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Earthquake Motion Characteristics of the 1995 Hyogo-ken Nanbu Earthquake Observed in Various Types of Ground in the Osaka Plain

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ABSTRACT

This report discusses the earthquake motion characteristics of various types of grounds, based on the record of the observation of the 1995 Hyogo-ken Nanbu Earthquake at points in the Osaka Plain and nearby mountainous region. Our study on the earthquake revealed the follwing:

(1) At each point, predominant periods are conspicuously influenced by the periodic characteristics at the hypocenter. As well, additional predominant periods, determined by local ground conditions, are found. As a result, predominant periods vary according to point.
(2) Peak acceleration varies according to ground conditions.
(3) Earthquake motion duration time in the central part of the Plain is longer than that in the mountainous region.
(4) Predominant period for the subsurface layers lengthens with the increase in peak acceleration. This presumably indicates that the velocity of shear wave propagation to the layers is influenced by ground shearing strain.

KEYWORDS

earthquake motion; amplification characteristics; periodic characterisitics; transfer founction; duration time; shearing strain

INTRODUCTION

The 1995 Hyogo-ken Nanbu Earthquake, with a magnitude of 7.2 and a 14.3 km-deep hypocenter in the sea near the northern end of Awaji Island, occurred at 5 : 46 a.m. on January 17, 1995. The earthquake inflicted great damages on Kobe and surrounding cities.
This report discusses the earthquake motion characteristics of various types of grounds, based on the observation record of the earthquake at points in the Osaka Plain and nearby mountainous region.

OUTLINE OF OBSERVATION POINTS

Fig. 1 shows earthquake observation points and peak ground maximum acceleration. The points are located 40 - 70 km distant from the hypocenter.
Also shown, for reference, are the observation record at Kobe Maritime Meteorological Observatory (point JMAK) approx. 20 km distant from the hypocenter, and at Osaka Meteorological Observatory (point JMAO) approx. 45 km distant from the hypocenter.

