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DENSE STRONG MOTION EARTHQUAKE SEISMOMETER ARRAY AT SITE WITH DIFFERENT TOPOGRAPHIC AND GEOLOGIC CONDITIONS IN SENDAI

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SUMMARY

The objective of the dense seismometer array in the Sendai area is to study how each of these factors would contribute to the actual ground motions with particular attention to the geological condition, and to estimate the earthquake motions for dynamic design criteria. The array network is composed of eleven stations with spacing of approximately 3 to 4km on the E-W and N-S lines passing through the center of Sendai City. At each station, three observation points are arranged vertically. A control and monitoring center is set up in the Building Research Institute (BRI) at Tsukuba via public telephone lines. As a result, the softer the soil condition is, the larger the maximum values of acceleration at the ground level and the magnification factor are.

INTRODUCTION

Strong ground motions induced by an earthquake occurrence are known to be affected not only by the earthquake process itself but by the propagating pass of seismic topographies and properties of ground surface layers as well. These factors apparently influence the type of structural damage. Therefore, many efforts, both theoretical and experimental, have been directed in clarifying the complex effects of surface soil-layers during an earthquake ground motion. The advent of large scale structures and important facilities after the 1960's has led to a remarkable increase in research with special reference to underground earthquake observation.

The dense seismometer array at various sites with different topography and geology was started in fiscal 1983, as a six year plan, and has been constructed in the Sendai area, in the northeastern part of Japan. The Sendai area has a wide variety of topography and geology, and there are many types and scales of structures. The Sendai area suffered severe damage from the 1978 Off Miyagi Prefecture Earthquake (M=7.4). After the earthquake, various studies were performed to examine the earthquake damage.

In this report, the dense seismometer array places at various sites with different topographical and geological conditions in the Sendai area are briefly introduced with particular attention to the geological conditions in the area and the plan configuration and the system of seismometer array and so on.

OUTLINE OF GEOLOGICAL CONDITION

Topographical Aspects In terms of geological conditions of surface soil, the Sendai district is generally classified into three areas (as shown in Fig. 1); (1) the hilly tertiary terrain, (2) the terrace area and (3) the alluvial plain. The oblique NE-SW line passing near the center of the map is called the Rifu-Nagamachi tectonic line. The area in the west of the tectonic line is characterized by the hilly tertiary terrain and several levels of the terraces. The surface deposit of this terrace is loam which is underlain by hard clay, gravel, pelite and shale. The hilly terrain is made of very hard andesite shale, but the surface is covered with loam at several places. The alluvial plain develops in the east of this line and mostly consists of sand, silt and gravel. The depth of the tertiary base rock varies abruptly near the tectonic line. There are several areas in the plain which are covered by very soft peat or mud.

Microtremor Measurement (Refs. 1,2) The microtremors are measured at several sites shown in Fig. 1 with electromagnetic seismometers having the natural period of 1.0 sec. to get dynamic properties of soil layers. The area, where the measurements were performed, have to two types of geological conditions-(2) and (3) mentioned above. The representative Fourier spectra of microtremors in the EW and NS directions are shown in Fig. 2, where sites G-06 through G-08, and sites G-17 and G-18 are on the outcrop of the terrace and on the alluvial plain, respectively. The peaks at long periods (more than 1.0 sec.) reflect the deep *ground characteristics, whereas the peaks at short periods (less than 1.0 sec.)* reflect the shallow ground ones.

ARRAY CONFIGURATION AND OBSERVATION SYSTEM

The Sendai area is designated as one of the ten high priority sites in Japan for the deployment of strong motion seismometer arrays. The array network is composed of eleven stations with spacing of 3 to 4 km on the E-W line passing through the center of Sendai City and the N-S line passing through the Nigatake and Oroshimachi which suffered severe structures damage in the 1978 Off Miyagi Prefecture Earthquake.

The layout of array configuration is shown in Fig. 3. As seen in Fig. 3, six observation stations have been installed respectively at Miyagino (MIYA) , Nakano (NAKA), Tsutsujigaoka (TSUT), Oridate (ORID), Okino (OKIN) primary schools, and Tamagawa (TAMA) secondary school. In addition to these schools, other five stations are scheduled to be installed by fiscal 1989 at Tsurugaya (TSUY), Tsurumaki (TSUK), Shiro-maru (SHIR), Nagamachi (NAGA) and Arahama (ARAH) primary schools.

