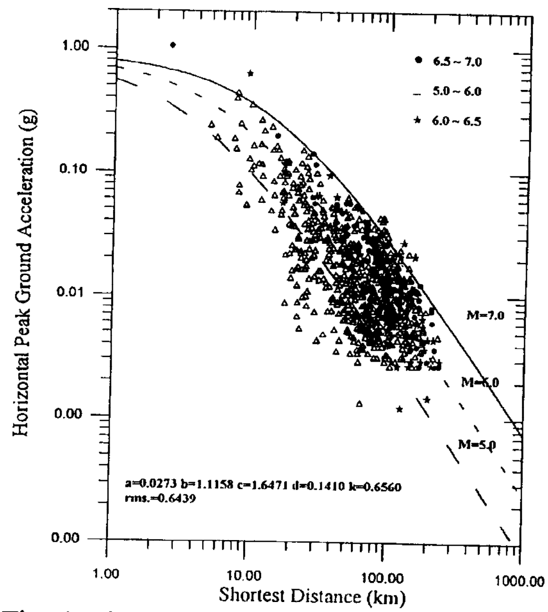

Fig. 4: Plot of horizontal PGA with respect to shortest distance for soft site condition in Taiwan area.

three-component accelerometer with a 16-bit resolution which makes the apparatus capable of recording high-resolution ground motion within ± 2 g and with a pre-event and post-event memory. Several events that triggered at this network. Table 2 listed the two biggest events that were recorded by this network. In this study, the characteristics of ground motion from these two events in the Taipei basin were analyzed both in time and frequency domains in order to understand the seismic response of the basin.

EARTHQUAKE ENVIRONMENT AND SEISMIC HAZARD ANALYSIS

The recent seismicity map adjacent to the Taipei basin is shown in Fig. 3 (events of which

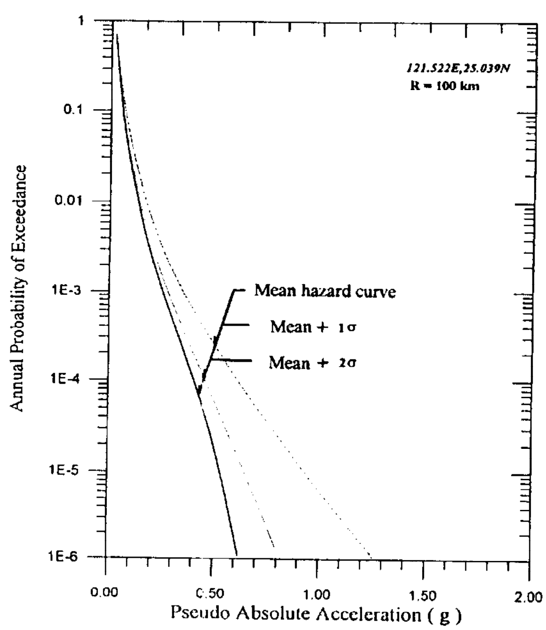

Fig. 5: Seismic hazard curve of Taipei area.

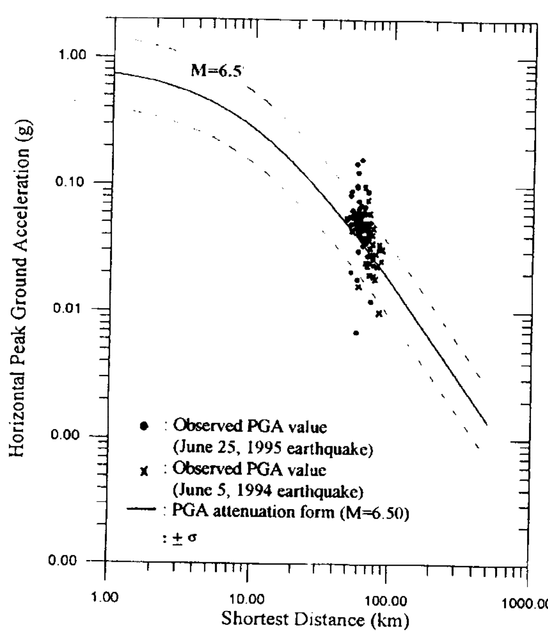

Fig. 6: Comparison of recorded PGA in Taipei basin with PGA attenuation form of M=6.50

