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

3-7-12

RESEARCH ON THE DESIGN EARTHQUAKE GROUND MOTIONS IN THE OSAKA PLAIN

Nobuyoshi MURAI[1], Takehiro MORIMURA[2] and Shintaro OHBA[3]

[1]Takenaka Technical Research Laboratory,
Minamikawachi-gun, Osaka, Japan
[2]Takenaka Komuten Co., Ltd.,
Higashi-ku, Osaka, Japan
[3]Department of Architecture, Osaka Institute of Technology,
Asahi-ku, Osaka, Japan

SUMMARY

A method is proposed for preparing design earthquake ground motion on the basis of earthquake observation records in the Osaka plain. The designed earthquake ground motion obtained by this method incorporates earthquake motion characteristics reflecting the local ground properties and sedimentary layer profile. The influence of the ATOYURÉ in particular should not be ignored in preparing design earthquake ground motion, since that wave, which travels through the sedimentary layer, exhibits a characteristic peak at 1 - 2 seconds in its velocity response spectrum, distinctive from the main motion.

INTRODUCTION

To ensure the aseismatic safety of a structure, it is of vital importance to assess and select appropriate design earthquake ground motion at the construction site, for use in analyzing earthquake response. In practice, however, earthquake waves recorded in the past at some particular site (El Centoro, Taft, Osaka 205 etc.) are substituted. Therefore preparation of design earthquake ground motions for various points nation-wide, with the influence of local and surrounding ground characteristics taken into consideration, is eagerly awaited. In the present report, the authors classify and examine input earthquake ground motion characteristics for the Osaka plain on the basis of earthquake waves observed over the past 18 years and prepare trial design earthquake ground motions for said plain.

OBSERVATION RECORDS

Fig. 1 shows locations of earthquake observation stations on the Osaka plain and epicenters of the observed earthquakes. Observation stations, 6 in all, are located on the bedrock (R and S), diluvium (A and Y) and alluvium (C and M). A total of 29 earthquakes were observed for the present study; 14 short-distance earthquakes, of within roughly 100 km epicentral distance, with magnitudes of 4.0 - 6.0 and J.M.A. seismic intensity scales in Osaka of I - IV, and 15 middle-distance earthquakes, of roughly 100 - 200 km epicentral distance, with magnitudes of 4.1 - 7.1 and J.M.A. scales of 0 - III.

Fig. 2 shows example seismograms simultaneously recorded for one earthquake. These records reveal that earthquake motion duration is markedly longer on the sedimentary ground in the Osaka plain (A and M) than on the surrounding mountain bedrock (R) (Ref. 1). This phenomenon is attributable to the influence of ATOYURÉ, the surface wave which enters from the surrounding mountain bedrock and travels through the sedimentary layer of the plain. ATOYURÉ, which arrives 10 - 20 seconds after the main motion and its short periodic component have diminished, varies in the time of arrival with the distance from the surrounding mountain bedrock and is known to travel at roughly 600 m/sec. Fig. 3 shows the Osaka plain earthquake wave propagation mechanism, arrived at from earthquake observation. Velocity response spectra were obtained to assess periodic characteristics of earthquake motion. For this purpose, recorded seismograms were divided, in light of the obvious difference in periodic characteristics, into main motion and ATOYURÉ. Fig. 4 shows the velocity response spectra (average, sv, confidence coefficient 80%; $\pm 1.28\sigma$) for these two elements of short-distance and middle-distance earthquakes. As regards short-distance earthquakes, the spectrum of main motion on the diluvium remains virtually flat at periods longer than 0.2 seconds, whereas that on the alluvium peaks at 0.15 and 0.5 seconds, remaining virtually flat at longer periods. The spectra of ATOYURÉ, both on the diluvium and alluvium, peak at 1.2 seconds, sloping down at shorter periods and remaining flat at longer periods. As regards middle-distance earthquakes, the spectra of main motion exhibit a downtrend at shorter periods, a gentle plateau at 1 to 2 seconds and, on the alluvium, a peak at 0.5 seconds; the spectra of ATOYURÉ exhibit a high plateau at 1 to 2 seconds and, on the alluvium, a characteristic peak at 0.5 seconds. Generally speaking, velocity response spectra present no marked difference between alluvium and diluvium, but exhibit different patterns by epicentral distance. The peaks at 0.15 and 0.5 seconds on the alluvium are considered attributable to the surface layer profile, the ATOYURÉ peaking at 1.2 and 1 - 2 seconds to the profile and shape of the entire sedimentary ground of the Osaka plain, with its depth and expanse.

