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A NEWLY DEVELOPED STRONG MOTION SEISMOGRAPH GIVING HIGH-FIDELITY SEISMIC DATA WITH OPERATIONS COMPLETELY UNDER THE COMMAND OF THE CENTER STATION

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SUMMARY

Recently there came out strong request from the side of earthquake engineers, to provide much more improved and precise informations on the characteristic nature of the input seismic design forces. In order to respond for these high-level request, we constructed a new type strong motion seismograph, named "Omega System". Analyzing and examining in detail the strong motion records obtained by this equipment, it was confirmed that Omega System meets all these severe requirements. Omega System is not only providing the highly qualified records of strong ground motion, but also is providing the operation as the most intelligent type strong motion recording system.

1. INTRODUCTION

The first strong motion seismograph was designed and constructed in 1932 under the leadership of USC&GS with the close corporation of related institutions and organizations. In Japan, Strong Motion Accelerometer Committee was established in 1951 headed by Kiyoshi Muto and the first SMAC came out in 1953 (Ref.1).

In these early stage, strong motion seismographs were all employed the analogue type recording system, and the main interest to utilize the observed records of strong ground motion was focused on the maximum peak acceleration that appeared in the records (Ref. 2).

Soon after this, there has been developed a more advanced technique of analyzing the strong motion records by G.W.Housner (Ref. 3) and others. Along with the development of the electronic computer machine, the technique to calculate the dynamic response of a simple oscillator having a single degree of freedom subjected to strong ground motion has made a great progress. This new technique opened a door to extend a extensive and high level researches to enable the construction of high-rise buildings withstanding the attack of the large destructive earthquake that might be taken place in the life time of these tall buildings.

The researches in this field have made a wonderful development within a very short period, and as a result of which the anti-seismic designing technique to be applied to these large structures and high-rise buildings has become to request much more precise and detailed informations on the strong ground motions.

About this period, along with the progress in the electronic technology,

seismological recording techniques also made a revolutional advancement. Old type mechanical recording strong motion seismographs were superseded by the electromagnetic seismograph. Furthermore, by use of the digital recording system the quality of the recorded data was improved greatly, and transmission of the recorded data to the distant center station was made practicable quite easily, without receiving any distortion. In addition, control of the site station from the distant center also became practicable. Finally, the introduction of IC card not only made it possible to carry out the troubleless recording, but also made it is easy to edit and reproduce the recorded data. A new type strong motion seismograph should be constructed using all these high-level modern technology. In such a case, the new seismograph will provide much advanced high quality data, so that great development is expected in the study of strong motion seismology.

2. NECESSITY OF NEW STRONG MOTION SEISMOGRAPH

In accordance with the rapid progress in the designing methodology of anti-seismic construction to be applied to the very important buildings and/or structures, the construction engineers have become to raise a request to provide much more reliable and trustable informations on the characteristics of the ground motions to be used as the design input earthquake force in case of the large destructive earthquakes.

The strong motion data that have been registered by the existing strong motion seismographs have proved too poor to stand for the advanced and precise requirements of earthquake engineers for deriving the input design earthquake force. Therefore, in order to respond all these very high-level requirements great many good efforts have been extended by many people concerned to work out completely new type strong motion seismograph. The main specifications required for the highly qualified strong motion seismograph are summarized as follows: (1) the new type strong motion seismograph should cover the whole frequency range that is needed, (2) it should have an adequately wide dynamic range, (3) it should have a very high signal-to-noise ratio, so that accurate and high-fidelity strong ground motions can be recorded, (4) vital units for giving basic functions of the seismograph should possess high-fidelity, (5) necessary informations of the recorded strong ground motions could be transmitted to the center station accurately and without delay, and (6) it should be equipped with devices for ensuring the troubleless maintenance of the total observation system.

The construction of a strong motion seismograph that satisfies all these specifications mentioned above is a matter of great difficult both in its high-level technology required for the construction and in its price to be supplied in the market. From the engineering point of view the latter item is also quite an important one. Overcoming all these difficulties, the coming out of a new type of strong motion seismograph is longed for deadly (Ref. 4).

