9Th International Workshop on Seismic Microzoning and Risk Reduction
21st-24 February, 2010
Cuernavaca, México

Microtremors as the Substitute for Earthquake Ground Motions

--- Are Microtremors Always Reliable and Useful? ---

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Abstract

Microtremors measurements are usually very convenient and economic tool to find out local site effects those could be included in earthquake ground motions. Since the early development of microtremors studies by Prof. Kanai, the features of microtremors had been discussed very often with interested researchers and engineers, most of all in Japan. The 1985 Mexico Michoacan earthquake has brought a fever of site effects studies for many researchers over the world in the field of engineering seismology and earthquake engineering. Microtremors has worked very well in Mexico City, because they explained the characteristics of strong motions and the condition of very soft soils everywhere in the basin district. After that, effects of surface geology on seismic motion have become collaborative topics among huge numbers of interested members. And microtremors measurements played a very important role in such researches.

As microtremors researches seem to be getting more popular among related members since the Mexico earthquake, we want to make a brief review about microtremors researches at this moment. As a matter of facts, we are hesitating to take spectral rations of microtremors between horizontal and vertical components. Very fundamental questions would be, for example: Can microtremors be a substitute for earthquake ground motions? Are microtremors always reliable and useful for engineering objectives? We need to answer the questions if we want to apply microtremors to practical engineering usage.

Key-words: microtremors, earthquake ground motion, site effects, the 1985 Michoacan earthquake

Introduction

In this paper, we are going to discuss the characteristics of microtremors dividing into three different ages. First of all, very traditional researches on microtremors, those had been made by Drs. Kiyoshi Kanai and Teiji Tanaka, will be introduced. Secondly very active discussions about microtremors, just after the 1985 Michoacan earthquake, must be introduced because the earthquake induced very serious structural damage due to local site effects. And microtremors worked very well to explain the fundamental characteristics of local site effects. In spite of many efforts, questions and uncertainties on

microtremors still remained, because microtremors often show different manner and behave in different way. Finally we would like to introduce our recent findings about microtremors.

By the way, we will discuss only microtremors defined by Dr. Kanai in this paper. It means microtremors excited by human activities such as traffic and machinery noises. It also means microtremors measured with a set of three component sensors. We did not use microtremors array in this study. We understand that microtremors array measurement is quite reasonable with very clear physical meanings. But it is completely different approach from the usage of Dr. Kanai's microtremors.

Traditional Researches on Microtremors by Drs. Kanai and Tanaka

According to Dr. Kanai, he expected his microtremors to show common predominant periods with earthquake ground motions. Because Dr. Mishio Ishimoto had already pointed out that earthquake ground motions should have their own predominant period related with individual soil condition. Then Dr. Kanai tried his efforts how to obtain such characterized microtremors. He got rid of so-called microseisms as the longer period components with a high-pass filter during the measurements (Fig.1). Very closed traffic noises were carefully omitted from the records to have stable predominant periods. He confirmed the fundamental characteristics of such microtremors as, 1) the predominant period can be almost explained with one dimensional multiple reflection theory of SH-waves, 2) such predominant period looks very stable in spite of the variation of amplitudes (Fig.4), 3) the amplitudes represent daily variation so that very large in daytime and rather small in night-time (Fig.5), and 4) therefore, the origin sources of microtremors could be traffic and machinery noises due to human activities.

