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Microtremor analysis as prediction tool for site dependent strong ground motion

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ABSTRACT: An attempt is made to study site effects on strong ground motion by using microtremors. Microtremor observation were made for Odawara City in Japan. Though microtremors operate at very law strain level as compared with strong ground motion, observations made for microtremors resemble those of strong ground motion characteristics in frequency content (predominant period, general spectral shape ...). In terms of absolute amptitude significant variations are observed between microtremors and actual earthquake ground motions.

INTRODUCTION.

Observations of past earthquakes have shown effects of sites on earthquake ground motion. Structural damage and recorded ground motions followed specific site dependent patterns. Earthquakes of similar magnitudes and epicenteral distances have caused significant damages in some areas while little damages are observed in other areas. An example is earthquake of M_s = 7.5 at R = 90 Km has caused a_{max} = .25 g in Lima Peru, in 1974, which is small compared with other areas.(1). As such cases could be influenced by source mechanism and travel path, a better approach is comparison of same general area subject to same earthquake there by reducing the effect of source and path to the minimum.

Earthquakes of San Francisco, U.S.A., 1906 and 1957, The great Kanto earthquake, Japan, 1923, Tonankai earthquake, Japan, 1944, Niigata earthquake, Japan, 1964, Moxico earthquakes of 1957, 1975, 1985, Caracas earthquake, Venezuela, 1967, Loma Prieta, U.S.A., 1989, Philippines earthquake 1990 are some of the earthquakes in which effects of sites on damage patterns or on recorded ground motion are seen unambiguously.

An attempt to study site effects has been done by varies people at varies times. A more scientific approach was started after the 1906 San Francisco Earthquake, by varies researchers after the 1923 kanto earthquake, and later by Kanai and Tanaka (2), Seed and Idriss (3,4,5,6,7), Ohsaki (8), Ishihara (9), and numerous other researchers.

Generally the objective of such studies have been either in estimating specific site response characteristics when a more precise response analysis of structures is required or for seismic microzonation of a given area by using rather simpler and easy techniques. These studies have been made by using quite varied techniques, such as from previous strong motion records or damage patterns, observation of small earthquakes, microtremors and microseisms, analytical models based on one or multi-dimentional model. The above methods have their own merits and demerits, while studies made based on strong motion records give more accurate results, such records are not available in enough number, small events and microtremors deal with small strain level motions unlike big events that are of interest. Analytical methods are based on varies simplifying assumptions and some methods require expensive field and laboratory investigation. Therefore, the study of site effect should be done based on specific requirement and condition by striking a proper balance between accuracy and economy.

1. STUDY OF SITE EFFECTS USING MICROTREMORS

Microtremors are low amplitude (0.1-1 microns) ground motions produced either by artificial noises such as traffic, machinery etc. (short period microtremors 0.1-1 or 1.6 seconds or by natural sources such as wind, ocean waves (long period microtremors 1.6 or 2.0 sec and above). The wave nature of microtremors have been explained differently by varies authors, as surface waves and as body wave, but it appears that long period microtremors have surface wave nature while short period microtremors have been found to exhibit both natures, though their interpretation based on body waves assumption for all practical purposes has passed no significant mistake.

The basic principle of applying microtremors to site effect studies is based on the following principle: Microtremors move as waves in the ground and they are amplified at periods which are synchronous with the natural period of the sub soil due to features of selective resonance, enhancing selected frequency components. While short period microtremors tend to reflect shallower ground formations, long period ones are more related to deeper formations.

The application of microtremors for site effect studies was mainly started by Kanai and Tanaka 1961 (10) and later by Katz 1976 (11), Katz and Bellon-1978, (12), Ohta et al-1978 (13), Kagami et al-1982 (14), 1986 (15), Kobayash, K.-1978 (16), 1990 (17), Kobayashi, H. -1978 (18), 1986 (19), 1990 (20), K.Seo -1989 (21), 1990 (22), Morales et al-1991 (23), etc. In almost all the above studies applications of the method to site effects have shown encouraging results while contrary observations were made at El-Centro by Udwadai and Trifunac 1973 (24).