3. THE CHARACTERISTICS OF NEWLY DEVELOPED OMEGA SYSTEM

In order to respond for these high-level requirements a new type strong motion seismograph, named "Omega System", was constructed. The outstanding characteristics of this strong motion seismograph are represented in the point that Omega System has been developed as the "intelligent type system". Heretofore existed strong motion seismographs were designed and constructed only to describe the ground acceleration or sometimes ground velocity, while making a striking contrast to these old type strong motion seismographs, Omega System was designed and constructed to comprise all such functions as the ability to make self-diagnosis to keep the scheduled operation of the system, maintaining the normal operation of the system, storing the recorded data, analyzing and displaying the observed ground motion data, and in some case providing prompt informations on

the expected local earthquake damage. In short, Omega System is equipped with all facilities to work as a total system. In this meaning Omega System is worthy to be called the most intelligent system in the observation of the strong ground motions. General idea of the construction of Omega System is shown in Fig.1.

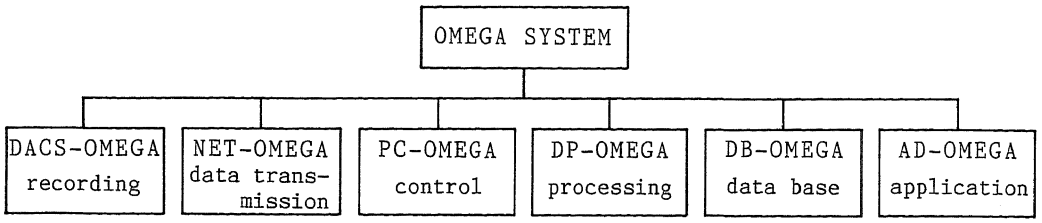


Fig. 1. System configuration of newly developed strong motion seismograph, "Omega System".

In Fig.1, DACS-Omega is representing a recording unit of Omega System, and is in charge of the fundamental importance of Omega System. Main functions of DACS-Omega are;

1) Frequency range As to the sampling frequency to be fixed, 100, 200, 500 and 1000Hz are available. Available frequencies are fixed in the ranges of 0.05 (or DC) to the cut-off frequency of the alias filter which is automatically fixed to one fourth of the fixed sampling frequency.
2) Dynamic range Dynamic range of DACS-Omega equipped with 16 bits A/D converter is as large as 90dB. Through introducing the 12 bits A/D converter furnished with the floating point amplifier, more larger dynamic range of 114dB is achieved. By the work of the floating point amplifier, even the small input signal is automatically adjusted to optimum amplitude that can bear the enough resolution of 12 bits A/D converter.
3) System noise (S/N ratio) For the maximum input voltage of 5 volts, the system noise is suppressed as small as 0.25 micro volt for 16 bits A/D converter and 10 micro volt in case of using the floating point amplifier. S/N ratio of Omega System has improved so much that system noise does not cause any ill effect in the subsequent data processing.
4) Control through RS-232C All the control of DACS-Omega are made through RS-232C transmission system. The operation of DACS-Omega at the observation site is performed with hand-held computer attached to DACS-Omega, and the operation can be also performed from the center station distant from the observation site by the use of personal computer through public telephone line.
5) Recording medium DACS-Omega employed IC card as recording medium. The introduction of IC card made DACS-Omega free from mechanical troubles which have been easily taking place from time to time in case of the advanced type of the strong motion seismograph using magnetic tapes. Recording capacity can be increased as high as 4 Mbytes.
6) Self-diagnosis capability DACS-Omega is provided with a self-diagnosis capability to check the whole parts including the sensors. The result of diagnosis is known on the display of hand-held computer or personal computer through RS-232C. This capability ensures stable operation of the system.
7) Electric power consumption Even where the commercial electric power is not available, as DACS-Omega is designed to consume as low power as possible, the observation is able to be continued for three to five days only using the dry cell battery assembly.
8) Device for time correction DACS-Omega is equipped with the highly accurate built-in time calibrator. Correction of the clock is made by using the broadcasted standard time wave of JJY, NHK or NTT with the accuracy of 1 milli second.

In order to ensure the complete operation of Omega System as a total system shown in Fig.1, it is vitaly important to enforce the software assembly, especially the repletion of the communication function in the system stands out the indispensable matter. By devoting great deal of effort to the repletion of the software, as will be explained later, not only Omega System is able to work as a single observation station, but also can form a large array system or seismic observation network by combining some units in Fig.1. In addition, Omega System is provided with the following remarkable functions.

1) By means of the operation of hand-held computer or personal computer, the elements of each record such as triggering time, maximum amplitude, record length, etc., that are compiled in IC card can be easily made visible, while, in case of the currently existing strong motion seismographs, these elements could be made known only through playback operation.

