0072

DESIGN BASED SEISMIC INPUT FOR SEISMIC ISOLATION SYSTEM

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SUMMARY

In this paper, the simple methodology for estimating earthquake strong ground motion for seismic isolation system was proposed. In general, The predominant periods of seismic isolation systems are in period range 1.0 sec. to 5.0 sec. It is well known fact that the surface wave, such as Love wave, must play an important role for earthquake strong ground motion according to magnitude of earthquake, depth of hypocenter and multi-layered structure of subsoil. So, the 5 % damping velocity response spectrum for design based seismic input for seismic isolation system was estimated, considering the effect of Love wave and Body wave, respectively.

INTRODUCTION

Recently, we have more than 500 seismically isolated buildings in Japan. Especially after 1995 Kobe Earthquake, the increase of number of seismically isolated building is in amazement (Fig.1). This might be a reason why people's confidence on Japanese earthquake engineering was betrayed in Kobe,1995, and as the reaction, a new technology(base-isolation) was over-welcome. However, most of big cities are built on soft and narrow alluvial planes. Consequently, base-isolated buildings are built on soft ground. So, some base isolated buildings may meet liquefaction around the buildings as shown in Fig. 2. In order to keep safety during large strong ground motions, it is very important to make a methodology to estimate the design based seismic input for seismic isolation systems considering the effects of surface wave and body wave on soft soil.

2. EMPIRICALLY MODIFIED VELOCITY RESPONSE SPECTRUM

The displacement Fourier spectrum of Love wave was cleared by Harkrider(1970), as follows,

$$U(\omega)= \Sigma S(\omega)k^{0.5}\exp(-3i/4\,\pi)X_{Lj}(\theta,d)A_{Lj}(\omega)/(2\pi r)^{0.5} \qquad (1)$$

This equation is characterized by source spectrum $S(\omega)$, wave number k, radiation pattern X_{Lj}, relative excitation factor A_{Lj}, hypocentral distance r, phase velocity, group velocity, etc. If the rump function was assumed as a source time function, the acceleration Fourier spectrum amplitude is constant in high frequency beyond the corner frequency.

Applying the following experimental relations into eq. (1),

$$\begin{aligned} \log Mo &= 1.5M + 16 \\ \log L_{*} &= 0.5M - 1.8 \\ \log \tau &= 0.5M - 3.2 \end{aligned} \qquad (2)$$

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the following empirical equation was obtained in period range 1.0 to 10 sec.

$$Acc(\omega) = [\ 4.79 \times 10^{21} \times 10^{0.5M} / R^{0.5}] \times I_L \qquad \text{(in gal} \cdot \text{sec)} \tag{3}$$

where, $Acc(\omega)$ is an acceleration Fourier Spectrum, I_L is a coefficient of amplitude of soil for Love wave. The coefficient of amplitude is determined by soil profile and depth of hypocenter. Kudo estimated this value of Kanto area, as an example, and got it approximately as $1.5 \times 10^{20.5}$ ($cm^{0.5} \cdot sec/dyne$). Applying this value into eq.(3), the following eq.(4)was obtained for Kanto area(Kudo, 1978).

$$Acc(\omega) = [\ 7.2 \times 10^{0.5M} / R^{0.5}] \tag{4}$$

In order to confirm the applicability of eq.(3) for Tsuruga area and eq.(4) for Kanto area, I compared the results of eq.(3) and eq.(4) with observed strong motion records(at Tokyo and Tsuruga sites) as shown in Figs. 3 and 4. To estimate numerical acceleration Fourier Spectrum, the soil profiles of each site shown in Table 1 are used. In this figure, the flat line is the enveloped acceleration Fourier spectrum of Love wave spectrum. The estimated amplitude seems to be approximately same levels as observed ones, especially in case of shallow earthquakes (d=10km).

