

LOCAL SITE EFFECT OF MEXICO CITY BASED ON MICROTREMOR MEASUREMENT

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ABSTRACT

Mexico city suffered severe damage during 1957 and 1985 earthquakes originating at Pacific coast subduction zone, the first one was in Guerrero and the second one was in Michoacan, both about 350 km west from Mexico city. At the coast near the source the damage was slight but at the bed of the old Texcoco lake in Mexico city, since the soil is very deep and water saturated, the damage was severe. In both cases, the damage was concentrated at the same location. For solving this situation there have been many studies performed since the earthquakes. But, knowing that the site effect and vulnerability of ground and structures is an important for earthquake disaster mitigation, detailed investigation of the city is still needed to be able to reliably prepared for the future earthquakes. As a part of project for developing earthquake disaster mitigation technologies, the present research has been started in Mexico City for detailed investigation of the ground. Total project includes investigation of the vulnerability of ground and different type of structures as well. Present paper will be focused on preliminary results from the ground investigation.

In August 1999, microtremor measurements were performed at about 200 ground points along four profiles which across hill zone, transition zone and fill zone from east to west (E-W) direction and one profile on north-south (N-S) direction. Sampling intervals between measurement points are 200 m along E-W profiles and 500 m for N-S profile, respectively. For the analysis, horizontal to vertical spectral ratio (H/V ratio, QTS) (Nakamura,1989) was used. QTS gave the surface ground dynamic characteristics as predominant frequency (F) and amplification factor (A). Vulnerability index K_g values which is basically derived from strains of ground in the time of earthquakes, are also calculated as $K_g=A^2/F$ (Nakamura,1996). Showing the weak points around on the investigated area, the present study shows good correspondence between the site condition and K_g indexes. Results are compared and confirmed with other studies based on microtremor and strong motion data recorded at the same area. Our purpose is to investigate every detail in a pinpoint sensitivity and prepare detailed microzonation map of Mexico city. This information is valuable and make possible to estimate damage distribution before an earthquake occurs.

Introduction

It is widely recognized that, site effect and vulnerability of ground and structures are an important issues for earthquake disaster mitigation. Determining these characteristics in advance and increasing durability of ground and structures beyond the presumed seismic force become a fundamental of earthquake disaster prevention. The geological features of Mexico city are characterized by the following three zones; the lacustrine clay zone by the old Texcoco lake, volcanic rock zone at the west side of Mexico city and the transition zone. (Espinosa-Aranda, 1990). Depending on this condition, most of the collapsed buildings during the earthquakes were located around the boundary between the lacustrine zone and the

transition zone, since the damage of the building was triggered by the amplification of the ground motions through the soft clay deposit which is surrounded by hard volcanic rock formations.

Mexico is located near the joint of three tectonic plates. The subduction process is the tectonic feature that has the highest seismic activity and the Cocos plate is the main surface of this activity. The observed occurrence period of major earthquakes in this part of the middle America trench is between 30-35 years. The San-Marcos and Guerrero Gaps have the highest seismic risk in this zone. If major earthquakes expected in the Guerrero gap takes place, the damage in Mexico City would be similar to the one occurred on September 19, 1985, because the seismic waves are enormously amplified at lake bed sites and even at hill zone sites. Considering this possibility, there is still a great need of detailed investigation of the ground and structures in Mexico City. Present study has been started in Mexico City for this purpose, These detailed investigation is expected to be useful tool for increasing precision of damage estimation (before the earthquake occurs).

The area which was damaged after the 1985 earthquake was divided with five profiles along E-W and N-S directions and microtremor measurements performed at about 200 points, every 200m in E-W and 500m in N-S directions. Location of these profiles are given in Fig. 1. Instead of random point microtremor measurements, measurements along profiles were performed, since information is more useful in this case making possible to follow change of behaviors along profiles. With these measurements, characteristics of surface ground is investigated with spectral ratio of horizontal to vertical component (QTS) of microtremor (Nakamura, 1989). Result of the measurements is compared with the observed earthquake damage situation as well as previous studies at the same area. From the preliminary analysis of the data, fundamental natural frequency F , amplification factor A and vulnerability index K_g values ($K_g = A^2/F$) are estimated.