2) As IC card is used as recording medium, the editing of the recorded events is made quite easily, which follows that unnecessary data in IC card can be erased away easily so that the memory capacity in IC card can be used most effectively.

3) Any seismic observation parameter such as amplifier gain, delay time, record length, trigger level, etc., can be controled easily even from the distant place. This capability proves the outstanding advantage to operate Omega System in the actual seismic observation.

4) Input signal, and/or waveform of the recorded event can be made visible on the display of hand-held computer or personal computer, so, it is not necessary to equip with such reproducing device as pen-recorder.

4. EXAMPLES OF SEISMIC OBSERVATIONS USING OMEGA SYSTEM

As mentioned above, Omega System not only can work as a single observation station but also can form a large array or network. Typical two examples of seismic observations using Omega System are described here. The locations of these two observation areas are shown in Fig.2.

1) Strong motion observation in Tomioka, Fukushima Prefecture

After the first Omega System came out in the early period of 1987, the strong motion observation was started in Tomioka from August, 1987 in order to confirm the availability in a practical utility of the system. Tomioka was selected as a test field because of the reason that the occurrence of an earthquake swarm in the area off Fukushima Prefecture was observed since the beginning of February, 1987. Fig.3 represents schematic diagram of the system. In this system, NET-omega and PC-omega have been used most effectively in practising remote control from Tokyo center station and transmission of the recorded data to the center station through public telephone line. The observed seismogram of the earthquake of magnitude 5.8 having the focus in this swarm region is shown in Fig.4.

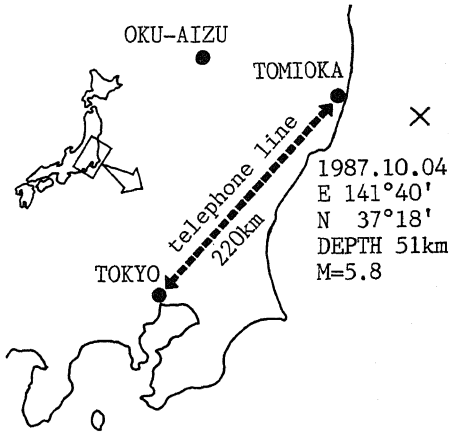


Fig. 2. Locations of Tomioka strong motion observation site and Oku-Aizu micro-earthquake observation network.
X : Epicenter of the Oct. 4, 1987 Earthquake (M=5.8) observed at Tomioka.

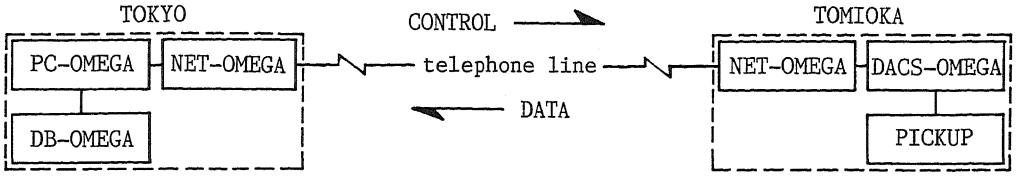
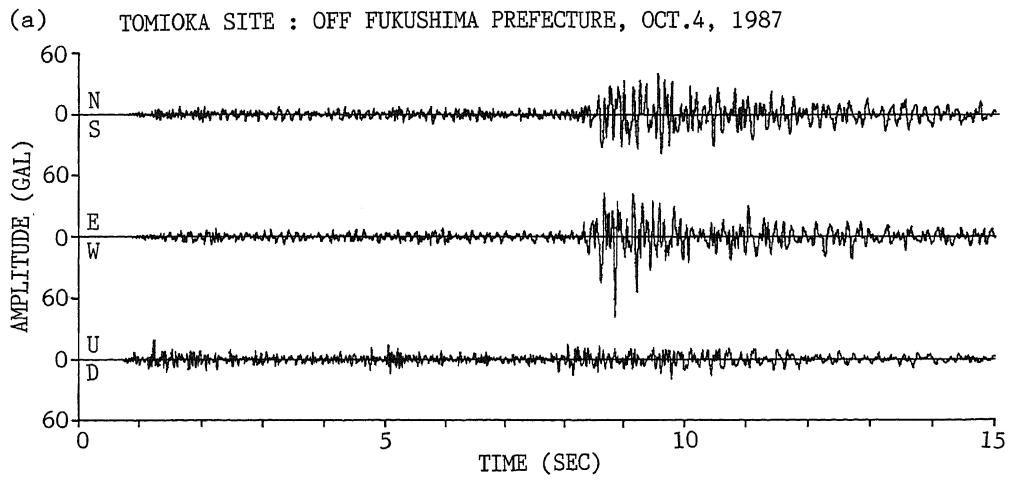


Fig. 3. Schematic diagram of the strong motion observation system at Tomioka. Control from Tokyo and data transmission to Tokyo are carried out through public telephone line.