The acceleration Fourier spectrum is approximately equal to the velocity response spectrum with 0 % of damping. So, as shown in Fig. 5, the averaged coefficient of spectral ratio (5%-damping velocity response spectrum / 0% damping velocity response spectrum) is 0.7 in period range 1 to 10 sec. So, we have 5 % damping response spectrum as follows;

$$Sve(h=5\%) = 0.7 \times Acc(\omega) \tag{5}$$

In case of large magnitude, shallow depth, and soil conditions, the spectral amplitude of body wave may be bigger than that of Love wave. In that case, the following empirical equation for body wave was proposed to use instead of one of Love wave (Ishida, 1982).

$$Sve(h=5\%) = 0.7 \times [\ 18 \times 10^{0.5M} / R\ ] \times H(\omega) \tag{6}$$

where, $H(\omega)$ is amplification factor of multi-layer for S-wave.

3. APPLICATION FOR DESIGN BASED SEISMIC INPUT

In slightly longer period range, the 5 % damping velocity response spectra of Love wave was shown in Fig. 6. This is the case of magnitude, M = 8, depth of hypocenter, d = 10 km, and distance, R = 50 km. The site is assumed to be located in Kanto area. This assumed earthquake is shallow earthquake. So, comparing the results obtained from eq.(5) and eq. (6), the response spectrum amplitude of Love wave was estimated to be bigger than that of body wave. In this case, we can use the spectral amplitude of Love wave as the design-based amplitude of input for seismic isolation system in period range 1.0 sec to 10 sec. On the other hand, the 5 % damping velocity response spectrum in short period range (less than 2 sec.), which was widely used for design of stiff structures in Japan, were proposed by Hisada, Ohsaki et.al.(1979) as shown in Fig. 6. In this figure, the point A is connecting with point B smoothly to obtain the wide-band spectrum for seismic isolation system for convenience-sake. To compare with observed ones, two observed spectrum of 1985 Mexico earthquake and 1983 Nihonkai-chubu Earthquake were analyzed. We can see that the design based seismic input for seismic isolation system estimated by eq. (5) (in period range 1.0 sec to 10 sec) are seem to agree with observed ones.

4. CONCLUSION

The strong ground motions are characterized by faulting and multi-layered soil conditions at the sites. So, in order to estimate the design based seismic input for seismic isolation system, we must simply consider the effects of faulting and amplification factor of soils for practical use. The methodology to estimate the design based seismic input was proposed and confirmed its applicability by using the observed large earthquakes. It is clear that the methodology to estimate the design based input for seismic isolation system is good for practical use.

5. ACKNOWLEDGEMENTS

I appreciate Dr. M. Takemura of Kajima Corporation and Dr. T. Watanabe of Shimizu Corporation for useful discussions.

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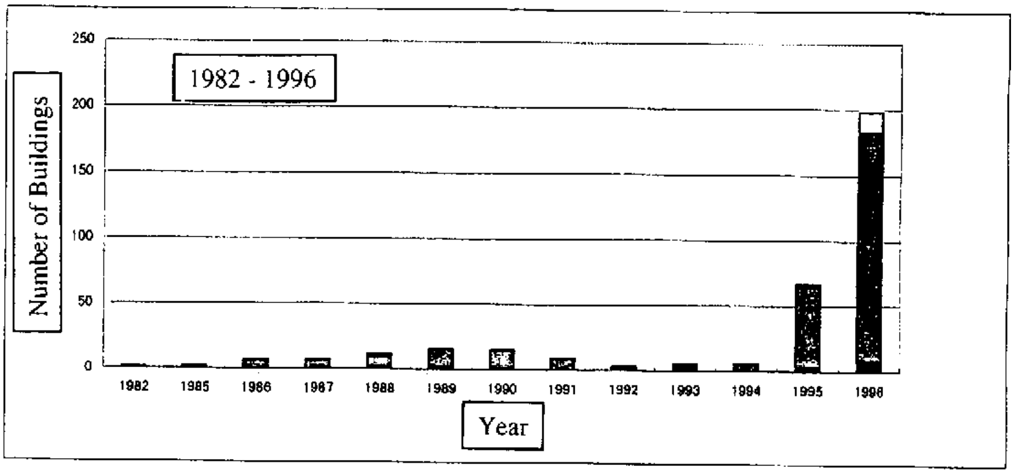

Figure 1: The number of seismically isolated buildings in Japan. After 1995 Kobe Earthquake very many seismically isolated Buildings were constructed.

