RECENTLY DEVELOPED STRONG MOTION EARTHQUAKE INSTRUMENTS ARRAY IN JAPAN

by

Research Committee of Strong-Motion Earthquake Instrument Arrays on Rock Sites

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SUMMARY

A strong motion earthquake instruments array has been established at suitable rock sites surrounding Tokyo. A large overall array is composed of four local arrays, in which each local array is comprised of a single sub-array of a triangle with 500 m side length, and with a short vertical array. Three components sensor units were employed. A control and monitoring center located in Tokyo was connected to the sub-arrays via telephone lines. Ever since the test run started in Dec. 1978, five excellent records have been obtained. With these recorded accelerograms some results of analysis are explained in this paper.

1. INTRODUCTION

With rapid progress in the fields of seismology and earthquake engineering, the demand for observations of a much more highly qualified strong earthquake motion records than in the past is keenly requested recently on an international scale.

In recognition of these circumstances, experts met together to discuss a project for establishing a strong motion array observation system in Japan equipped with the most qualified instrumentations as possible, so that advanced studies could be stimulated, a) in the near field ground movements in related to the mechanism of faulting which produced the energy release, b) in the effects of local vibrational characteristics due to nearby large earthquake at the rock site, c) in the change of the frequency characteristics modified by the geology of the region through which the earthquake waves travel, and others. Materialized discussions have been made among experts as to how to overcome such difficulties as the selection of sites, selection of instrument types, and the design of the arrays.

About this time, an International Workshop on Strong-Motion Earthquake Instrument Arrays was held at the East-West Center, Honolulu, Hawaii, in May 2-5, 1978, convened by the International Association for Earthquake Engineering, sponsored jointly by the US-NSF and UNESCO. In this workshop, Prof. Yorihiko Ohsaki introduced our Project as one of the expected future array program in Japan.

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For this purpose, a special committee was established, with the co-operation of many agencies and experts who held deep concern to this project, for executing a large project of recording strong ground motions by means of large instrument arrays at suitable locations near Tokyo.

2. OBSERVATION ARRAYS

i) *Site selection*: The site selection poses a problem, especially in Japan, and is the most important subject requiring careful examination in setting up the strong motion instrument array network system. Major items to be considered are; (1) high seismicity region, so that many records of moderate earthquakes can also be obtained, (2) simplicity in the geological and topographical feature of the site, (3) thin coverage of the surface layer of younger geological formations, (4) existence of a fairly hard bed-rock having a considerably high shear wave velocity at a suitable depth, (5) existence of a flat surface enough to the extent for setting up a sub-array of the dimension of several hundred meters, (6) easy accessibility from Tokyo.

Overcoming all these difficulties four sites were selected to form a large overall arrays, within the distance of the order of 100 km between the adjacent locations. These locations and abbreviations are: Higashi-matsuyama City (HMY), Shuzenji Town (SZJ), Choshi City (CHS) and Tateyama City (TTY), (Fig. 1).

ii) *Overall arrays and sub-arrays:* The overall array is composed by four local stations forming two triangles having one side in common and showing the length of each side in the order of about 100 km. At each local station the sub-arrays were established except CHS station. Aiming at obtaining adequate informations for the seismic wave propagation both in the horizontal and the vertical directions, the sub-arrays were arranged horizontally as well as vertically. The layout of sub-arrays at each local station of overall arrays are also shown in Fig. 1.

The side length of each triangle of all sub-arrays was about 500 m except CHS station. For the purpose of obtaining good records of rock motion of large earthquakes, the surface seismometers were placed not on real ground surface but at a depth of a few meters where somewhat hard soil was found. The exceptions were the surface seismometers installed on the real ground surface at HMY and CHS stations. At each station a down hole seismometer was placed at the depth of about 100 m below the surface. In doing so it was intended to obtain available data by which a study on the effect of the amplification of the surface layer could be carried out.

