(26) GROUND STRAIN CHARACTERISTICS DEDUCED BY USING DENSE SEISMOGRAPH ARRAY DATA

By

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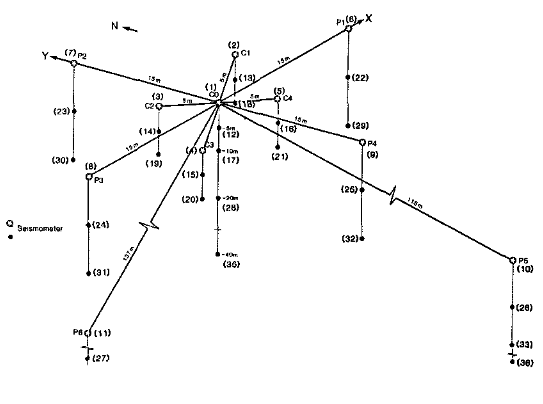
ABSTRACT. In the present study the characteristics of ground strains during three recent earthquakes are investigated. These events, with magnitudes ranging from 6.0 to 7.9, seem to have substantially different characteristics which have great effects on the engineering properties of ground strains. The behaviours of ground strains are compared with those of ground acceleration, velocity and displacement. Ground strains are evaluated by using acceleration data obtained by a very dense seismograph array system. The effects of several factors on the evaluated strains are discussed.

INTRODUCTION. A dense seismograph array network located in Chiba Experiment Station of the Institute of Industrial Science, the University of Tokyo, has been operating since April, 1982. In this network a total of 138 components of ground motions including 108 components of ground acceleration on and in the ground as well as 30 components of strains in ground and in buried pipes are simultaneously recorded. The layout of the observatoin system is shown in Fig. 1. The detailed explanation of the system is given elsewhere (Refs. 1 and 2). Ground strains are evaluated by employing finite element method with a basic element of tetrahedral shape. By using this method it is attempted to study the following objectives: a) the accuracy of evaluated strains, by comparing them with directly



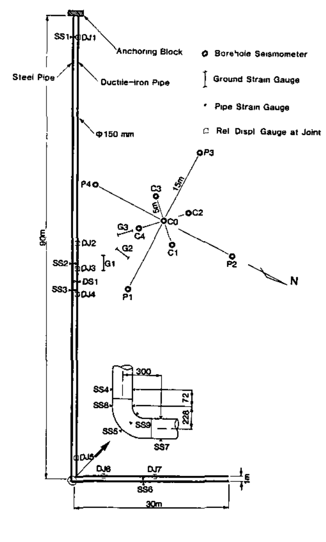


Fig. 1 Layout of Observation System and Array Network

observed strains; b) effects of size of chosen elements and band-pass filtering on the accuracy of evaluated ground strains; c) behaviours of strains at different depths; and d) behaviours of strains at different locations within a specified site.

RESULTS. The results of three recent earthquakes are presented here. The characteristics of these events are summarized in Table 1.

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Table 1 List of Earthquakes

DATE	M	FOCAL DEPTH (km)	EPICENTRAL DIS.(km)	MAX*			MAX STRAIN
				ACC (gal)	VEL (kine)	DIS (cm)	($\times 10^{-6}$)
1983.2.27	6.0	72	35	48	4.0	0.9	15.5
1984.3.06	7.9	452	705	22	3.3	0.7	9.5
1984.9.14	6.8	2	232	4	2.0	2.0	18.6

* Components in pipe direction at (CO, -1m)

The first event occurred in the southern part of Ibaragi Prefecture which is the strongest one so far recorded by the array network. Ground acceleration has dominant frequency components ranging from about 1 Hz to 5 Hz. Fourier spectrum of observed strain in the buried steel pipe and its time history as well as acceleration, velocity and displacement time histories at a typical point (CO,-1m)) in pipe direction are shown in Fig. 2. Amplitudes of acceleration, velocity, displacement and strain decrease with the lapse of time. The strain has a dominant frequency component of about 1 Hz.

For the second event, a deep and distant earthquake, although with the lapse of time the acceleration amplitude shows dramatic decrease, the strain amplitude does not decrease significantly. The velocity also shows some decrease but the amplitude of displacement is almost the same. For strain, with dominant frequency component of 0.43 Hz (T=2.3 s), higher frequency components are dominant for the initial part, but as the time lapses the lower frequency components become dominant.

The last event, a shallow earthquake which occurred in Nagano Prefecture, shows quite different characteristics. The maximum recorded acceleration at the site did not exceed 4.0 gals with dominant frequency components ranging from 0.14 Hz to 0.5 Hz (T=2 s to 7 s). The acceleration is almost the same for deeper layers up to 40 m. The ground strain is small in the initial part of the record, however, in the latter part (after about 120 s) the strain level becomes large with dominant frequency components ranging from 0.14 Hz to 0.2 Hz (T=5 s to 7 s). Fourier spectrum of strain and its time history as well as acceleration, velocity and displacement time histories are shown in Fig. 3.