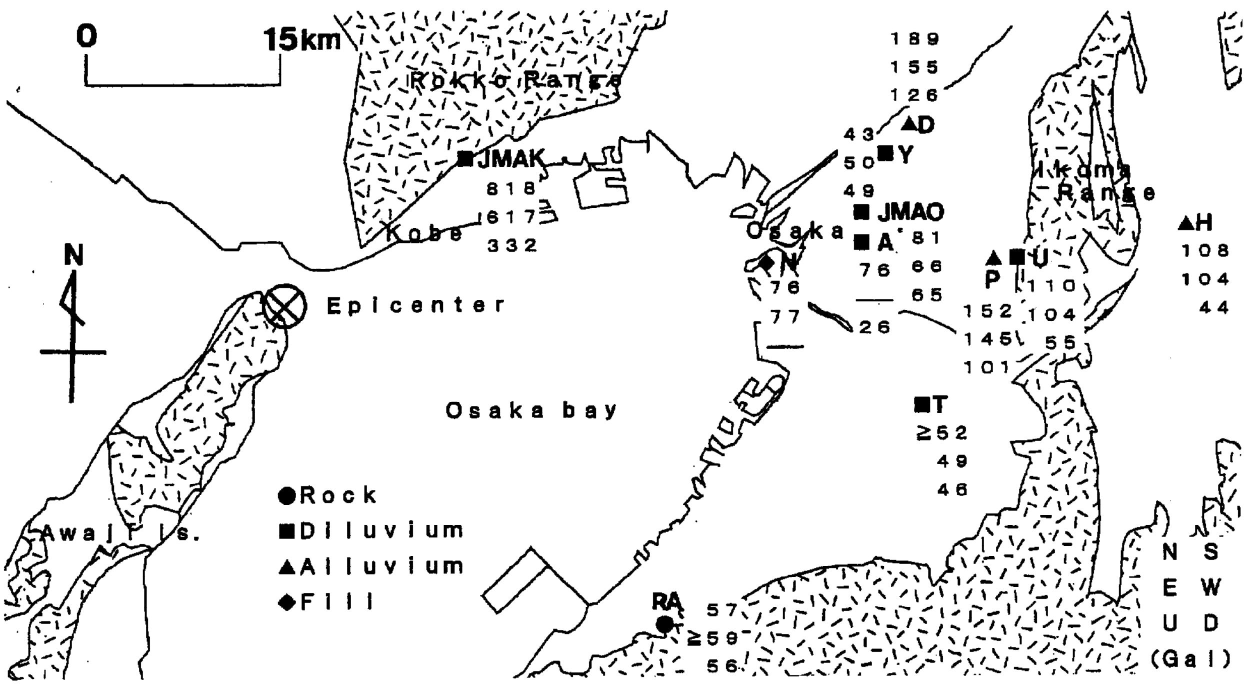

Fig. 1. Earthquake observation points and peak ground acceleration

This report discusses the record at 11 points located on 4 types of grounds. Point R_A is located on a bedrock, points JMAK, JMAO, Y, U, A, and T on a diluvial ground, points D, P and H on an alluvial ground, and point N on a filled ground.

PEAK ACCELERATION DISTRIBUTION AND DISTANCE-RELATED ATTENUATION

Earthaquake motion acceleration waveforms (NS components) recorded at the observation points are shown in Fig. 2, and the relation between peak acceleration and distance from the hypocenter in Fig. 3.
Figs. 1 and 2 show that, at point JMAK (the nearest point to the hypocenter), the main earthquake duration time is short (10 seconds or less), and the waveform is monotonous.
However, both the horizontal and vertical accelerations at this point are extremely large (NS component: 818 Gal; EW component: 617 Gal; UD component: 332 Gal).
At point R_A on a bedrock in the mountainous region near the Osaka Plain, approx. 40 km distant from the epicenter, part of the waveform is saturated. Amplitude at this point, however, is generally small. At points JMAO, Y, U, T, and A on the diluvial ground, main motion duration time is longer than that at point R_A.
At point P, D and H on the alluvial ground, main motion duration time is even longer than those at points on the diluvial ground. At the former points, long periods (1 second or more) are predominant. At point N on the filled ground, motion duration time is longer than at any other point, and long periods are conspicuous.
Fig. 3 shows that acceleration amplitude attenuates with the increase of distance from the hypocenter. Attenuation ratio varies with ground conditions.
Compareing 4 types of ground, the earthquake motion on the bedreck in mountainous surrounding the Osaka plain, approx. 40 km distant from the hypocenter, generally had smaller acceleration amplitudes.
Acceleraion amplitude increases as the type of ground goesto diluvial ground to alluvial ground. However, it is noteworthy that the ground, with a 15 m - deep filled layer on a 30 m - deep alluvial layer had less amplitude.

