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Ground Motion Characteristics of the San Francisco Bay Area Detected by Microtremor Measurements

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SYNOPSIS:

Microtremor measurement was done mainly in the damaged areas in San Francisco and Oakland after the 1989 Loma Prieta earthquake. The observation areas were (1) the Marina District, (2) Cypress Street, (3) the Embarcadero, and (4) South of Market District. Predominant frequency(Fp) and amplification factor(Ap) obtained from a spectral ratio between horizontal and vertical components were evaluated for each observation cite. Difference in the degree of damage in the areas (1) and (4) was coincident with difference in Ap and Fp. Significant difference could not be found in Ap and Fp between the areas (2) and (3).

INTRODUCTION

News of the October 18, 1989 California earthquake (the Loma Prieta earthquake) reached us around 10:00 a.m. local time. TV programs kept informing us about earthquake damage in the San Francisco Bay Area all day. Undeniably, collapse of the Cypress Viaduct on Nimitz freeway looked most shocking. According to an overview, the damaged area looked limited to the place where the Bay Mud, or artificial fill, covers the ground surface.

In the Tokyo metropolitan area, especially along Tokyo Bay, there are many so-called water front projects under construction as well as under planning. Regarding such projects, safety against earthquake damage is one of the most important elements because every Japanese suspects that safety of the projects is much associated with earthquake response to filled land in the area. From this viewpoint, the Japanese have much to learn from the latest case of the San Francisco Bay Area.

Accordingly, the authors made an investigation tour to the Bay Area October 21 through October 26, 1989. A main emphasis of this tour was placed on microtremor measurements at several damaged areas which included the Cypress Street, the Marina District, Embarcadero(Foot of Market District), and South of Market District. In addition to these severely damaged districts, the measurement was also conducted at several points in Santa Cruz and downtown San Jose.

In this paper, results from the severely damaged areas are briefly summarized. In the authors' belief, a summary paper will be helpful not only to the Japanese, but also for those in the United States who are much concerned with the recent earthquake disaster.

Table 1 Dimensions and functions of PIC 87

(1) Dimension	560mm(W) × 330mm(D) × 195mm(H)
(2) Weight	14kg (main body)
Amplifier	
Number of channels	6 ch.
Gain	0 - 120 dB(5 dB step)
Frequency band	0.18 - 200 Hz
Low pass filter	5 Hz/ 10 Hz/20 Hz
(3) A/D converter	
Resolution	12 bits, 24 μ s
Multiplexer	16ch.
(4) Microcomputer	
16bitCPU	μPD70216
Displacy	640 × 400-dot Liquid crystal
Floppy disk drive	3.5 inch single drive (built in)
Interface	RS232C, Centronics
Power supply	12V (2.6AH) battery and 12V (7 AH) battery
Power comsumption	10W maximum with FDD accessed
(5) Sensor	
Number of channels	6 ch.(= 3 comp. × 2 sets)
Frequency band	0.8 - 200 Hz
Extention cable	50 m × 2 sets

OUTLINE OF THE MICROTREMOR MEASUREMENTS

a) Instruments used

An instrument named PIC 87 which had been developed by Railway Technical Research Institute was used for the microtremor measurements. It consists of two sensor units, cables and a main body built in an alminium case which contains amplifiers, an A/D converter and a microcomputer. Dimensions and functions of the instrument are shown in Table 1.

b) Procedures for measurement and analysis

In the San Francisco Bay Area, points for the microtremor measurements were mainly selected in severely damaged areas. Several nearby points from hardly damaged area were also added for the sake of comparison. Accordingly, the points were focused in the Marina District, South of Market District, and along the Embarcadero Viaduct in San Francisco as shown in Fig. 1 for which geological units are cited from Borcherdt(1975), and along the Cypress Viaduct in Oakland as shown in Fig.2.

At every observation point, three components (two horizontal and one vertical) of microtremor of the ground were recorded at every 1/100 sec for 40.96 sec. The measurement was repeated three times at a point to secure highest quality of recordings.