To show the efficiency of the proposed method to evaluate the ground strains some examples are given here. Also the effects of different factors on the accuracy of calculated strains are discussed.

1. Effect of band-pass filtering: Figure 4 shows the directly observed strains (second event) and the evaluated strains in an element with the sides of about 40 m. The evaluated strains were processed with a poorly and also an elaborately chosen band-pass filter. The results are shown in Figures 4b and 4c, respectively. There is a very good agreement between the evaluated strain with proper filter (Fig. 4c) and the observed strain (Fig. 4a).
2. Effect of the size of the elements: Observed strain (first event) is shown in Fig. 5a while figures 5b and 5c show the strains calculated in elements with the sides of about 40 m and 140 m. Good agreement exists between observed and evaluated strains except for higher frequency components which are specially suppressed for the larger element.

For the last event with the maximum acceleration of only about 4 gals the observed and the evaluated strains also show good agreement (Fig. 6) but the amplitude of the evaluated strains is larger specially for smaller element. For this event surface waves are dominant with phase

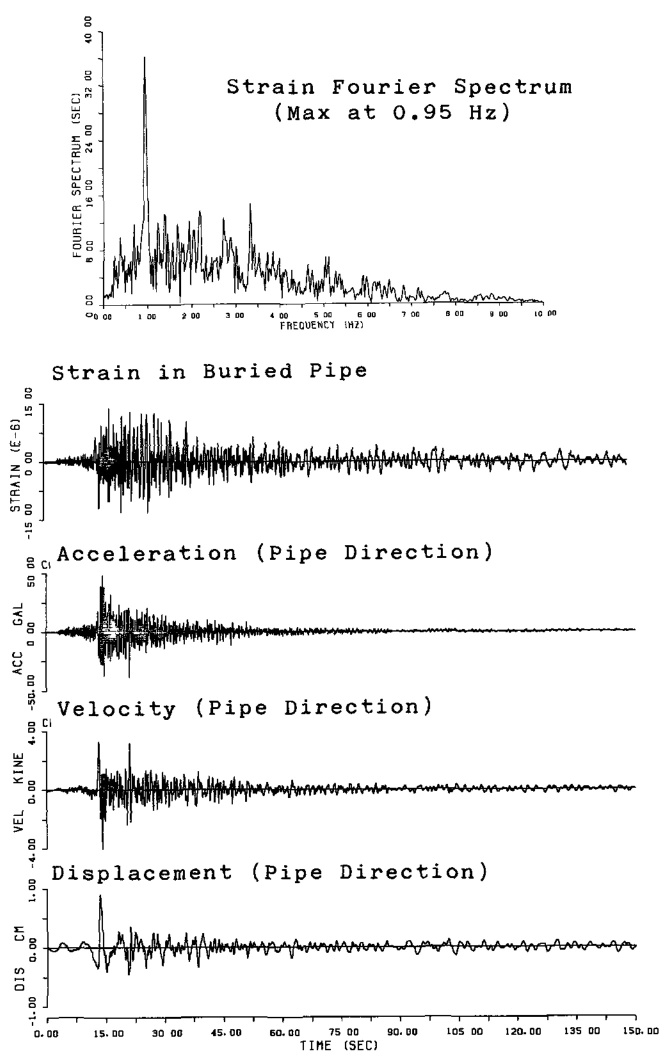

Fig. 2 Observed Strain, Acc., Vel., and Dis. (Event 1982.2.27)

