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MEASUREMENT OF SHEAR WAVE VELOCITY OF SUBSURFACE IN MEXICO CITY BY BOARD BANGING METHOD TRIPARTITE OBSERVATION OF MICROTREMOR

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SUMMARY

Shear wave velocity in subsurface in Mexico City was measured by Board Banging Method and Tripartite Observation of microtremors. It was made clear that the velocity of soft soil was 20m/s to 100m/s, but consolidated artificial fill with the velocity of 200m/s to 400m/s was exist above soft soil. On the continuous observation of microtremor at four sites, it was confirmed that microtremor in Mexico City was originated by human activities, but its predominant period was stable. Temporal Observation of microtremor carried out along six lines crossing the lake zone in Mexico Valley showed that predominant period of microtremor was affected by subsurface structure. Mean value of shear wave velocity of subsoil was estimated at about 60m/s from the equation of T=4H/Vs.

INTRODUCTION

Damages in Mexico City during the 1985 Michoakan Earthquake is found to be distributed in the central part of Mexico City, and this pattern of damage distribution has repeatedly appeared at the time of preceding earthquakes. The similar damage pattern for different earthquakes suggests that strong ground motion in Mexico City is affected by local soil conditions to a great extent. Therefore, it is very important to make clear the local effects in subsoil in Mexico City.

In this point of view, systematic measurement of microtremor had carried out by some Japanese groups immediately after the 1985 earthquake (Ref.1,- 4). In consequence, two important conclusions on seismic characteristics of subsoil have been obtained. Predominant period of microtremor has good agreement with that of strong ground motion accelelograms in several sites in Mexico City. Predominant period and amplitude of microtremor change drastically in accordance with the thickness of sediment in lake bed zone. Some studies on seismic response of subsoil up to date suggest that long period of one to two seconds and large amplitude of strong motions obtained at some sites in lake bed zone are due to the thick sediment up to the depth of 60m in the center area of the Lake Texcoco.

Our understanding on seismic characteristics of subsoil in Mexico City seems to succeed for the present. However, several problems to be solved are newly presented to enhance the detailed understanding on seismic properties of subsoil in Mexico City. At this moment, the origin and stability of microtremor, the relation between characteristics of microtremor and geological structure of subsoil, shear wave velocity and its spatial distribution in Mexico City, etc. are important problems to be discussed.

In the present paper, the following field study was carried out to understand the seismic characteristics of subsoil in Mexico City.

1) Measurement of shear wave velocity of subsurface by Board Banging Method.
2) Measurement of velocity and direction of propagating microtrmor by Tripartite Observation.
3) Measurement of microtremor at several sites to confirm its origin and stability.
4) Measurement of microtremor along several lines across Lake Texcoco, Lake Xochimilco and Lake Chalco to make clear the relation between microtremor and soil condition.

MEASUREMENT OF SHEAR WAVE VELOCITY BY BOARD BANGING METHOD

METHOD A wooden plate of about 3m long, 50cm wide and 5cm thick was loaded by a heavy vehicle to fix the plate with the ground surface. Then SH wave was generated by hitting one side of the plate in the horizontal direction perpendicular to the expansion line. Three pick-ups were set on the ground surface by several meters spacing. To record the origin time, the fourth pick-up was always set at the plate. To ensure the arrival phase of SH wave, a hitting from the reversed direction was made later on. Then, upon completion of recording at a distance, three pick-ups were forwarded to a more distant position.

SITES Measurements were carried out at sites 2, 3 and 4 in Fig. 1. It is well known that uppermost ground surface in Mexico City is usually covered with concrete or artificial fill, which have higher velocity than soft soil of our interest that lies below such artificial fill. The thickness of such inverse layer is several meters, hence it will be very difficult to obtain information of soft soil. To avoid the problem of inverse layer, the measurements were attempted under the following consideration. At site 2, the measurements were carried out at two sites, with and without artificial fill, which are apart about 500m each other. At site 3, measurements were carried out at level -3.45m (in artificial fill) and -9.33m(in soft clay) at the construction area of Metro. At site 4, unconsolidated soft soil is exposed to the ground surface.