As will be mentioned below, the observation system was aimed at recording the acceleration amplitudes. At CHS station, the velocity and displacement amplitudes were also recorded. At TTY sub-array, its construction was started later than other three stations, and is expected to enter operation by April, 1980. At five km north-west of TTY station, a single set of strong motion accelerograph, known as SMAC-M2, has been installed on the outcrop of mudstone for comparison purpose.

iii) *Site description*: In the Kanto Plain where overall array is considered, the suitable free rock fields for the sub-arrays are found only at the outer edge of the Plain. At CHS station, the geological period is the Mesozoic in Cretaceous which is the oldest of four sites, and geology is sandstone with shale. At other three stations, their geological period is the Miocene in Tertiary respectively, and the geology is mostly mudstone. Geological characteristics at each site are summarized in Table 1.

At each site velocity logging was carried out with the boreholes which was dug exclusively for this purpose so that accurate data on the P and S wave velocities, Vp and Vs, could be obtained down to the depth at least 100 m. Vs in the rock was the highest at CHS station giving the figure of 1.4 km/sec and the lowest at SZJ station with the figure of 0.7 km/sec.

3. OBSERVATION SCHEME

The main purpose of the present existing strong motion seismographs system is generally focused on recording the major part of acceleration time history during strong earthquakes at specific sites. These records, however, are limited in their utilities as they are recorded independently, so that the spatial propagation of earthquake ground motion is hard to analyze using these data. On the contrary, the observation scheme of the project described herein is prepared to provide the essential data with three-dimensional spatial time history of ground motion. Careful considerations were payed so that accurate absolute time code as well as the initial shock of P wave could be recorded.

i) *Operating system*: Four local stations were located at HMY, SZJ, CHS and TTY sites afore-mentioned. Control and monitoring center (CMC) to operate these local stations was established in the laboratory of the Kajima Institute of Construction Technology in Chofu City, suburb of Tokyo. This CMC and the local stations are connected by public telephone lines, thus enabling a check of the functions of each instrumentation system of the stations, and to transmit the data of the records to CMC without site visits. Fast data collection and automatic processing were established by this adequate stable performance of the system. Fig. 2 shows the rough schematic block diagram.

ii) *Instrumentations*: The specifications of seismic sensors and observation equipments are shown in Table 2. The sensor unit at each subarray is composed of three components of EW, NS and UD. Digitized data of about five seconds are always stored in the delaying circuit. Should an event occur, and as soon as the ground motion should exceed a pre-set level in the selected signal channels, the recording system is triggered to start recording the stored data in the delaying circuit into the recording devices, together with time code and AGC signal. AGC has a range down to 1/10, so even the very intensive ground motion can be received.

Seismic wave informations from sensors are recorded by the analog data recorder (ADR) and the digital cassette recorder (DCR). Although the capacity of the latter recorder is limited to record only four earthquakes, the data in DCR can be transmitted to CMC in accordance with a call from CMC through the pulse code modulation (PCM) process. Even if the telephone lines are broken during strong earthquake and the transmission of data by telephone lines should be interrupted, the ADR will continue to record the seismic events due to aftershocks as much as required. For this reason, the dual application of data recorder, ADR or DCR, is used in parallel in this system.

4. RECORDED EARTHQUAKES

i) *Epicenters of recorded earthquakes*: After precise adjustment and preoperational observations during six months from December, 1978, the formal operation was started in June, 1979. About 140 earthquakes were recorded in eleven months time. Most of recorded acceleration levels were very small, so only five earthquakes were recorded simultaneously at HMY, SZJ and CHS. Epicenters of these five earthquakes are shown in Fig. 3 by solid circles. In addition, those simultaneously recorded at two local stations are shown by open circles.

ii) *Example of recorded earthquakes*: An example is reproduced in Fig. 4, represented by an earthquake of May 5, 1979 having the magnitude 4.7 by Richter Scale and located very close to HMY station giving the epicentral distance of only 35 km at depth of 20 km. The maximum acceleration of upper portion in the rock layer at HMY station was about 10 gal or more. Two other stations also recorded this shock giving definite time delay of about 20 and 30 seconds at respective station, corresponding to the differences in their propagation lengths. As can be seen in Fig. 4, the beginning of the initial P wave motions are also clearly identified.