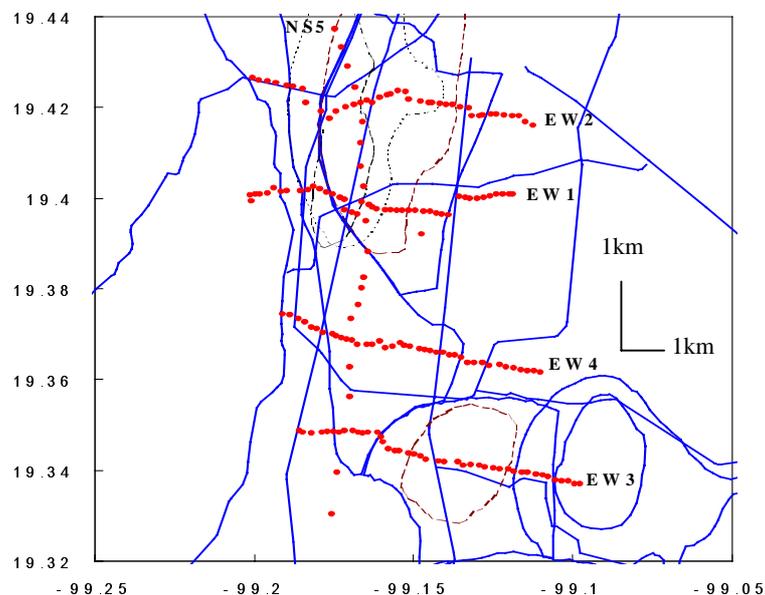


Figure 1. Profiles that microtremor measurements were performed in east-west direction (EW1, EW2, EW3, EW4) and north-south direction (NS5)

Measurement

An instrument named Portable Intelligent Collector (PIC) was used for microtremor

measurements. PIC includes two sensors, connection cables, main body installed in a metal case that contains A/D converter, portable computer and amplifiers. Three components (two horizontal and one vertical) of microtremor are recorded at every measurement points. Sampling interval is 1/100 sec and the length of each record is 40.96 sec. Measurements was repeated three times at each observation point.

Analysis

After measurements, Fourier spectrum for each components are calculated and smoothed eighty times with Hanning spectral window. With this operation band width approximately become 0.5Hz. One frequency spectrum of one component was estimated by averaging the three Fourier spectra. Then, from a spectral ratio of horizontal to vertical components QTS spectrums (Quasi-Transfer Spectrum) are calculated, Nakamura (1989). Predominant frequency (F) and amplification factor (A) which represents dynamic characteristics of the ground are found from this analysis and Vulnerability index (Kg) are calculated as explained below. Details of the methodology can be found in Nakamura (1989, 1996).

Vulnerability Index (K values) for Ground

For the vulnerability index Kg of surface ground, shear strain γ is considered (Nakamura, 1996). According to the Ishihara (1982) ground soil becomes plastic state at about $\gamma=1000 \times 10^{-6}$ and for $\gamma>10000 \times 10^{-6}$ landslide or collapse of foundation occurs. Fig. 2. Shows the simplified shear deformations of the surface ground.

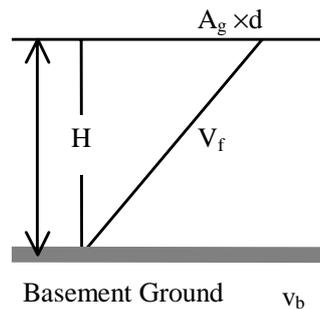


Figure 2. Shear deformation of surface ground.

Average shear strain γ can be estimated as $\gamma=Ad/H$, where **A** is amplification factor of surface layer, **H** is thickness of surface layer, and d is seismic displacement of basement layer. Details about formulation can be find in Nakamura(1996). Without going into a details, we are going to write shear strain as follows (Nakamura, 1996);

$$\gamma = \frac{A^2}{F} \cdot \frac{a}{\pi^2 \cdot v_b}$$

In this equation, A^2/F is called as Vulnerability index, **Kg value** for surface ground. **a** is the acceleration in the basement. v_b is the S wave velocity of the basement.

Results and Discussion

Fig. 3 shows the relation between depth of surface layer and natural period (predominant frequency) . This figure is in a good agreement between the current microzonation of the city. Low period correspond to hard rock zone and higher periods seen in the lake zone. In Fig.3, on the right, the same distribution in two dimension (Period versus surface layer depth) are given. Since depth information for all points were not available, distribution of EW3 profile and also some points on the west side of each profiles could not be included to this graphs,