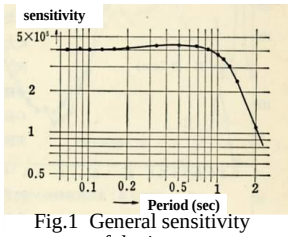


Fig.1 General sensitivity of the instrument

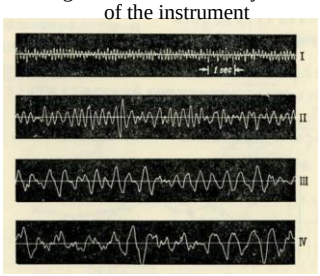


Fig.2 Microtremors measured in different soil condition

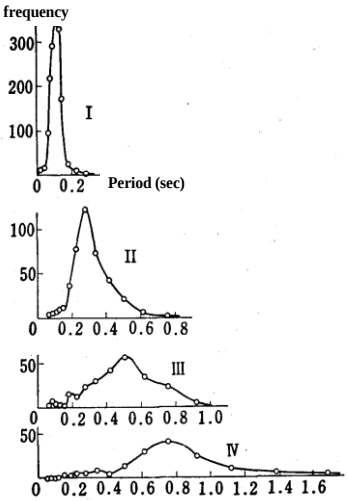


Fig.3 Period – frequency diagram of microtremors (Fig.2)

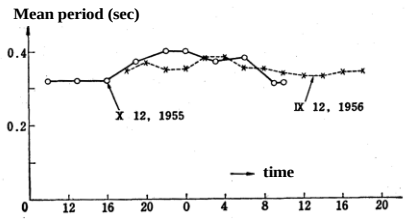


Fig.4 Mean period variation in microtremors

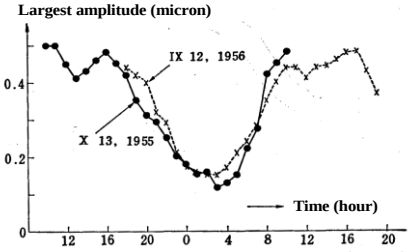


Fig.5 Largest amplitude variation during the continuous measurement of microtremors

On the other hand, there was another discussion about microtremors in southern California. According to Udwadia and Trifunac, it looked very difficult to explain ground motion characteristics of El Centro region with only microtremors. Alcock sent a comment telling that it might have some problem on their analytical process. Then Udwadia and Trifunac replied that the problem was not in the analytical process but in the site condition. In addition they said that it would be very successful if they had tried microtremors in the better condition of ground motion characteristics like Mexico City.

Discussions about Microtremors after the 1985 Mexico Michoacan Earthquake

Microtremors were measured many times by many researchers in Mexico City after the 1985 earthquake. Microtremors measurements were very successful in deed to explain the characteristics of

strong motion distribution there (Figs.6 and 7). Not only microtremors, general researches related to site effects on seismic motion became very popular. One of such scientific actions was the International Joint Research on “Effects of Surface Geology on Seismic Motion (ESG)”.

After that, we visited Mexico almost every year to perform microtremors studies. We wanted to do the same thing with Dr. Kanai about microtremors. We tried mobile measurements (Fig.8) of course, continuous measurements both on soft volcanic ashes (SCT, one of strong motion stations) and on a hard lava-flow (UNAM, another strong motion station) (Fig.9). As results, it was found that, 1) the long period microtremors on soft soils showed stable predominant peak and the daily variation of amplitudes

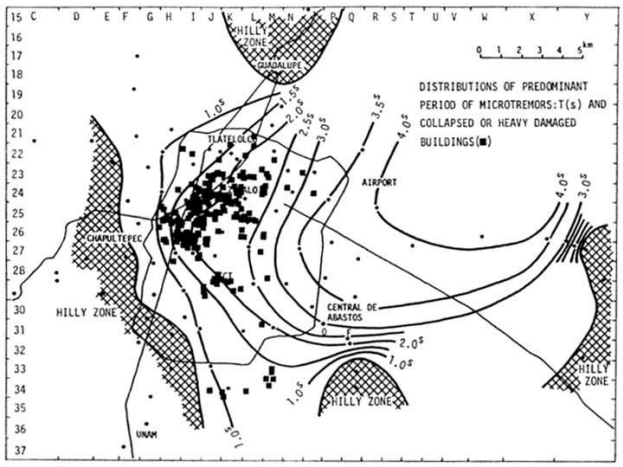


Fig.6 Distribution of predominant period of microtremors and collapsed or heavily damaged buildings in Mexico city