Photo I shows overview of the observation hut at the MIYA station, as an example. The soil profiles and the results of seismic prospecting test at the NAKA station on the soft soil, the MIYA station on medium soil and the TAMA station on the hard soil are shown in Fig. 4. The transfer function (Uo/U_B) by the Haskell Method with damping of 5% is defined as the ratio of the wave on the ground surface, Uo, to the wave at the structural base rock, U_B , for the underground structure at the NAKA, MIYA and TAMA station in Fig. 5.

At each station, three observation points are arranged vertically; one on the surface, one in 20 to 30m underground with a shear wave velocity of 300-400m/s, and one in the structural base rock having a shear wave velocity of 700-800m/s and lying at a depth of 50 to 60m. A control and monitoring center is set up in the BRI. The center is connected to a sub-center at Sendai, and the sub-center is further connected to each observation station via public and exclusive telephone lines. Figure 6 shows a block diagram of the dense strong motion seismometer array system. Figure 7 shows a plan and a section of the standard observation hut.

The array observation system consists essentially of an accelerometer sensor, an amplifier, an A-D converter, a pre-event memory, a digital magnetic tape recorder and a time code generator. In order to obtain large dynamic range and high resolution in recording, a digital system is used. Specifications of the array observation system are shown in Table 1.

EXAMPLE OF EARTHQUAKE RECORD

Operation of the MIYA station initiated in March 1984. Much valuable data have been accumulated year by year. As an example, acceleration records and displacement calculated by FFT method with a digital band pass filter of 0.2 to 25Hz for removing the low and high frequency components, on the ground surface and underground layer at the three observation sites in EW component during the Earthquake off Fukushima Prefecture. The Earthquake of 1988 (M=6.5 Epicenter: Lat. 37° 04'N, Long. 141°37'E, Focal Depth: 49km) are shown in Fig. 8. The magnification factors between ground surface and base rock vs. epicenter distance at the three sites are shown in Fig. 9. The softer the soil condition is, the larger the maximum values of acceleration at the ground level and the magnification factor are, as seen in those figures. The spectral ratio and phase lag between the surface and underground layer at three stations are shown in Fig. 5. Judging from these figures, the predominant frequency of the soil-layers corresponds to the values in the transfer function. But absolute peak values do not correspond to the calculated ones at TAMA Station.

CONCLUDING REMARKS

The system of the dense seismometer array and the plan configuration have been established. The number of observation sites has increased year by year and high quality array data will be accumulated in the near future. In relation to the increase of data, dissemination of the data is necessary for cooperation and coordination between the earthquake observation sites under individual projects. Under these circumstances, establishment of a national data bank system for information exchange is hoped for in the near future.

ACKNOWLEDGMENTS

In order to discuss the array observation plan, the committee of dense strong motion earthquake seismometer array (Chairman: Y. Osawa, Professor emeritus of Tokyo University) is organized in KKSK, (Society for Promoting Building Research). The authors wish to express their sincere thanks to member of the committee and persons concerned. Some of the earthquake records used in this paper were obtained through the dense strong motion earthquake observation project which is operated as a cooperative research project by the BRI and the KKSK. For the management of this project, the dense strong motion eq. obs. man. com. (1987-1991) was established in the KKSK. This committee is composed of the BRI, 16 const. companies and a group of architecture design offices.

REFERENCES

1. Report on the Damage by 1978 Off-Miyagi Prefecture Earthquake (in Japanese), Rept. of BRI, No. 86, pp. 75-81, 1978.
2. Y.Kitagawa and Y.Matsushima;Evaluation of Dynamic Ground Characteristics and Seismic Microzoing, Proc. of Third South Pacific Regional Conference on Earth. Eng., New Zealand, pp. 73-83, 1983.

Table 1 Specification of Array Observation

Instrument	Specification
Accelerometer	Triaxial force barance type, Overall frequency range: + 1G, 0.05-30Hz
Amplifier and A-D Converter	16bit ADC, Dynamic Range: 96dB Sampling Rate: 1/100 or 1/200sec.
Pre-event Memory	Delay device utilizing IC memory, Delay time: 5 sec.
Time Code Generater	Quartz with accuracy of 10^{-7}- 10^{-8}, Absolute time: Japanese standard time within error of + 0.01sec. by NHK (J.B.C)
Digital Data Recorder	Digital magnetic tape with 9 track, half inch in width and 1600 BPI in recording density.

Note: A telemetric monitoring device is used. The device transmits data, such as peak acceleration, tniggered time, duration of recording, on the operating condition of the system. The central system enables one to calibrate the recording sensiticity and to adjust remotely the triggering level of the recording device.

