A STUDY ON THE GROUND MOTION CHARACTERISTICS OF TAIPEI BASIN, TAIWAN, BASED ON OBSERVED STRONG MOTIONS AND MEASURED MICROTREMORS

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ABSTRACT :

Taipei basin suffered serious damage on building structures during the 1999 Chi-Chi earthquake, even though it was located 100 km away from the epicenter. The purpose of this paper is to discuss the relationship between the damage occurred and the ground motion characteristics observed in the Taipei basin and to draw a seismic microzoning map for the region by taking into account the analyzed results about the earthquake motions, microtremors and the damage distribution. For more discussion about site effect evaluation, observed strong motions of two earthquakes, which happened in 1994, 1995 will be used in addition to the 1999 earthquake. Such records of strong motions of those earthquakes were offered by the Central Weather Bureau (CWB), Taiwan. Measurements of microtremors inside Taipei basin were made in 2000 after the Chi-Chi earthquake.

KEYWORDS: Ground Motion Characteristics, Taipei Basin, Seismic Microzoning, The 1999 Chi-Chi earthquake, Building damage

1. BACKGROUD AND PURPOSE

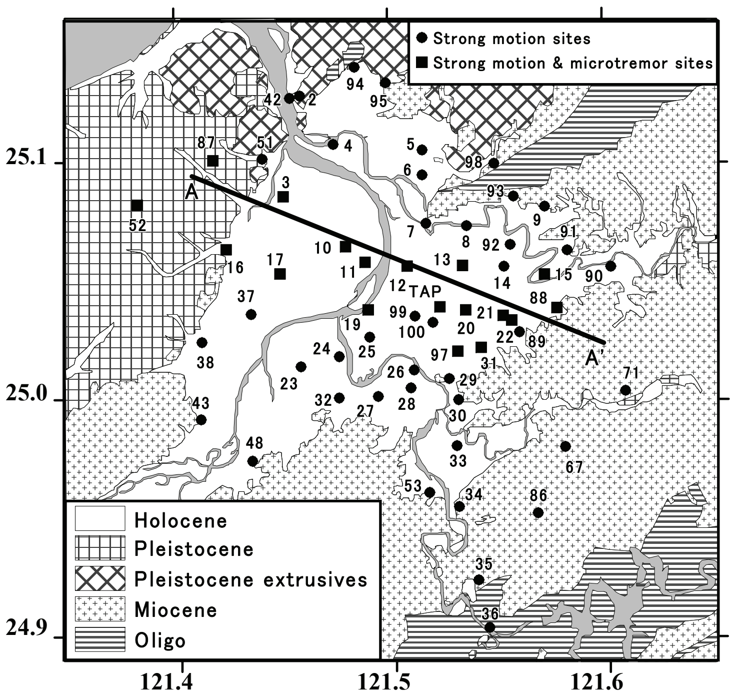

Figure1 Geological condition and Location of CWB strong motion stations around Taipei basin

Taiwan, located in the western part of Circum-Pacific seismic zone, often suffers earthquake disaster. About 1/3rd of the population of Taiwan concentrates in Taipei basin, and the urban development is expending from Capital Taipei to the whole of Taipei basin. So it is very important to make sure the relationship between earthquake damage distribution and the ground motion characteristics of Taipei basin.

Taipei basin (Figure 1) has a triangle shaped alluvium structure, and the area (about 240 square kilometers) is almost flat with an altitude lower than 20 meters. The geological structure inside the basin (Figure2) consists of the Quaternary layers, which were classified into four stratigraphic formations **(Deng, 1996)** above the Tertiary base rock.

