Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.II)

3-4-17

INTERPRETATION OF STRONG GROUND MOTIONS IN MEXICO CITY DURING THE MEXICO EARTHQUAKE OF SEPT. 19, 1985

Yoshitaka YAMAZAKI[1], Kazuoh SEO[2] and Takanori SAMANO[3]

[1]Present Address, Geotechnical Institute, OYO Corporation, Saitama, Japan
[2]Associate Professor, Tokyo Institute of Technology, Yokohama, Japan
[3]Research Associate, Tokyo Institute of Technology, Yokohama, Japan

SUMMARY

Dynamic properties of soft soil in Mexico City are presented, based on field experiments performed in Central de Abastos (CDA). S-wave velocity of upper clay layer (FAS) is confirmed to be 50 m/s to 60 m/s, which makes a sharp contrast with that in the firm layers below. Accordingly, predominant period of ground motion appears clearly. Estimated ground structure model at the site gives a good fit with the experimental results. Thickness of FAS is 36 m at Office in CDA (CDAO), *changing drastically in CDA around CDAO. This may be an* important factor to interpret strong ground motions in CDA.

INTRODUCTION

It is noteworthy that Mexico City has suffered the severest damage due to the 1985 Mexico Earthquake, in spite of its epicentral distance at far as 400 km. At that time, National Autonomous University of Mexico (UNAM) had succeeded in recording strong motions at various sites in Mexico, including eight stations in Mexico City. These valuable records had supplied basic information to enhance understanding of damage and other phenomena related to earthquakes.

In considering ground motion characteristics in Mexico City, the effect of soft soil of less than 100 m thick is confirmed by basic agreement in spectra of microtremor and strong motions (1). The nature of microtremor in the City is well understood by now through its long term measurements (2).

At this moment, the remaining problem when microtremor is *effectively put to use is the* disagreement in spectral characteristics between microtremor and strong motion at CDAO site. At CDAO site, long lasting later phase with period of 4 seconds was observed during the 1985

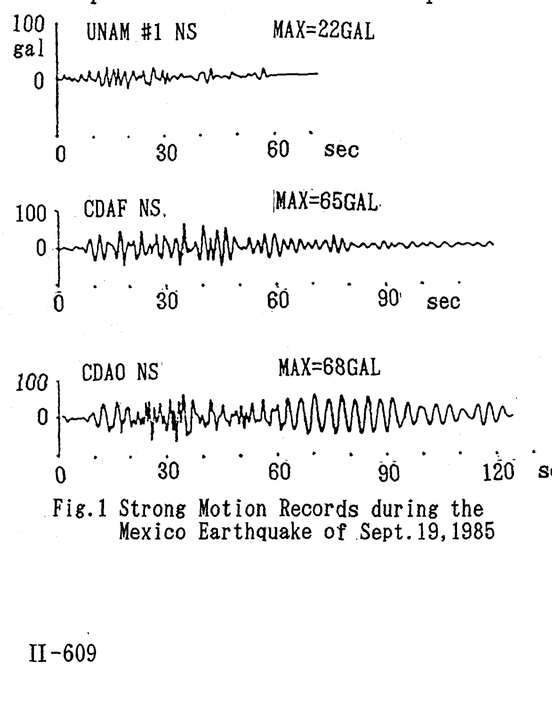

Fig.1 Strong Motion Records during the Mexico Earthquake of Sept.19,1985

Earthquake, while no such phase were recognized at CDAF site in spite of close distance of 1.4 km as seen in Fig. 1. Empirically, this later phase may be a surface wave phase due to local soil conditions. However, local soil data were not available in CDA by then. Therefore, in this paper, with an objective to interpret this phenomenon, local soil conditions in CDA are discussed through plank hammering, tripartite measurement of microtremor and surface wave excitation experiment.

