DYNAMIC BEHAVIOR OF PIPELINE DURING THE MIYAGI-KEN-OKI EARTHQUAKE IN 1978

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SUMMARY

Some records of stresses and accelerations on a pipeline were obtained during the Miyagi-Ken-Oki (offshore Miyagi Pref.) Earthquake. Observed stresses were compared with those calculated from the observed acceleration. As a result it was found that both stresses agree approximately. Observed data of thirteen earthquakes after setting instruments to observe are described below.

INTRODUCTION

On June 12th in 1978, the Miyagi-Ken-Oki Earthquake struck Sendai City with the Magnitude of 7.4.

This paper describes the dynamic behavior of a water steel pipeline (1200 mm in diameter) observed in Hachinohe City, the epicentral distance of which was about 270 km as shown in Fig. 1. It was reported that a part of water pipeline system was damaged in Hachinohe City.

Japan's earthquake resistant design method of today is based on the following criteria[1)]. A sinusoidal S-Wave comes at an angle with respect to a pipeline axis, and strains in soil are gradients of displacement of the soil. And it is assumed that stresses arise on the pipeline corresponding to the strains of adjacent soil in the direction of the pipeline axis.

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Real earthquakes, however, are so complicated that the above criteria involve the following problems:

(1) As wave shapes are different from each other, only one wave cannot represent the whole earthquake waves.

(2) How should the wave length be determined?

EARTHQUAKE RESPONSE MEASUREMENT

The observation instruments were installed in Hachinohe City which is located in the northeastern part of Japan Main Island as shown in Fig. 1[2]. It was reported that part of water pipeline system which was not in this area of observation was damaged in Hachinohe City and that 106 households' water supply was stopped.

Fig. 2 shows that part of water pipeline with 1200 mm diameter and 16 mm thickness has been observed since April in 1975. The measurement was conducted at eleven points of water pipeline and at one point of adjacent exposed rock, thus totally at twelve points. Eleven points of water pipeline involve a valve pit and bellows-type expansion joints. The location of station 1 through to 12 is shown in Fig. 2. The soil profile around the instruments is shown in Fig. 3. As shown in Fig. 3, it is considered that the exposed rock at St. 12 leads to a bed rock under surface stratum around the pipeline.

Observed items are:

(1) Three component accelerations of surface stratum and rock

(2) Axial accelerations and horizontal accelerations perpendicular to axis of pipeline

(3) Axial and circumferential stresses of pipeline

(4) Expansion and contraction of the bellows

(5) Acceleration of valve pit

Remarkable earthquakes observed between April in 1975 and December in 1978 are shown in Table 1. The relationship between magnitude, epicentral distance and the maximum seismic strain observed at a submerged tunnel was reported by Prof. Tamura and others[3]. Observed results in our case of pipeline, which are shown in Table 1, are plotted in Fig. 4. Although both cases are different in structure and ground condition, the tendency of strain in relation to epicentral distance and magnitude is approximately the same in both cases. The component at which the maximum strain arose was axial component of St. 4 in the most case and it is considered that the station involves pipe bent. By way of exception, at St. 6 and 1, maximum strains were observed during the Miyagi-Ken-Oki Earthquake (M = 7.4) and Earthquake of Near Kunashiri Island (M = 7.7), when great strains, a little less than those at the above-mentioned stations, were observed at many points including St. 4.

Japan Meteorological Agency reported that the focal depth of the Miyagi-Ken-Oki Earthquake was 40 km and that maximum displacements were 6.4 mm NS, 6.8 mm EW and 10.0 mm UD in Hachinohe City[4]. The maximum values in our observation were 11 x 10^{-6} of strain of pipeline, 0.5 mm of expansion and contraction of bellows, 80 gal of acceleration on pipeline, 104 gal of acceleration of ground and 23 gal of acceleration of rock. Observed time histories of expansion or contraction of bellows and strain of pipeline are shown in Fig. 5 (a) and Fig. 6 (a). Furthermore, Fourie Spectra of these time histories are shown in Fig. 5 (f) and Fig. 6 (f). It is obvious that the predominant period is 0.2 ∿ 0.5 sec.

