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Site amplification through measurement of long period microtremors: Predominant period of motion

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ABSTRACT: Predominant period of ground motion is determined by using long period microtremors with periods ranging from 0.5 to 10 sec. Repeated recordings were performed at two sites in the Los Angeles metropolitan area and at one site in San Francisco area. A total of 155 records were obtained at these three sites from which the predominant period of motion was determined. The results show that repeated measurements at a given site produce a consistent value of predominant period of motion.

1 INTRODUCTION

Even in the absence of earthquakes the ground is continuously vibrating. The amplitude of such vibrations may be less than several microns with periods ranging from several tens of a seconds to several seconds (Kanai, 1983). The motion of this type is called microtremors. It is common to distinguish two types of microtremors: (i) Long period microtremors or microseisms (with periods $T \geq 1$ sec) and (ii) short period microtremors ($T \leq 1$ sec). Microseisms are defined as oscillations of ground of periods 2 - 20 sec which are not due to earthquakes or to local causes such as traffic or gusts of wind (Longuet-Higgins, 1950; Hasselman, 1963). In present paper long period microtremors denote microtremors with periods ranging between 0.5 - 10 sec.

Microseisms are generated essentially in three ways (Hasselman, 1963): (i) Action of ocean waves on coast, (ii) atmospheric pressure variations over ocean, and (iii) nonlinear interactions between ocean waves.

Michoacan earthquake of September 19, 1985 which devastated Mexico City prompted Kobayashi et al. (1986) to measure the long period microtremors within the Mexico Valley shortly after the earthquake. The measurements were performed at 95 sites in and around of Mexico City. For sites in downtown area (area of many damaged buildings) microtremor measurements indicate predominant periods from 1 to 2.5 sec which correspond to the natural periods of the collapsed buildings in this region.

Predominant period is defined as a period of the peak spectral amplitude of predominant component of motion.

Recently, Lermo et al. (1988) extended the microtremor measurements of Kobayashi et al. (1986) for a total of 181 sites. In the transition and the lake bed zones of the Valley of Mexico these measurements show that the period at which peak in microtremor Fourier velocity spectra occurs correspond to the natural period of the sites. Excellent agreement was obtained between natural period estimates using microtremor spectra and from strong ground motion records.

Since the microtremor measurements are inexpensive and fast they provide an ideal method for estimation of natural period of sedimentary basins (Lermo et al., 1988). Consequently, long period microtremors may be very powerful tool in studies of earthquake hazards for large structures in urban environments.

The purpose of this study is to investigate the predominant periods at several sites through multiple recordings of microseisms. For that purpose three sites were chosen. Two in Los Angeles basin and one in San Francisco. The sites were a part of large scale microtremor measurements which were recently undertaken in metropolitan areas of Los Angeles and San Francisco (Dravinski et al., 1991; Yamanaka et al., 1992).

2 INSTRUMENTS

Instrument setup consists of a seismometer, amplifier and a recorder. The seismometer is a one-component moving coil velocity type controlled by a servomechanism. Its natural period is 0.8 seconds, but apparent natural period can be extended up to 12 seconds with a feedback servomechanism. Period range of measurement for the seismometer is between 0.02 to 12 sec. In order to eliminate noise, shorter periods (less than 0.5 sec) have to be eliminated through use of RC filters in a head amplifier. in addition, a 12V DC power supply is required.

Amplifier has 80 dB maximum gain. Short period components, including noise, are cut off by using RC (resistant and condenser) circuits both before and after the amplifier. Cut-off frequency is variable, and for these measurements it was set at 2 Hz. Characteristic amplification function for seismometer and head amplifier (including the RC filters) is flat between 0.5 and 10 sec. Therefore, subsequent analysis applies for microtremors within that period range.

Both digital and analog recorders were used in this study. The former was employed at two sites (La Canada and Yerba Buena Island) while the latter was used at one site (USC). The analog recorders are four channel, FM cassette types. The digital data recorder consists of a portable personal computer with a 12-bit A/D converter. Sampling rate of the recorder is 10 Hz.

3 MEASUREMENTS

The measurements in Los Angeles metropolitan area were carried out at two sites. The first site is located on the campus of the University of Southern California (USC) in downtown Los Angeles and the second site in La Canada, about 30 km north from the first site. The USC site is characterized by deep sediments while the La Canada site is a rock site. The measurements at the two sites took place from November 9, 1990 - November 13, 1990. At La Canada site records were obtained every two hours and at USC site every six hours. Total of 87 records of 480 sec duration were obtained at La Canada site and 34 records of 600 sec duration at USC site (Yamanaka et al., 1992). Two horizontal velocity components of motion (EW and NS) were recorded at these two sites.