For spectral analyses, three sets of 10.24 sec long simulataneous recordings were selected from the three sets of the 40.96 sec long recordings. Fourier spectra were calculated for the selected recordings and then smoothed

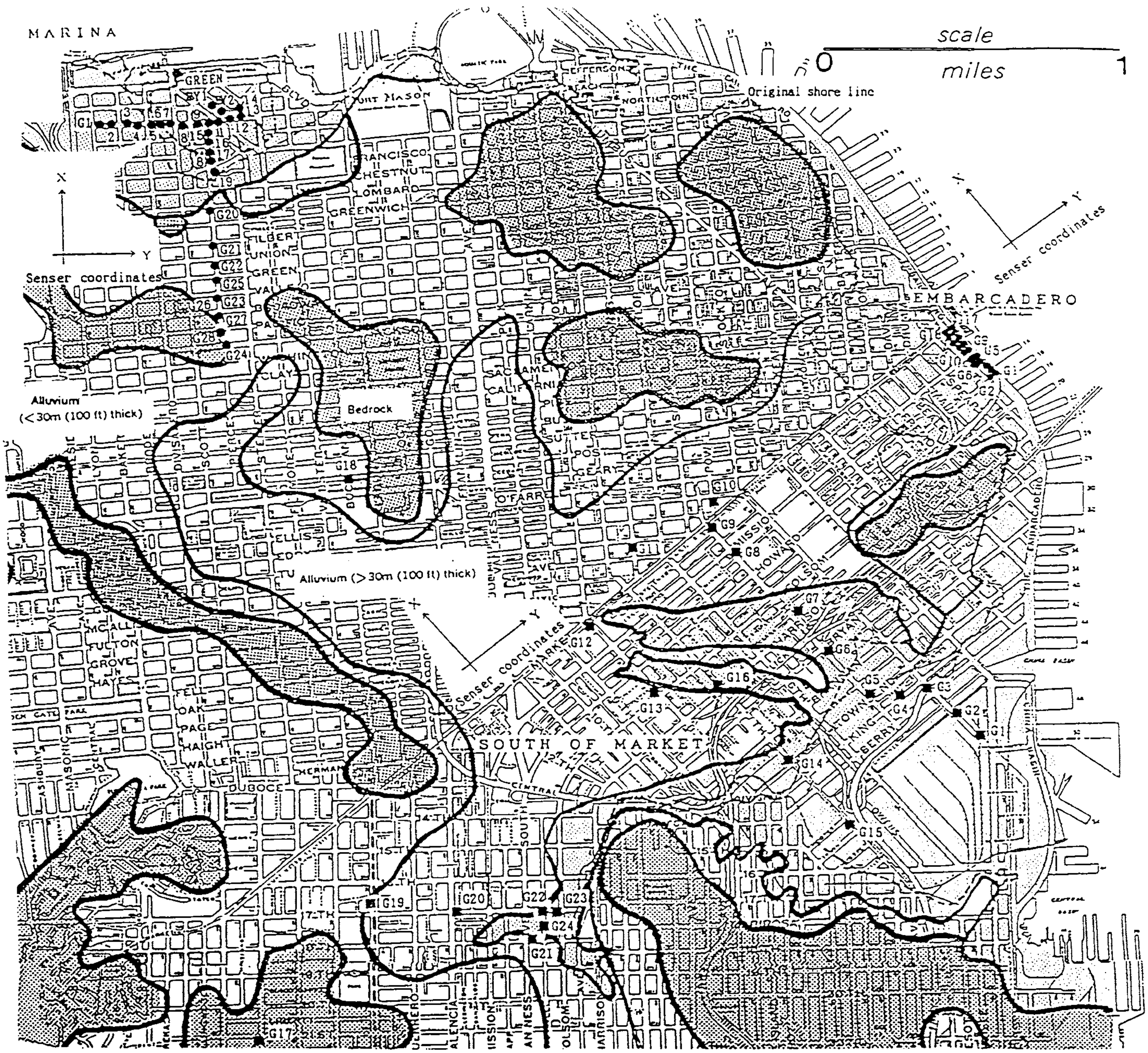

Fig.1 Location of observation points in San Francisco

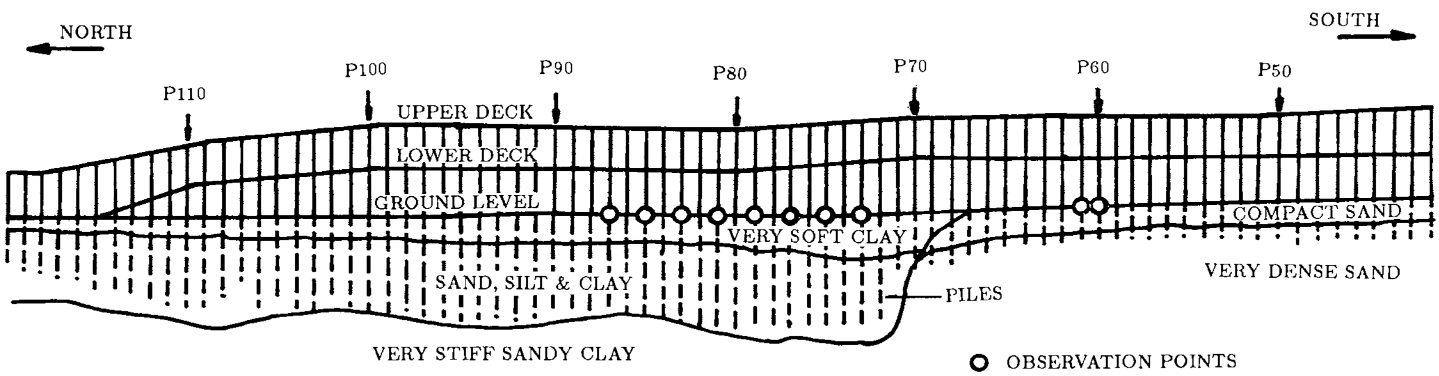

Fig.2 Location of observation points along the Cypress Viaduct

five times by using the Hanning spectral window. Finally, a frequency spectrum of one component of the microtremor was estimated by averaging the relevent three Fourier spectra.

The frequency spectra resulting from the above procedure are likely only to reflect vibration characteristics of not only the ground itself, but also those of particular driving sources such as running machinery and moving vehicles if any. To remove effects of the latter, an additional procedure was applied to the estimated frequency spectra. It calculates a spectral ratio between horizontal and vertical components. The spectral ratio provides a handy measure to estimate ground motion characteristics(Nakamura,1989), and is temporarily called a spectral amplification factor of the ground.

MICROTREMOR RECORDINGS AND THEIR IMPLICATIONS

a) Marina District

The microtremor measurements at the Marina District were conducted mainly on the roadside along Beach Street and Pierce Street. Fig. 3 shows typical recordings along Pierce Street, and the direction of the recordings is parallel to the shore line. In Fig. 3, an amplitude scale in each vertical axis is different for each recording, but a time scale in the horizontal axis is common. Apparently, the microtremor charactristics change between the points MG19 and MG20.

The change in the microtremor characterisitics can also be seen in the Fourier spectra shown in Fig. 4. In Fig. 4, the spectra for the Marina District underlain by Bay Mud and filled land are arranged on the left, and those for the hillside above MG20 are on the right. The change appears more conspicuous in Fig. 5, which shows the spectral amplification factor.