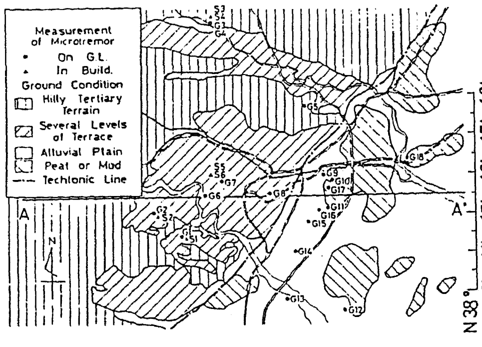


Fig. 1 Geological Condition

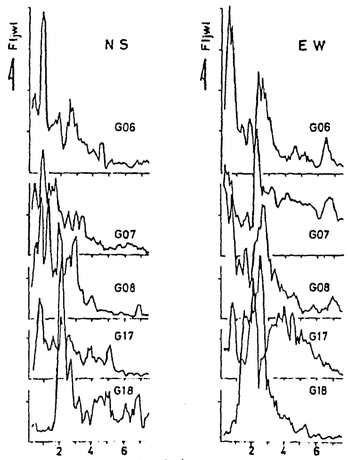


Fig. 2 Fourier Spectra of Microtremors

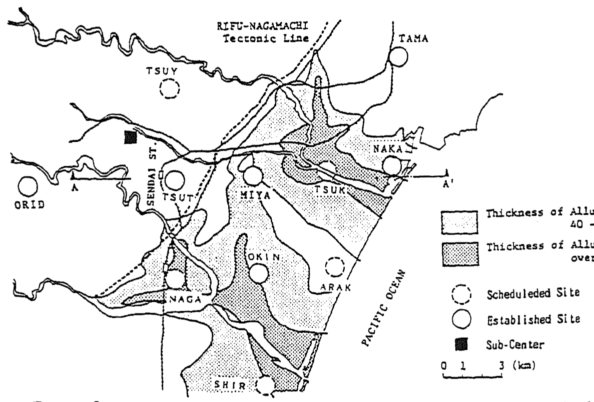
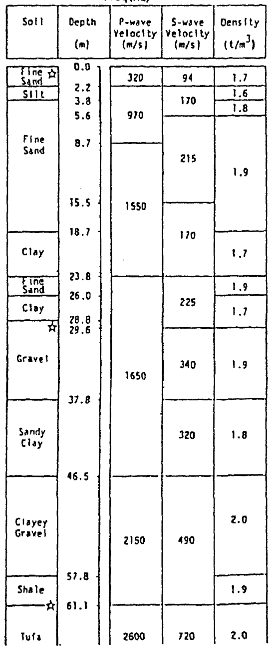
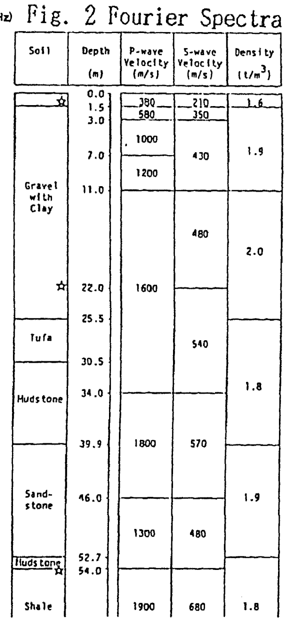


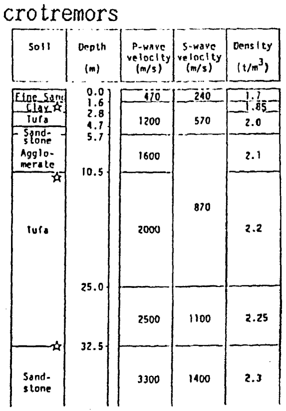
Fig. 3 Layout of Array Configuration in Sendai Area