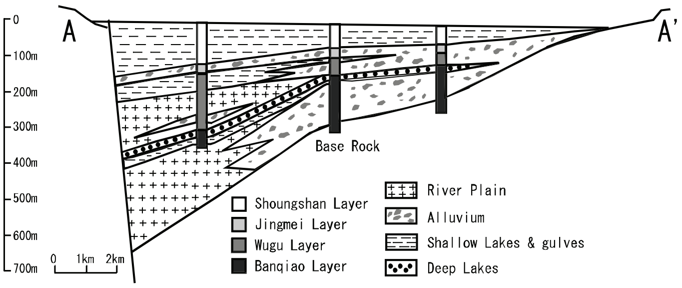

Figure 2 A-A' section

Regarding the previous studies on Taipei basin, **Wen et al. (1995, 2000)** and **Sokolov et al. (2000)** have discussed on the seismic amplification of the basin. **Tsai et al. (1999)** identified Taipei Basin into 4 groups using the shapes of response spectral ratios according to the predominant frequencies. In this study, the measured microtremors (Figure 1) and observed strong motions of three earthquakes, those happened in 1994, 1995 and 1999 (Table 1, Figure 3) have been used, considering site 36, which is on the hard rock in Taipei region as reference point, to classify the site characteristics of Taipei basin.

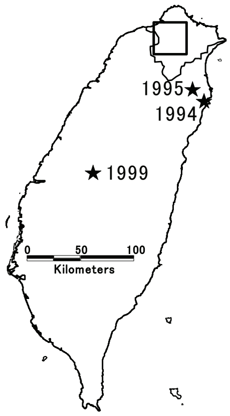

Figure 3 Location of epicenters and the objective region

Table 1 Focal information of the earthquakes happened in 1994, 1995 and 1999

EQ	Origine Time	Lon (°)	Lat (°)	Depth (km)	M_L
1994	1994/06/06 09:09	121.8	24.5	5.3	6.2
1995	1995/06/25 14:59	121.7	24.6	40	6.5
1999	1999/09/21 01:47	120.8	23.9	8	7.3

2. GROUND MOTION CHARACTERISTICS USING STRONG MOTIONS AND MICROTREMORS

2.1. Ground Motion Characteristics of Strong Motions

For the evaluation of ground motion characteristics in the basin, it is necessary to remove the source and propagation path effects. Then we considered Site 36 with the hardest site condition as the reference point in this study. Figure 4 shows the response spectra of strong motions at the reference point Site 36.

Figure 1 shows the scheme of the Taipei Basin and sites of Taipei strong motion observation network those were used in this study. Figure 3 shows the epicenters of earthquakes and the objective region. Table 1 shows the focal information of the earthquakes those happened in 1994, 1995 and 1999.

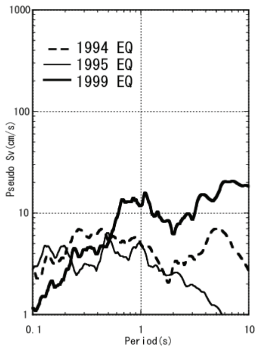

Figure 4 The response spectral of strong motion at Site 36

As Taipei basin suffered serious damage during the 1999 Chi-Chi earthquake, it is important to investigate the ground motion characteristics due to the 1999 Chi-Chi earthquake data. Considering Site 36 as the reference point, the response spectral ratios of the 1999 Chi-Chi earthquake were obtained as Figure 5. Following to different surface geologic conditions, such as a)hard rock, b)basin edge, c)soft rock with thin sediments, d)thin sediments and e)thick sediments regions, we identified observed strong motion characteristics into 5 regions (Figure 5).

