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

3-5-11

COMPARISON OF THE STRONG GROUND MOTION IN MEXICO CITY AND OGATA VILLAGE DURING EARTHQUAKE

Masato MOTOSAKA[1)], Tokiharu OHTA[2)], Shigeto HIEHATA[3)],
Masaki KAMATA[1)] and Eiji KITAMURA[3)]

1.Kobori Research Complex, Kajima Corporation, Tokyo, Japan
2.Kajima Institute of Construction Technology, Tokyo, Japan
3.Information Processing Center, Kajima Corporation, Tokyo, Japan

SUMMARY

Characteristic accelerograms recorded in Mexico City are discussed and compared with accelerograms recorded in Japan. Strain dependency of Mexico's lacustrine clay is less remarkable than that of Japanese alluvial clay. Beat waves calculated using BEM-FEM hybrid model for SV and SH waves problems are harmonious with the ones redorded at Central de Abastos Oficina (CDAO) and Secretaria de Comunicaciones y Transportes (SCT). At CDAO site, it seemed that seismic waves propagated from the west hill and the south volcano toward opposite directions. An accelerogram recorded at Ogata Village, Japan during the 1983 Japan Sea Earthquake is very similar to that of CDAO and the same BEM-FEM hybrid analyses are addressed.

INTRODUCTION

On September 19, 1985, an earthquake of magnitude Ms=8.1 occured with the epicenter near the south coast of central Mexico and caused severe damages. In Mexico City, nearly 400km from the epicenter, strong-motions were observed at some stations (ref. to Fig.1).

Accelerograms in Mexico City are characterized by an extreme amplification on the very soft soil deposit on the basin structure, by beat waveforms of 2 to 4 seconds and by a duration time of 1 to 3 minites.

In Japan very similar acceleration records were observed at Ogata Village (OGV, ref. to Fig.3) during the 1983 Japan Sea Earthquake, Ms=7.7, Δ=100km. Soil conditions of OGV are similar to those of Mexico City. This paper describes a comparison of the strong ground motion observed on the sedimentary layers and the analytical studies based on the 2-dimensional BEM-FEM Hybrid analysis.

CHARACTERISTICS OF OBSERVATION RECORDS AND LACUSTRINE SEDIMENTARY LAYERS

In Mexico City, strong-motions were recorded by Universidad Nacional Autonoma de Mexico (UNAM) at 11 locations including 3 locations on lava plateau of UNAM. Although the subsurface structures of the lava plateau is not clear, it is assumed herein to be of bedrock. This paper reviews the records of 2 sites of the Lake zone, Secretaria de Comunicaciones y Transportes (SCT) and Central de Abastos Officina (CDAO). Fig.2 shows the observed acceleration waveforms in Mexico City. The ground motions at the two sites SCT and CDAO are characterized by a relatively long period, 2 to 4 seconds, and beat waveforms following. The acceleration record observed in Ogata Village (OGV) located at the east side of Lake Hachirogata as shown in Fig.3 is very similar to that at CDAO. The waveforms and the corresponding response envelope spectra are compared and the result is shown in Fig.4. The change of predominant periods due to bady waves and the dispersive surface waves are seen.

In Fig.5, the shear strain dependency of the shear modulus of lacustrine clay in Mexico-City 1)2) is compared with those of the average Japanese alluvial clay. 3)4) The values of OGV and CDAO which were estimated by using the relation of maximum shear strain and the maximum velocity are almost the same and the shear dependency of these sites is less conspicuous than the average Japanese cohesive soil. The value of SCT suggests that the nonlinearity is not so strong.

ANALYTICAL STUDIES ON LATER PHASES IN THE MEXICO-CITY-TYPE ALLUVIAL DEPOSITS

LAKE ZONE IN MEXICO CITY Fig.6 shows three geological models analyzed. Based on the geological data, specifications pertaining to the ground conditions corresponding to each of the models have been given. The values are shown in Table 1. Model 1 (top layer Vs=40m/s;thickness 40m) and Model 2 (top layer Vs=70m/s; thichness 30m) are used to make a qualitative study of the ground motion corresponding to the EW sections of CDAO and SCT respectively. Model 3 is used to study the ground motion corresponding to the NS section including CDAO site. The BEM-FEM hybrid model was applied to these three models[5].