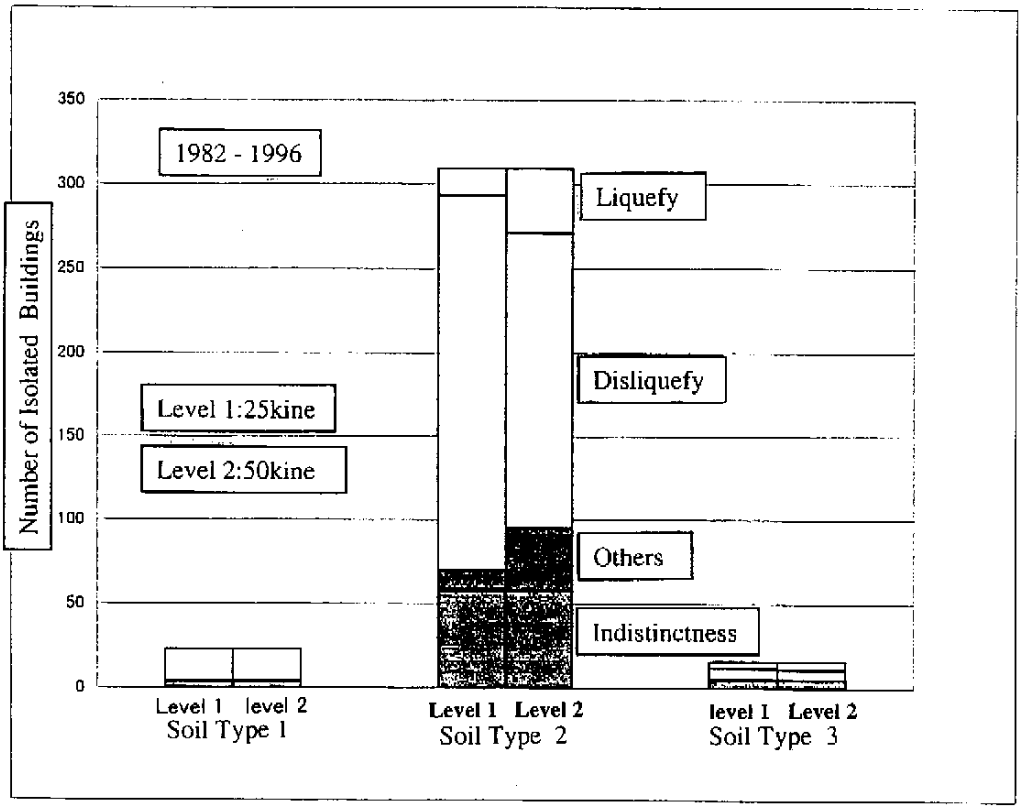

Figure 2: The number of seismically isolated buildings which will be experienced liquefaction .