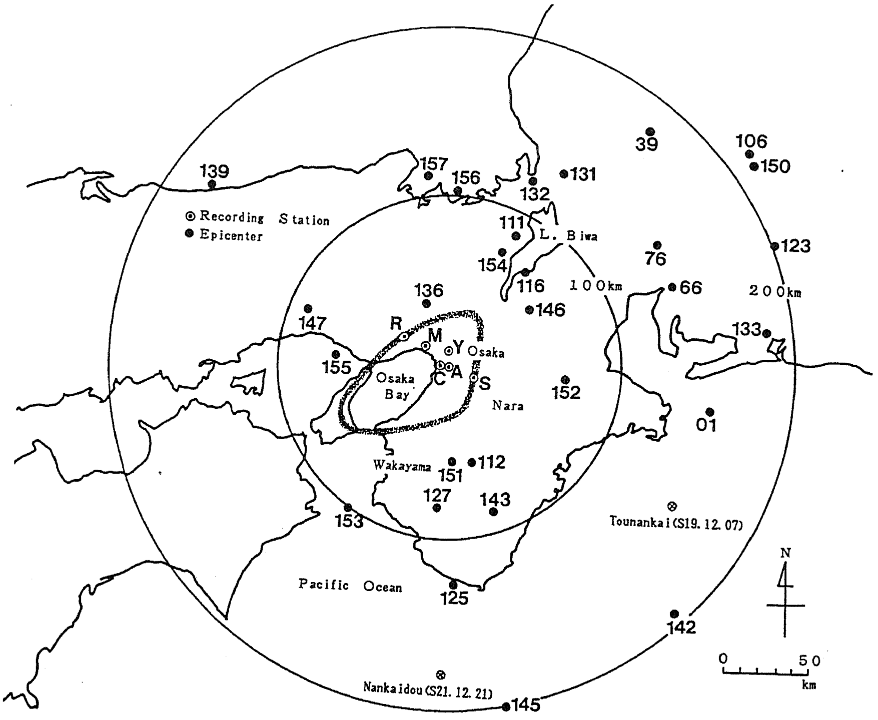
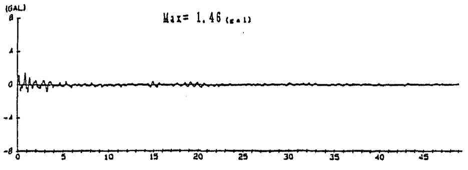
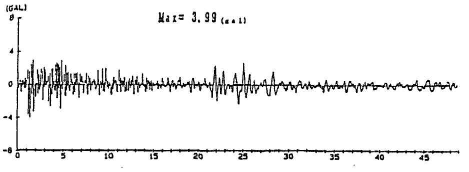


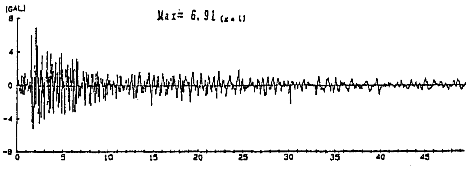
Fig. 1 Location of Observation Stations and Epicenters (●01 - 157: Earthquake registration numbers)



1) Bedrock (station R)

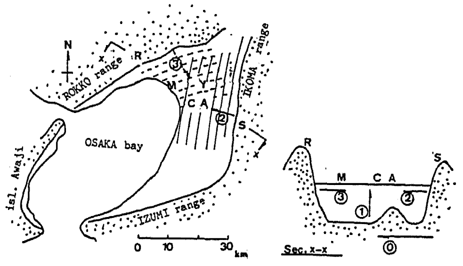


2) Diluvium (station A)