The time histories of axial acceleration at St. 1, 3, 6 and 7 are shown in Fig. 5 (c) (d) and Fig. 6 (c) (d). If the record at St. 1 is compared with that at St. 3, their amplitudes are different from each other but both phases are almost the same. The same relation is true of the records at St. 6 and that at St. 7. Judging from small difference of phase, it is considered that waves propergate vertically upwards.

The difference between the acceleration at St. 1 and that at St. 3 is relative acceleration of both ends of bellows and is shown in Fig. 5 (e). Relative acceleration of the straight pipe is obtained in Fig. 6 (e) by the same method. These are then integrated twice, and furthermore, decomposed periods over 0.5 sec and under 0.2 sec are neglected. Expansion and contraction of bellows are then obtained from calculation as shown in Fig. 5 (b). At the straight pipe the same method is used. The relative displacement is divided by the distance between St. 6 and 7, and calculated average strain is obtained in Fig. 6 (b). Observed expansion and contraction of bellows and strain on straight pipe are compared with those calculated from acceleration, and these pairs resemble each other. From this result it was understood that expansion and contraction of bellows and strain on straight pipe can be estimated to some extent even if accelerograms are installed instead of displacement gauges and strain gauges.

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2) Miyajima N., Miyauchi J., Shirakawa K. and Aono Y., 1976, An Example of Seismic Design and Earthquake Response Measurement of a Buried Pipeline, Proceedings of U.S.-Japan Seminar on Earthquake Engineering Research with Emphasis on Lifeline Systems, pp. 177-196