MEASUREMENT OF MICROTREMOR IN THE VICINITY OF CDA

Before initiating the experiments within CDA, measurements of microtremor were performed to overview the variation in local soil conditions as dotted in Fig. 2, so as to cut across the southern part of the City. This is because not so many measurements were performed in this area at the time of last measurement (3).

The resulted records in Fig. 3 show that the prodominant period of microtremor tends to be longer in the eastern part of the City, and its amplitude increases at the same time. The record at site No. 1 through No. 3 must be distinguished from others because they are microtremor on the lava flow area, where amplitude is very small. Notably, microtremor at CDAO site has considerably large amplitude, with predominant period as long as 3 seconds. No such a long period can be seen at other sites in CDA, i.e., predominant period is 2.4 seconds at No. 17 (CDAF) and those at other sites such as No. 14 or No. 16 are about 2 seconds. This face suggests that there exists very thick soft soil at CDAO, and that its thickness changes drastically in its vicinity. This may be an important clue to interpret the appearance of later phase in strong motion uniquely recorded at CDAO site during the 1985 Earthquake.

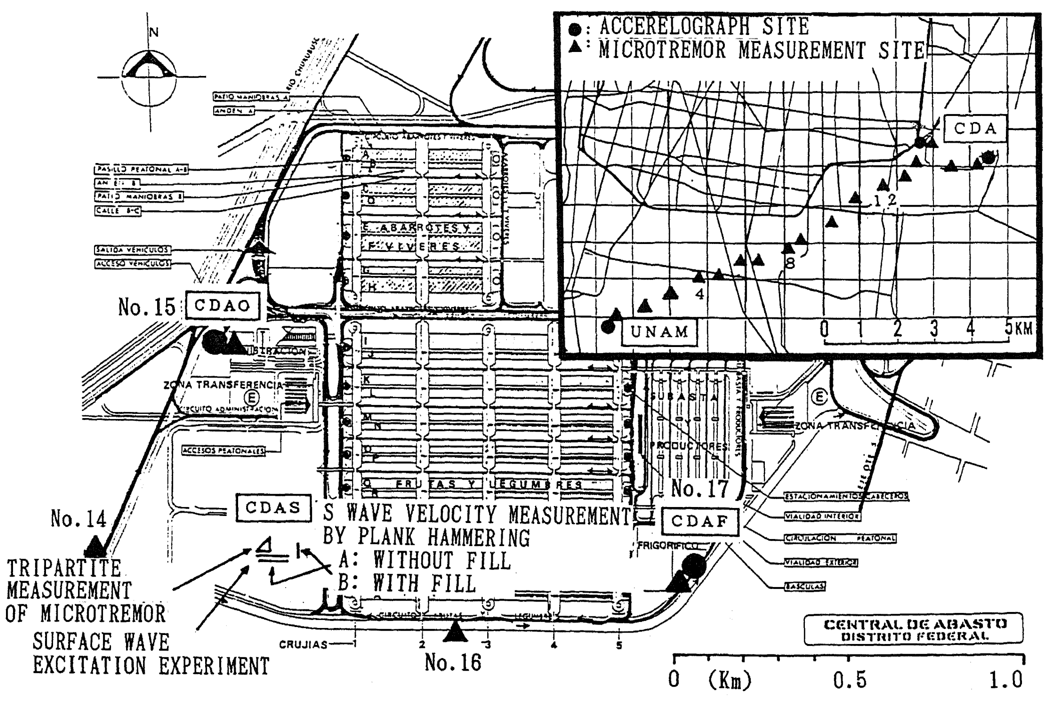

Fig.2 Measurements Sites in Mexico City

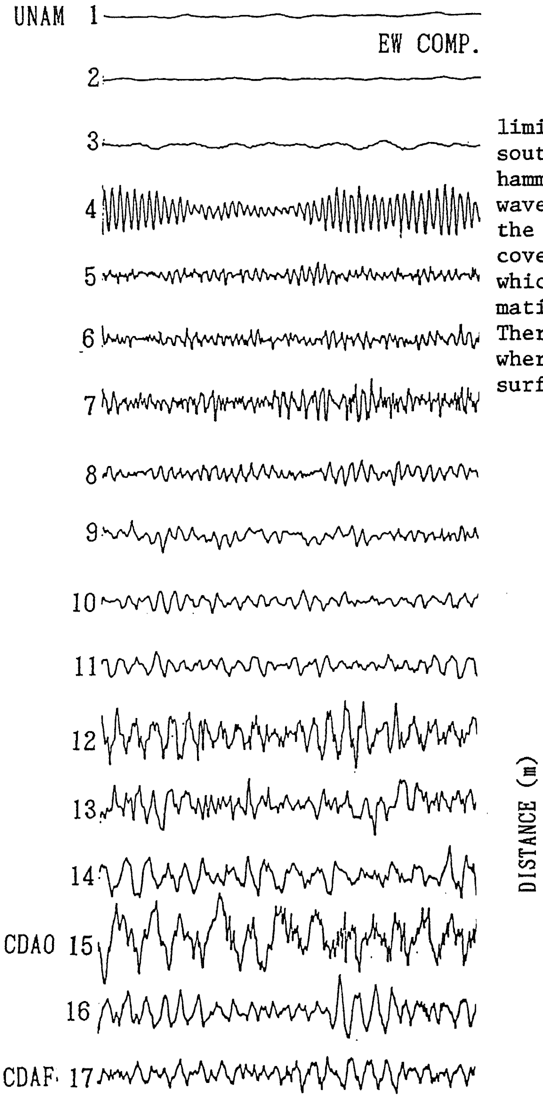

Fig.3 Microtremor Records Between UNAM and CDA

SHEAR WAVE VELOCITY MEASUREMENT OF SOFT SOIL BY PLANK HAMMERING

From this section, discussion is limited within CDAS site, located 500 m southward from CDAO. At the outset, plank hammering was attempted to obtain shear wave velocity of soft soil. However, in the most part of the City, soft soil is covered with consolidated fill or pavement which makes it difficult to obtain information of soft soil beneath them. Therefore, plank hammering was performed where no such layer are found at the ground surface.

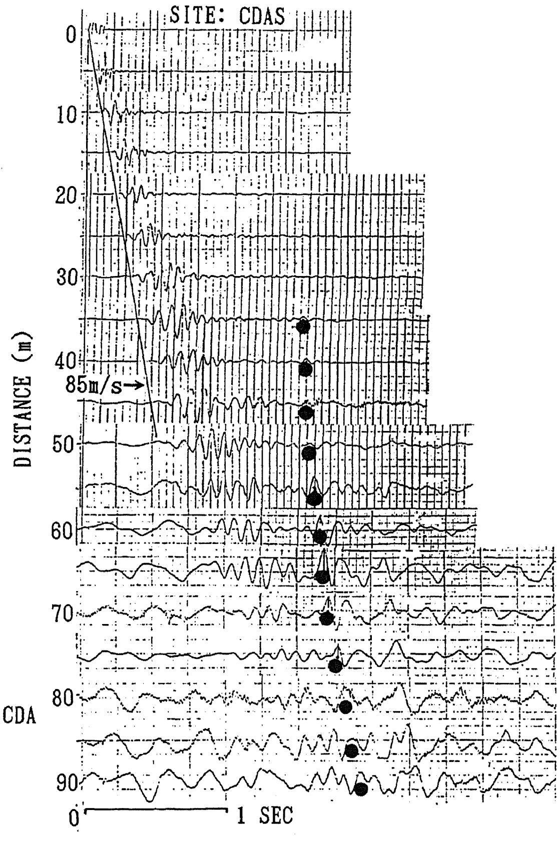

Fig.4 Records of S-Wave Velocity Measurement By Plank Hammering

The resulted records are presented in Fig. 4. In this case, S-wave velocity of 85 m/s was obtained by picking first arrivals. Though this is relatively higher than expected value of 60 m/s or so (4), this may be due to the fact that the upper most part of soft soil is half-dried because of natural evapolation.