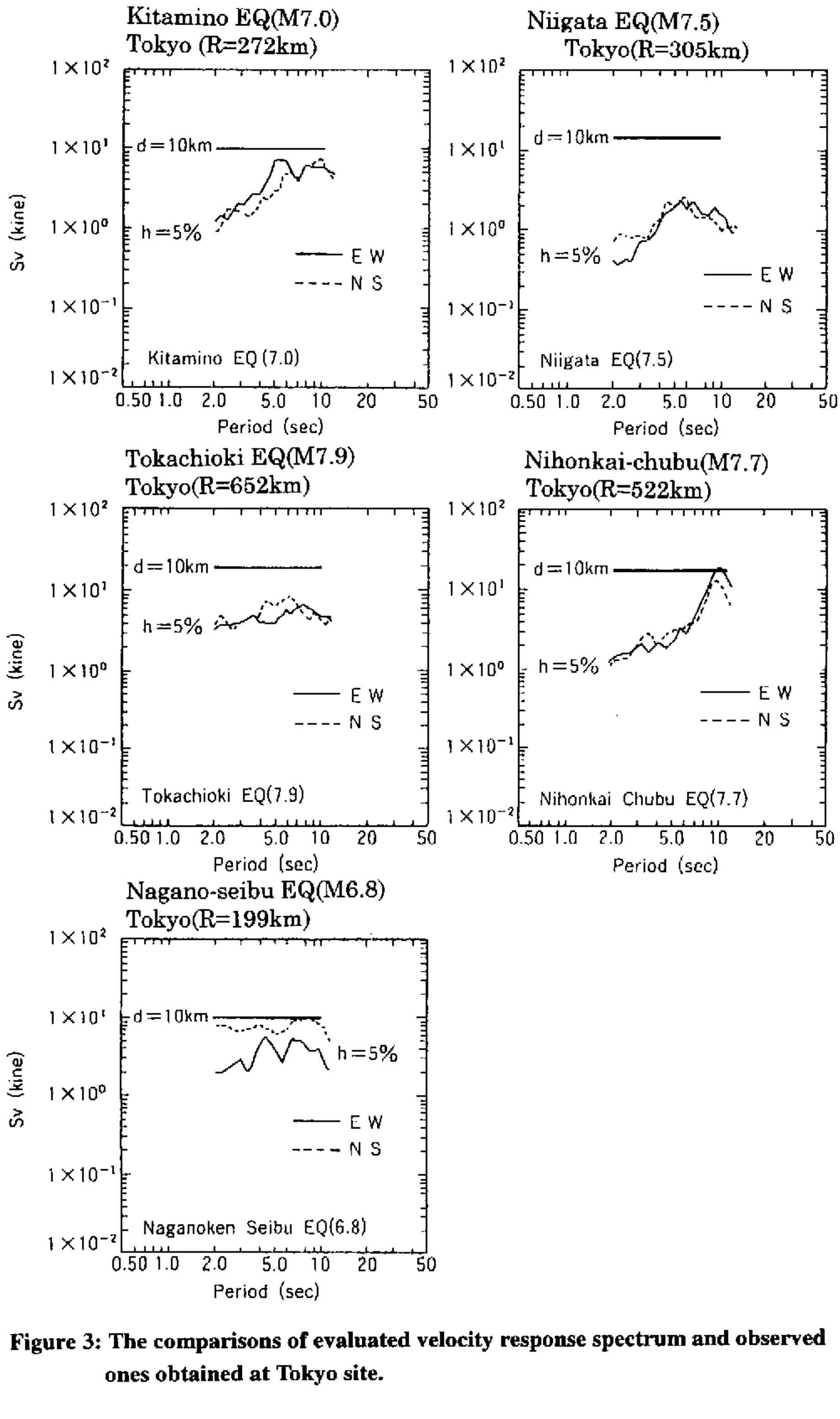

Figure 3: The comparisons of evaluated velocity response spectrum and observed ones obtained at Tokyo site.