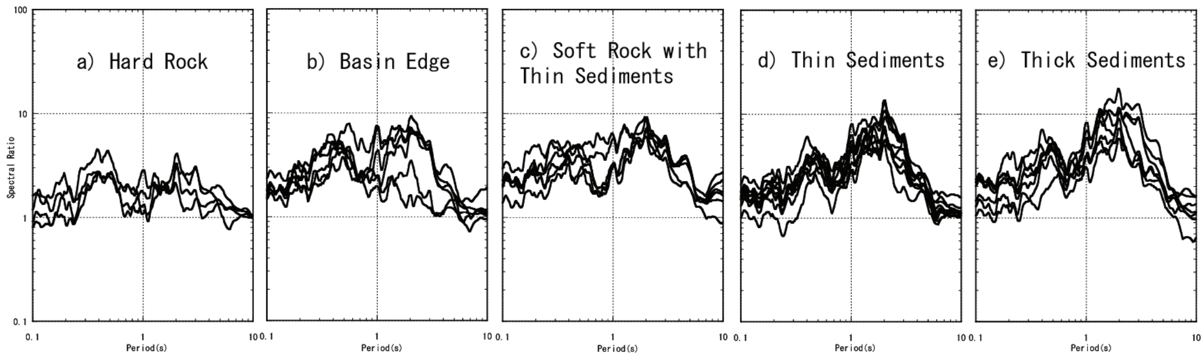

Figure 5 Identification of the response spectral ratios using the 1999 earthquake data (h=5%)

Similar identification was also done using the 1994 and 1995 earthquakes. Figures 6 and 7 show the results of identified response spectral ratios using the 1994 and 1995 earthquakes, respectively.

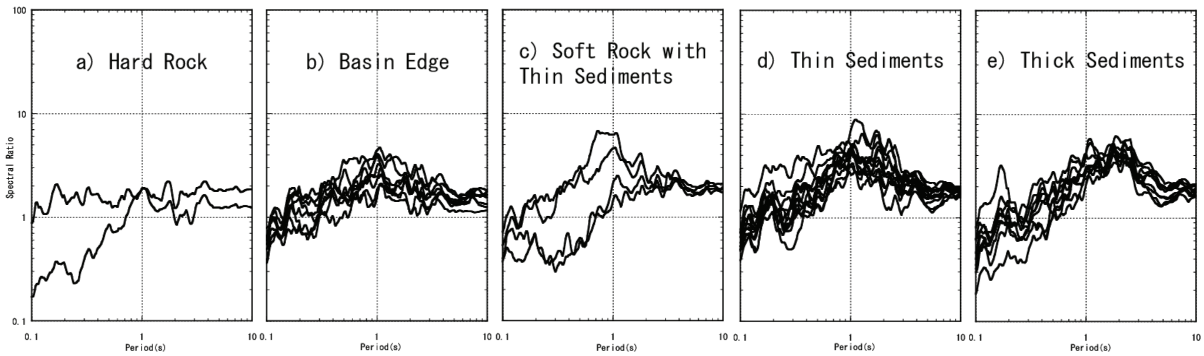

Figure 6 Identification of the response spectral ratios using the 1994 earthquake data (h=5%)

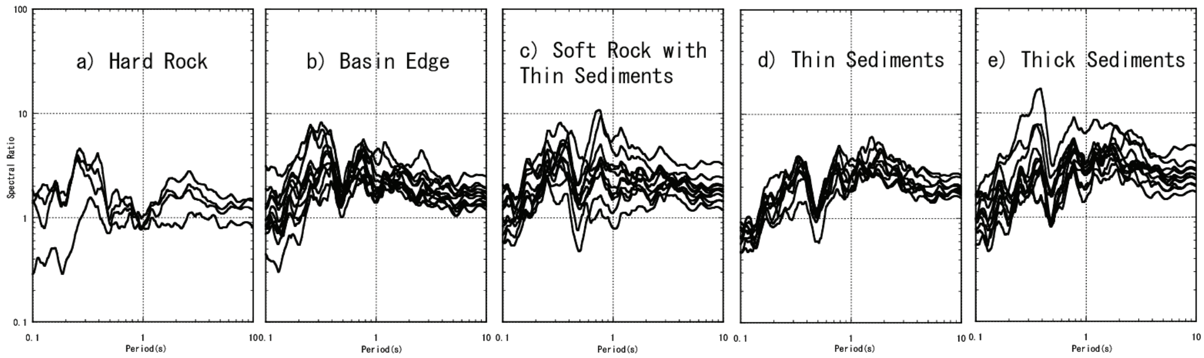

Figure 7 Identification of the response spectral ratios using the 1995 earthquake data (h=5%)