Interestingly, distinct later phase begins to appear away from 30 m's distance as indicated by dot in Fig. 4. It is very likely to be a reflected phase, taking its arrival time and amplitude into account, which suggests the existance of a firm layer at 30 m to 40 m below the ground surface.

TRIPARTITE MEASUREMENT OF MICROTREMOR

S-wave generated by plank hammering has frequency higher than ground motion subjected to earthquake. Therefore, use of longer period wave would be more desirable to investigate deeper portion of soft soil. For this purpose, tripartite measurement of microtremor is performed at CDAS site, using three sets of pick-ups distributed by 40 m's spacing on the ground surface.

Since predominant period of microtremor is 2.3 seconds at CDAS site, component higher than 0.5 Hz was filtered out, and resulted records at three stations are shown in Fig. 5. Good correspondence of phases among three stations are recognized as indicated by dotts. Upon picking up time lags between these phases at three stations, their propagation velocity are calculated to be in the range from 30 m/s to 200 m/s. Furthermore, their particle orbit shows that they are composed of Love wave and Rayleigh wave as seen in Fig. 6. Such low propagation velocity of microtremor suggests that surface wave with period from 2 to 4 seconds propagates mostly within soft soil.

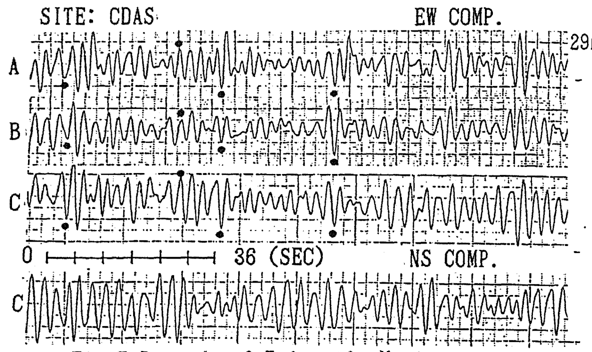

Fig.5 Records of Tripartie Measurement of Microtremor

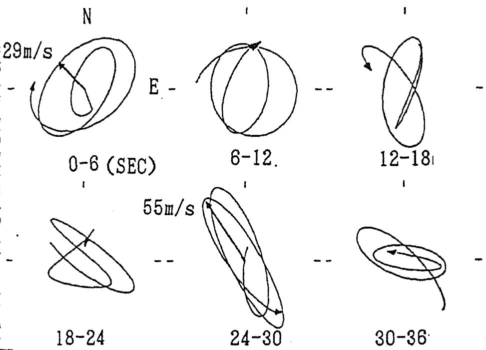

Fig.6 Particle Orbit of Microtremor

SURFACE WAVE EXCITATION EXPERIMENT USING TRUCK

Dissatisfactions still remain with former experiments, i.e., microtremor is a long period wave, but its source cannot be specified. Plan hammering works as an explicit source, but only in higher frequency. In an attempt to overcome those shortcomings, an weighty truck was dropped to a shallow ditch so as to give a heavy impact on soft soil. At this time, recording was made at ground surface using the same set of pick-ups used in previous section. The pickups are arranged on the ground surface at every 20 m, as far as 100 m.

As a result, ground motion was recognized mainly in vertical and radial components, showing typical motion of a Rayleigh wave. An example of paste-up for vertical component is shown in Fig. 7. Its apparent velocity of 47 m/s shows low velocity of soft soil. To extract information using dispersive nature of surface wave, multiple filtering technique is applied to vertical comoponent record at 100 m, where surface wave may be well excited. As a result, inverse dispersion is recognized in the period range from 0.5 second to 1 second as seen in Fig. 8. Though the period is still shorter than that of earthquake ground motions, deeper portion of subsurface is extracted to some extent by this experiment. This inverse dispersion character shall be a key to evaluate overall soft soil structure at CDAS in the following section.