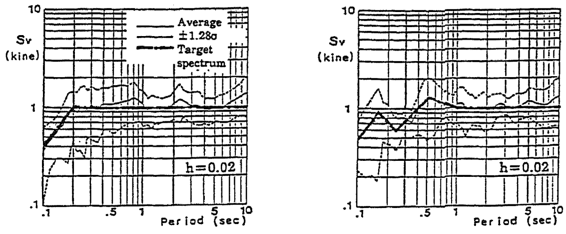
3) Alluvium (station M)

Fig. 2 Simultaneously Recorded Siesmograms (No. 127)

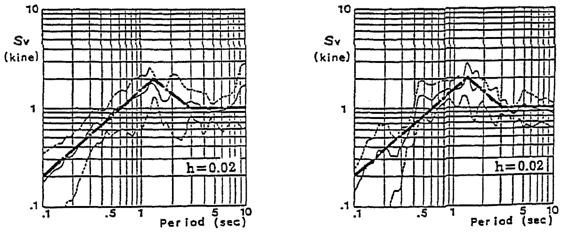


COURSE
⓪ Travelling Wave from Source
① Main Wave with S-Wave multireflection
② Surface Wave (ATOYURÉ)
③ Surface Wave (ATOYURÉ)

Fig. 3 Travelling Course of Earthquake Wave to Plain

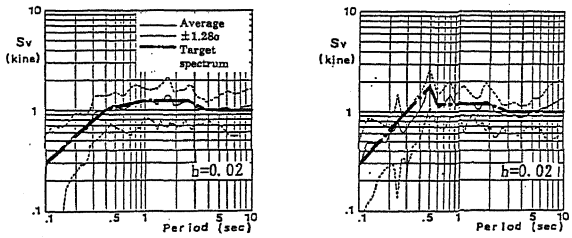


Diluvium (A・Y) Main motion Alluvium (M)

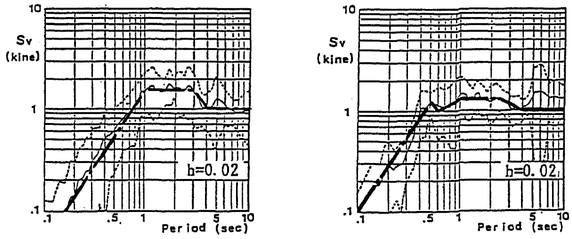


Diluvium (A・Y) ATOYURÉ Alluvium (M)

(a) Short-distance earthquake



Diluvium (A・Y) Main motion Alluvium (M)



Diluvium (A・Y) ATOYURÉ Alluvium (M)

(b) Middle-distance earthquake

Fig. 4 Average Velocity Response Spectra (spectrum mean: 1 kine)

METHOD OF PREPARING DESIGNED EARTHQUAKE GROUND MOTION

Since the ground surface velocity response spectra of observed earthquakes remain constant with classification by epicentral distance (short and middle) and by ground type (alluvium and diluvium), a method was chosen which permits determination of periodic characteristics for earthquake motion simulation in terms of the velocity response spectrum. Fig. 5 shows the flowchart for preparing design earthquake ground motion. In this method, the irregularity of earthquake motion is expressed via the average phase within the frequency band, obtained via Fourier transformation not of the determined strength function but of discrete data on actual earthquake motion.

PREPARATION OF DESIGN EARTHQUAKE GROUND MOTION OF OSAKA PLAIN

The parameters necessary for preparing designed earthquake ground motion were determined on the basis of earthquake observation records for the Osaka plain, in accordance with the following procedures;

Step I: White noise $[X(t), \Delta t]$ was determined.

Step II: Phase characteristics for the frequency band were determined by obtaining the frequency distribution for the difference between the two sequential phases, i.e., phase-difference $\Delta\Phi$

$$\Delta\Phi k = \Phi(k+1) - \Phi k \qquad (k = 0,1,2,.....,n-1) \; .... \; (1)$$

where $\Delta\Phi$ is defined within the range of $-2\pi \leqq \Delta\Phi k \leqq 0$, and n equals the number of data.