The group of respective sites are categorized as following.

a) Hard rock region (34, 67, 71, 86,98)
b) Basin edge region (2, 7, 9, 29, 30, 35, 43, 48, 53, 91, 93, 94, 95)
c) Soft rock with thin sediments region (15, 27, 32, 33, 42, 51, 52, 87, 88, 89,90, 92)
d) Thin sediments region (4, 5, 6, 8, 12, 13, 14, 19, 22, 23, 24, 26, 28, 31)
e) Thick sediments region (3, 10, 11, 16, 17, 20, 21, 25, 37, 38, 99, 100, TAP)

The predominant peak period around 2.0 seconds can be seen in all regions during the 1999 Chi-Chi earthquake. It is probably because of the surface wave caused by the deep sediments in the basin. In the 1994 earthquake, 1.0 second peak period can be seen at the basin edge and soft rock with thin sediments regions. On the other hand, 0.35 seconds and 0.8 seconds componentsare obvious in the response spectral ratios of the 1995 earthquake.

2.2. Ground Motion Characteristics of Microtremors

We measured the microtremores along the section A-A' of Taipei basin (Figure 1). Because we want to try the similar identification of site conditions with microtremors as well as strong motions. Where the characteristics of microtremors will be evaluated using H/V spectral ratios. They were classified into the following three groups.

1) Soft rock with thin sediments region (15, 52, 87, 88)
2) Thin sediments region (12, 13, 19, 22, 31, 97)
3) Thick sediments region (3, 10, 11, 16, 17, 20, 21, TAP)

Here the groups 1), 2) and 3), classified with microtremors are in correspondence with the group c), d) and e) identified with strong motions, respectively.

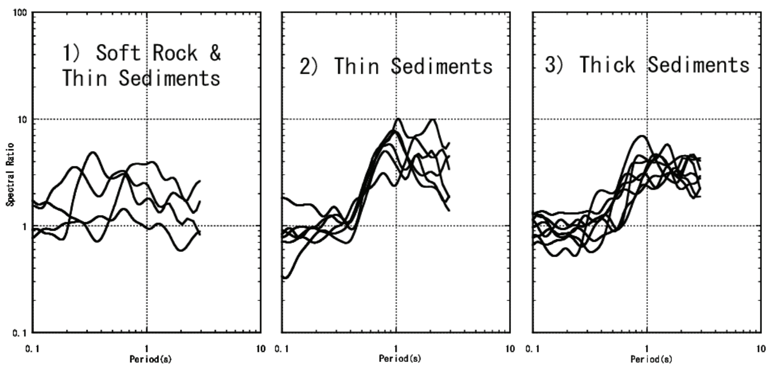

Figure 8 Classification of microtremors H/V spectral

As shown Figure 8, we can see quite different ground motion characteristics on microtremors. For example, they look very flat in the soft rock with thin sediments region. There is no sharp peak in thick sediments region, and 1.0 second peak period can be seen very clearly in thin sediments region.

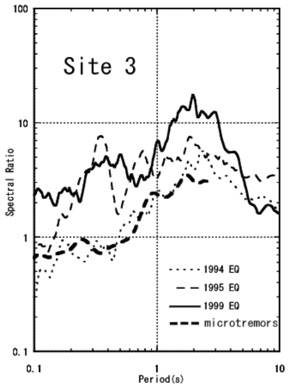

Figure 9 Spectral comparison of microtremors with earthquakes at Site 3

Figure 9 shows the comparison of response spectral ratios among the 1994, 1995, 1999 three earthquakes response spectral ratios and the H/V spectral ratio of microtremors at Site 3. It was observed that the H/V spectral ratio of the microtremors were almost similar to the response spectral ratios of strong motions, especially similar to that of the 1994 earthquake.