magnitude are larger than 6 are plotted based on the data from Central Weather Bureau). The seismic activity around the basin is not so high at present. Generally, a seismic hazard analysis was employed to that site in the first place. The probability of the intensity Y exceeding y at that site in one year is given by:

$$P\left[Y > y\right]_{1\text{ year}} = \sum_{i=1}^{n} \left\{ \int_{m_0}^{m_u} P\left[Y > y \middle| E_i(m)\right] f_M(m)\, dm \right\} v_i \Big/ v \tag{1}$$

where m_0 and m_u are the lower and upper bound magnitudes ($m_0 = 4.5$), and $f_M(m)$ is the density function of earthquake magnitude. E_i is the occurrence of the earthquake in source i, and n is the number of potential earthquake sources in the region. v is the average occurrence rate of earthquake. As expected, much of the effort in a seismic hazard analysis requires the determination of the parameters, and among these hazard parameters the peak ground acceleration (PGA) attenuation relationship is the most important one. The PGA attenuation form with soft site condition developed from data collected from Taiwan area was adopted, as shown in Fig. 4, for hazard analysis. It plotted the PGA value with respect to the shortest distance R, and expressed as follows:

$$y = 0.0273 f\, e^{1.1158\,M} \left(R + 0.141\, e^{0.656\,M}\right)^{-1.6471} \tag{2}$$

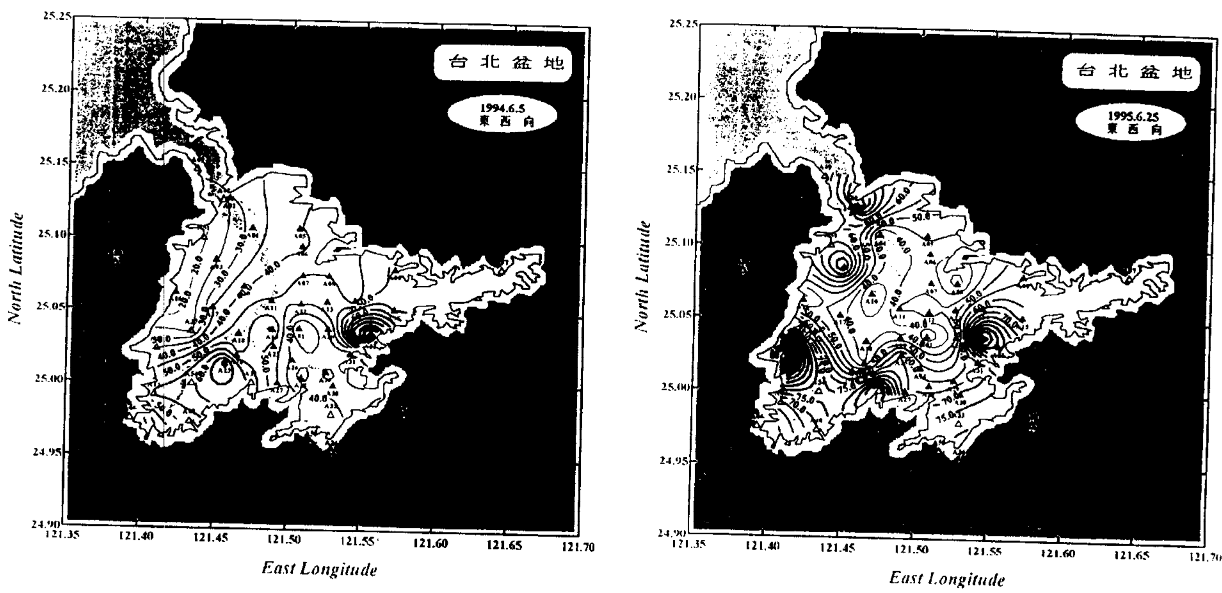

Fig.7: Peak ground acceleration contour map of Taipei basin (East-West direction only).
(a) for June 5, 1994 earthquake; (b) for June 25, 1995 earthquake.