Fig. 6 shows average phase-difference frequency distributions of main motion and ATOYURÉ, based on observation records classified by ground type and epicentral distance, as with velocity response spectrum. In this figure, phase difference $\Delta\Phi k$ was shifted so that the median class was set at zero. This figure also shows probability density distribution, obtained on the assumption that said graphed phase-difference frequency distribution can be approximated via Gaussian processing. Phase-difference frequency distribution, although it tended to show slightly higher values around the median class than the approximated Gaussian distribution, was considered to be represented by the Gaussian distribution shape. The average phase was determined using the phase-difference frequency as a random number based on the Gaussian distribution.

Step III: It is appropriate that the target spectrum be determined on the basis of velocity response spectra $[Sv(f), \Delta f]$ (Fig. 4) constantly obtained from observation records. Such spectra, smoothed to facilitate parameter determination, were set as shown, with alternate long and short dash lines, in that figure.

Steps IV, V and VI: The velocity response spectrum was calculated for the waveform incorporating white noise and phase characteristics and was corrected in Step VI. These three steps were repeated until the spectrum thus obtained converged into the target spectrum.

The main motion and ATOYURÉ waveforms obtained in accordance with the procedures to Step VI are shown in Fig. 8 for short-distance and middle-distance earthquakes at observation station A on the diluvium.

Step VII: To compound the main motion and ATOYURÉ waveforms, it is necessary to establish the arrival time of ATOYURÉ, the surface wave which travels from *the surrounding mountain bedrock through the sedimentary ground. This can be* determined by the horizontal distance from the surrounding mountain bedrock to the observation station, as shown in Fig. 7, and the wave propagation velocity of 600 m/sec. For observation station A, for example, the distance to the bedrock is 12.8 km, resulting in an arrival time of approximately 20 seconds after the main motion. Compounding the main motion and ATOYURÉ waveforms with that time lag taken into account yielded the designed earthquake ground motion shown in Fig. 8 for observation station A in the Osaka plain. This waveform was obtained with the velocity response spectrum mean set at 1 kine, for convenience. By a similar method, a designed earthquake ground motion can be obtained for any place in the plain.

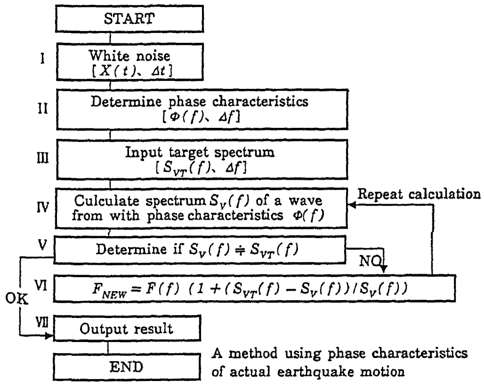


Fig. 5 Flow Chart for Preparing Earthquake Motion Simulation

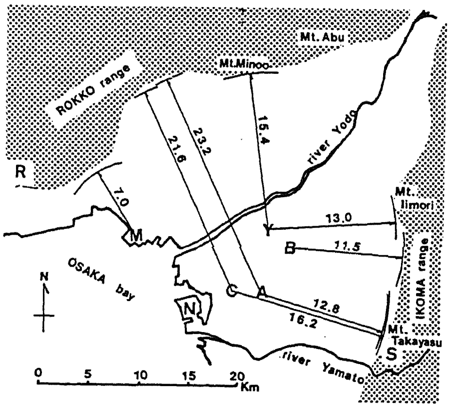
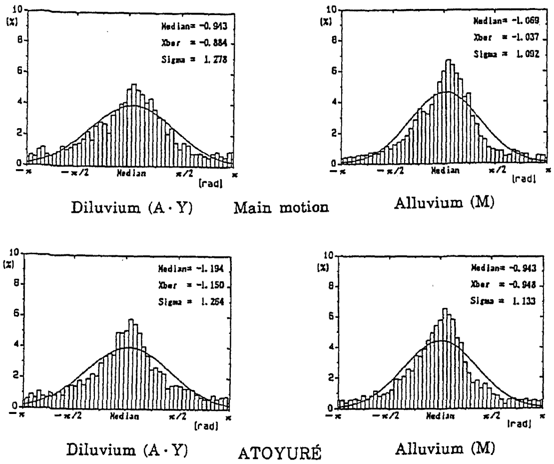
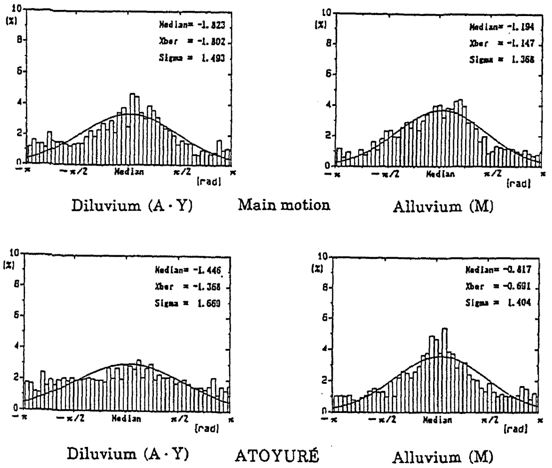