Measurements in San Francisco were performed at a rock type of a site at Yerba Buena Island. By recording microtremors every two hours from August 12 - 15, 1990 total of 34 records of 600 sec duration were obtained. Only one horizontal velocity component of motion (E-W) was considered at this site (Dravinski et al., 1991).

4 DATA PROCESSING

Data recorded by the analog recorder were digitized using an A/D converter with sampling rate of 10 Hz. Fourier spectra were calculated only from the portion of the record (204.8 sec) showing no artificial disturbances. Since for all recording sites the instruments were placed in a basement of buildings (a three story building at USC, a residence in La Canada, and a single story building at Yerba Buena Island) we found the records to be of excellent quality with almost no contamination (Dravinski et al., 1991; Yamanaka et al., 1992). For each record a DC-shift was eliminated from the raw data. After that, the data in time domain were cosine-tapered (10 % from each end). The FFT spectral analysis is done by using 2048 points. The 5-point Hanning spectral window was used to smooth the spectra.

5 VELOCITY SPECTRA

La Canada Site. A typical microtremor velocity spectra for two successive records at site are depicted by Figs. 1 and 2.

The predominant period of motion can be easily identified from these figures. Although the spectral amplitude may change with time the predominant period of motion remained practically unchanged for both horizontal components of motion. This was characteristic for the entire set of records obtained at this site.

Los Angeles Site. Velocity spectra for two successive measurements at the USC site are shown by Figs. 3 and 4. As in the case of a rock site the records at this sediment site display similar characteristics in predominant period. The predominant period Tp appears to be the same for the two components of motion, and there is very little change in the value of Tp between the two measurements.

San Francisco Site. Finally, for two successive measurements at Yerba Buena Island site the velocity spectra (EW only) are presented by Figs. 5 and 6. Here again, the predominant period can be clearly identified from the velocity spectra.

In order to show the variation of predominant period with time at the three sites we present the corresponding histograms determined from the velocity spectra. Figure 7 shows the histogram for the La Canada site.

The average predominant period for this site is calculated to be Tp=6.83 sec. It is obvious from Fig. 7 that the multiple measurements produced a consistent value for predominant period with very little scatter from the mean value.

For USC site corresponding histogram is shown by Fig. 8. By comparing Figs. 7 and 8 it is evident that the results at USC site show stronger scattering from the mean value than at La Canada site. Still, the average predominant period of motion appears to be stable at this site as well. (It should be noted the difference in the number of measurements at the two sites.) The average predominant period of motion at USC site is calculated to be Tp=6.59 sec. For the Yerba Buena Island site the histogram of predominant periods is displayed by Fig. 8.

Although the results show more scatter from the mean value than for La Canada site, the average predominant period observed at this site appears to be consistent throughout the measurements.

6 CONCLUSIONS

Based on multiple measurements of long period microtremors at three different sites the results shoe that although the amplitude and shape of the velocity spectra may change with time, the predominant period of motion determined from these spectra appear to be stable. Presented results show that in order to determine the predominant period of motion more accurately multiple recordings of microtremors at a given site are required. Since microtremor measurements are inexpensive and fast the proposed method of determining predominant period of motion of sediment sites appears to be very effective.

7 ACKNOWLEDGMENTS

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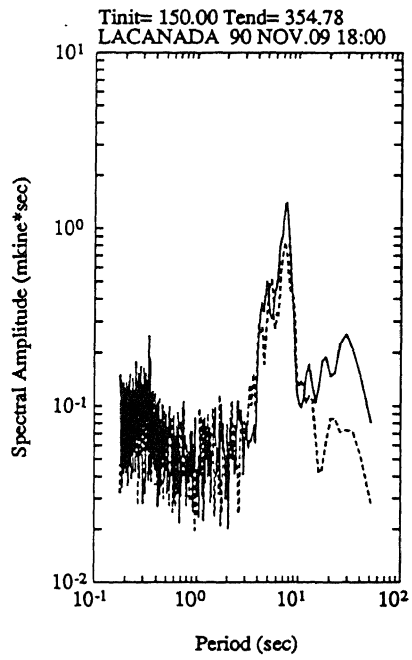

Figure 1: Velocity spectral amplitude as a function of period at La Canada site for November 9, 1990 at 18:00 hrs. EW-solid line; NS-dash line. Tinit and Tend are the initial and end time mark of the data used for the spectra calculation.