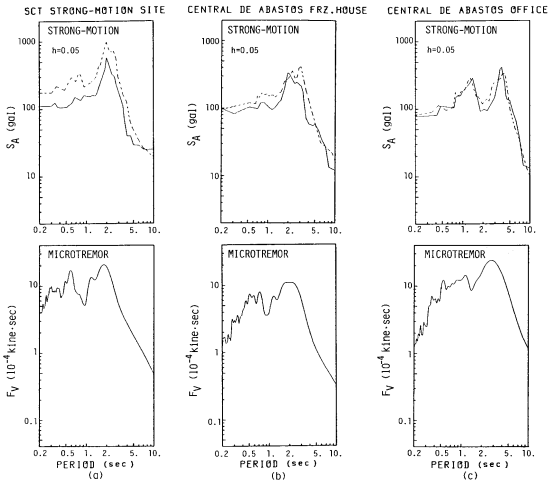
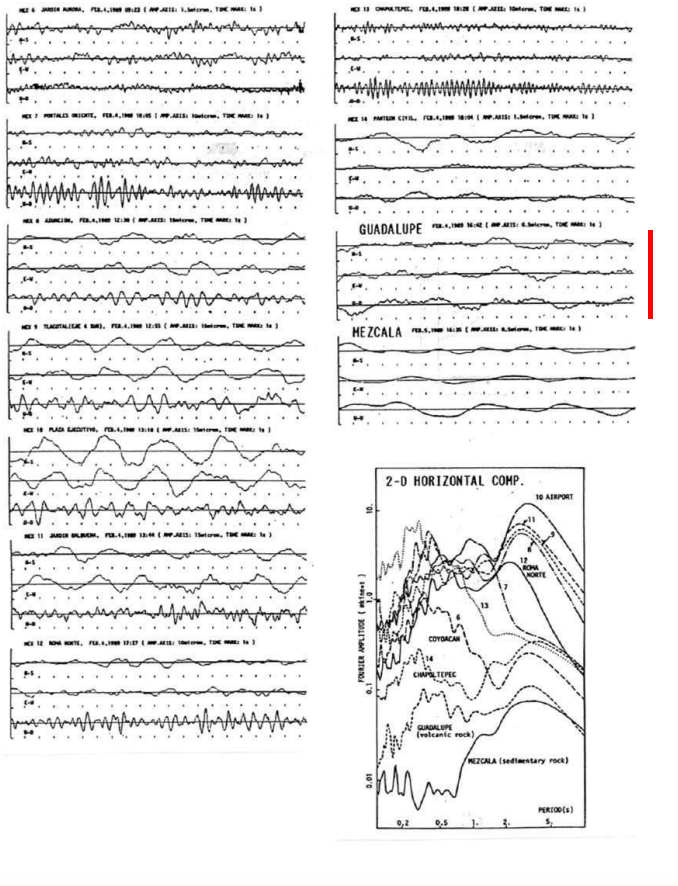


Fig.7 Comparison of predominant peaks and spectral shapes between strong motions (upper) and microtremors (lower)

Lava-flow in UNAM

Very soft soil condition



Outcrop of Granit

Fig.8 Measured microtremors among different soil conditions from very soft sediments of volcanic ashes through lava-flows and volcanic rocks to very stiff sedimentary rocks outside the Mexico valley.

Granit

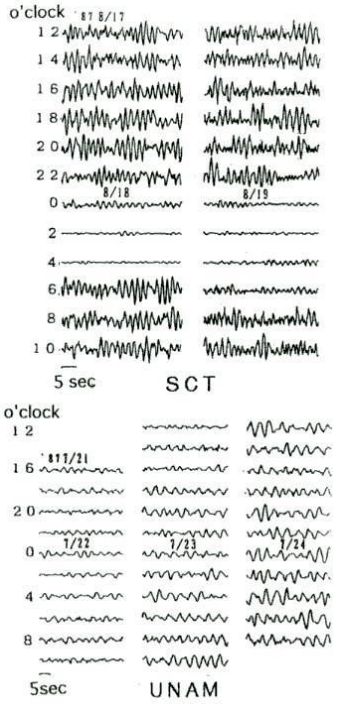


Fig.9 Continuously measured microtremors at SCT (soft soil) and UNAM (lava-flow)