From the above studies the following observations were made: Period distributions and spectral shapes of microtremors follow definite pattern for a particular site showing clear resemblance to spectrums obtained by other methods of analysis or observations made from actual ground motions, though variations of amplitudes of microtremors show variation in spectral characteristics when observed over a longer period of time.

The use of microtremors for site effect study is favorable because of simplicity, ease of operation, short duration required, less cost, minimal disturbances to other activities and environment. But shortcomings should be noted: microtremors unlike earthquakes operate at very low strain level, effect of source on microtremors is significant, instabilities are often observed and application to complicated formations is limited.

2. OBSERVATION OF MICROTREMORS IN ODAWARA CITY.

Microtremor measurements were taken in Odawara city, Ashigara valley, Japan at sites designated as KR1, KS1, KS2, R7, S7 and S8. The instrument used was a seismometer of natural period 1 sec. which can be extended to 5 sec. electrically, it consists 3 components (NS,UD,EW) seismometers and amplifier. Readings and data recording were directly controlled with Epson lap top computer equipped with analog digital conversion card.

Measurements were made at each site both for 1 sec. and 5 sec.. For site S8 additional continuous readings were taken for long period components every one hour for 23 hours. Fourier analysis was made by dividing each 300 sec. record into seven sections each with about 40 sec. duration and their averages were taken. Smoothing was done using Parzen window 0.3 Htz wide. For 2-D horizontal component geometric averages of NS and EW components were taken. Spectral ratios were calculated by taking site KR1 as reference for mobile measurements at the sites and by taking mid night as references for the stationary measurement at S8. Time histories for sites KR1 and KS1 are shown as an example in Fig.1, Fourier amplitude spectra are shown in Fig. 2 spectral ratios are shown in Figs. 3 and 4.

For the mobile measurements, relative increase in amplitudes were observed, with lower amplitudes for rock sites KR1 and R7 and higher for other soil deposites. Predominant periods of 0.2 sec. for KS1 and increasing to about 0.3 sec. for other soil deposites and a flat response for rock site KR1 with a forced peak around 0.2 sec, probably due to some source is observed. For long period measurements predominant peaks around 3 to 4 sec. were noticed. For the continuous measurements stability with respect to period distribution was observed, while amplitudes varied at shorter periods with the smallest at mid night and increasing as cultural noise increased.

CONCLUSIONS.

Carefully observed microtremor measurements resemble those of strong ground motion in some aspects. Microtremors on soft soil deposite have bigger relative amplitude as compared with those on stronger formations. Spectral analysis of microtremors show similarity with strong ground motions in frequency content. Though prediction of strong groun motions in a precise manner is not possible by using microtremors especially interms of absolute magnitude, strong motions could be understood in a relative way from microtremor measurements.

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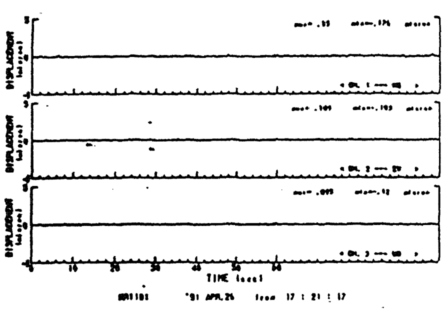
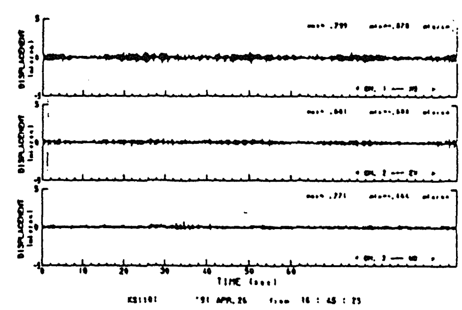
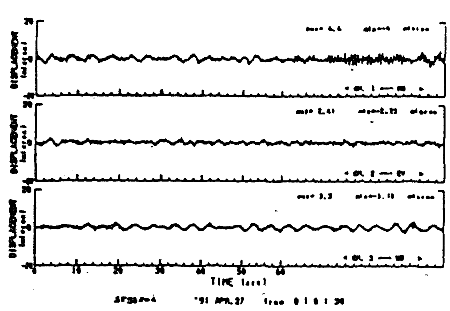