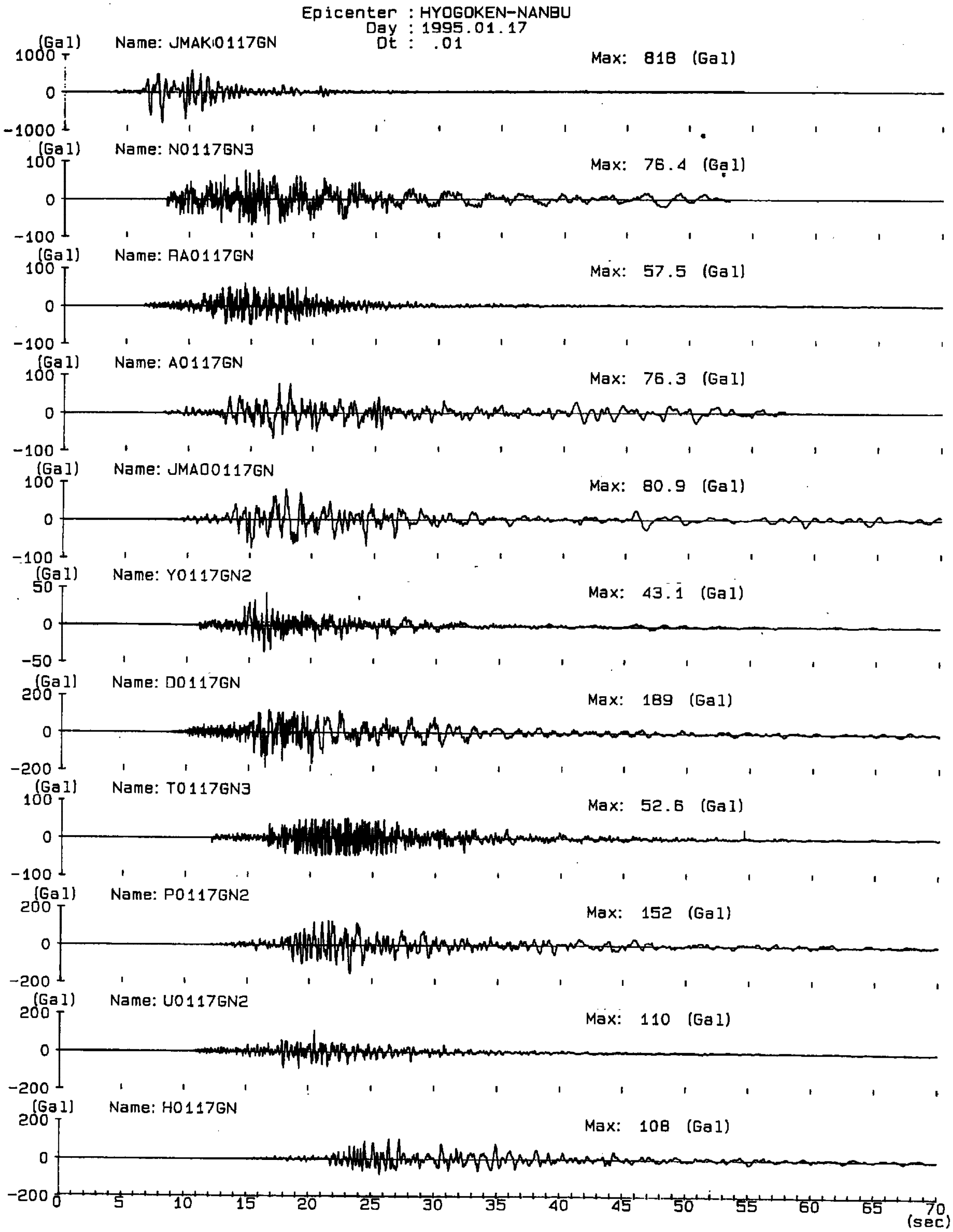

Fig. 2 Earthquake motion acceleration waveforms (NS components) recorded at the observation points