AT NAKA site



AT MIYA site



AT TAMA site

☆ Location of Seismometer

Fig. 4 Soil Profile

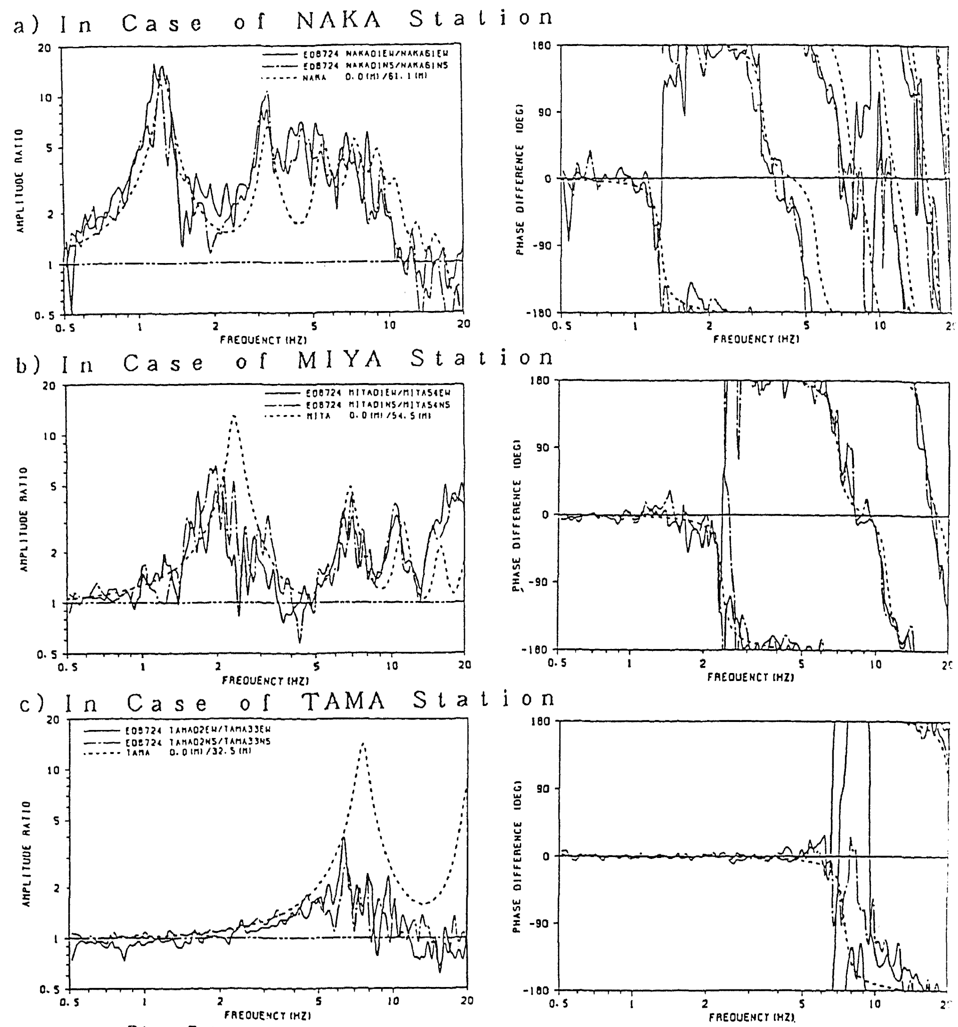


Fig. 5 Transfer Function by Haskelled Method and Spectral Ratio

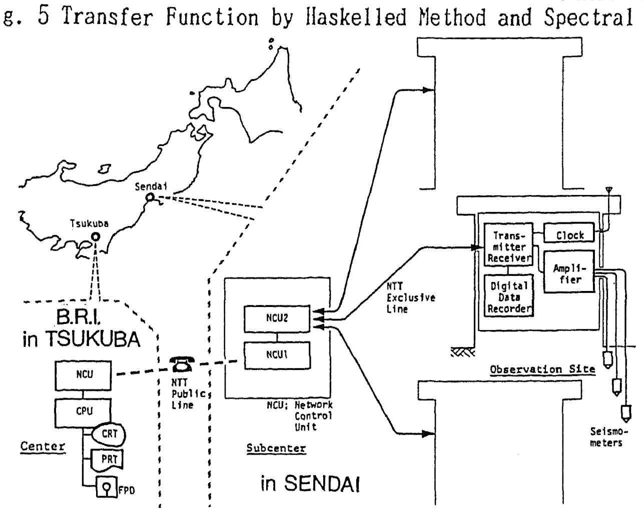


Fig. 6 Block Diagram of Dense Array Observation System

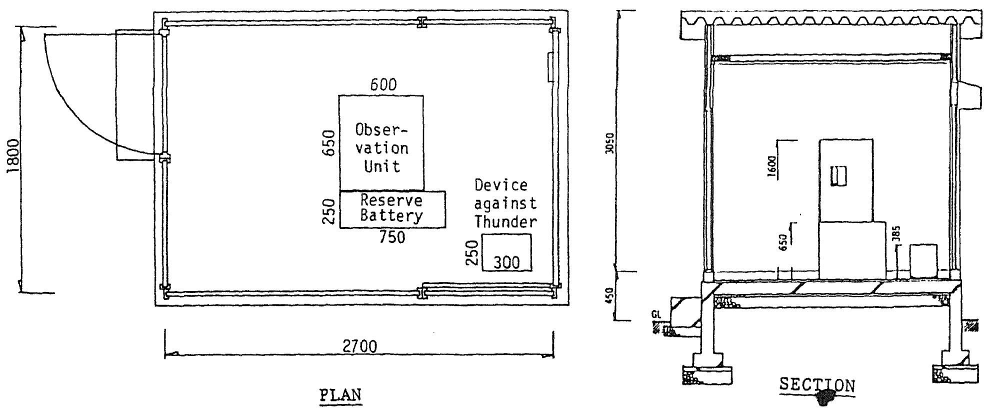