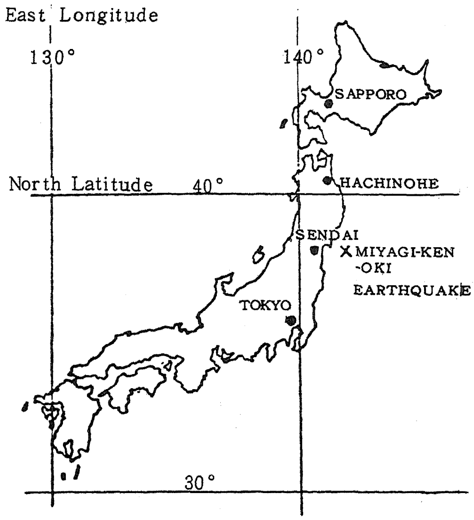

Fig. 1 Locations of HACHINOHE and Epicenter

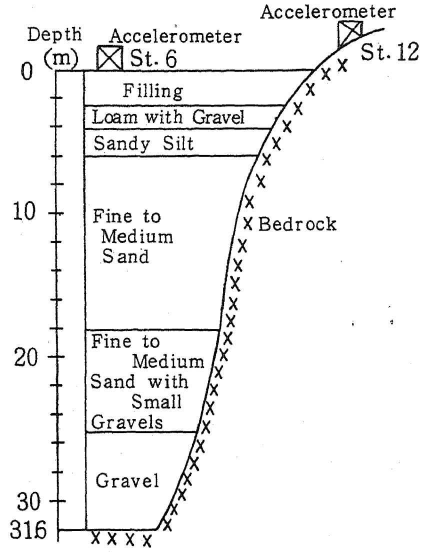

Fig. 3 Soil Boring Log

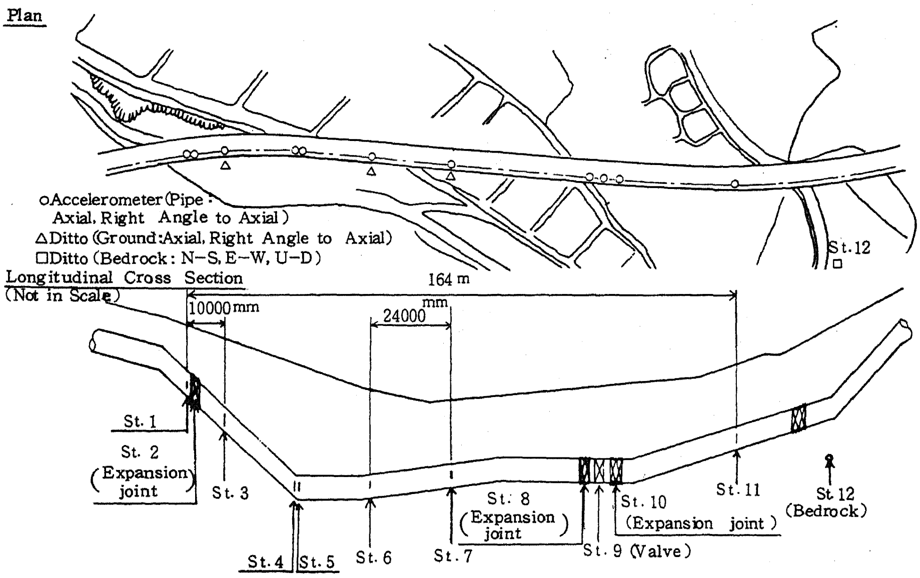

Fig. 2 Location of Instrument Stations

3) Tamura C., Okamoto S. and Kato K., 1978, Earthquake Observations on Tunnels in the Soft Ground, Proceedings of the Fifth Japan Earthquake Engineering Symposium, pp. 953-960

4) Japan Meteorological Agency, 1978, Report on the 1978 Miyagi-Ken-Oki Earthquake, Technical Report of the Japan Meteorological Agency, No.95, pp. 49-53

Table 1 Records of Observed Earthquakes

No.	Date	Location	Magnitude	Depth (m)	Epicentral Distance (km)
①	1975. 6. 16	Off Iwate Pref.	4. 9	3 0	8 7
②	6. 18	East Off Aomori Pref.	5. 5	3 0	1 5 0
③	9. 20	Off Urakawa	5. 9	5 0	1 7 6
④	10. 30	Off Urakawa	6. 0	6 0	1 9 0
⑤	1976. 6. 2	East Off Aomori Pref.	5. 0	6 0	1 1 1
⑥	7. 8	Off Iwate Pref.	5. 9	3 0	8 4
⑦	1977. 2. 18	East Off Aomori Pref.	5. 4	6 0	1 0 9
⑧	9. 28	Coast of Iwate Pref.	4. 8	6 0	9 1
⑨	1978. 2. 20	Off Miyagi Pref.	6. 7	5 0	2 0 5
⑩	5. 16	East Coast of Aomori Pref.	5. 8	1 0	4 8
⑪	〃 〃	〃	〃	〃	4 6
⑫	6. 12	Off Miyagi Pref.	7. 4	4 0	2 6 9
⑬	12. 6	Near Kunashiri Island	7. 7	1 0 0	6 4 6