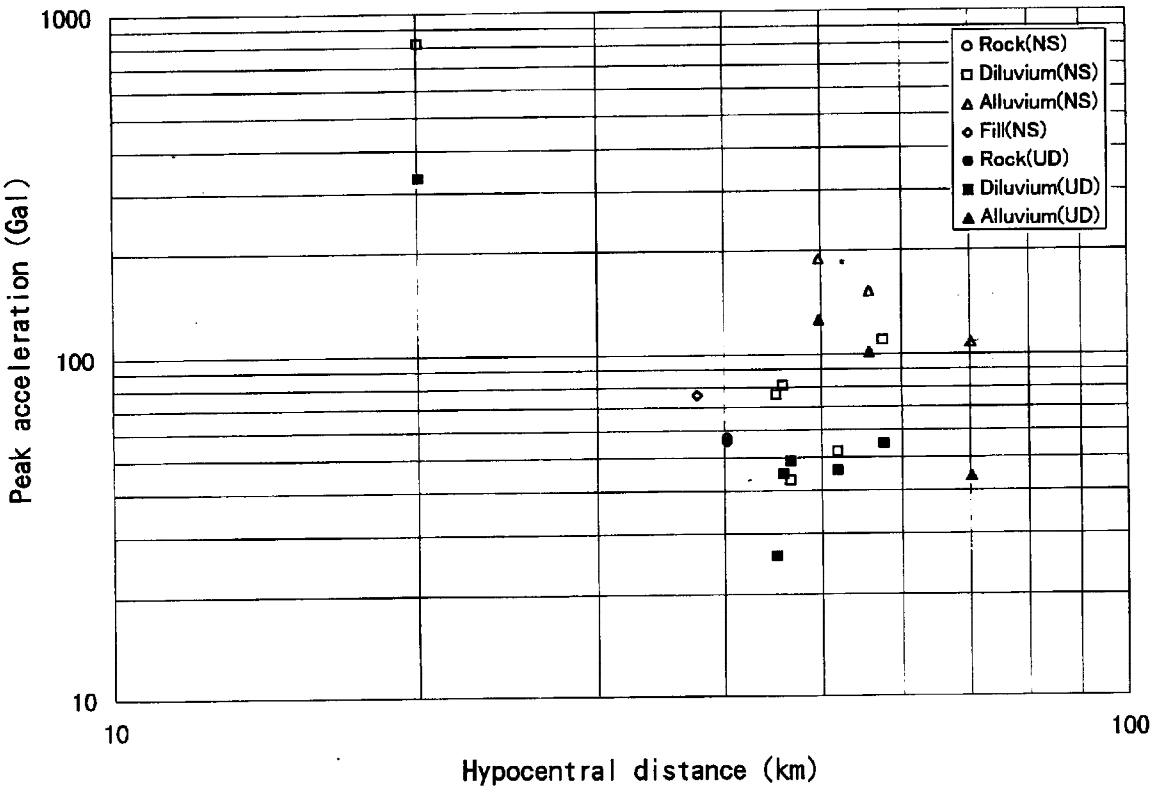

Fig. 3. Relation between peak acceleration and hypocentral distance

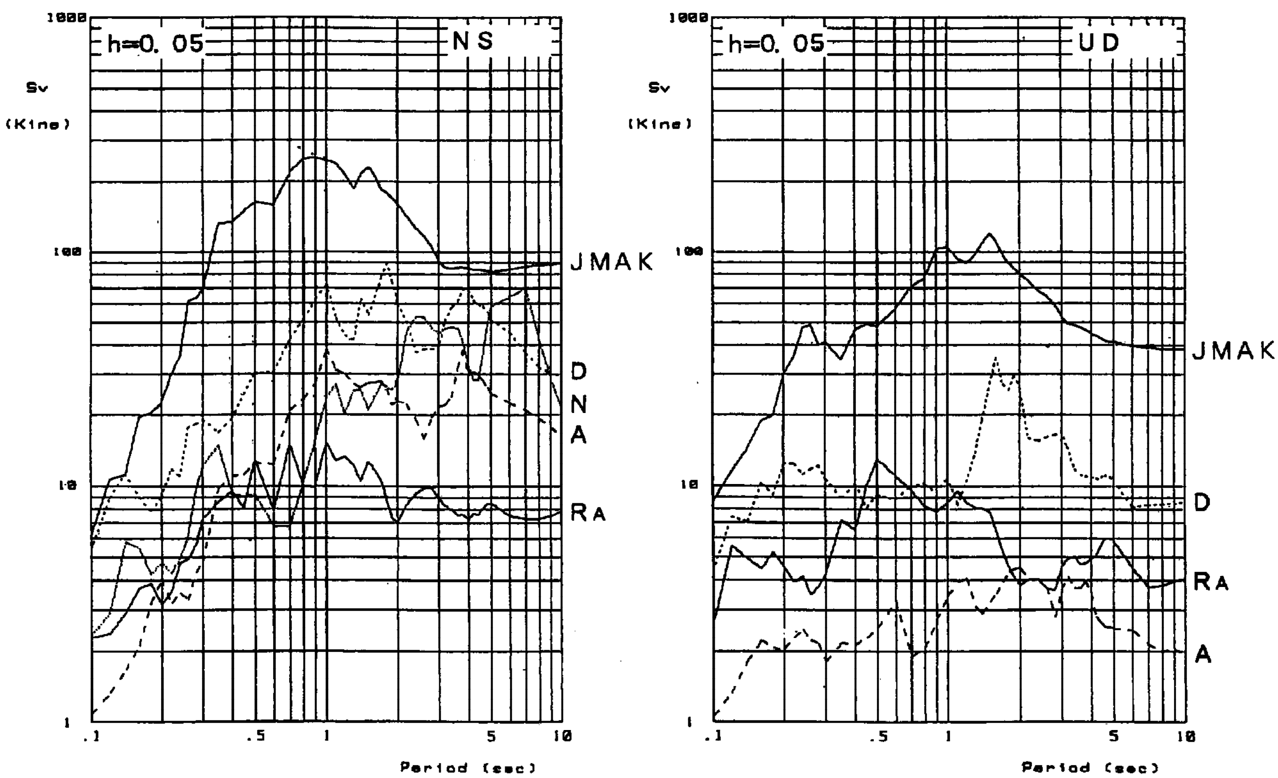

Fig. 4. Velocity response spectra (NS, UD)

PERIODIC CHARACTERISTICS OF VARIOUS TYPES OF GROUNDS

Fig. 4 shows velocity response spectra determined at point JMAK and other 4 points on different types of grounds, for horizontal motion (NS component) and vertical motion. As shown in this figure, the velocity response value at point JMAK, the nearest point to the hypocenter, is conspicuously larger than those at the other points on the Osaka Plain. For both horizontal and vertical motions, predominant periods at point JMAK are approx. 1 and 1.6 seconds. Since point JMAK is located on a hard ground close to the hypocenter, it is assumed that earthquake motion characteristics at this point are highly similar to those at the hypocenter, and therefore can be regarded as basis for examining earthquake motion at the other point. At point R_A on the bedrock, the response level is lower than that at point JMAK due to difference in distance from the hypocenter. At this point, the predominant period is approx. 1 second for both horizontal and vertical motions, and the spectrum is similar to that at point JMAK. At point A on the diluvial ground, conspicuously predominant periods of 1 and 4 seconds are found for horizontal motion. At point D on the alluvial ground, predominant periods for horizontal motion (1, 1.8 and 4 seconds) are generally longer than those at point A, and a sharp peak is found at approx. 1.5 seconds for vertical motion. At point N on the filled ground, long periods of 1 second or more are more conspicuous than at point D, and predominant periods are 2.5 and 5 - 7 seconds. For horizontal motion, a period of approx. 1 second is predominant at point JMAK, and well as at the other points. These findings indicate that long periods of 1 second or more are more predominant in a soft ground than in a hard ground.

INFLUENCE OF EARTHQUAKE MOTION STRENGTH ON PREDOMINANT PERIOD

Fig. 5 shows a sample record of the main and after shocks observed at point D

Fig. 6 shows the Fourier spectrum ratio (of the aboveground value to the underground value), determined to clarify the characteristics of erthquake motion propagation from an underground point (GL - 25 m) to an aboveground point (GL - 1.5 m).

The predominant periods of the main and after shocks, shear wave velocity in the alluvial layer is determined using the expression: Vs = 4H/T (H: layer thickness [m]; T: period [sec]). Fig. 7 shows the relation between peak acceleration for surface ground and predominant period.

Figs. 6 and 7 show that predominant period for the subsurface layers lengthens with increased peak acceleration. This presumably indicates that the velocity of shear wave propagation to the layers is influenced by ground shearing strain.