but with the data we have, we can follow that, natural period increases while depth of the basin increases. This period distribution is also compared with the study of Lermo and Chavez-Garcia (1994) who produced this kind of map both using microtremor and acceleration data. Although distribution of the measurement points are quite different, their model and our experimental values are in a good agreement. Additionally, Shear wave velocity of surface layer in Mexico city ranges between 51m/sec to 134 m/sec. By simply using the period and depth relation on the graphs in Fig. 3, shear wave velocity of the surface layer were also calculated. The equation used is $F=V/4H$. Here; ($F=1/T$) Predominant frequency, (V) Shear wave velocity, (H) is depth of surface layer. Then, $T=4H/V$ where $4/V$ is the slope of the distribution of period versus surface layer depth, in each graph on Fig. 3. Calculation for each profile gave velocities as 50 m/sec, 90m/sec and 60m/sec for EW2, EW1 and EW2 profiles, respectively. In Fig.3, there is a slope change on profile EW2 and EW1 when surface layer reach to 35m. Calculation of velocity from the slope of this part of the graph, gives very low values of V . The reason for this might be because of the error on the data of H in deeper part of the surface layer. By simply measuring microtremor, we can also reach the velocity information of surface layer. Distribution of amplification factor (A) is given in Fig. 4. Amplification is high within Mexico City valley because of the presence of very soft clay layer. This layer present almost everywhere where damage has been observed in the past destructive earthquakes. With these dynamic parameters of the ground, subsurface geology characteristics are confirmed as hill zone, transition zone and lake zone.

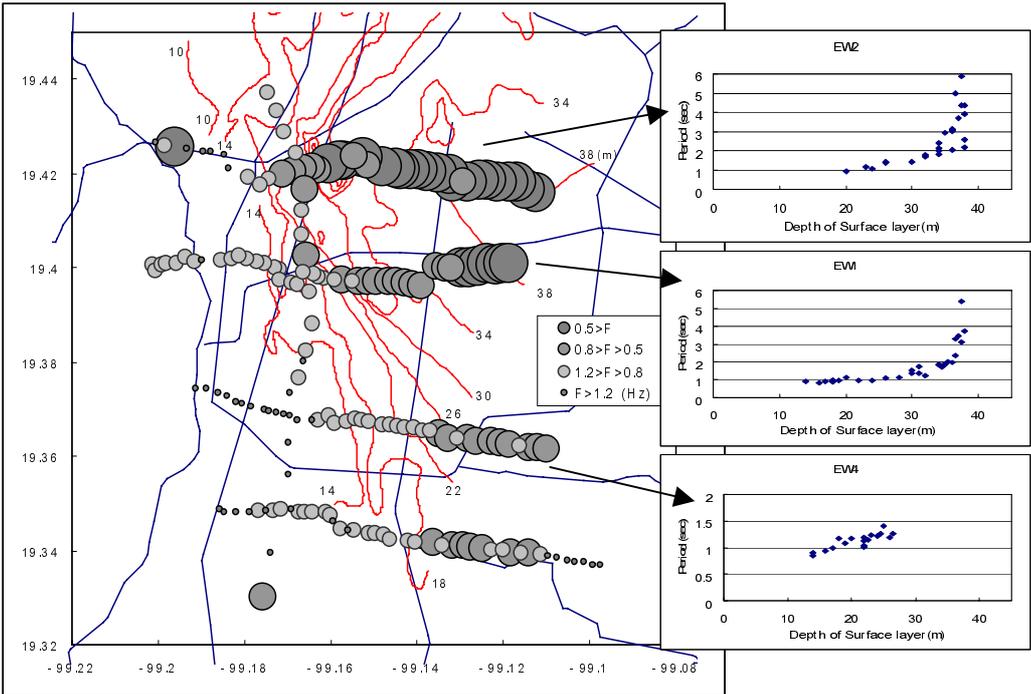


Figure 3. Relation between depth of surface layer and natural frequency (period).

After confirming dynamic characteristics of ground, in the present study, the vulnerability index (K_g), which makes possible to estimate the weak points of the ground surface, of each measurement points were also calculated. Fig. 5, shows relation between structural damage distribution and Vulnerability index of ground (K_g) along the profiles. K_g values, are directly calculated from the frequency (F) and amplification (A) information. It has been proved in many application (Nakamura, 1996, 1997) that, K value is high where the damage risk is high. The present study also shows the same agreement, when we compared estimated K_g values

with the damaged area of the 1957, the 1979 and the 1985 earthquakes. From Fig. 5, in previously damaged areas K_g has high values. Since this approach is possible to apply before the earthquake, this information can be useful tool for damage estimation. Main target of this approach is using this information for earthquake disaster prevention. In Fig.5, some profiles perfectly match with the reported damage distribution, on the other hand in some profiles (ex. EW4) there is no building damage, but K_g has a high values. In further part of the project, the reason for this will also be confirmed by searching liquefaction data as well as building characteristics.