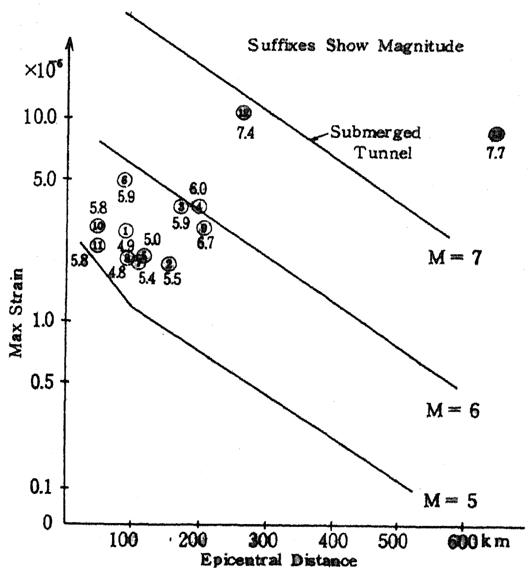

Fig. 4 Relation Among Maximum Strain, Magnitude and Epicentral Distance

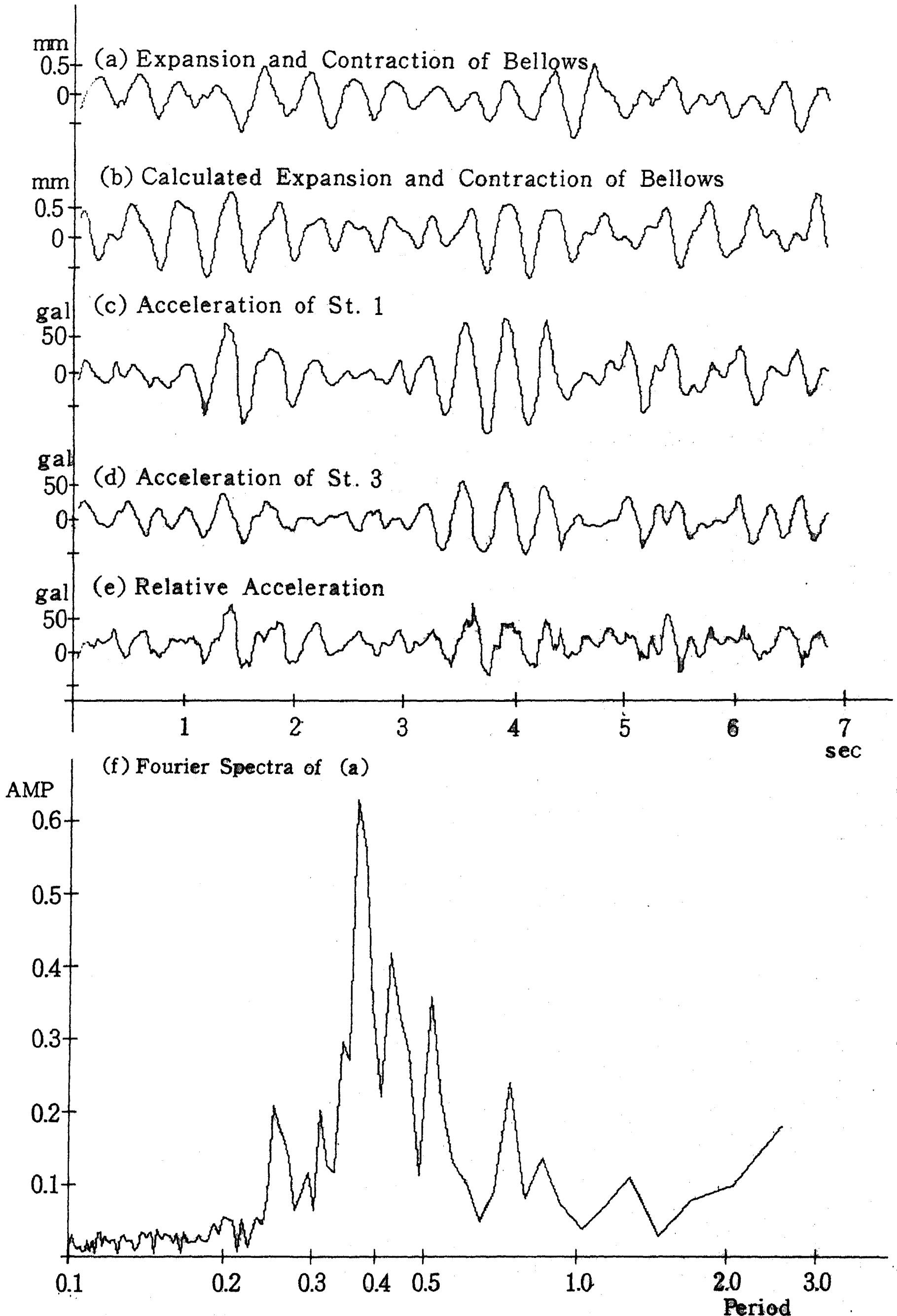