SUBSURFACE STRUCTURE MODELING FOR CDAS SITE

Finally, those obtained results are integrated to estimate ground structure

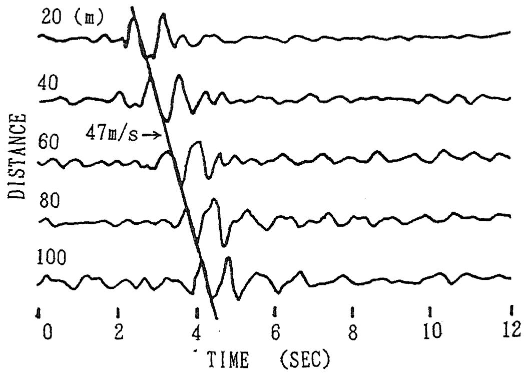

Fig.7 Paste-Up of Records Obtained by Surface Wave Excitation Experiment

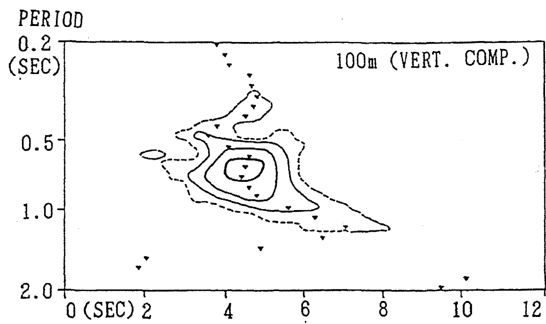

Fig.8 Multiple Filterd Record Obtained by Surface Wave Excitation Experiment

at CDAS site, referring to the results of PS loggings as shown in Table 1, performed independently to this study at CDAO site and CDAF site (5, 6). According to these results, ground structure down to 60 m can be described with five major layers.

The uppermost part down to 5 m is consolidated fill having S-wave velocity around 100 m/s at CDAO site or at CDAF site. In this case, S-wave velocity of 85 m/s is adopted for CDAS site, which was obtained by plank hammering as shown in Fig. 3.

Beneath this inverse layer lies upper clayey layer (FAS), with average S-wave velocity from 50 m/s to 60 m/s, and its associated water content as high as 200% to 400% (5, 6). Its thickness is 36 m at CDAO, while it is 22 mm at CDAF, showing the major difference between two sites as seen in Table 1, which was already inferred from the difference in predominant period of microtremor as shown in Fig. 3. FAS is definitely the most contributing layer to the ground motion characteristics, since it has the lowest S-wave velocity and occupies the largest portion among subsurface layers. Now, the thickness of FAS is estimated to be 27 m for CDAS site, so that calculated predominant period of site amplification factor matches with that of microtremor at CDAS site, i.e., 2.3 seconds.

Then, FAS is interbedded by silty layer (CD), then encounters lower clayey layer (FAI). Firm layer of tertiary origin deposite (DP) exists at 57 m in depth at CDAO site and 42 m at CDAF site. The proportion of the thickness of CD to that of FAI for CDAS site is chosen from the logging result obtained at CDAO site. As a result, estimated ground structure model for CDAS is presented in Table 1.

Table 1 Ground Structure model for CDAO, CDAF and CDAS

SITE	CDAO				CDAF				CDAS (Estimated)			
LAYER	H m	Vs m/s	Vp m/s	ρ g/cm³	H m	Vs m/s	Vp m/s	ρ g/cm³	H m	Vs m/s	Vp m/s	ρ g/cm³
F	5	104	1326	1.42	5	107	1378	1.34	2	85	1326	1.35
FAS	36	52	1370	1.22	22	60	1497	1.24	27	52	1370	1.22
CD	5	203	1511	1.60	5	153	1410	1.48	5	203	1511	1.60
FAI	11	167	1638	1.49	10	180	1327	1.25	11	167	1638	1.49
DP	--	387	1704	1.96	--	397	1724	1.96	--	387	1704	1.96

Theoretical dispersion curves are calculated as shown in Fig. 9 based on estimated ground model for CDAS site. Dotts indicate group velocity obtained by surface wave excitation experiment. The theoretical curve for Rayleigh wave agrees well with these dotts, in the tendency of inverse dispersion. Aars indicate propagation velocity of microtremor obtained by its tripartite measurement. These bars are in the range of theoretical dispersion curves of Rayleigh wave and Love wave, since microtremor may be a mixture of them.