The two-dimesional BEM (Boundary Element Method) model with 35 nodes has been used at the outer boundaries, and FEM (Finite Element Method) model with about 900 nodes has been used at the inside areas. The frequency range to be analyzed is from 0.14Hz (7sec) to lHz. The incident angle should be 20', which has been obtained by using the structures of the crust and mantle studied by J. E. Fix[6] and other materials.

In this analysis, it is assumed that an input wave takes the waveform of UNAM No.2, as the incident wave of outcrop.

Fig.7 to Fig.9 show the transfer functions of the surface soil layer. It also shows a conspicuous difference depending on the location. Although remarkable changes of predominant frequency are observed in the inclined part of Model 2 and model 3, a transfer function similar to that of one-dimensinal theory was also observed where no incline existed.

Fig.10 shows the distribution of the maximum acceleration Amax of the ground surface in case of Model 1 to Model 3. Even if the same seismic wave arrives at the bedrock, Amax of the ground surface differs greatly depending on the place. Amax distribution of Model 2 tends to increase at the west edge of the soft layer, and this result is corresponding to the state of the damages.

Fig.11 shows the comparison of the recorded waveforms with the analytical ones to SH-Wave (a) and SV-Wave (b) respectively. Both waveforms show an extremely good agreement. In Fig.12, the recoded waveforms of the NS direction of CDAO are compared with the analytical ones at point D of Model 3, which corresponds with the analytical model used for studying the effect of waves carried from the direction of a small volcano on the south side. In Fig.13, the recorded waveforms of NS of CDAO is compared with the analytical ones of Model 1, used for studying the effect of surface waves due to the input from the west side. While the analytical waveform of Model 3 (NS section) shows a beat waveform harmonious with the observed one in NS direction, the analytical waveform of Model 1 (EW section) contains a few beat parts and differs in the later phases from the observed one. According to the above results, the computed beat waveform coinciding with the recorde one at CDAO, NS suggests the possibility of the effect of seismic waves carried from the south.

OHGATA VILLAGE IN JAPAN Similar analyses to the Mexico City were performed by modelling A-A' section in Fig.2 as shown in Fig.14.[7] Fig.15 shows an analytical model (2-dimensional BEM-FEM hybrid model). An analysis performed as the SH problem is shown herein. The frequency range to be analized is limited from

0.14Hz (7sec) to 1Hz. Based on the geological data, values pertaining to the soil conditions have been assigned as shown in Table 2. In this analysis, the acceleration record observed in Akita (Δ=120km) is used as input wave (control wave at outcrop) after converting the direction from N-S to NW-SE and applying decomposition analysis. The incident angle is assumed to be 10°.

Fig.16 show the comparison of calculated waveform with observed one. Calculated wavetorm by BEM-FEM hybrid model is similar to observed waveform.

CONCLUDING REMARKS

An analytical review was made to evaluate the qualitative characteristics of ground motion with the Mexico Valley in mind. The summary of the analytical studies are as follows:

1. The maximum acceleration becomes large at the side of input. This tendency matches the location of the damaged places.
2. The beat waves at CDA originate in the subsurface structure inclined toward north from the small volcano in the south, and the motion of waves propagating diffractively produces a great effect.
3. The analyzed waveforms of SH and SV wave for SCT show an extremely good correspondence with the records. On the distribution of the maximum acceleration for the lake zone by analysis, the maximum acceleration on the surface ground in the center of this zone is larger than that of the circumference, and this tendency corresponds to the situation with occurrence of building damages.

The strong motion of Ogata Village during the Japan Sea Earthquake in which several conditions were similar to those of Mexico Earthquake was compared with the recordes of Mexico City.

4. The accelerogram at CDAO, EW resembles OGV, NS, due to similar soil conditions. The change of predominant periods due to body waves and tendency of dispersive surface waves are clarified at OGV, NS.

ACKNOWLEDGEMENTS

The accelerograms of Mexico City of the Michoacan-Guerrero, Mexico Earthquake 1985, used in this paper is based on the digitized records (Tape No. MX0003) offered by UNAM. The authors extend sincere gratitude to Prof. J. Prince at the Institute of Engineering, UNAM.

REFERENCES

1)Lomnitz, C. and E. Rosenblueth, Seismic Risk and Engineering Decisions, Elsevier Sientitic Publishing Company, pp 85, (1976), The Original Result fo the Tests by Leon et al was included.

2)Arechiga, J.L.L., Pruebas dinamicas de muestras "inalteradas" realicadas en ei aparato de columna resonante. X reunion national de mecanica de suelos, pp 100-111.