Fig. 7 Input Line from Range to Each Observation Point

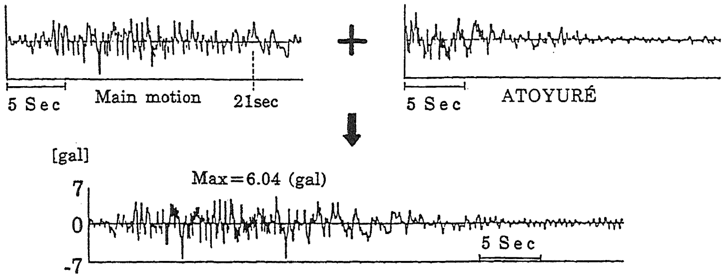


(a) Short-distance earthquake

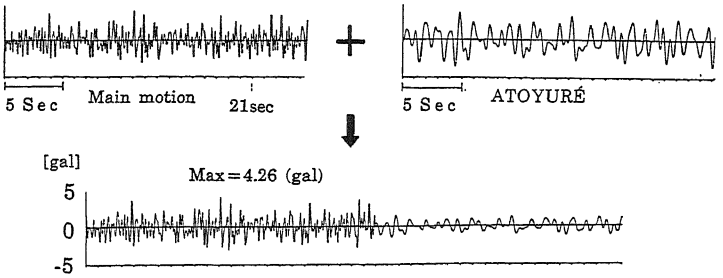


(b) Middle-distance earthquake

Fig. 6 Phase-difference Frequency Distribution Characteristics



(a) Short-distance earthquake, diluvium (station A)



(b) Middle-distance earthquake, diluvium (station A)

Fig. 8 Design Earthquake Ground Motion for the Osaka Plain

CONCLUSION

Design earthquake ground motion obtained by the method described above is based on earthquake observation records in the Osaka plain and incorporate earthquake motion characteristics reflecting the ground properties and sedimentary layer profile of the plain. The influence of the ATOYURÉ in particular should not be ignored in preparing design earthquake ground motion, since that wave, which travels through the sedimentary layer, exhibits a characteristic peak at 1 - 2 seconds in its velocity response spectrum, distinctive from the main motion.

ACKNOWLEDGEMENT

The authors wish to express their sincere appreciation to Prof. Isao Toriumi, Faculty of Engineering, Fukui University, for his kind guidance and contribution of the Osaka plain's earthquake observation data for the present research.

REFERENCES

1. Toriumi, I., Ohba, S. and Murai, N., "Earthquake Motion Characteristics of Osaka Plain", 8th W.C.E.E., Vol. II,761-768 (1984)

2. Murai, N., Morimura, T., Ohba, S. and Toriumi, I., "Research on the Design earthquake Ground Motions in the Osaka Plain", Summaries of Technical Papers of Annual Meeting of A.I.J. (Oct. 1987)

3. Toriumi, I., Ohba, S. and Murai, N., "Research on the Design Earthquake Ground Motions in the Osaka Plain", 21st Japan National Conference on Soil Mechanics and Foundation Engineering (June 1986)