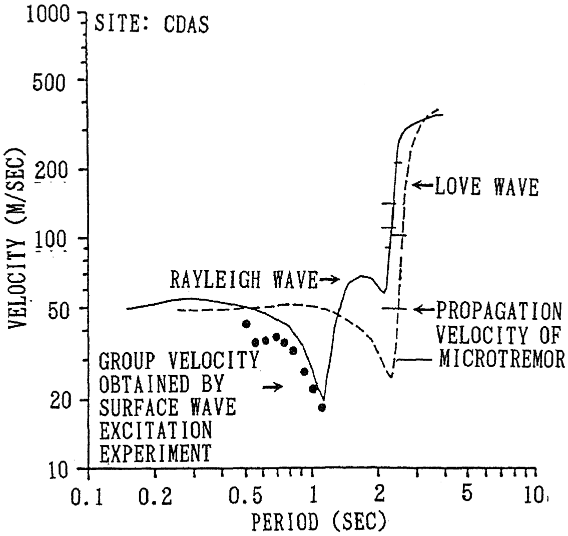

Fig.9 Dispersion Curves

CONCLUSION

Wave propagation velocity less than 100 m/s in soft soil in Mexico City was confirmed through experiments at CDAS site, as shown in Fig. 4, 5 and 7. Estimated ground structure model for the site well explains these results as shown in Fig. 9.

PS logging results as CDAS and CDAF show that FAS is the most contributing layer to ground motion features, taking its S wave velocity of 50 m/s to 60 m/s and its proportion among subsurface into account Predominant period of 2 to 3 seconds appears easily in ground motion, due to the clear contrast between FAS and firm layers below.

FAS is as thick as 36 m at CDAO, while 27 m thick at CDAF. Its thickness is expected to change drastically in the vicinity of CDAO in CDA area, from the results of microtremor measurements as seen in Fig. 3. This should be one of the principal factor to interpret the later phase uniquely recorded at CDAS site during the 1985 Earthquake.

ACKNOWLEDGEMENT

This study was done under the support by Institute of Engineering, National Autonomous University of Mexico and Federal Commission of Electricity, Mexico, when one of the author (Y.Y.) was visiting UNAM as a research student from T.I.T. Supports from these institutions are acknowledged to the greatest extent. Mr. Masatake Nagano and Dr. Kazuaki Masaki had helped field experiments. Also, numerous helps of our colleagues are greatly acknowledged.

REFERENCES

1. Kobayashi, H. et al., "Estimated strong ground motion in Mexico City due to the Michoacan Mexico Earthquake of Sept. 19, 1985 based on characteristics of Microtremor," Tokyo Institute of Technology, (1986).
2. Masaki, K. et al., "Measurement of shear wave velocity of subsurface in Mexico City by board banging method and tripartite observation of microtremor," Proceedings of 9WCEE, (1988).
3. Kobayashi, H. et al., "Measurement of microtremor in and around Mexico D.F.," Tokyo Institute of Technology, (1986).
4. Seo, K. et al., "Interpretation of strong ground motion in Mexico City during the Mexico Earthquake of Sept. 19, 1985," Proceedings of 7th Japan Symposium on Earthquake Engineering, 307-312, (1986).
5. Jaime, A. et al., "Caracteristicas del subsuelo en el sitio CDAO," UNAM, (1987).
6. Jaime, A. et al., "Caracteristicas del subsuelo en el sitio CDAF," UNAM, (1987).