Fig. 7 Plan and Section of Standard Observation Hut

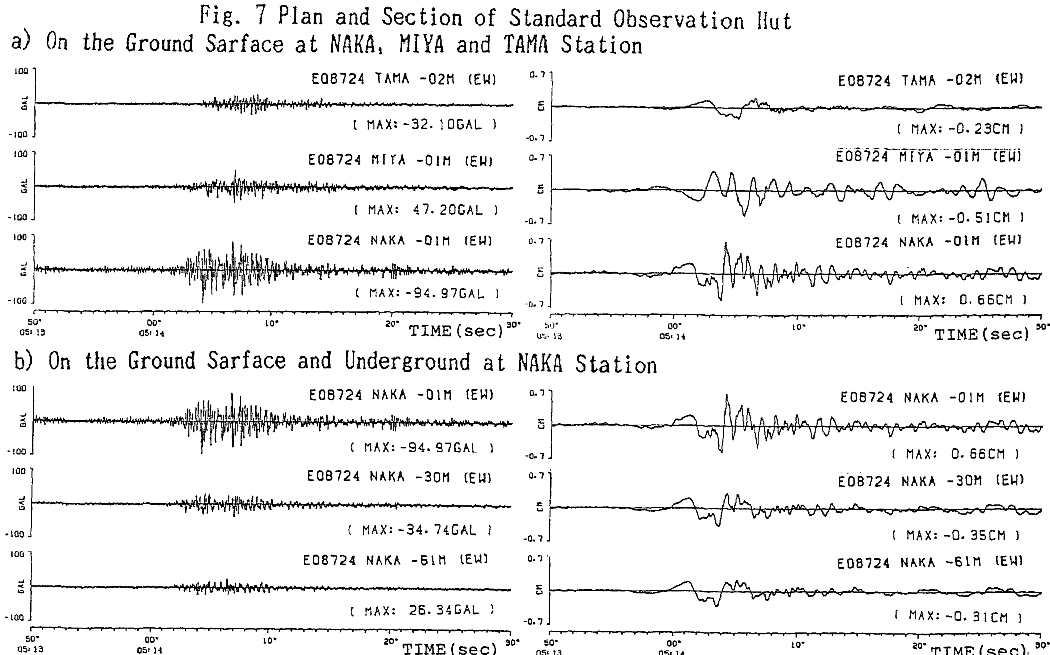


Fig. 8 Example of Acceleration Records and Calculated Displacement

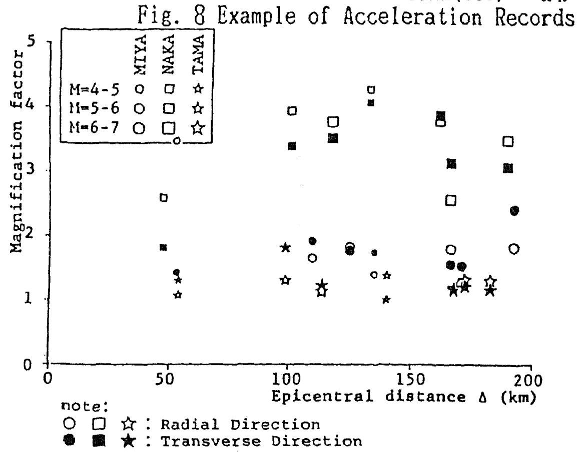


Fig. 9 Magnification Factor VS. Epicenter Distance

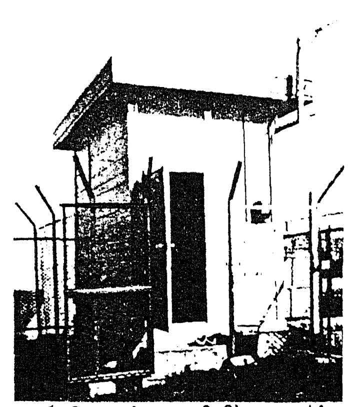


Photo 1 Overviews of Observation Hut at MIYA Station