3. COMPARISON OF THE DAMAGE DISTRIBUTION AND THE GROUND MOTION CHARACTERISTICS IN TAIPEI BASIN DURING THE 1999 CHI-CHI EARTHQUAKE

According to “ The first report of the building damage during the 921 Chi-Chi earthquake” **(1999)** , the most serious damage was found along the seismic fault regions of course, but the second serious damage appeared in Taipei basin, which was more than 100km away from the epicenter of the 1999 Chi-Chi earthquake. It is reported that 500 buildings were damaged inside the basin. On the other hand, there was almost no damage outside the basin.

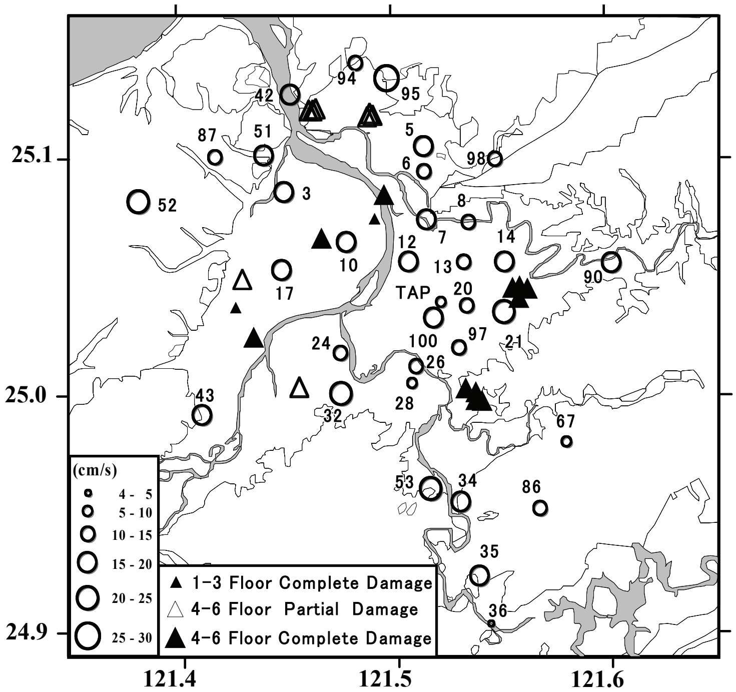

Figure 10a Comparison of the distribution of damaged 1-3,4-6 floor buildings and the average response velocities in 0.2-0.6 seconds period during the 1999 Chi-Chi earthquake