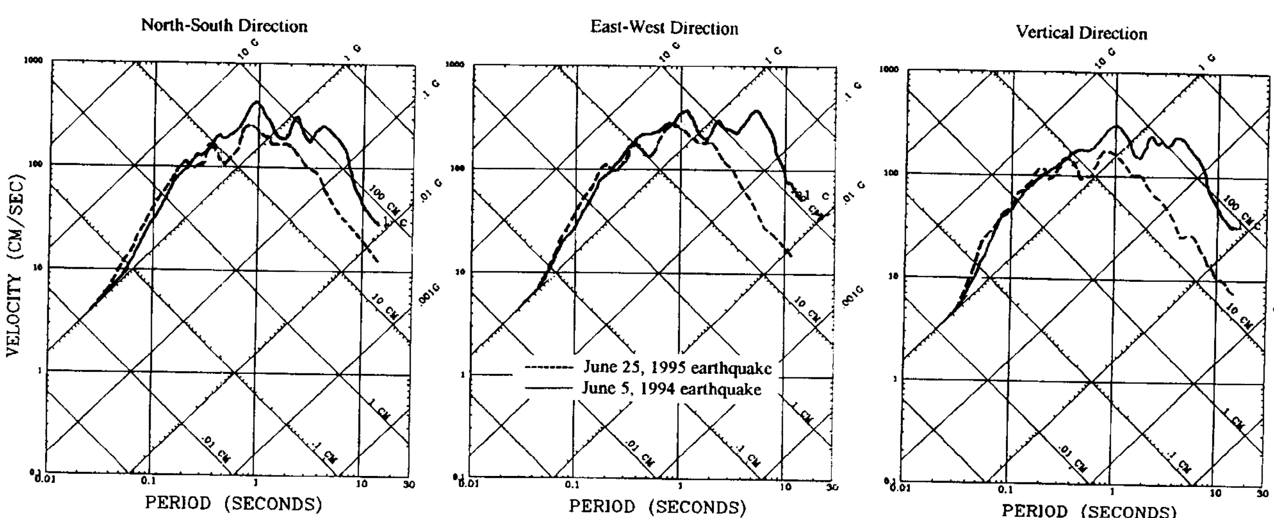

Fig.8: Comparison on the mean plus one standard deviation response spectrum (5% damping).
(a) North-South direction, (b) East-West direction, (c) Vertical direction.

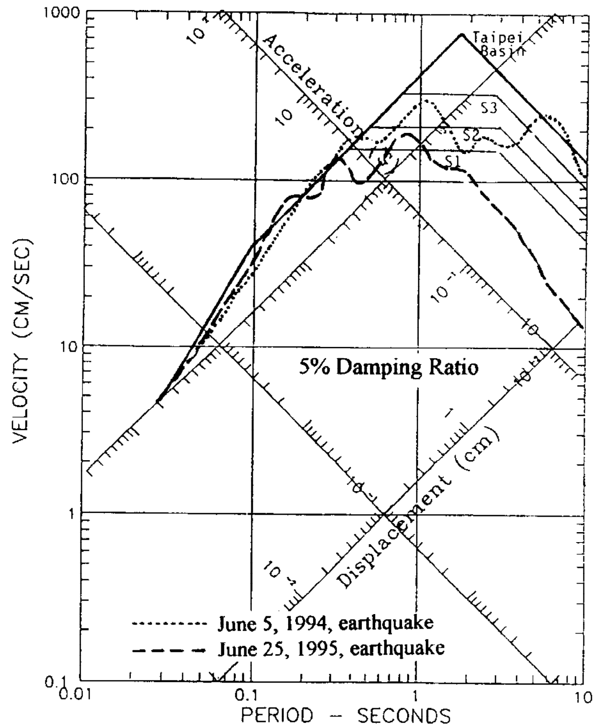

Fig.9: Normalized mean response spectrum of two events from the Taipei basin. The code-provided design spectrum of Taiwan area is also shown for comparison.

the standard deviation of the logarithm of PGA dispersion is 0.644. Based on Eq. (1), the seismic hazard curve at the Taipei basin is shown in Fig. 5. For return period of 475 year (i.e., $P[Y > y] = 2.1 \times 10^{-3}$) the estimated PGA value is 0.21 g (if one standard deviation of PGA dispersion is considered). The attenuation equation shown in Eq. (2) is good for the estimation of seismic hazard at Taipei basin. Figure 2 shows the comparison on the recorded PGA value (for two events shown in Table 2) with the PGA attenuation form of $M = 6.5$.

