

I - 625

CHARACTERISTICS OF VERTICAL GROUND MOTIONS IN NORTHRIDGE EARTHQUAKE

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INTRODUCTION

Recent earthquakes such as Hyougoken South and Northridge earthquakes have produced vertical ground motions that have been significantly greater than the corresponding horizontal ground motions. These occurrences being motivated by the increasing importance of vertical ground motions for design purposes have stimulated the current studies to further an understanding of ground motions in general.

COMPARISON OF INTENSITIES OF VERTICAL AND HORIZONTAL ACCELERATIONS

It has been observed in some past earthquakes that there have been strong motion records where the vertical accelerations have been greater than the other two orthogonal horizontal acceleration components. Utilizing the ground accelerations at 27 strong ground motion stations operated and maintained by the CSMIP program, a graph showing the ratio of the vertical to horizontal ground accelerations as a function of distance from the epicenter is shown in Figure 1. For each instrumental station, three points are shown on the graph. As can be seen in Figure 1, The ratios get nearly linear relations with the epicentral distances getting shorter at the sites where epicentral distances are less than 30 km in spite that at the sites being over 30 km from epicenter it does not strongly show some relation.

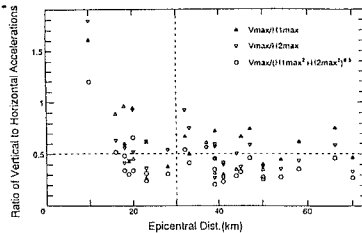


Fig.1 Ratio of max. vertical acc. to max. horizontal acc.

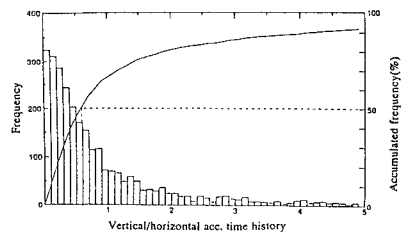


Fig.2 Frequency distribution of vertical acc. to horizontal acc.

The mean value of

ratios is 0.502. At the site of 10 km away from epicenter the ratio exceeds 1.0, it means that greater maximum vertical acceleration can occur in the near field of the earthquake rupture zone. Figure 2 shows the distributions of frequencies and accumulated frequencies of ratios of vertical accelerations to horizontal accelerations at Alhambra being 39 km away from the epicenter. As can be seen from Fig.2 that the ratio of vertical ground accelerations to the horizontal is 0.5 to 0.6 when its accumulated frequencies reach 50%.

STRONG MOTION RECORDS ANALYZED FROM THE NORTHRIDGE EARTHQUAKE

Figure 3 shows the ratios of mean value and sum of mean value and its standard deviation of vertical acceleration Fourier spectra to horizontal acceleration Fourier spectra. Figure 4 shows the ratios of mean value of vertical velocity response spectra to the horizontal's. It can be found that for periods of 0.05 to 0.3 seconds the ratio of Fourier spectra gets greater and greater with the period

being shorter and shorter, for periods of 0.3 to 1.0 seconds the ratio of Fourier spectra is roughly steady, for periods of 1.0 to 5.0 the ratio of Fourier spectra once more gets slowly greater with period being greater; on the other hand the ratio of response spectra shows

the same tendency. Figure 5 shows the relations of the integration of average energy content that ground motions act on structures and the integration of absolute

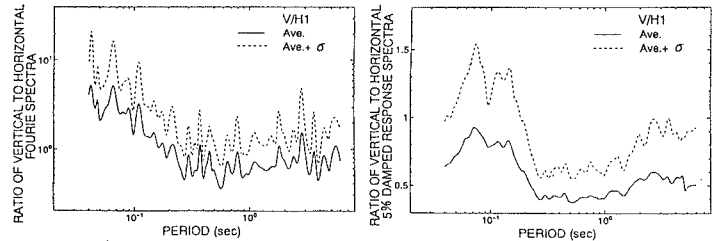


Fig.3 Ratio of mean value of vertical to horizontal acc. Fourier spectra

Fig.4 Ratio of mean value of vertical to horizontal vel. response spectra

accelerations of ground motions. Figure 6 shows the relations of integration of absolute ground accelerations and their epicentral distances. It can be found that there are high correlations between accelerations and average energy contents in both horizontal and vertical directions; in vertical direction the correlation is higher, meanwhile the attenuation of response energy is higher in vertical direction too.

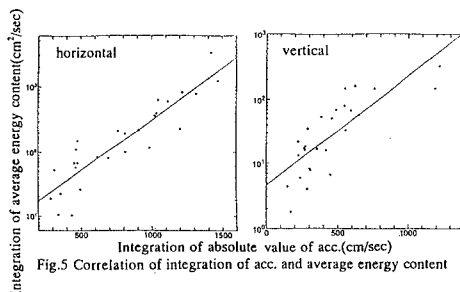


Fig.5 Correlation of integration of acc. and average energy content

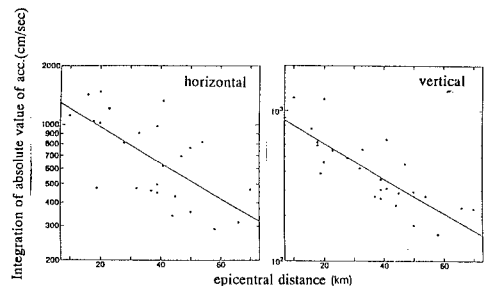


Fig.6 Correlation of integration of absolute value of acc. and epicentral distance

CONCLUSIONS

- 1) The ratios of vertical ground accelerations to the horizontal's are not regular, but the average value of the ratios gets more than 0.5, even the ratios can exceed 1.0 near the field of the earthquake rupture zone. The traditional practice of assuming that the maximum vertical acceleration is about half of the maximum horizontal accelerations would not rational, it is maybe more appropriate to assume the different percentages for distances greater and less than 30 km.
- 2) Vertical responses of a structure to the earthquake ground motions are different compared with horizontal responses at different periods, at short periods of 0.05 to 0.3 seconds, vertical response is maybe greater than horizontal response; for periods of 0.3 to 1.0 seconds, vertical response is much smaller than horizontal response; at long periods of 1.0 to 5.0 seconds vertical response becomes stronger again.
- 3) Vertical response shows higher correlations with input ground motions though it attenuates more quickly than the horizontal's.
- 4) vertical ground motions are not amplified or damped very much in the ground compared with the horizontal's.
- 5) The conclusions should be considered very preliminary for the reasons of limited data and local sites.