RESULTS The paste-ups of records are presented in Fig. 2. Extremely low velocity as well as 22m/s was obtained at site 4. This is considered to be equal to the shear wave velocity of unconsolidated soft soil in Mexico City. Shear wave velocity at site 3 is found to be 51m/s for soft clay(-9.33m) and 185m/s for artificial fill(-3.45m). These velocities are as well as those obtained from borehole loggings at several sites in Mexico City(Ref. 6). The shear wave velocity of the ground without artificial fill at site 2 is founded to be 85m/s, which is still high for the value of soft soil. This can be interpreted that the surface is naturally dried up, hence ground surface is consequently consolidated to some extent than soft soil of lower part. In fact, the velocity of surface wave excited by truck dropping is found to be 47m/s(Ref. 5). Much higher velocity of 350m/s is obtained on the ground with artificial fill at site 2. Such high velocity may be due to the effect of rock materials included in artificial fill.

TRIPARTITE MEASUREMENT OF MICROTREMOR

SITE AND METHOD Tripartite measurement of microtremor was carried out in hilly zone(site 1), transition zone(site 5) and lake bed zone(site 2, 4). Three pick-ups with single component were set each corner of triangular array with a spacing of 60m to 85m. Records of each station were centered to an analogue cassette tape recorder. High cut filtering technique was applied to these records to extract the propagation velocity in the period range of predominant period.

The phase difference among three station's records was obtained by picking corresponding maximum of peaks. Propagation velocity was calculated from the phase differences on the assumption that microtremor is propagating only in the horizontal direction.

RESULTS Calculated velocities are presented in a vectorial form in Fig. 3. Site 1(Mexico University) is located on the lava flow. It seems that microtremor is propagationg to random directions with velocity from 200m/s to 500m/s. Velocity at Site 3(Viveros) which is located in transition zone is 200m/s to 300m/s which is lower than that at Site 1. Velocities at Site 2 and Site 4(Lake Texcoco) which are located in lake bed zone are from 100m/s to 200m/s. It is made clear that the propagation velocity of microtremor is high in hilly zone and slow in lake bed zone.

The other difference in the result is the direction of propagation of microtremor. Observed direction at Site 1 is random, but at other sites dominant in peculiar direction which seems to be equal from the capital road. This suggests that the origin of microtremos in hilly zone is different to other zones. This problem will be discussed in the following section.

CONTINUOUS MEASUREMENT OF MICROTREMOR

Kobayashi et al(Ref. 1, 2) measured microtremor in extensive area in Mexico City immediately after the earthquake of 1985. They presented the iso-period map of predominant period of micretremor and estimated the intensity distribution of ground motion due to the main shock of 1985 earthquake on the analysis of microtremor. However, several questions such as stability of microtremor still remain.

METHOD At five accelelogragh sites 1, 2, 2', 6 and 7 in Fig. 1, continuous measurement of microtremor was performed to check the stability of microtremor. At each site, the measurement continued at least 24 hours to 66 hours at maximum five minutes' recording was made in every two hours by using the measurement system in which natural period of one second of pick was extended electronically to five seconds.

RESULTS Fig. 4 shows the time history records in every two hours at Site 1(hilly zone) and Site 6(lake bed zone). Typical fourier velocity spectra at daytime and nighttime are presented for each site in Fig. 5. In every sites, changes of peak periods in spectrum are not recognized within one day, i.e., peak period is in a stable in every sites. Amplitudes of component less than one second at Site 1 and Site 7(hilly zone) reduce during the nighttime. Amplitudes at Site 2, 2' and 6(lake bed zone) reduce also during nighttime.

Typical operation schedule of metro shown in Fig. 6 explains the traffic situation in Mexico City. Periodic change in amplitude of microtremor mentioned above has good agreement with the traffic condition in Mexico City. It suggests that microtremor in Mexico City is mainly originated by human activities.