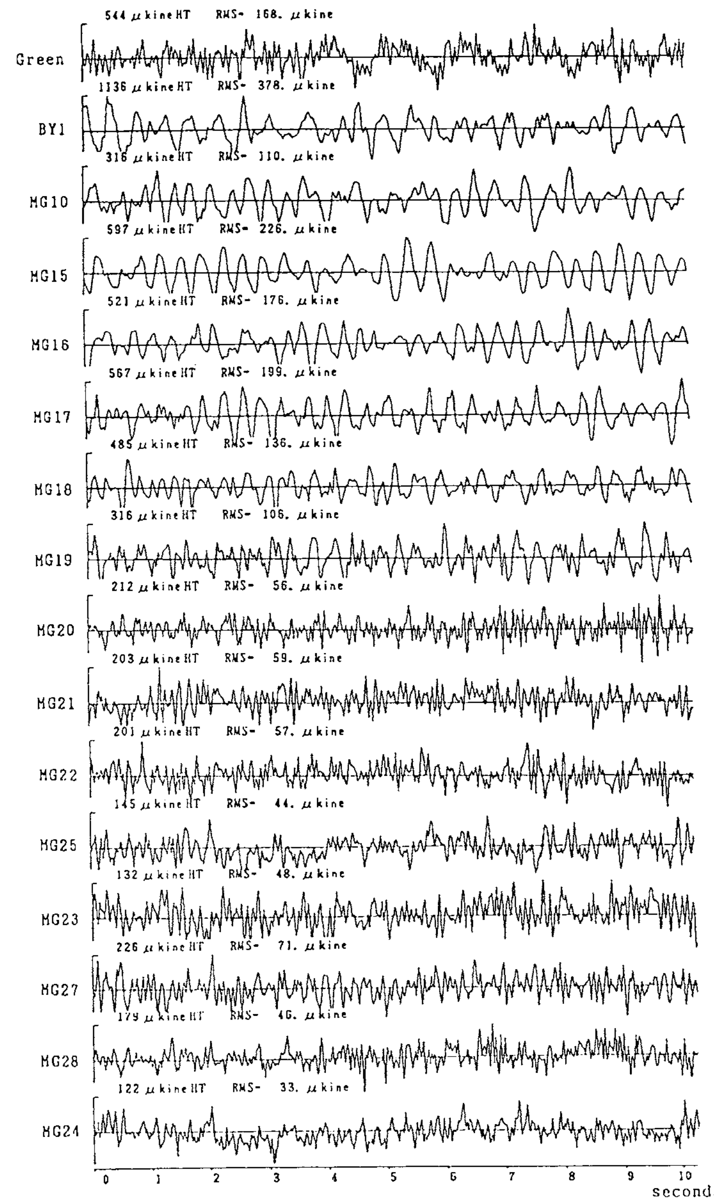

Fig.3 Typical microtremor recordings along Pierce Street

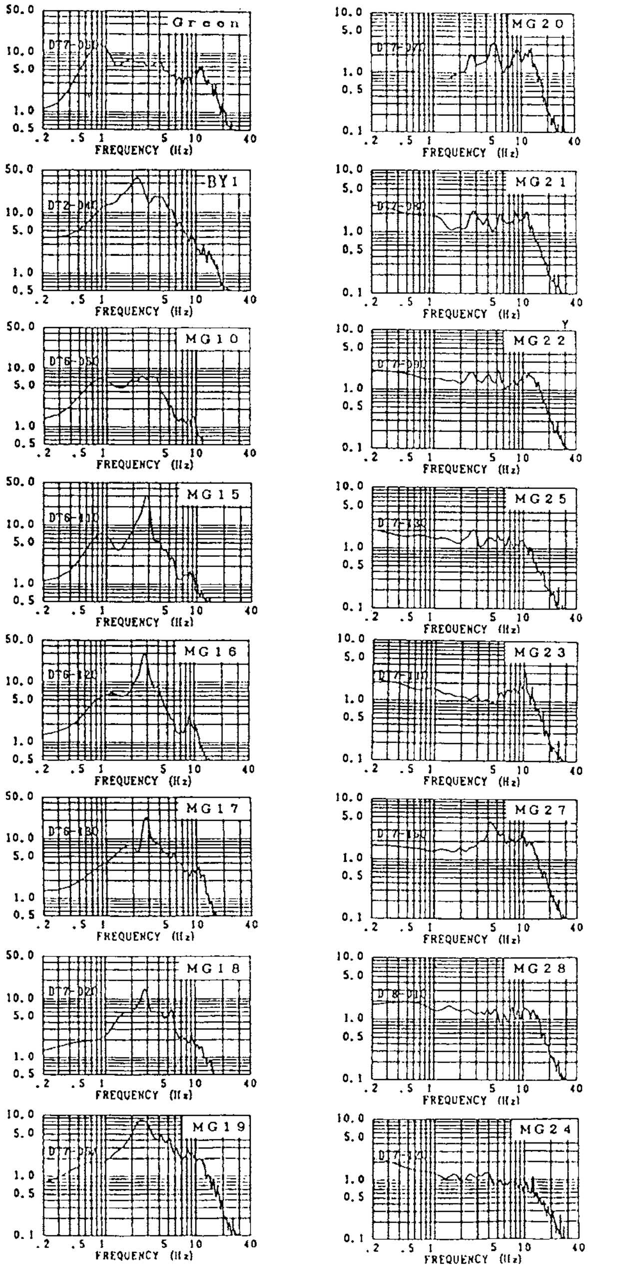

Fig.4 Fourier spectra of microtremor along Pierce Street

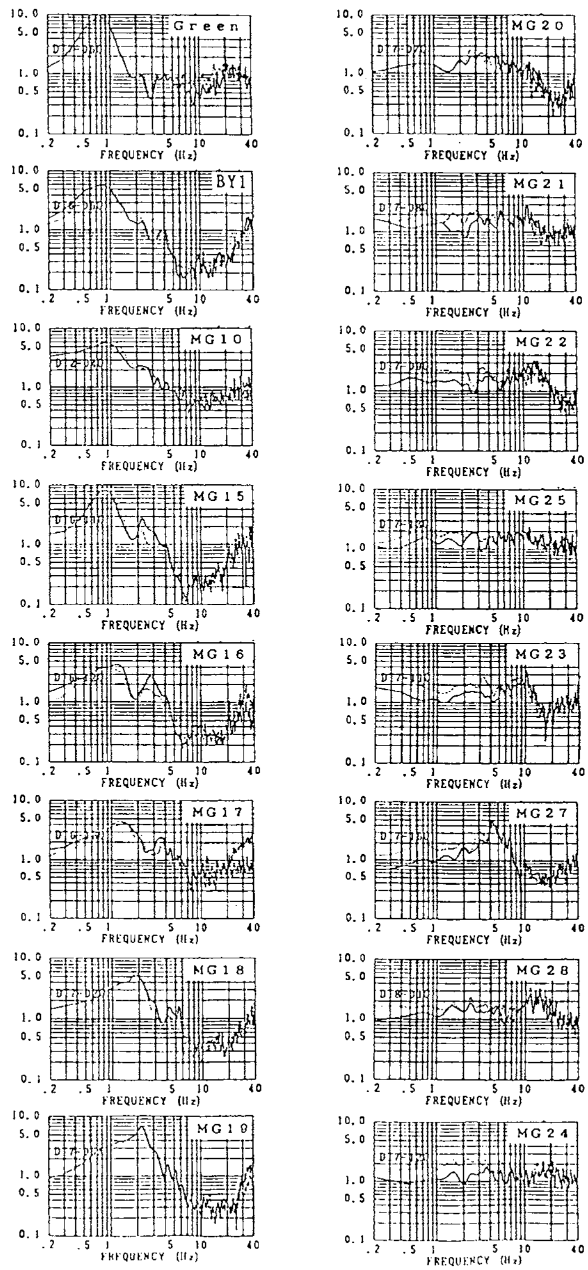

Fig.5 Spectral amplification factor along Pierce Street

Between MG19 on Toledo Way and MG20 on Lombard Street is Chestnut Street along which a so-called police line (or a barricade) was streched to restrict free access to the Marina District. The police line was a simple indication of a border of a heavily damaged area.

From Fig. 5, a predominant frequency (Fp) and an amplification factor (Ap) at the frequency Fp are found to be as shown in Fig. 6. There is an obvious trend that the predominant frequency increases from 0.8 Hz to 3 Hz with an increase in the distance from the shore line, while the spectral amplification factor decreases from 9 to 3. This trend seems to agree with the degree of damage in the area concerned.

b) Cypress and Embarcadero Viaducts

The Cypress Viaduct in Oakland and the Embarcadero Viaduct in San Francisco feature similar geometry and design, but quite different damage. Thus, the microtremor measurements were conducted at both sites in order to compare their ground motion characteristics. All the ten observation points are located along the foot of the west columns of the Cypress portion of the Nimitz freeway.

Predominant frequencies (Fp) and amplification factors (Ap) estimated in the same procedure that described before are shown in Fig. 7. Open marks are for the motion in the transverse direction, and closed marks are for the motion in the longitudinal direction, respectively. The amplification factor fluctuates from point to point, but it is around 5 in each direction. The factor looks a little larger in the transverse direction than in the longitudinal direction. At the points P62 and P61 where the Viaduct did not collapse, the factor is relatively low.

Fig. 8 shows predominant frequencies and amplification factors in the longitudinal and transverse directions to shore line observed at the foot of the Embarcadero Viaduct. Apparently, at the points between EG4 and EG18 where structural distress such as concrete cracks and ground settlement was observed, the amplification factor is about 10 or larger, even if the predominant frequency is almost the same as that along the Cypress Viaduct. This may suggest that intensity of the earthquake ground motion input to the Embarcadero structure should not be smaller than that input to the Cypress structure. Accordingly, the difference in damage would mainly be attributed to the detailed structural difference of the Viaducts.

c) South of Market District

In the South of Market District, including the Mission Creek area, boundaries of geological units are extremely complicated. Due to the geological complication, ground motion characteristics must vary irregularly from place to place. To take such geological condition into account, two observation lines were set in this district.