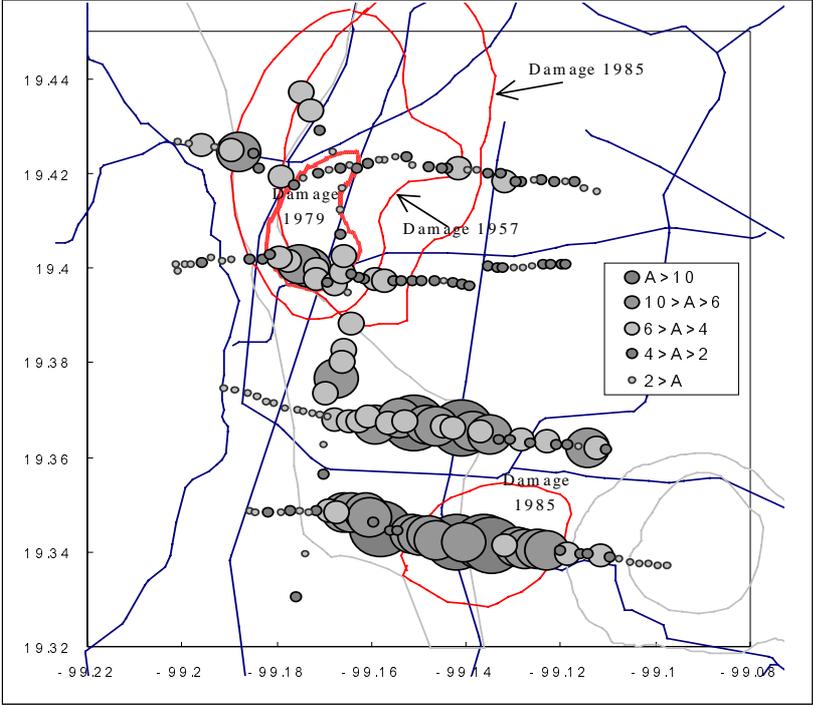


Figure 4. Distribution of Amplification factor.

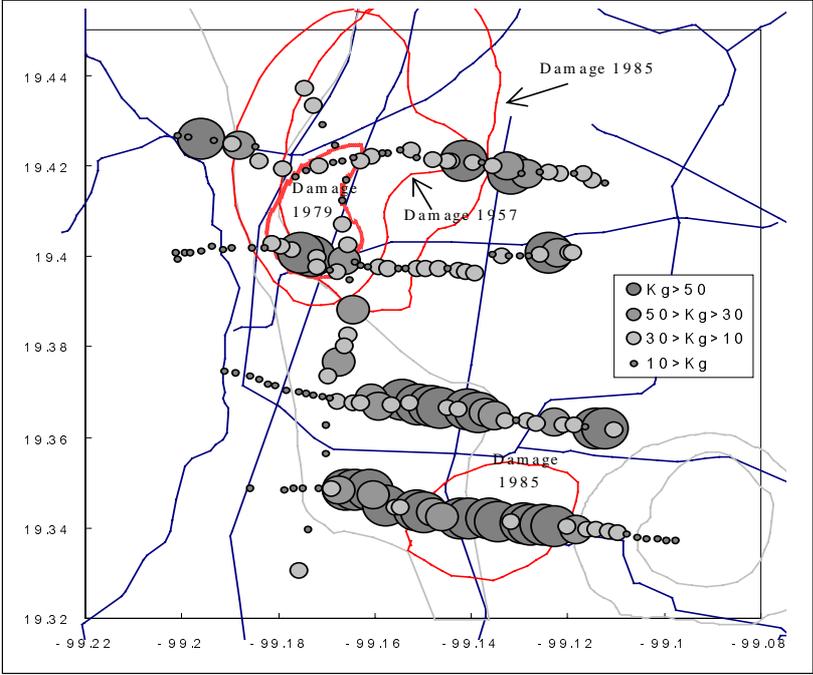


Figure 5. Damage distribution and vulnerability index K_g .

Conclusion

Site effect and vulnerability of ground and structures is an important issues for earthquake disaster mitigation, and detailed microzonation of any city which is waiting for the earthquake is still needed, to be able to reliably prepared for the future earthquakes. For developing earthquake disaster mitigation technologies, the present research has been started in Mexico City for investigating ground characteristics with a pinpoint accuracy and preparing microzonation map of the city. Comparative studies will be carried out with the collaborators in Mexico. Total project includes the investigation of vulnerability of different type of structures, also. The present paper, gives only the preliminary results for ground investigation.

This approach allow one to determine weak areas in the cities, and list important points from most vulnerable one to the least one. With this information, amount of damage can be decreased by taking appropriate countermeasures. Making quick and precise damage estimation possible this type of detailed preparatory study in highly seismic areas is very promising for the future disaster prevention activities. In future part of the present project, building characteristics and interaction between ground and structures will also be investigated in detail. We would like to mentioned that this is the only practical and easy method that gives the information about the vulnerability of the ground without giving any harm to the objects. Therefore it can be applied to any place for the hazard estimation.

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