GROUND MOTION CHARACTERISTICS OF BASIN EFFECTS

Before the analysis of ground motion characteristics of the Taipei basin, it is pointed out that the source characteristics of the recorded two events (shown in Table 2) are not similar. One is the shallow earthquake with depth $D = 5.3$ km (June 6, 1994 earthquake) and the other one is the deep earthquake with depth $D = 39.9$ km (June 25, 1995 earthquake). The following topics are discussed from the analysis of the data:

Peak Ground Acceleration Distribution – Consider only the motion along East-West direction only. The PGA distribution of these two events are not similar. For event 1 the largest PGA occurred on the east-south part of the basin, and for event 2 the largest PGA value occurred on the west part of the basin. Figure 7 shows the contour of the PGA distribution of these two events.

Response Spectrum Analysis – The mean plus one standard deviation of the response spectrum from these two events are calculated and shown in Fig. 8. It is found that the response spectrum of the basin of June 5, 1994 earthquake contains much more longer period waves than that of June 25, 1995 earthquake. Comparison on the calculated mean plus one standard deviation response spectrum of these two events with the code-provided response spectra of Taiwan area is shown in Fig. 9.

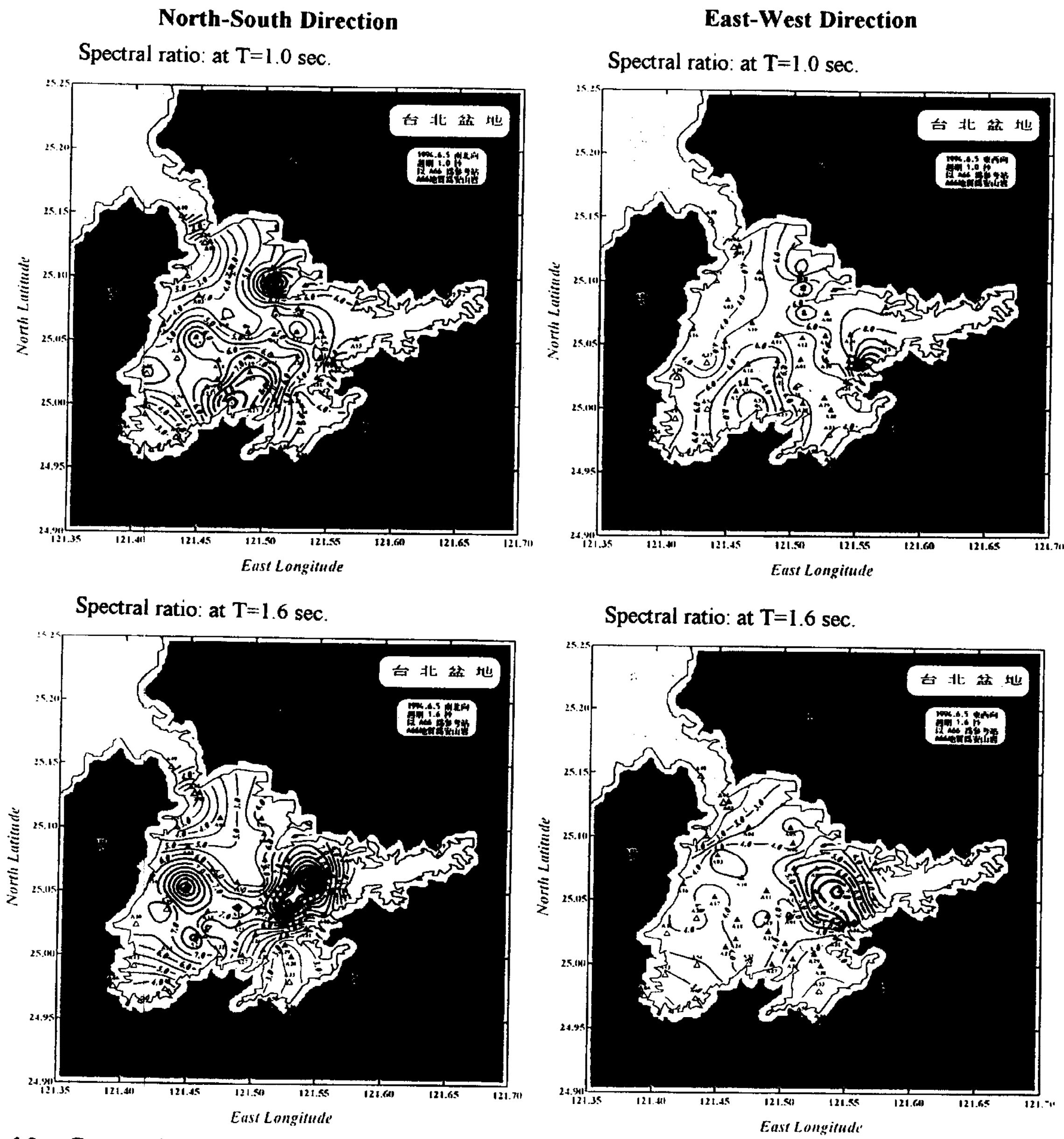

Fig.10a: Comparison on the contour map of spectra ratio of the Taipei basin of June 5, 1994 earthquake for T=1.0 sec and T=1.6 sec. (a) North-South direction, (b) East-West direction.

Spectral Ratios – To compute the spectra ratios the response spectra (pesudo-acceleration) for 5% of critical damping was first calculated. Then the ratios in each direction were computed for each earthquake at each station in the Taipei basin relative to station A66 (a reference site with rock site condition) in the same direction. Figures 10a and 10b show the contour map of spectra ratios at periods of 1.0 sec and 1.6 sec from these two events. It is found that larger site amplification was observed on the west side of the basin for event 2 where the soil layer is deepest (probably due to the waves propagate vertically from the bottom of the base rock since event 2 is an earthquake with focus of 40 km). For event 1 larger spectra ratio was observed at south east part of the basin.

Correlation of Strong Motion Duration with Site Amplification – Strong motion duration for event 2 correlated very well with the spectra ratio contour. Larger spectra ratio will have longer strong motion duration. On the contrary the strong motion duration for event 1 is inversely proportional to the spectra ratio contour. Larger spectra ratio will have shorter strong motion duration for event 1. Figure 11 shows the duration contour of these two events along east-west direction.