3)Hara, A. et al, Stress-strain Model of Soil for Seismic Analysis, Proceedings of the Fifth Japan Earthq. Eng. Sym. (1978).

4)Iwasaki, T. et al, Experimental Studies Research on Dynamic Properties of Clay, Proceedings of the Annual Meeting of JSSMFE, (1979).

5)Muto, Kiyoshi, M. Motosaka, and et al 3-Dimentional Earthquake Response Analysis of Embeded Reactor Building Using Hybrid Model of Boudary Elements and Finite Elements, Transaction of 8th SMIRT, (1985).

6)Fix, J.M., The Crust and Upper Mantle of Central Mexico, Geophys. J.R. astr. Soc. 43, pp 453-499, (1975).

7)Asada Lab., The Damage Survey on the Ground and Geological Structures in the Nihonkai-Chubu Earthquake of 1983, Tohoku Inst. of Tech. August, (1983).

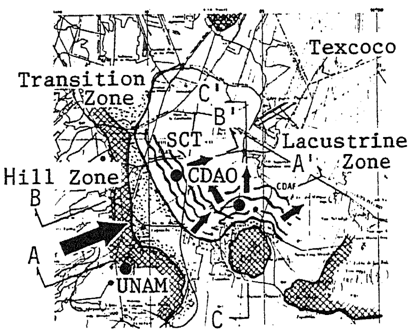


Fig.1 Strong-Motion Sites and Location of Analytical Models in Geological Map

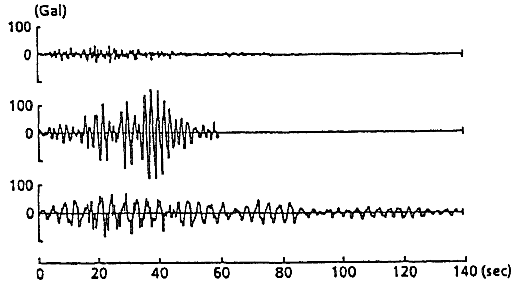


Fig.2 Observed Records in Mexico-city (E-W Components)

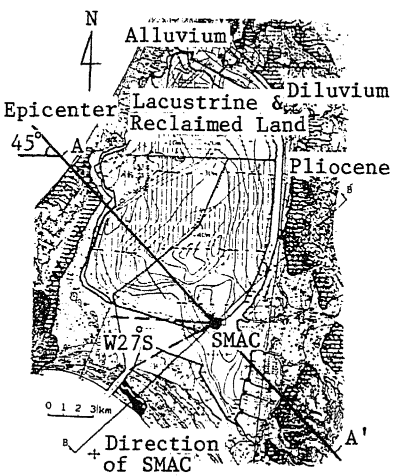
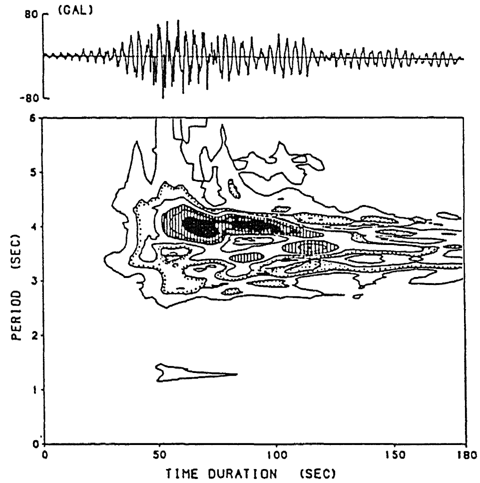
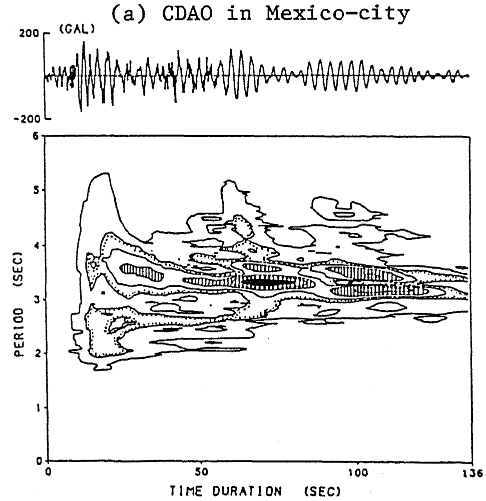