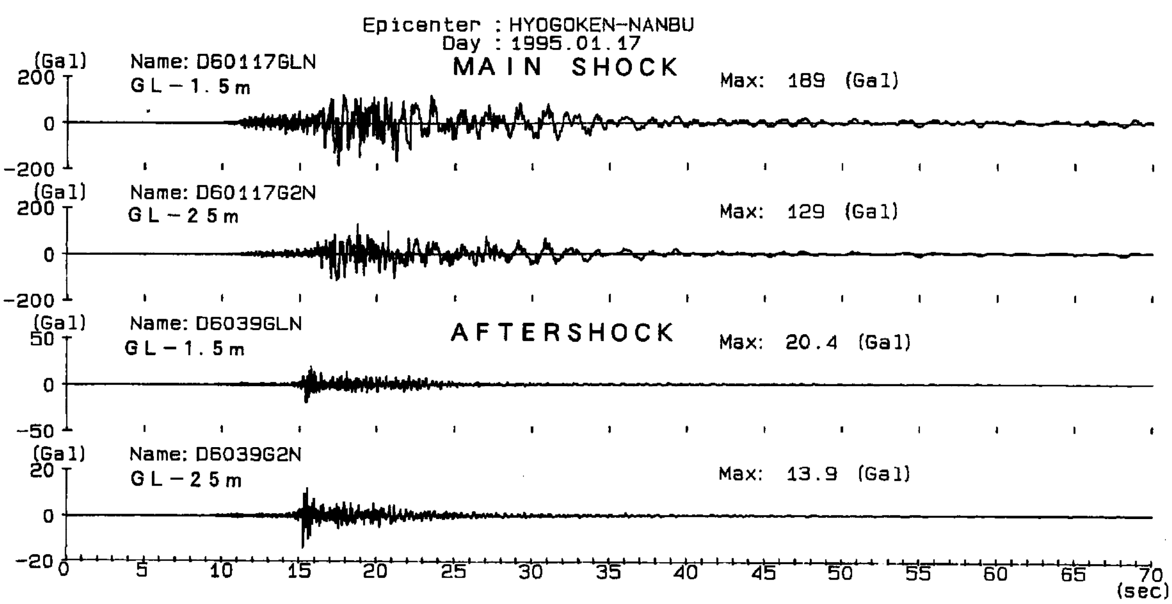

Fig. 5. A sample record of the main and after shocks observed at point D

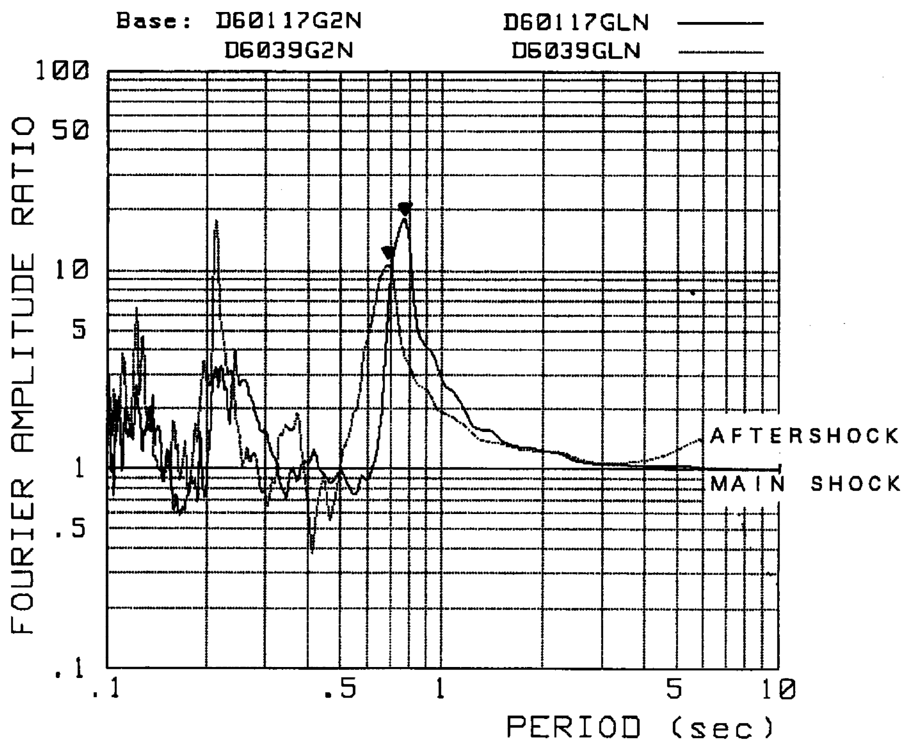

Fig. 6. Fourier spectrum ratio (of the aboveground value to the underground value)

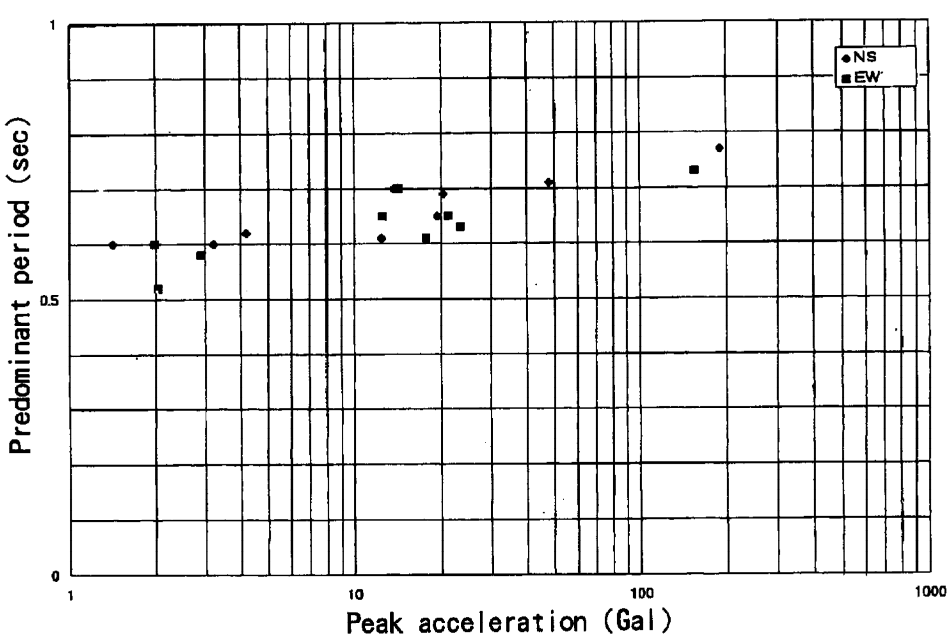

Fig. 7. Relation between peak acceleration and predominant period

CONCLUSION

The following points have been made clear as a result of investigations:

(1) At an observation point, predominant periods are conspicuously influenced by the periods at the hypocenter. At a main shock, a period of approx. 1 second predominates at all points. As well, additional predominant periods, determined by local ground conditions, are found. As a result, predominant periods vary according to point.

(2) Acceleration amplitude attenuates with the increase of distance from the hypocenter. Attenuation ratio varies with ground conditions. Compareing 4 types of ground, the earthquake motion on the bedreck in mountainous surrounding the Osaka plain, approx. 40 km distant from the hypocenter, generally had smaller acceleration amplitudes. Acceleraion amplitude increases as the type of ground goes to diluvial ground to alluvial ground. However, it is noteworthy that the ground, with a 15 m - deep filled layer on a 30 m - deep alluvial layer had less amplitude.

(3) Earthquake motion on the ground surface of the Osaka plain is of much longer duration than that on the surrounding mountainous region.

(4) Predominant period for the subsurface layers lengthens with the increase in peak acceleration. This presumably indicates that the velocity of shear wave propagation to the leyers is influenced by groiund shearing strain.

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