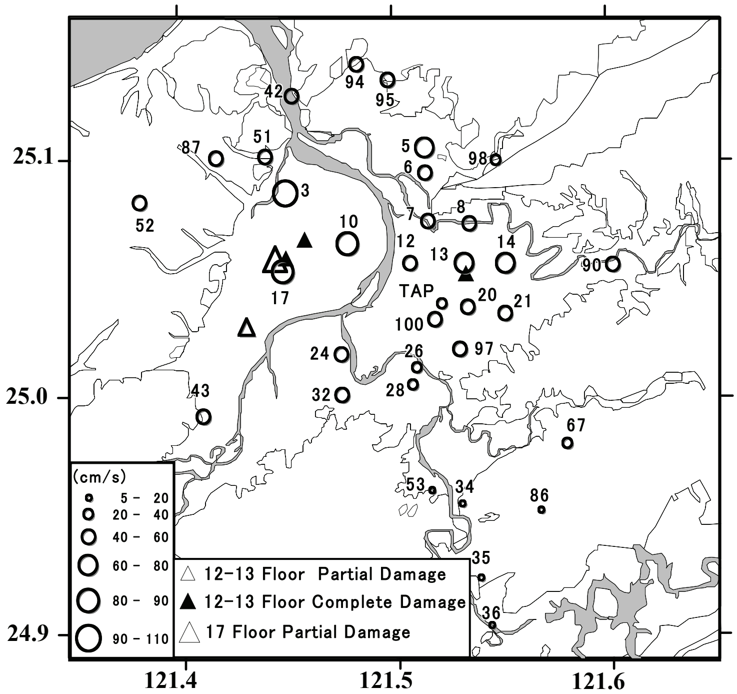

Figure 10b Comparison of the distribution of damaged 12-13,17 floor buildings and the average response velocities in 1.0-3.0 seconds period during the 1999 Chi-Chi earthquake

From the response spectral ratios during the 1999 Chi-Chi earthquake, peak period of 0.4 seconds can be seen in every region. So we think that the serious damage happened because of such component. Figure 10a shows the comparison of damage distribution on the 1-3, 4-6 floor buildings and period average response velocities of the strong motions in 0.2-0.6 seconds period. Similarly, peak period of 2.0 seconds can be seen too. Then, Figure 10b shows the comparison of damage distribution on the 12-13, 17 floor building and period average response velocities of the strong motions in 1.0-3.0 seconds period. As we can see in Figures 10a and 10b, the relationship between the building damage distribution and the distribution of related response velocities are almost consistent each other.

4. DISCUSSION AND CONCLUDING REMARKS

As there are a lot of high buildings in the basin, we can assume that the strong motions of around 2 seconds period will affect those buildings. We draw the amplification contour of the average response spectral ratio in the period ranges of 1.0 ～3.0 seconds during the 1999 Chi-Chi earthquake, considering Site 36 as reference point (Figure 11). We can see the maximum amplification reached to 10 times around Site 3. So it is the most vulnerable area for the high buildings in Taipei basin, in the case that a very large and shallow earthquake occurs around the area.

Sokolov et al. (2000) thought the seismic network in Taipei basin, despite of large number of the stations, couldnot provide a reference site which is suitable to be accepted, undoubtedly, as “hard-rock reference” site. So they modeled a hypothetical very hard rock site of the 1999 Chi-Chi earthquake in Taipei basin by the single-corner frequency Brune ω^{-2} source model. They Considered the very hard rock site as the reference point, the contour for distribution of the maximum amplitudes of the amplification in the period ranges 1.0 ～3.0 seconds during the 1999 Chi-Chi earthquake, was drawn. Compared with their study, the amplification distribution obtained in our research is almost consistent.

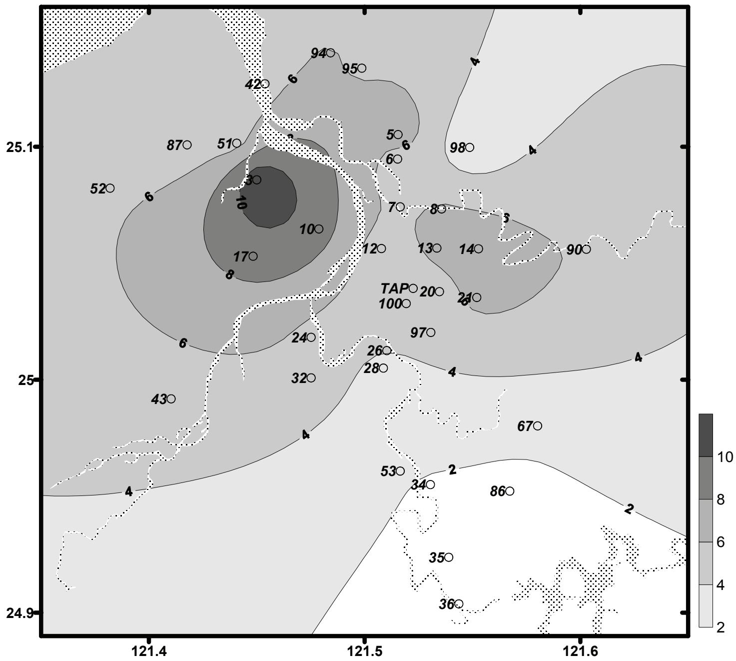

Figure 11 Contour of average response spectral ratios for the period range 1.0～3.0 seconds in Taipei basin, using the 1999 Chi-Chi earthquake data