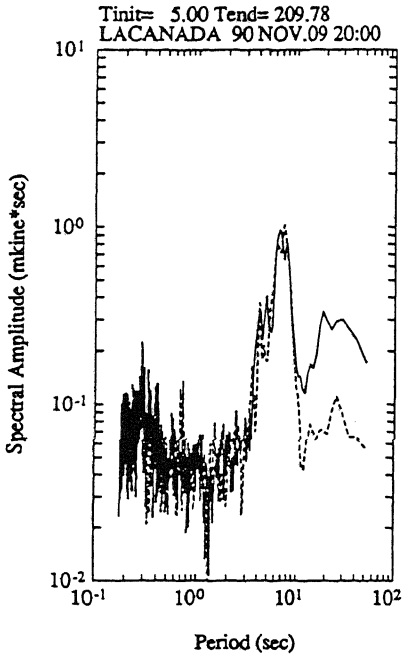

Figure 2: Velocity spectral amplitude as a function of period at La Canada site for November 9, 1990 at 20:00 hrs.

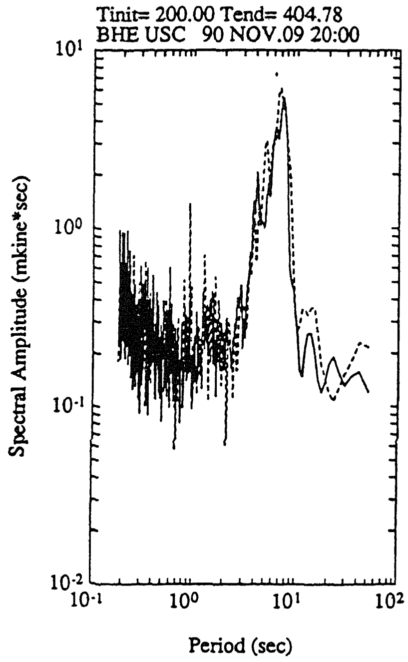

Figure 4: Velocity spectral amplitude as a function of period at USC site for November 9, 1990 at 20:00 hrs.

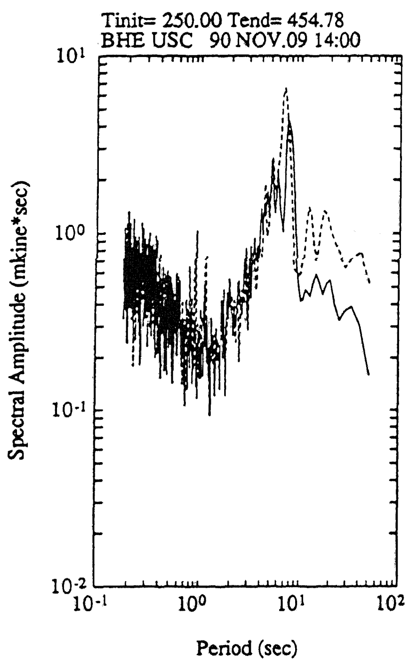

Figure 3: Velocity spectral amplitude as a function of period at USC site for November 9, 1990 at 14:00 hrs. EW-solid line; NS-dash line.

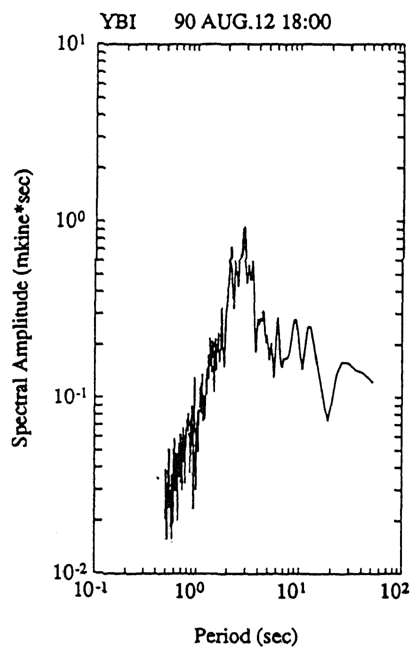

Figure 5: Velocity spectral amplitude (EW) as a function of period at Yerba Buena Island site for August 12, 1990 at 18:00 hrs.