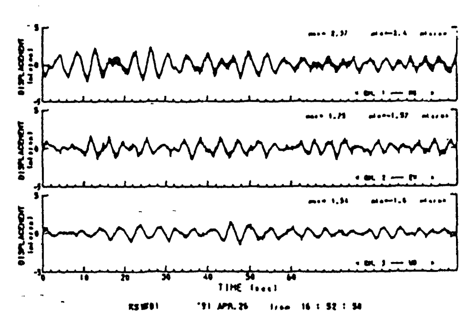
a) 1-Sec. Rock Site



b) 1-Sec. Soil Site



c) 5-Sec. Rock Site



d) 5-Sec. Soil Site

Fig. 1 TIME HISTORY OF MICROTREMOR MEASUREMENTS, ODAWAR

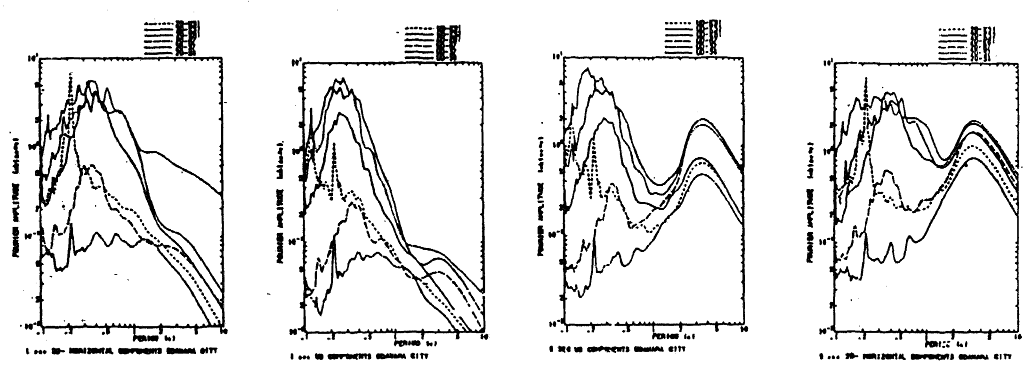
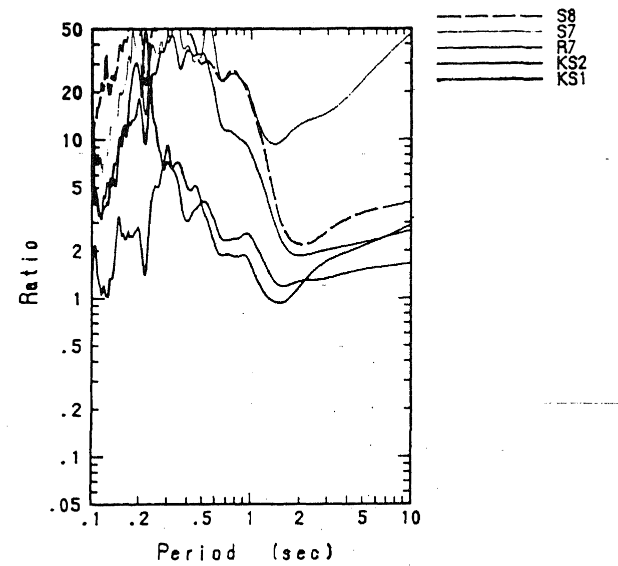
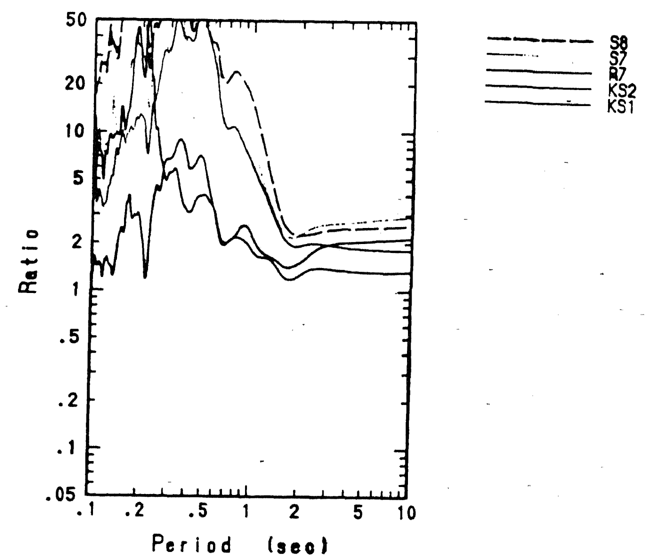