Fig.3 Lake Hachiro-Gata and Location of SMAC



(a) CDAO in Mexico-city



(b) OGV in Japan

Fig.4 Comparison of Waveforms and Response Envelope Spectra

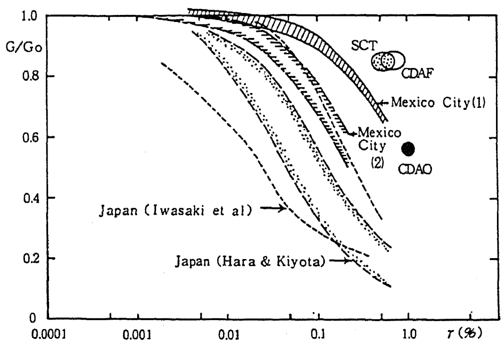


Fig.5 Shear Strain Dependency of Shear Modulus (G/Go)

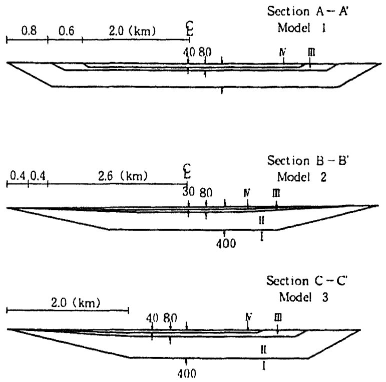


Fig.6 Geological Models for Analysis

Table 1 Geological Constants of Analytical

a) Model 1 and Model 3

	Ⅰ	Ⅱ	Ⅲ	Ⅳ
unit weight (t/m³)	2.0	1.8	1.5	1.2
Vs (m/sec)	1250	500	300	40
poisson ratio	0.4	0.4	0.45	0.45
damping (%)	1	2	3	5

b) Model 2

	Ⅰ	Ⅱ	Ⅲ	Ⅳ
unit weight (t/m³)	2.0	1.8	1.5	1.3
Vs (m/sec)	1250	500	300	70
poisson ratio	0.4	0.4	0.45	0.45
damping (%)	1	1.5	2	3