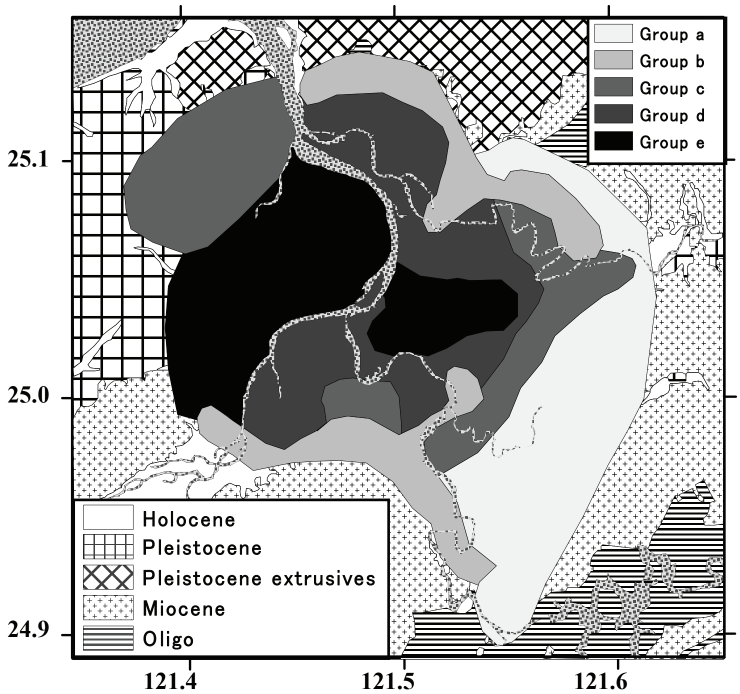

Figure 12 Seismic microzoning map of Taipei basin

We tried to draw the seismic microzoning map of Taipei basin (Figure 12), considering the observed strong motions and measured microtremors, and also the damage distribution in Taipei basin during the 1999 Chi-Chi earthquake. We identified different site conditions into 5 groups. The characters of respective groups can be summarized as follows.

Group a) on the hard rock, in the east of the basin: The response spectral ratios are almost flat and the amplification is very low.

Group b) on the edge of basin: The short peak period of 0.4 seconds is obvious.
Group c) on the soft rock with thin sediments: When a deep earthquake occurs, the peak period of 0.8 seconds will be observed. When a shallow earthquake occurs, the peak period will become much longer. If the scale of earthquake is larger, the peak period will be longer.
Group d) on the thin sediments: When a deep earthquake occurs, the amplification will be small. When a shallow earthquake occurs, the amplification will be big.
Group e) on the thick sediments: In case of a shallow earthquake, long peak period of 2.0 seconds will be resonant. When a deep earthquake occurs, short peak period of 0.35 seconds will be obvious.

According to **Tsai et al. (1999)**, the objects are 52 sites in the Taipei basin and the strong motion data were obtained from more than 20 earthquakes. Taipei basin was classified into 4 groups by response spectral ratios. The peak periods of Group1, Group2, Group3, Group4 are 2 seconds, 1.65 seconds, 0.15 seconds and 0.9 seconds, respectively. Compared with this study, the amplification distribution obtained in our research is almost consistent.

In conclusion, we found that the sediments regions inside the basin will resonate around 2.0 seconds period, when a large and shallow earthquake occurs even far from Taipei basin. So those buildings, which have a predominant period around 2.0 seconds, will be in danger. The application of microtremors is an effective method for compensating for the microzoning as microtremors are in correspondence with strong motions.

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