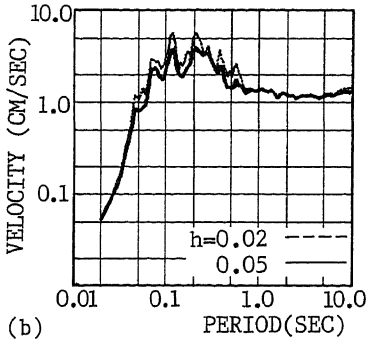


Fig. 4. Strong motion seismogram of the Oct. 4, 1987 Earthquake (M=5.8) at Tomioka.

(a) Three component accelerograms.
(b) Velocity response spectra in EW component.

2) Microearthquake observation in Oku-Aizu geothermal area, Fukushima Prefecture

Having the advantage of improved S/N ratio, Omega System is applicable to microearthquake observation. The operation of the microearthquake observation in this area has been continued since August, 1987 by Okuaizu Geothermal Co., Ltd.. As shown in Fig.5, four DACS-Omegas are distributed in this area taking suitable distance each other to form a microearthquake observation network. Each DACS-Omega is individually linked to PC-Omega in the center station located at the center of this observation net by NET-omega. Remote control from the center station and data transmission to the center are carried out through leased telephone line. At the center station automatic phase picking of the seismograms, calculation for determining the focus location, origin time and magnitude of the event and display of the epicenter location are carried out by DP-Omega assembled into this observation system. Fig.6 shows typical example of recorded event.

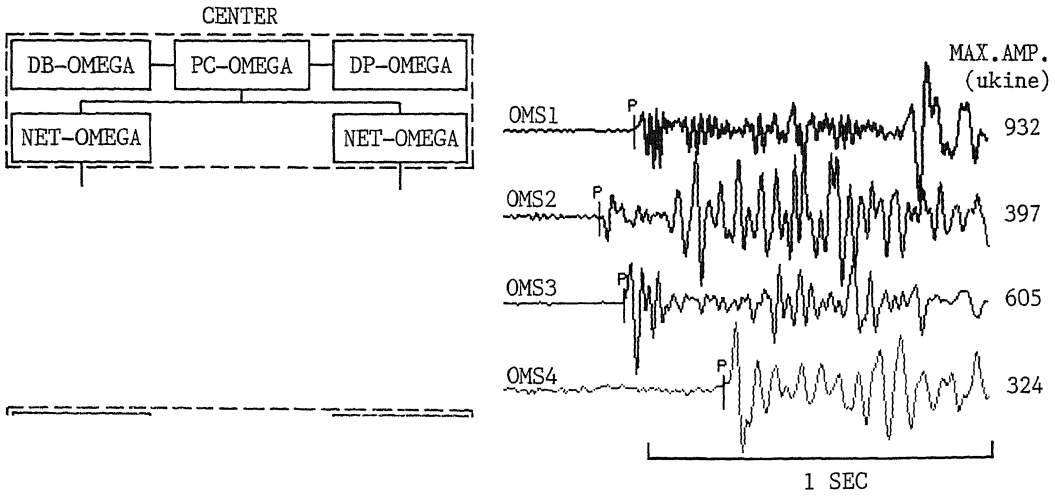


Fig. 6. Example of waveforms at Oku-Aizu microearthquake observation network. P arrivals picked automatically are indicated in the figure.

CONCLUDING REMARKS

The capability of this new strong motion seismograph, Omega System, meets all requirements of the advanced technology of earthquake engineering. Omega System is not only providing the high quality records of the strong ground motions, but also carry out the most stable operation of the system as a whole at all time under the complete command from the center station very distant from the observation site. Great many excellent characteristics of Omega System including the capability of communication, control and data management was attained by the repletion use of the software technique. In particular, the enforcement in the software technique on communication and control has made it possible for Omega System to be used either as a single observation station or as a group of observation stations to form a large observation network system or a seismic array observation system. In this way, Omega System is constructed to work as a complete total system from the data acquisition to the data processing and analysis. In this meaning, Omega System which is now reporting is well worthy to be called the most intelligent seismic observation system.

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