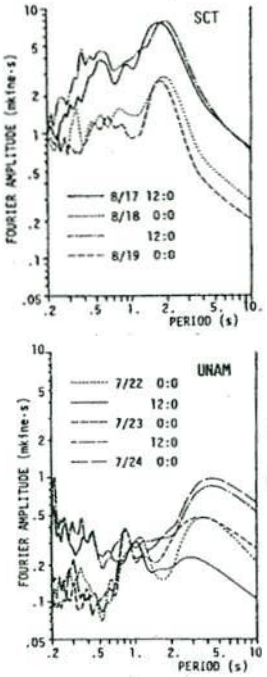


Fig.10 Variation of Fourier spectra of microtremors at SCT and UNAM

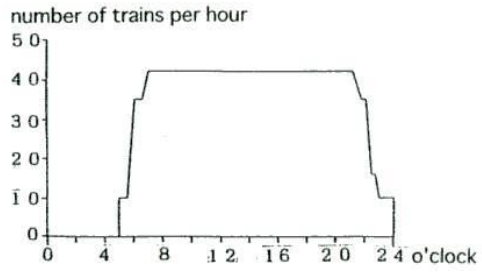


Fig.11 Serving amount of subways in Mexico city as one of indicators to know the characteristics of human activities

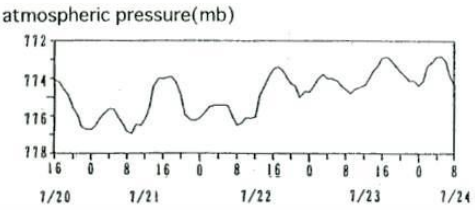


Fig.12 Variation of atmospheric pressure as The indicator of knowing weather condition

just like Dr. Kanai's microtremors, and 2) the similar long period component at UNAM was recognized as micro-seisms because individual predominant peaks moved along with the weather condition (Fig.10). The daily variation of human activity was estimated with the serving amount of subways (Fig.11).

In the same period, Nakamura's method was getting very popular among researchers and engineers who wanted to apply microtremors into site effect evaluations. According to Dr. Nakamura, H/V spectral ratios of microtremors could be used as a substitute of the amplification factor of SH-waves, assuming that, 1) characteristics of vertical component at the basement were almost the same with those of horizontal one, 2) such vertical component would not be amplified in the upper layers in our discussing period range, and then 3) H/V spectral ratios of microtremors on the ground surface could be almost similar with the spectral ratio of horizontal components between the ground surface and the basement. He also suggested that his H/V spectral ratio had another meaning to eliminate the component of Rayleigh waves from microtremors. On the other hand, Dr. Tokimatsu and his group pointed out that the H/V spectral ratios of microtremors clearly showed the principal characteristics of Raylrigh waves. Therefore we are still in confusion how to understand H/V spectral ratios of microtremors.

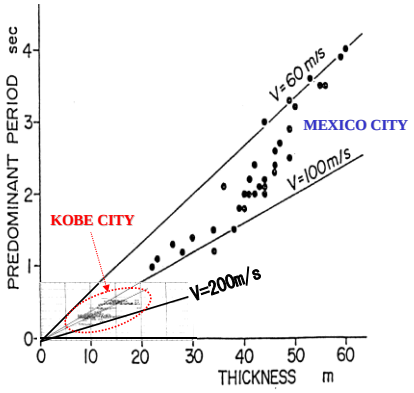


Fig.13 Comparison of soil condition between Mexico city and Kobe those are evaluated by means of microtremors measurements

Recent Findings about Microtremors

Recently the authors of this paper measured microtremors again to solve the confusion mentioned above. There are several findings as follows. Although they are not new, but we believe they are quite important as the fundamental characteristics of microtremors.