Although the Vs value at HMY station is less than that of CHS station, because of the very short epicentral distance, high frequency components are predominant in the record at HMY station. This fact is also demonstrated by the pseudo velocity spectra in Fig. 5. Records at CHS and SZJ stations have the components of longer period than HMY station which would be caused by the longer epicentral distances of these stations.

At CHS station, with regard to the earthquake of Oct. 13, 1979, the velocity record and acceleration record were obtained. The calculated velocity record, by means of the digital integration of the observed acceleration record, was compared with the observed velocity wave forms. In the course of the integration calculation by means of the Cal-Tec's method, filtering was performed by three cut-off frequencies (COF), [illegible], 0.11 and 0.21 Hz. The result is reproduced in Fig. 6. Better agreement is seen between the calculated and observed velocity wave forms for the case when the COF is somewhat higher. In the case of the COF of 0.07 Hz, long period component seems to remain in the filtered wave form as can be seen in the top line in Fig. 6.

iii) *Availability of recorded data*: These data produced by above-mentioned processes are stored in magnetic tape and/or disc in digital format for computer use, so that it is possible for researchers of different organizations to carry out effective analysis on any subject related to this study project.

iv) *Anticipated results:* Gradual accumulation of these data in future will offer the authors the general characteristic of earthquake ground motion in upper portion of rock, and the informations for clarification of wave propagation and of source mechanism and etc.. These results should bring a more qualified resolution of earthquake mechanism through ground motion record analyses and hopefully a more idealistic methodology of the aseismic design through the elucidation of the characteristics of the strong ground motions.

5. CONCLUDING REMARKS

In view of the urgent necessity for establishing overall array system equipped with sub-arrays in Japan a special committee for this project was set up in December 1977 by all persons concerned in the field of earthquake strong motion observations. This project is jointly founded by six electric power companies. For the purpose of establishing basic policies of this project and giving the most effective instructions in the execution thereto, a steering committee was formed as the responsible body for this project. In addition to the present authors, these committee members are:

T. Hisada (Kajima Inst. of Const. Tech.), Y. Osawa (Earthquake Research Inst., Univ. of Tokyo), E. Shima (E.R.I.), M. Watabe (Building Research Inst.), and others.

Also, a working group was formed to support the committee with following members:

Y. Kitagawa (B.R.I.), K. Kudo (E.R.I.), T. Mochizuki (Tokyo Metropolitan Univ.), S. Nagahashi (Nagasaki Inst. of Applied Science), and others.

Site arrangements were started in March 1978, and completed in August 1978 due to the kind cooperation of land owners at respective sites. The manufacturing of instruments was started in March 1978. After the six months test observation, the regular seismic observations were started in Dec. 1978.

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3) Trifunac, M.D., 1970, Low Frequency Digitization Errors and a New Method for Zero Baseline Correction of Strong-Motion Accelerograms, Earthquake Eng. Res. Lab. EERL 70-07, C.I.T.

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Table - 1. GEOLOGICAL CHARACTERISTICS

	Higashi-Matsuyama (HMY)	Shuzenji (SZJ)	Choshi (CHS)	Tateyama (TTY)
topography	gentle hill	mountain district	level land	gentle hill
elevation(m)	40-60	130-260	approx. 25	150-170
geology	mudstone Tokigawa form. Miocene Tertiary	tuff Yugashima form. Miocene Tertiary	sandstone shale Choshi group Cretaceous Mesozoic	sandstone mudstone Tikura form. Miocene Tertiary
Vs (km/s)	0.7-0.8	0.65-0.75	1.4	0.6-0.7 (presumption)
thickness of unconsolidated bed(m)	32-74	14-45	4.6	10