Fig. 9 shows predominant frequencies (Fp) and amplification factors (Ap) along the loop observation line. In Fig. 1, the points SG8 through SG16 are on the alluvial layer of less than 30 m depth, and the rest are on the Bay Mud layer in places covered by artificial fill. The factors demonstrate larger amplification of the Bay Mud layer except at the points SG3, SG4 and SG5. The estimation of these three points is less reliable, because these points are located in Caltrain yard, and a steady vibration components predominates in the recordings at about 6.2Hz.

Fig.10 shows the predominant frequencies (Fp) and amplification factor (Ap) in a horizontal direction along an observation line in the Mission Creek area. The point SG17 is on the Noe hill. The points SG24, SG22 and SG23 are on the Bay Mud layer. The factor Ap is less than 3 at the point SG17, and tends to increase on the Bay Mud layer. The predominant frequency along the observation line ranges between 1.5 Hz and 2.0 Hz.

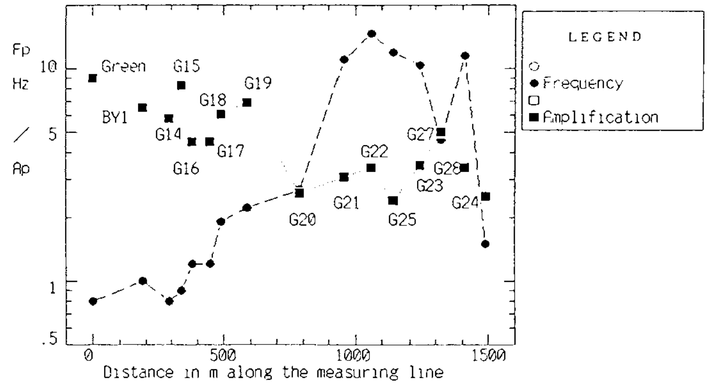

Fig.6 Predominant frequencies and amplification factors along Pierce Street

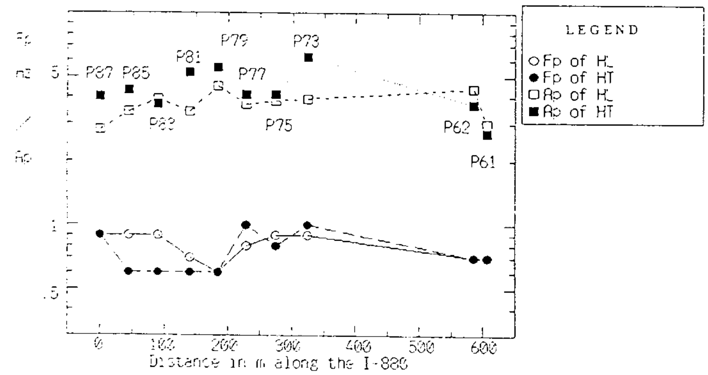

Fig.7 Predominant frequencies and amplification factors of the ground along Cypress Viaduct

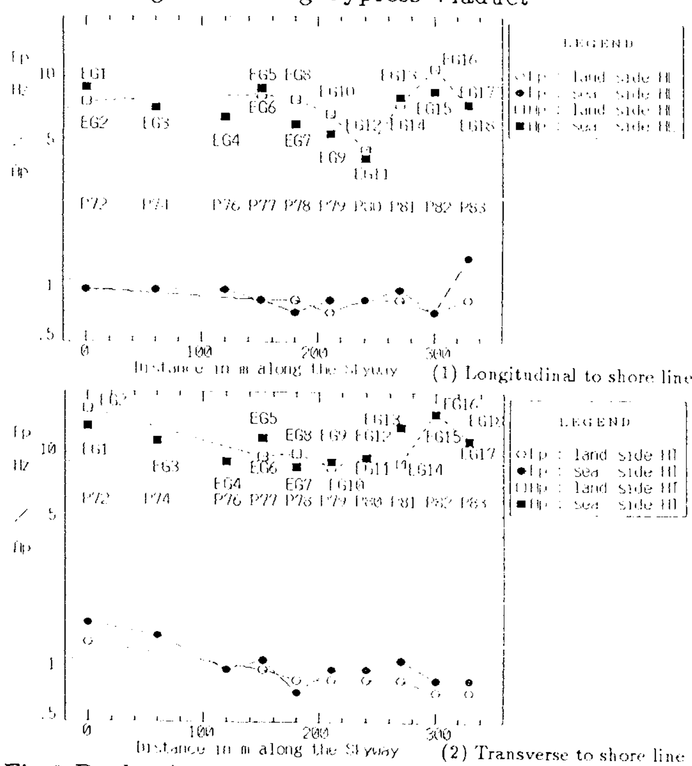

Fig.8 Predominant frequencies and amplification factors of the ground along Embarcadero Viaduct

