WAVELET ANALYSIS APPLICATION TO NEAR FAULT STRONG GROUND MOTIONS

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1. INTRODUCTION

In this study, it is objected to investigate the earthquake motion characteristics of Kocaeli Earthquake (August 17, 1999), Ji-Ji Earthquake(September 21, 1999) and Hyogo-ken Nanbu Earthquake(January 17, 1995) with the application of wavelet analysis which provides us to understand time-frequency characteristics of the motions.

2. OBSERVED STRONG GROUND MOTIONS

The ground motions with peak accelerations as shown in **Figure 1** were used in this study. The JMA-Kobe record was obtained in a station located on a small hill about 20km NE of the epicenter. The YPT record was obtained at Yarimca Petrochemical complex about 10km NW of the epicenter, and the TCU129 record was obtained in the epicentral area in an elementary school building which is located 13.2km W of the epicenter at Ji-Ji. The important quantities related to the intensity of ground motion for above 3 earthquakes are summarized in **Table 1**. The PSA and PSV of the 3 earthquakes are shown in **Figure 2**. The Total Energy in Table 1 was identified using the following conventional formulation;

$$E_T = \int_0^{t_d} \ddot{u}_g^{\,2}(t)dt \qquad \textbf{(1)}$$

Here, $\ddot{u}_g(t)$ is the ground acceleration-time history and t_d is its time duration. The total energy gives the energy of acceleration record, and as a ground motion intensity it is sometimes a more appropriate index than peak acceleration itself since it doesn't depend only on acceleration amplitude but also on time duration. In **Figure 3**, the variation of total energy with time is shown for above mentioned 3 earthquakes. It is observed from the figure that although JMA-Kobe record has a sharp increase in a very short time period, YPT and TCU129 records have a slight increase in a long time period.

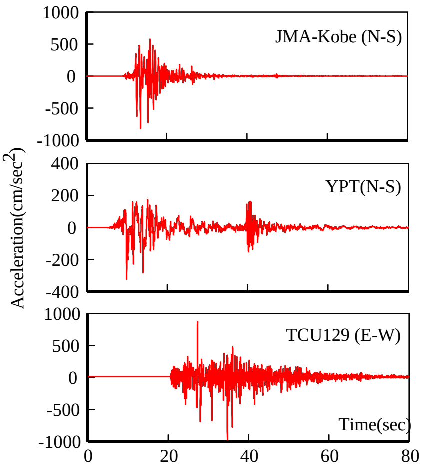

Fig. 1 Acceleration records

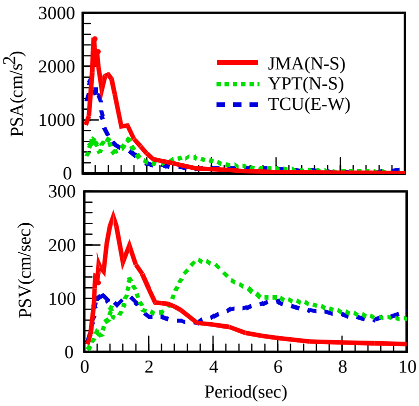

Fig.2 PSA and PSV of the records

3. WAVELET ANALYSIS

Wavelet analysis provides us to characterize the ground motions in both frequency and time domain. It decomposes the original signal into a set of level signals.

$$WC(a,b) = WC(j,k) = \sum_{t\in Z} f(t)\varphi_{j,k}(t)\ , \quad \varphi_{j,k}(t) = 2^{-j/2}\varphi(2^{-j}t - k) \qquad \textbf{(2), (3)}$$

$$a = 2^j \quad b = k2^j \quad j \in N \quad k \in Z$$

where j is frequency level, k is time shift, WC is wavelet coefficient, and φ is wavelet function. Daubechies' 10 coefficient mother wavelet function as shown in **Figure 4** was used for wavelet analysis of ground motions. In **Figure 5** the time-frequency characteristics of each earthquake motion was presented. It shows that JMA-Kobe record has 2 main frequencies around 1.2 and 2.3 Hz. The YPT record has low and high frequency content in first 20 seconds, however around 40 seconds only high frequency content appears. The TCU129 record shows quite high frequency content.

Earthquake	Record	PGA (cm/s^2)	PGV (cm/s)	Total Energy (x 10^5 cm^2/s^3)	Main motion duration (s)
Hyogo-ken Nanbu	JMA-Kobe (N-S)	820.6	91.7	5.30	15
Kocaeli	YPT (N-S)	322.2	89.0	1.00	35
Ji-Ji	TCU129 (E-W)	972.1	50.3	5.90	30

Table 1 Ground motions intensities for each earthquake

4. ENERGY DISTRIBUTION IN WAVELET DOMAIN

The equation (1) can be applied for each frequency level in wavelet analysis. Using the decomposed signal wavelet coefficients instead of original signal, the total energy of each frequency level is obtained as in equation **(4)**.

$$E_{j,T} = \int_0^{t_d} WC_{j,k}^{\,2}(t)dt \qquad E_{j,T} = 2\int_{\omega_{1j}}^{\omega_{2j}} |F(\omega)|^2 d\omega \qquad \textbf{(4), (5)}$$

Through the Parseval's theorem the total energy can be obtained in frequency domain as in equation **(5)**. Here $|F(\omega)|$ is the Fourier amplitude of the original signal in the frequency range from ω_{1j} to ω_{2j}, where;

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$$\omega_{1j} = 2^{-j-1} / \Delta t \; ; \omega_{2j} = 2^{-j} / \Delta t \qquad (6)$$