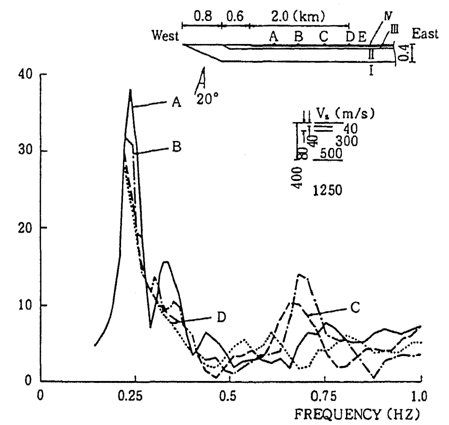


Fig.7 Transfer functions of Model 1, EW section, SV wave

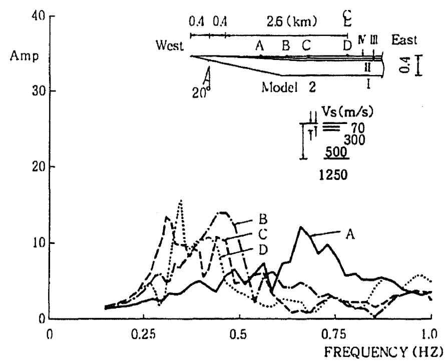


Fig.8 Transfer functions of Model 2, EW section, SV wave

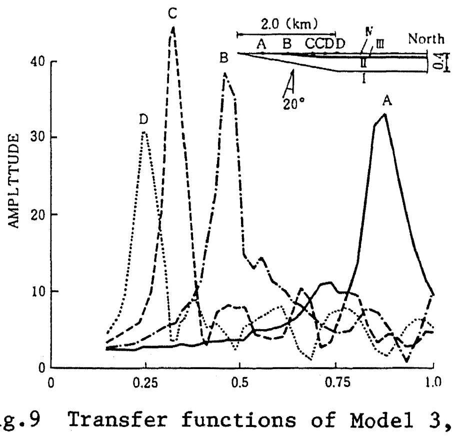


Fig.9 Transfer functions of Model 3, NS section, SV wave

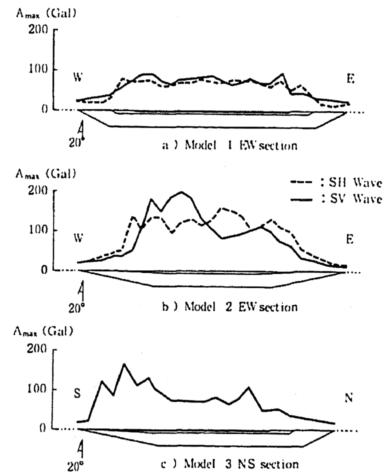


Fig.10 Distribution of Amax

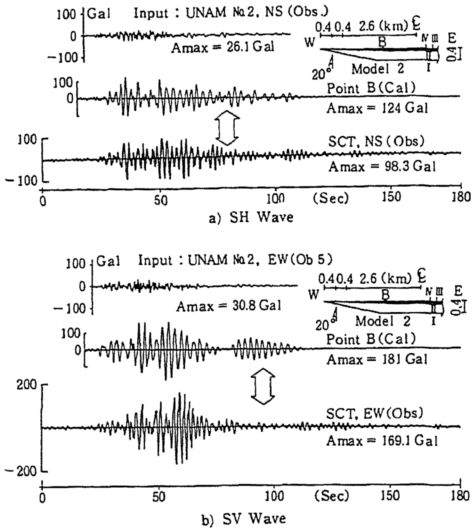


Fig.11 Comparison of Calculated and Recorded Waveforms, SCT, EW Section

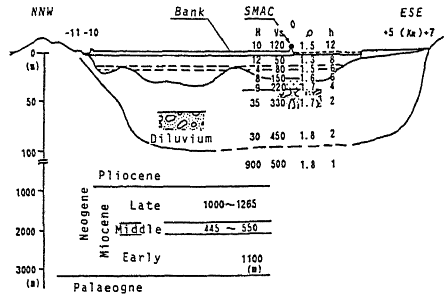


Fig.14 Geological Section of OGV (A-A'Section)

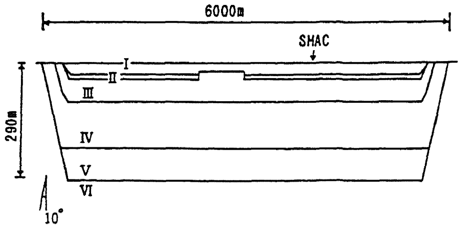


Table 2. Analytical Model (OGV)

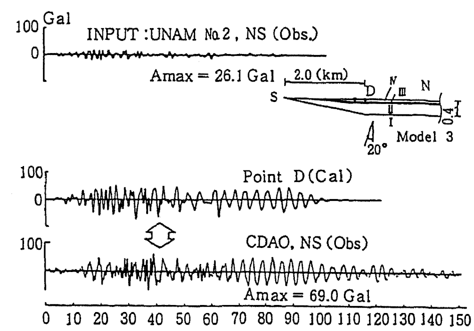


Fig.12 Comparison between Calculated and Recorded Waveforms, CDAO, CDAF, NS section, SV Wave

Fig.15 Geological Constants (OGV)

No.	Thickness (m)	Vs (m/s)	Density (t/m³)	Damping (%)
I	30	45	1.4	5
II	10	90	1.5	4
III	55	270	1.6	3
IV	117	400	1.7	2
V	78	500	1.8	1
VI	−	650	1.9	1

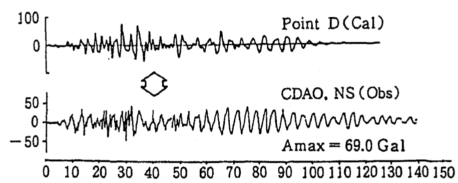


Fig.13 CDAO, EW Section, SH Wave, Model 1

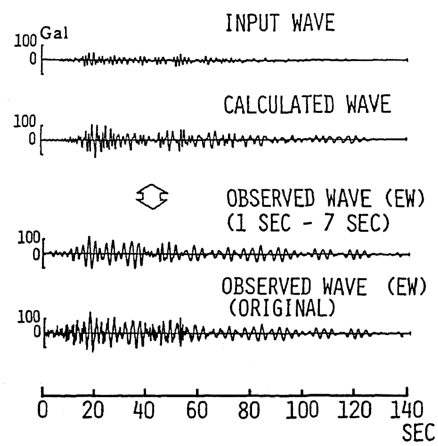


Fig.16 Comparison of Computed wave with Observed wave