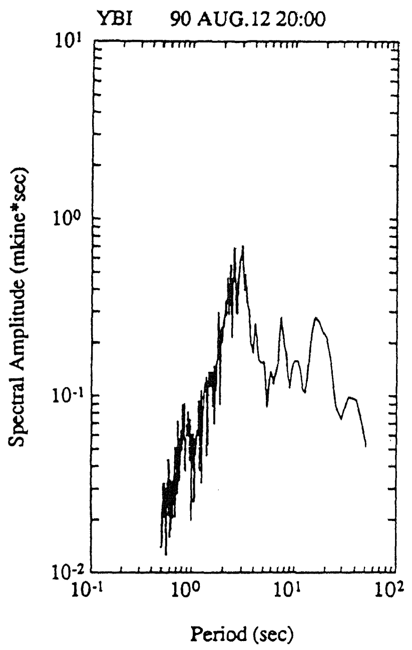

Figure 6: Velocity spectral amplitude (EW) as a function of period at Yerba Buena Island site for August 12, 1990 at 20:00 hrs.

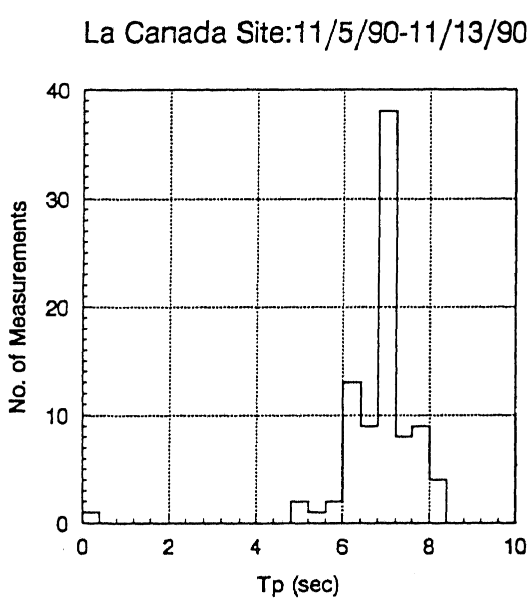

Figure 7: Histogram for predominant period measurements at the La Canada site. Total number of measurements 87. Average Tp = 6.83 sec.

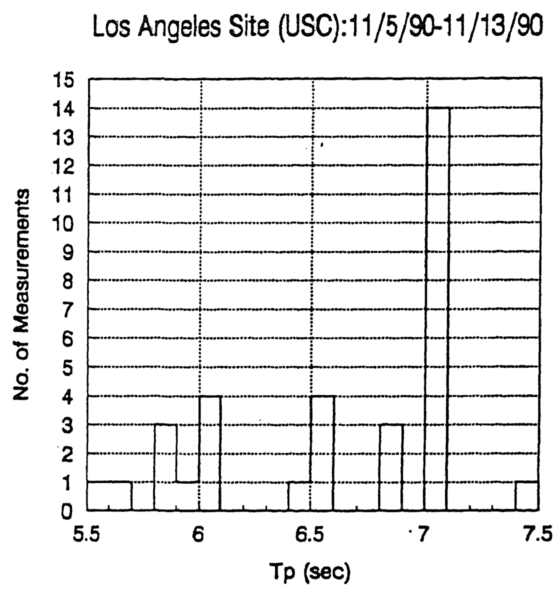

Figure 8: Histogram for predominant period measurements at USC site. Total number of measurements 34. Average Tp = 6.59sec.

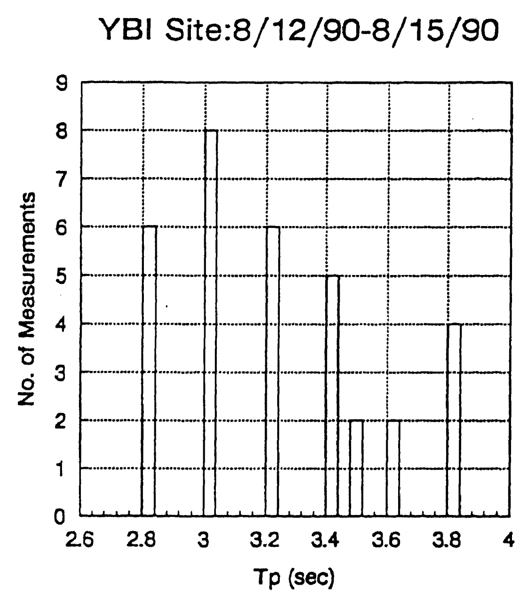

Figure 9: Histogram for predominant period measurements at Yerba Buena Island site. Total number of measurements 34. Average Tp = 3.25sec.