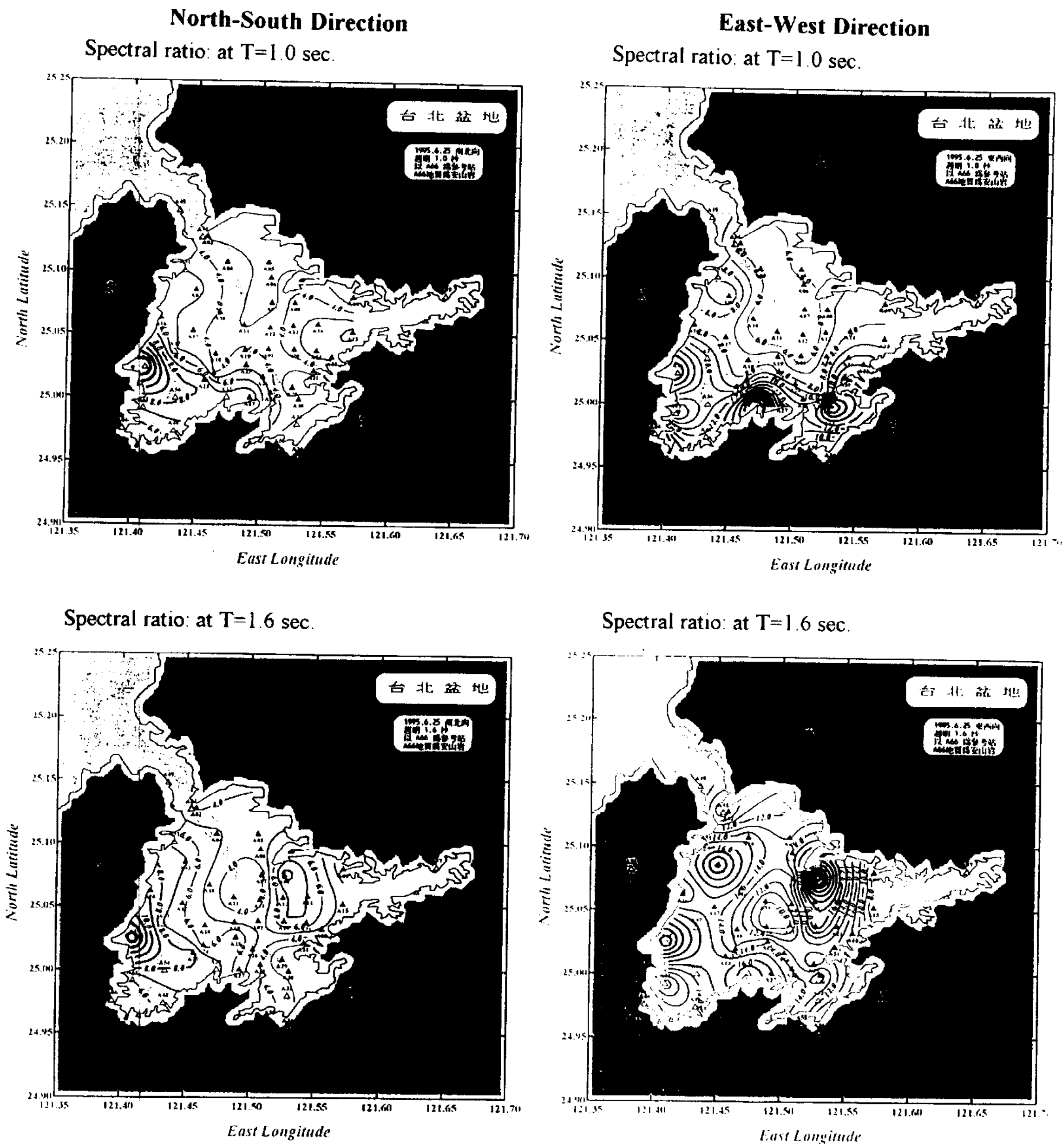

Fig.10b: Comparison on the contour map of spectra ratio of the Taipei basin of June 25, 1995 earthquake for T=1.0 sec and T=1.6 sec. (a) North-South direction, (b) East-West direction.

<u>Principal direction analysis</u> -- The principal direction of the ground motion is determined from the three orthogonal acceleration components of ground motion. Using frequency window, the variance-covariance matrix of three-dimensional ground motion along three mutual perpendicular direction is evaluated. the direction of principal axes are the eigenvectors derived from the covariance matrix. Fig.12 shows the result of analysis at station no.11 of the Taipei basin instrumentation network. The principal directions of these two events in low frequency bands are either parallel or perpendiculat to the source rupture direction.

CONCLUSIONS

This research provides information on the fundamental study of site amplification from two seismic events data recorded by the strong motion observation network in Taipei basin. Because of the entirely two different seismic source (event 1 is the shallow earthquake and event 2 is the deep earthquake) the results of site amplification, such as peak ground acceleration distribution, spectra ratio contour in the basin and the distribution of strong motion duration, are quite different. If the assumption of the variation in the spectral ratio at a given site are random