Fig. 9 Records and Calculated Results about Bellows

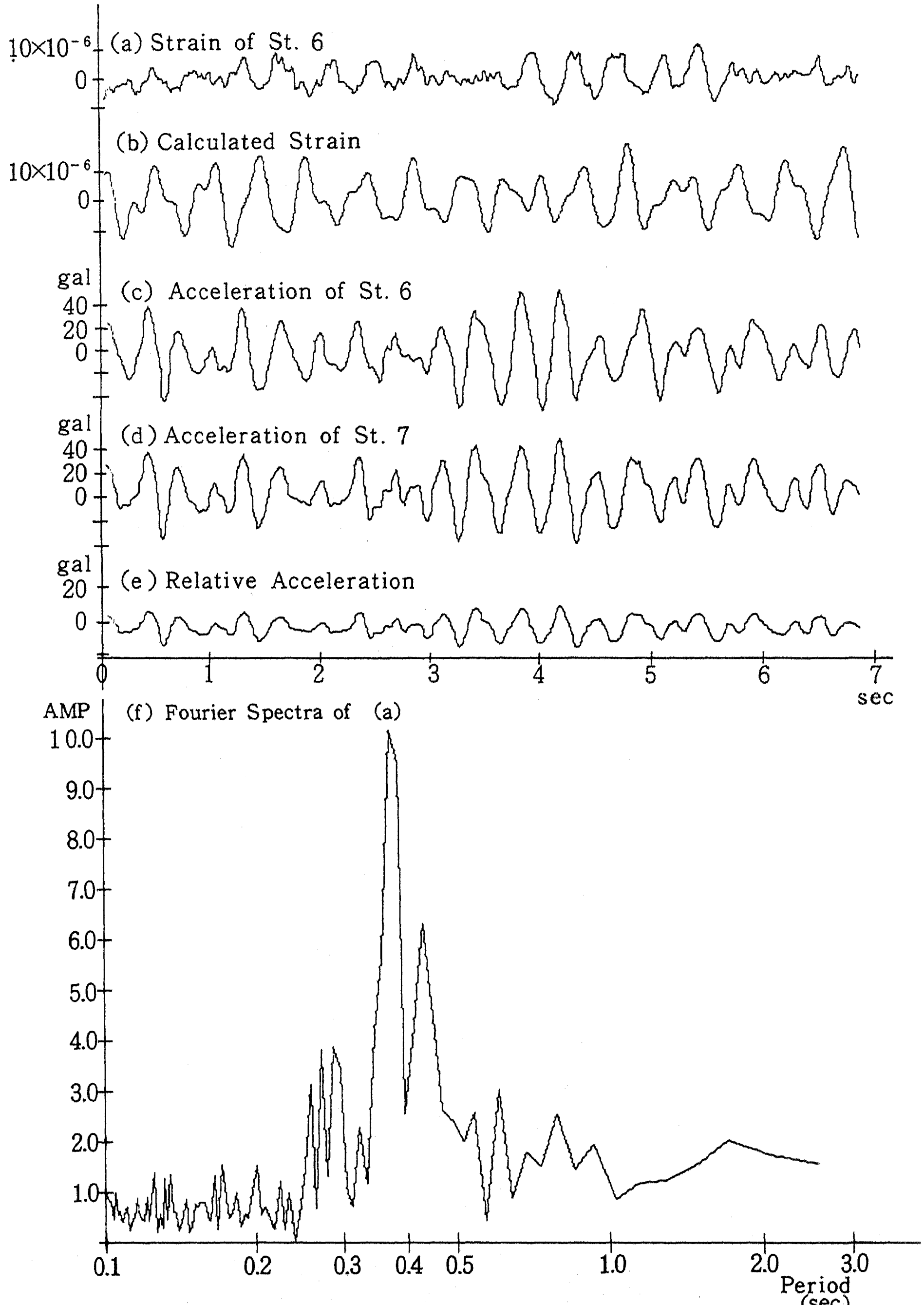

Fig. 6 Records and Calculated Results about Strain of Pipe