Fig. 7 shows the meteorological data measured at Tacubaya Observatory for a long time. It seems to be some correlation between atmospheric pressure and amplitude of microtremor of five seconds at Site 1. This suggests that microtremor of five seconds in hilly zone does not have its origin in human activities but meteorological affect.

TEMPORAL MEASUREMENT OF MICROTREMOR ALONG LINE

METHOD Kobayashi et al(Ref. 1, 2) attempted to measure microtremor along the line crossing the Mexico Valley including central part of the city from east to west, and presented that spatial variation of amplitude and predominant period of microtremor had good agreement with shallow geological structure in the Valley. Additional measurements were attempted along six lines which across Lake Texcoco, Lake Xochimilco and Lake Chalco to get more detail characteristics of microtremor to subsoil condition. The whole measurements were carried out in the daytime, when the characteristics of microtremor are considered to be stable.

RESULTS Fig. 8 shows the distribution of predominant period of microtremor obtained in this measurement. Contour lines show the previous results presented by Kobayashi et al. Both results have a good correlation.

Fig. 9 shows the relation between the depth of sediment and characteristics of microtremor along the west-east line crossing Lake Texcoco from Tacubaya to Texcoco City. Predominant period and spectral amplitude of microtremor have a good agreement with depth of sediment.

Fig. 10 shows the relation between predominant period of microtremor and thickness of sediment. Solid line presents the relation of T=4H/Vs in the case that shear wave velocity is given to be 60m/s. The figure suggests that average value of shear wave velocity of sediment in Mexico Valley is 60m/s, but lower in the center area in the lake and higher in the marginal area. Cubes are the data obtained from strong motion records whose predominant periods seem to be a little longer than those of microtremor. It may be nonlinear effect of soft soil.

CONCLUSION

The seismic characteristics of subsurface in Mexico City are made clear by systematic field survey in and around the city. Shear wave velocity in subsurface in Mexico City is found to be 20m/s to 100m/s by the Board Banging Measurement and microtremor observation. The velocity in consolidated fill above soft soil is much higher than that in soft soil. Origin of microtremor in Mexico City is human activities, but meteorological affect in the period of five seconds in hilly zone. Characteristics of microtremor has a good relation with soil condition, therefore it is useful to survey soil structure in Mexico City.

ACKNOWLEDGMENTS

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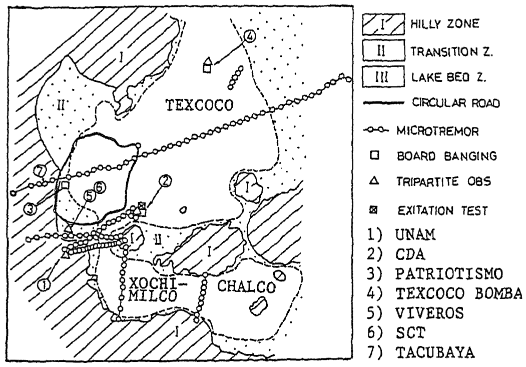

Fig. 1 Location of observation points and zoning map of Mexico Valley.

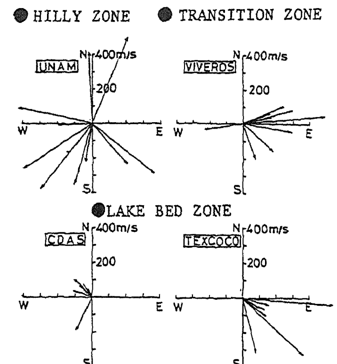

Fig. 3 Propagation Velocity and direction of microtremor.