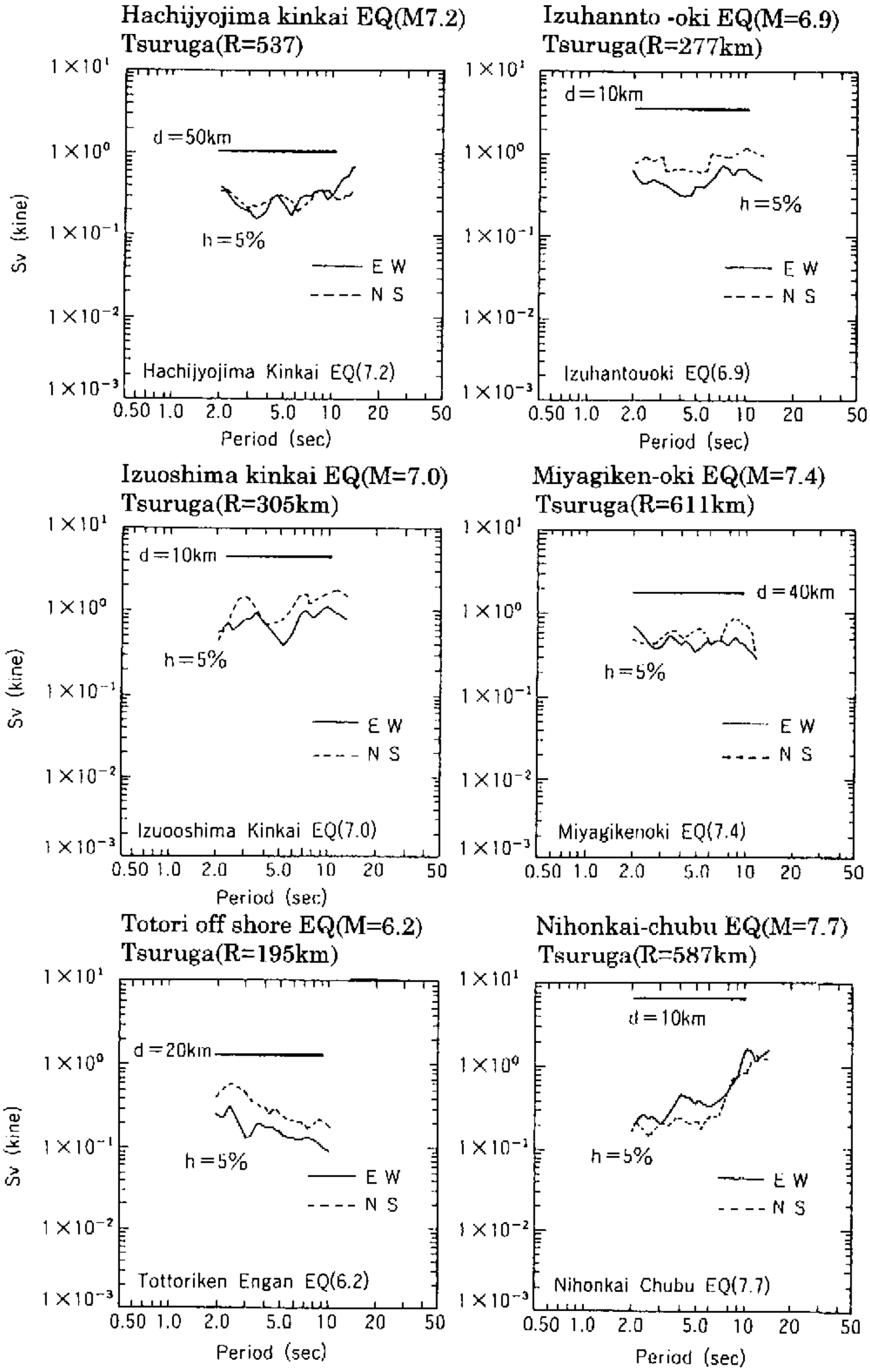

Figure 4: The comparisons of evaluated velocity response spectrum and observed ones obtained at Tsuruga site.

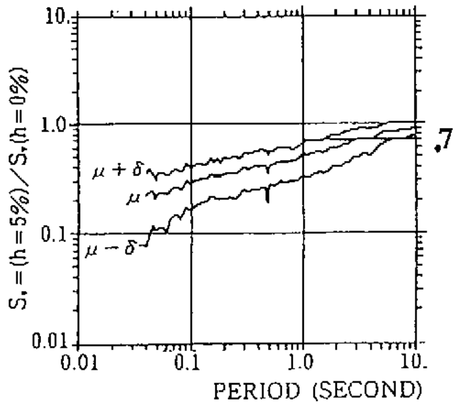

Figure 5: The coefficient of transforming 0% velocity response spectrum to 5% ones obtained from spectral ratio.

Table 1: Layer model of Tokyo and Tsuruga sites.