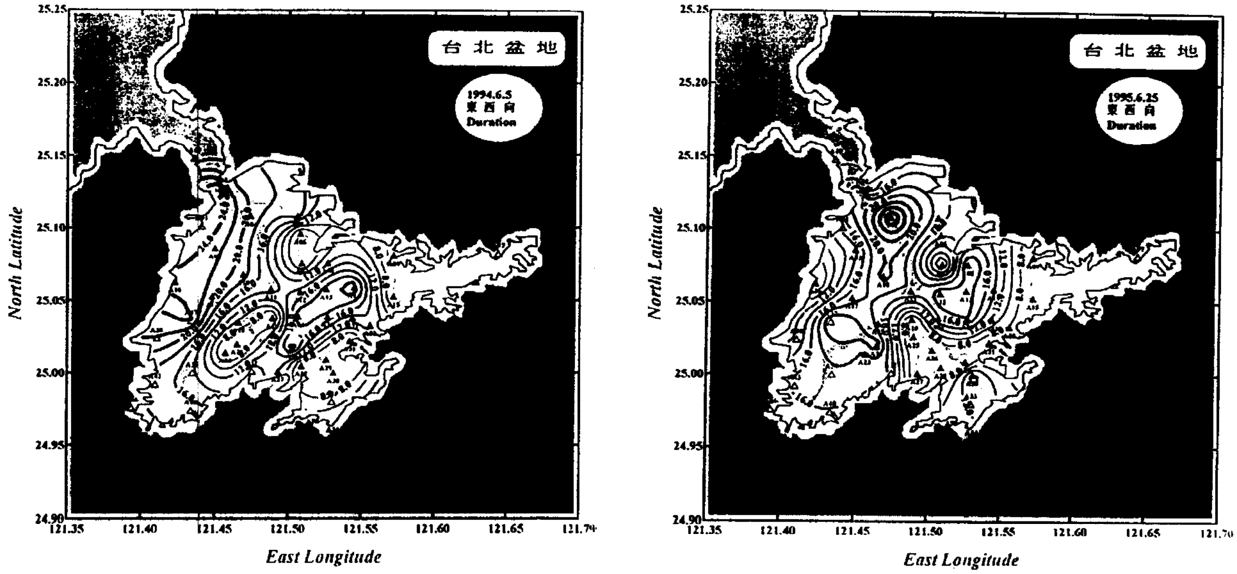

Fig. 11: Contour map of the strong motion duration in East-West direction, (a) for June 5, 1994 earthqake, (b) for June 25, 1995 earthquake.

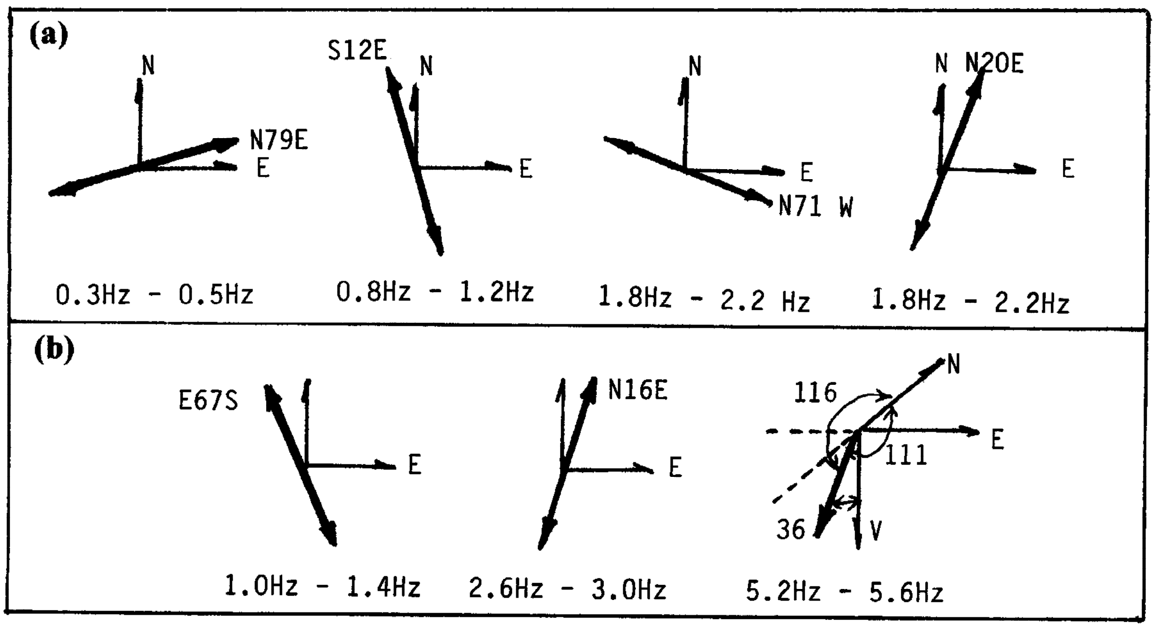

Fig. 12: Principal direction analysis at station No.11 of the Taipei basin; (a) for June 5, 1994 earthquake, (b) for June 25, 1995 earthquake.

and not functions of the earthquake focal characteristics, it is appropriate to use average ratios instead of single event for each site as the corresponding estimators. For the seismic design implementation more seismic data are needed for further study.

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