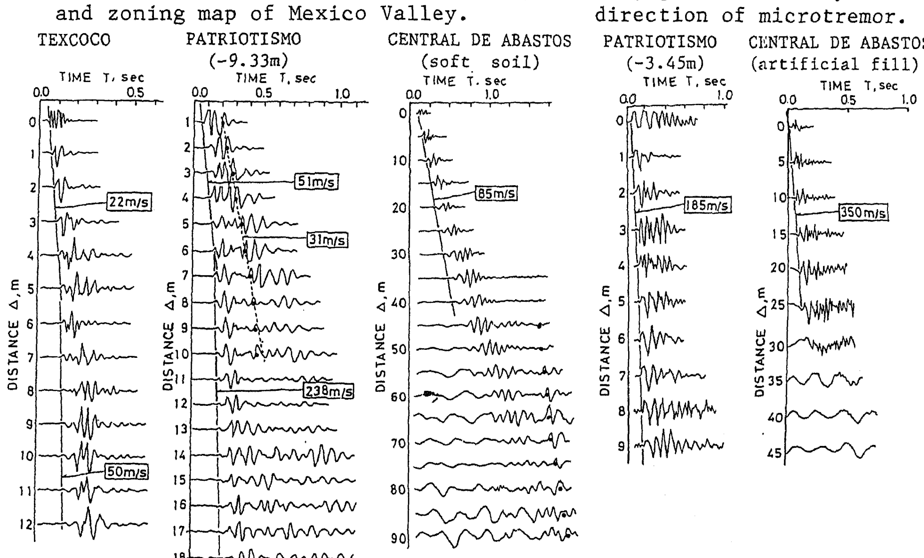

Fig. 2 Shear wave velocity obtained by Board Banging Measurement.

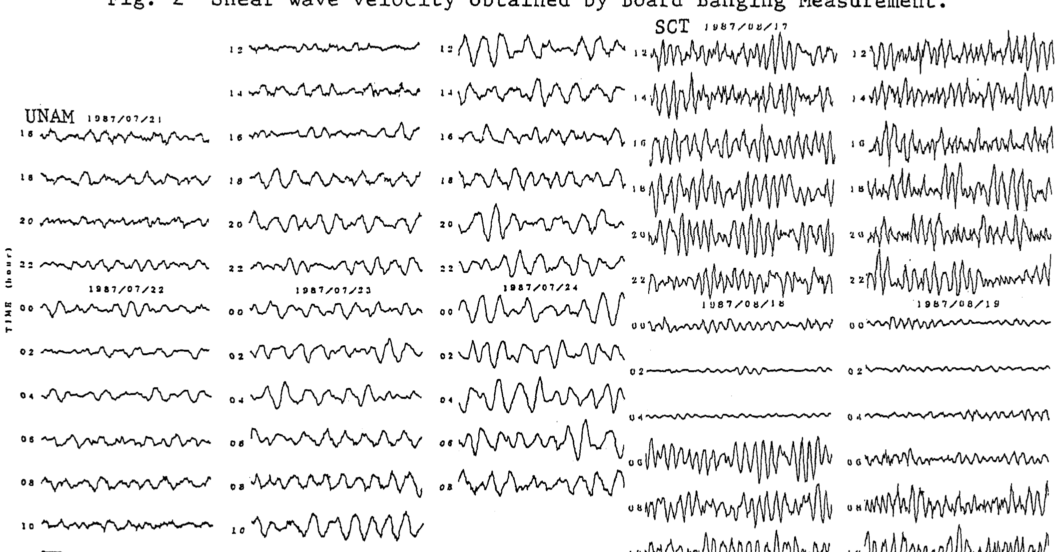

Fig. 4 Records of microtremor obtained by continuous observation at UNAM and SCT.