Fig. 2 FOURIER AMPLITUDE SPECTRA FOR MICROTREMOR MEASUREMENTS IN ODAWARA



-Figure 3a Spec. ratio for sites in Odawara (1 sec - H2D)
Rock site KR1 taken as reference.



-Figure 3b Spec. ratio for sites in Odawara (5 sec - H2D)
Rock site KR1 taken as reference.

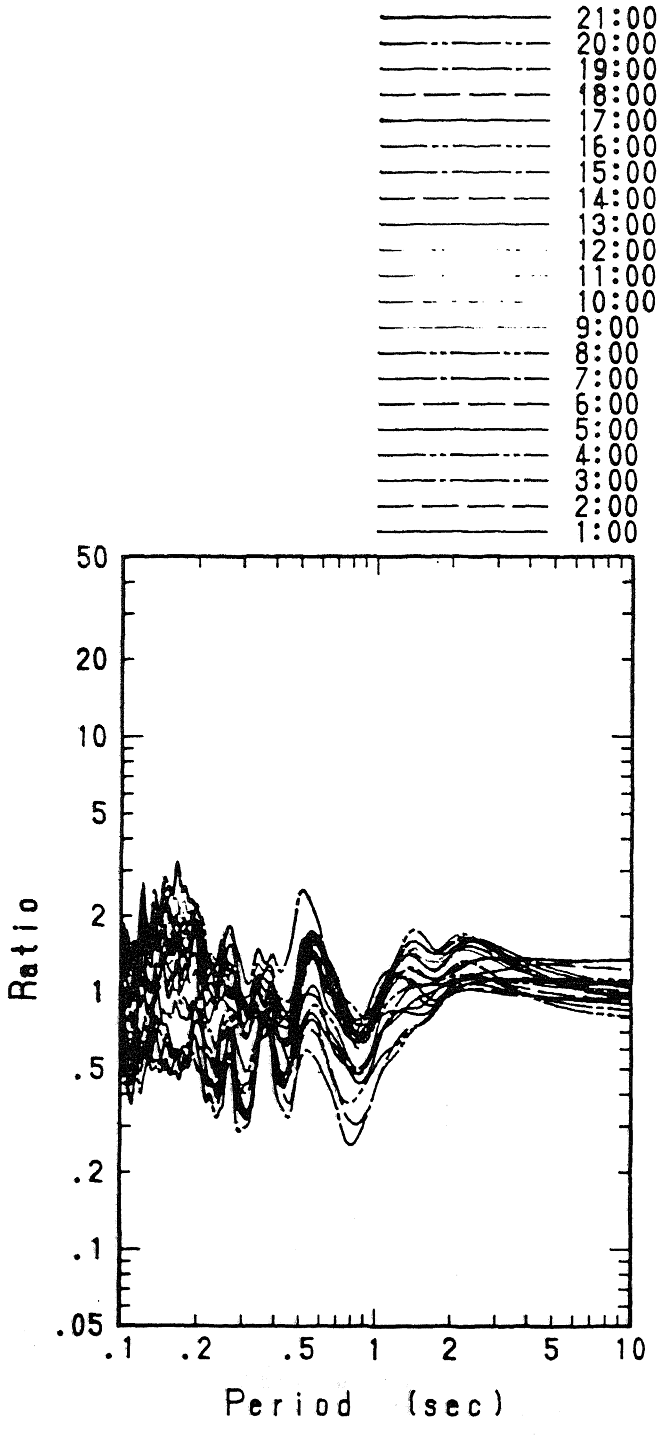


Figure 4 Spec. ratio for stationary measurement site S8 at Odawara. Mid night taken as reference (5 sec - H2D).