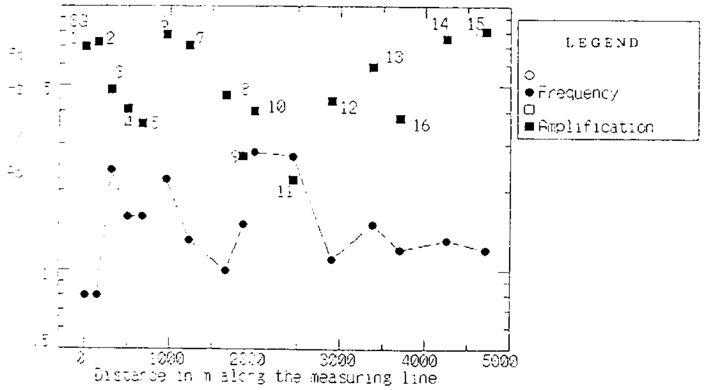

Fig.9 Predominant frequencies and amplification factors of the ground, South of Market

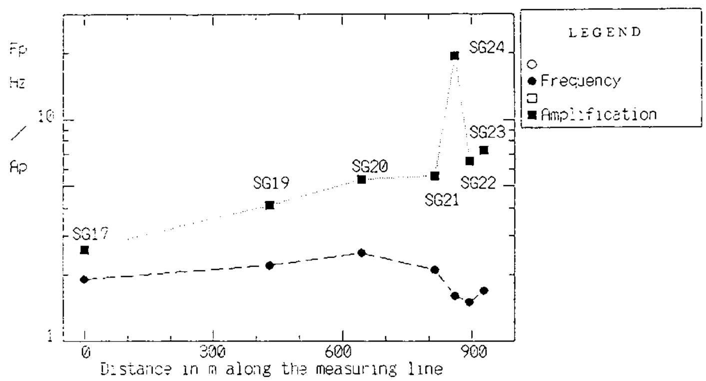

Fig.10 Predominant frequencies and amplification factors of the ground in Mission Creek

Table 2 Summary of predominant frequencies and amplification factors

	Fp (Hz)	Ap	Rank of Damage *
Marina			
MG1-MG4	1.0 - 1.2	4 - 5	B
MG5-MG19	0.8 - 1.0	5 - 9	A
MG20-MG28	> 3.0	2 - 3	C
Cypress			
P87-P73	0.6 - 1.0	3.7 - 6.2	A (HT) **
	0.6 - 0.9	2.8 - 4.5	(HL) ***
P62, P61	0.7	3.7, 2.7	C (HT)
	0.7	4.4, 3.0	(HL)
Embarcadero			
EG1-EG18	0.7 - 1.5	9 - 16	B (HT)
	0.7 - 1.6	9 - 16	(HL)
South of Market			
SG1-SG5	0.8 - 1.6	4 - 8	B
SG14, SG15	0.8 - 1.6	4 - 8	B
SG7-SG16	1.0 - 2.8	2 - 7	C
SG19-SG23	1.5 - 2.5	2 - 7	B
SG24	1.5 - 2.5	20	A

* Rank of Damage: A.....severely damaged.
B.....damaged.
C.....slightly or hardly damaged.

** HT: in the transverse direction of the viaduct.

*** HL: in the longitudinal direction of the viaduct.

CONCLUSIONS

Through a series of microtremor measurements followed by spectral analyses, predominant frequencies and amplification factors of the ground are estimated as shown in Table 2. The results lead us to the following conclusions:

(1) In the Marina District and South of Market, the high rank of damage is much coincident with the large amplification factor.
(2) Structural difference might affect the degree of the damage in the Cypress and Embarcadero Viaducts.
(3) The amplification factor and the predominant frequency used here give a practical rule of thumb in detecting ground motion characteristics, although their theoretical basis is still left unclarified.

ACKNOWLEDGEMENTS

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REFERENCES

1) Borcherdt, R. D. (1975), "Studies for Seismic Zonation of the San Francisco Bay Region", Geological Survey Professional Paper 941-A.
2) Nakamura, Y. (1989), "A Method for Dynamic Characteristics Estimation of Subsurface using Microtremo on the Ground Surface", QR of RTRI, Vol. 30, No.1.