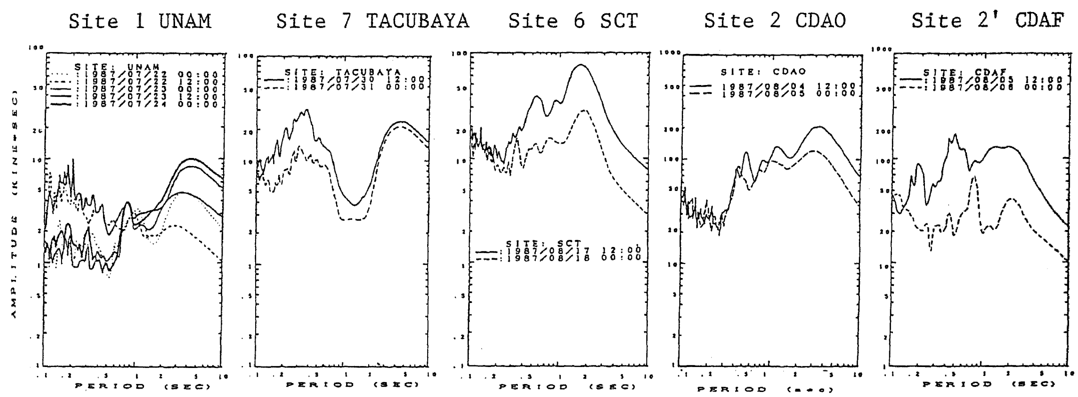

Fig. 5 Spectrum of microtremor observed at strong motion accelerogram station.

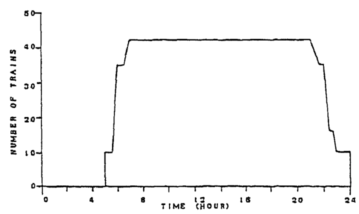

Fig. 6 Schedule of Metro in Mexico City during one day.

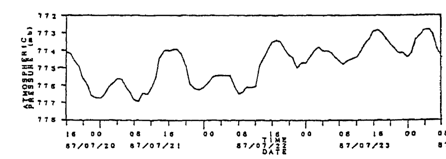

Fig. 7 Atmospheric pressure record at TACUBAYA Observatory in Mexico City during four days.

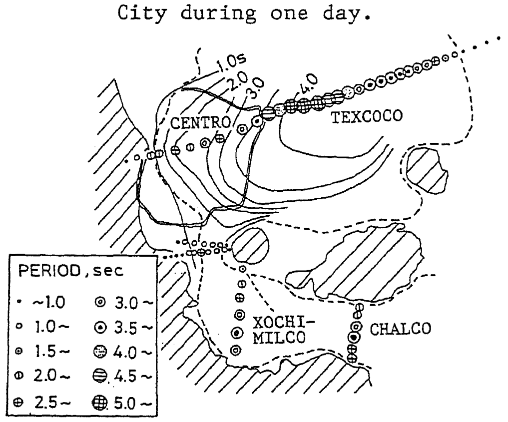

Fig. 8 Distribution of predominant period of microtremor in Mexico Valley.

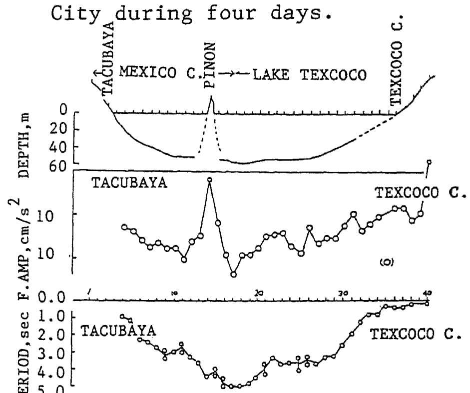

Fig. 9 Soil structure, predominant period and spectral amplitude of microtremor.

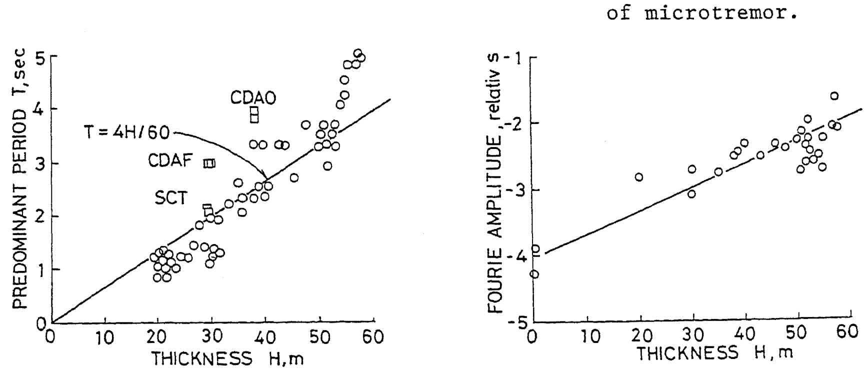

Fig. 10 Relation between predominant period and thickness of sediment.