Layer No.	Vs(km/s)	Density(g/cm)	Thickness(km)	Note
1	0.7	2.0	1.0	Kanto Area
2	1.5	2.3	1.6	
3	3.0	2.5	3.5	
4	3.4	2.6	-	
1	0.25	2.0	0.008	
2	0.25	1.9	0.005	Tsuruga area
3	0.5	2.1	0.134	
4	3.0	2.5	-	

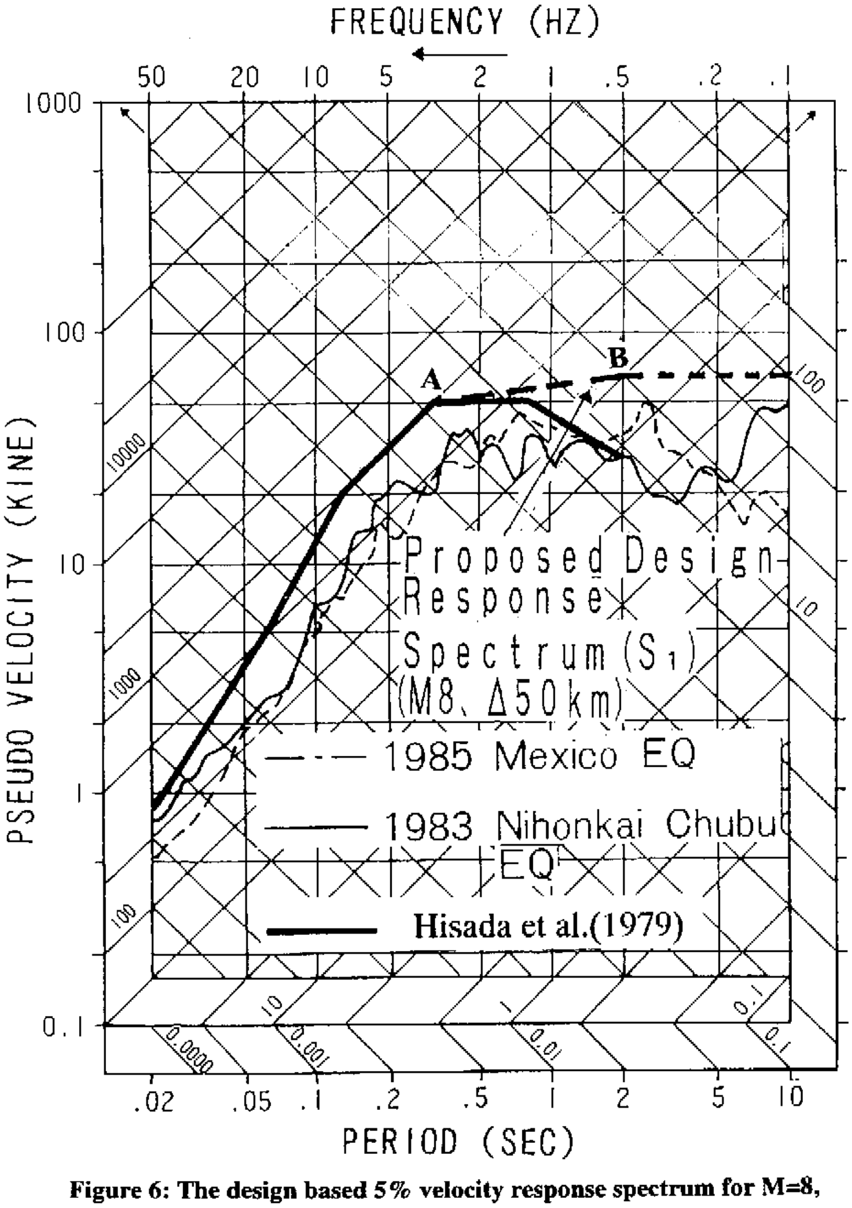

Figure 6: The design based 5% velocity response spectrum for M=8, Distance R=50km, and depth of hypocenter d=10km.