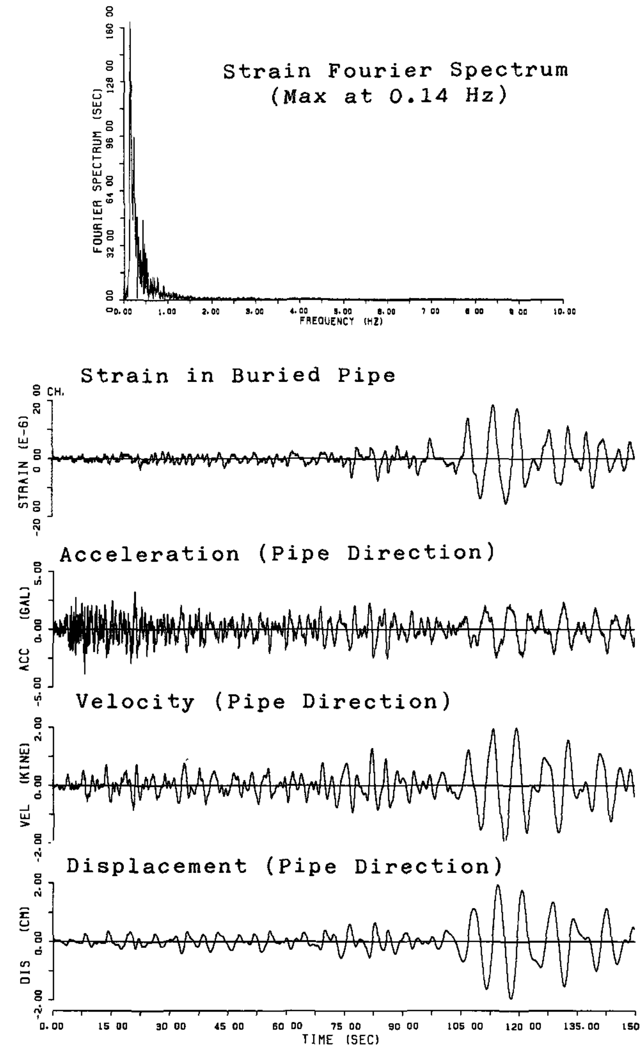

Fig. 3 Observed Strain, Acc., Vel., and Dis. (Event 1984.9.14)

velocity of about 1.1 km/s (in EW direction) and maximum ground velocity of 2.0 cm/s. Using the simplified relation of $\varepsilon = V/C$, the maximum strain is found to be about 16.5×10^{-6} which is in good agreement with the maximum observed strain.

CONCLUSIONS. In this paper the characteristics of ground strains during the three recent earthquakes were discussed. It was found that the frequency content of ground strains generally shows closer similarity to those of ground velocities. However, the trend of decreasing or increasing of strain amplitude with the lapse of time is in better agreement with those of ground displacements. It was also shown that the ground strains evaluated by the proposed method show good agreement with the directly observed strains. The accuracy of evaluated strains mainly depends on the size of chosen elements and band-pass filtering process.

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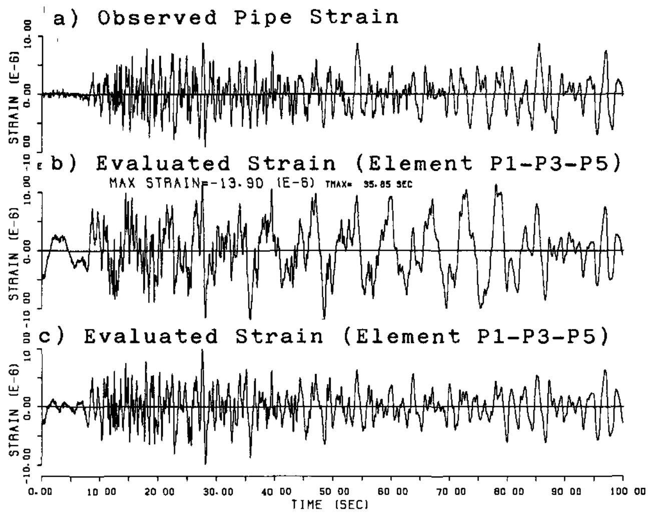

Fig. 4 Observed and Evaluated Strain (Event 1984.3.6)

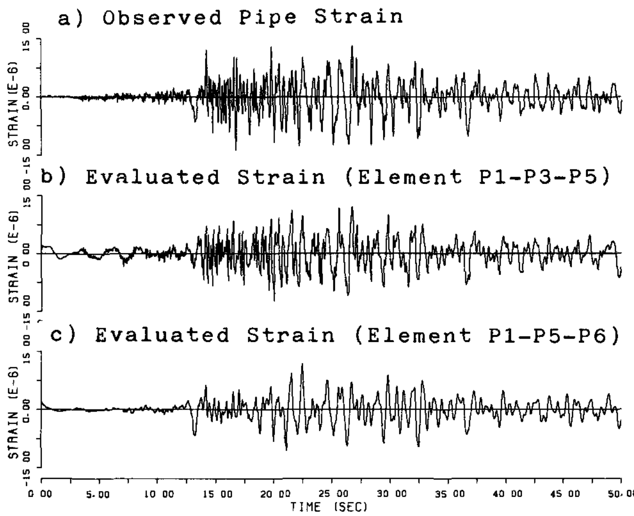

Fig. 5 Observed and Evaluated Strain (Event 1983.2.27)

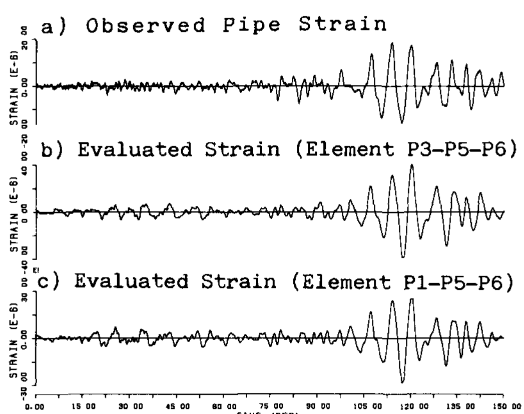

Fig. 6 Observed and Evaluated Strain (Event 1984.9.14)