Table - 2. SPECIFICATIONS OF OBSERVATION SYSTEM

instruments	specifications
sensor	accelerometer ;force balance type, f=450 Hz, h=0.7 velocity meter ;high-damping type, f=1.6-1.2 Hz, h=0.7 displacement meter;PELS* type, T=10-6 sec, h=0.64
signal conditioner	acc; 0.1-1000 gal, vel; 0.01-100 kine, displ; 0.01-30mm
delaying device	A/D converter ; 12 bits 100 Hz sampling delaying time ; 10.24 sec or 5.12 sec selectable
trigger, AGC	starter ; 0.1-30 gal selectable, AGC ; x1/3, x1/10
time code generator	clock ; x'tal clock+auto-calibrator by radio time signal time code ; slow code 30 sec frame, BCD** code output
analog data recorder	FM recording, 14 channels
digital recorder	3M-type, 4 trucks, cassette MT
telemetering	public telephone line, 1200 bit/sec. PCM
power supply	surge absorbed AC line with battery of 6 hrs capacity
SMAC-M2	500 gal max., 5 gal start, analog FM cassette recorder

*: Portable Easy-Operation Long-Period Seismometer (ERI, Univ. of Tokyo)
**: Binary Code Decimal

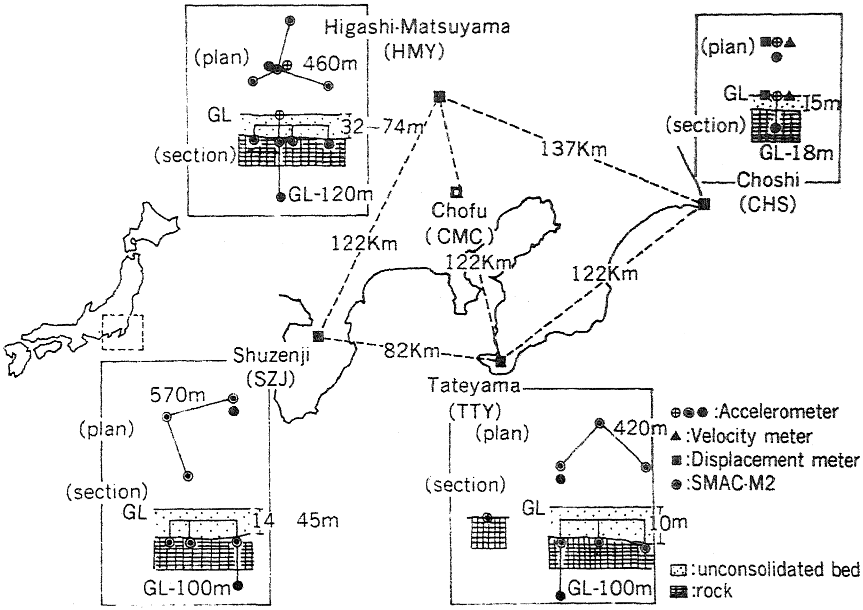

Fig. 1 overall array observation network and detail of sub-arrays

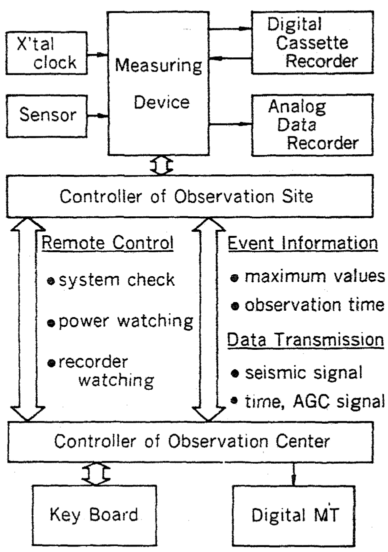

Fig. 2 schematic block diagram

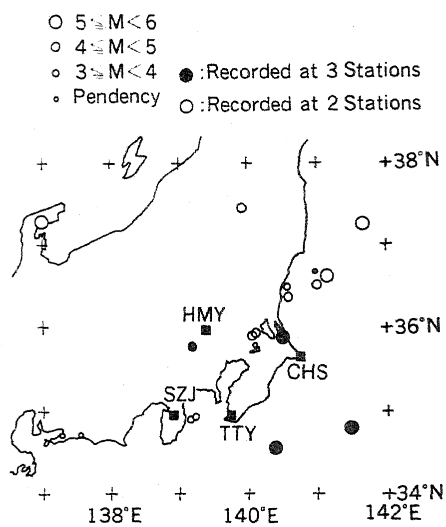

Fig. 3 ditribution of epicenters

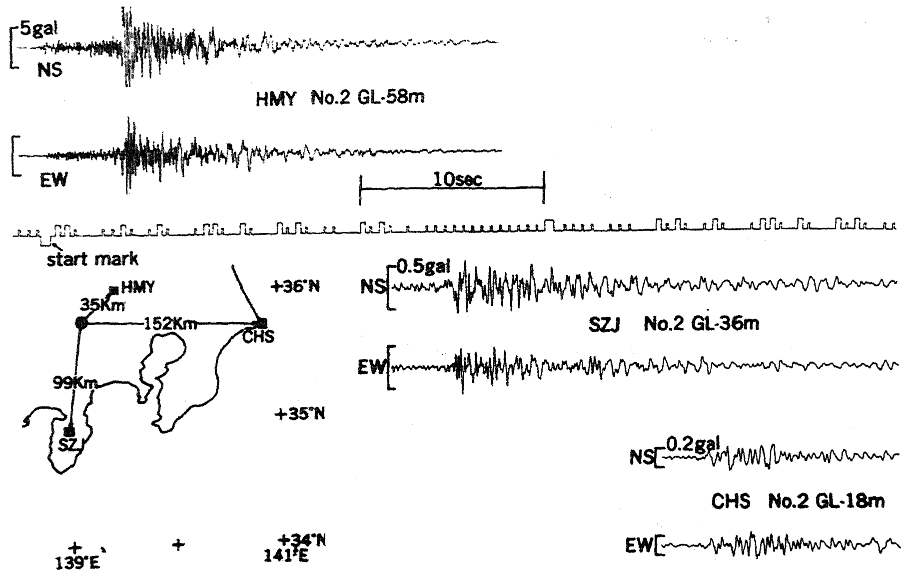

Fig. 4 simultaneous record accelerograms on May 5, 1979

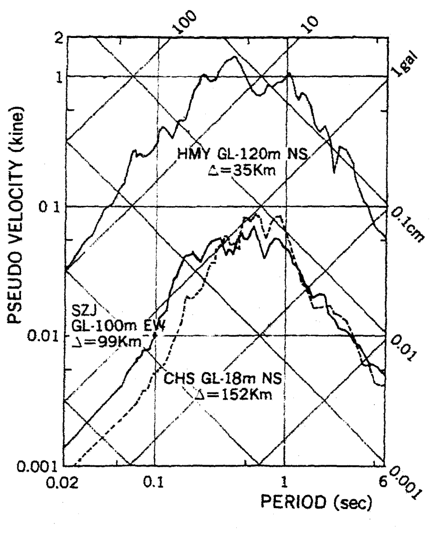

Fig. 5 pseudo velocity spectra on May 5, 1979

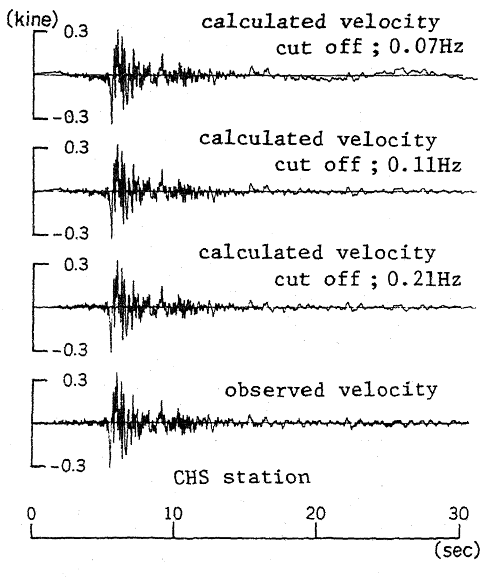

Fig. 6 comparison between calculated velocity and observed velocity