In **Figure 6**, the total energies for each earthquake in different frequency bands are presented. It is seen that if the total energies in each frequency bands are added to each other, the total energy of the conventional method which is shown in Figure 3 is obtained. It can be figured out from Figure 6 that JMA-Kobe record has main total energy within the frequency range from 0.78 to 3.125Hz. The YPT record has almost same level total energy for each frequency bands. For the TCU129 record, it is apparent from the figure that the record has the main total energy in the high frequency band within 3.125-6.25Hz range. The energy input for each frequency level becomes as follows by averaging the square of Fourier amplitude in each frequency range.

$$E_{j,I} = \frac{1}{\omega_{2j} - \omega_{1j}} \int_{\omega_{1j}}^{\omega_{2j}} \left| F(\omega) \right|^2 d\omega \qquad (7)$$

and using the equations **(4), (5)** and **(6)**, it is converted to time domain as follows;

$$E_{j,I} = 2^{-j} \Delta t \int_0^{td} WC_{j,k}^{\ 2}(t) dt \qquad (8)$$

In **Figure 7**, the Energy input into structures in different frequency bands is shown. This equals to the energy input into a SDOF system with a mass of 2 in different frequency ranges. Although TCU129 record in Figure 6 has the total energy 10 times larger than YPT record, it is seen from the Figure 7 that the Energy input into structures are almost same in two records but in different frequency ranges. The YPT record shows that the main energy input into the structures is in long periods, and for the TCU129 record it is in short periods.

5. CONCLUSION

The ground motion characteristics of Hyogo-ken Nanbu, Kocaeli and Ji-Ji earthquakes were studied with wavelet analysis application. The conventional energy principles were applied to wavelet analysis. The results showed an agreement with the conventional methods and wavelet analysis. The wavelet analysis revealed the ground motion characteristics in both time and frequency domain.

6. REFERENCES

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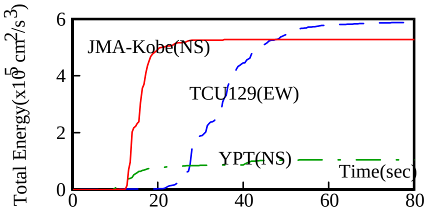

Fig.3 Total Energy of 3 acceleration records

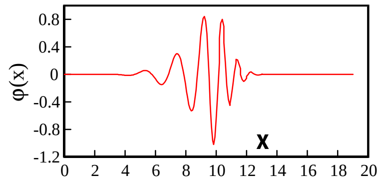

Fig.4 Daubechies 10 coefficient Wavelet function

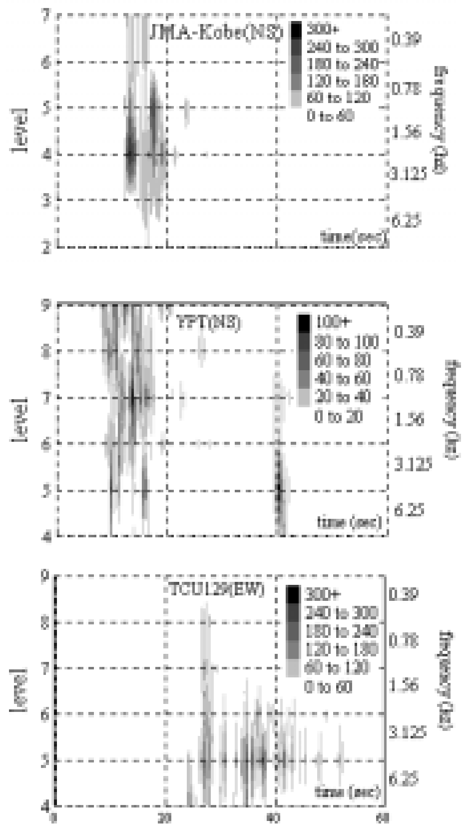

Fig.5 Time-Frequency representation of earthquake ground motions

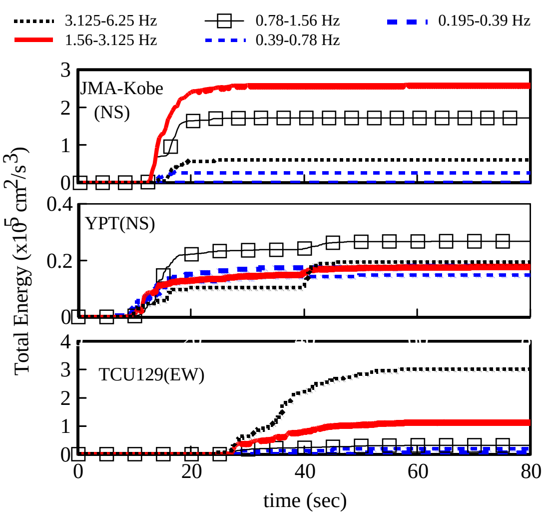

Fig.6 Total Energy in Frequency Bands with Wavelet analysis

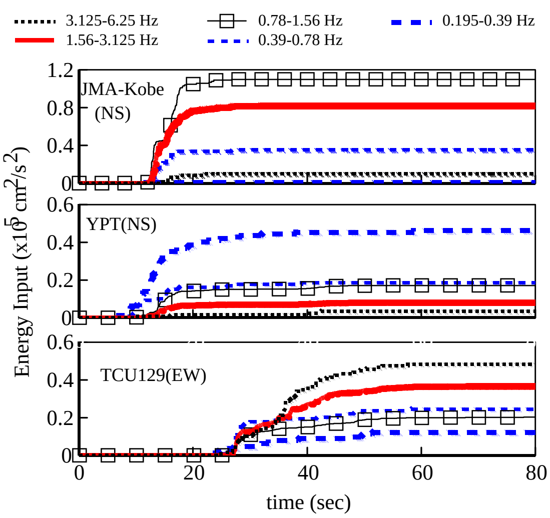

Fig.7 Energy Input in Frequency Bands with Wavelet analysis