Strong–Motion Seismograph Model 83

for the Japan Meteorological Agency Network

by

Seismology and Volcanology Research Division, M. R. I.

Abstract

An earthquake of Richter magnitude scale 5.6, subsequently called the Parkfield Earthquake, occurred along the San Andreas fault on June 27, 1966 near Cholame, California, U. S. A. The accelerographs of the strong-motion instrument array across the fault were activated by the direct shock. Among them, the horizontal component perpendicular to the strike of the fault reached 50 percent of gravity at the station only 80 meters apart from the surface trace of the fault. The accelerogram was integrated numerically. The displacement wave form is most impressive, because it shows a single pulse of 20 cm in amplitude and a duration of 2 seconds. This wave form afforded a capital opportunity for studying the focal process as described in the following.

Aki and Haskell proposed independently a moving dislocation model to interpret this impulsive displacement wave form; that is, a right lateral dislocation started from one end of the fault zone (vertical fault, 3 km deep and 37 km wide) to the other end, and was propagated horizontally with a speed of 2.2km/s; the final dislocation reached 60 – 90cm, and the rise time was 0.3 second. Excellent agreement was obtained between their synthetic seismograms based on the model and the integrated displacement wave form, which means that the proposed model is acceptable as an approximation of the first order. Since then, the study of the focal process has been developed by many seismologists. Near-field seismograms are hardly distorted by the effect of unknown underground paths, and are thus effective in the study of the focal process as described above. Here lies the significance of strong-motion observation in seismology.

The Japan Meteorological Agency (JMA) has 114 strong-motion observation stations all over the Japan Islands. The current seismograph is a purely mechanical one designed in the early 1950's. The main use of the seismograph is for the circum-Pacific tsunami warning service for which the JMA is responsible. Its natural period and damping ratio are 6 seconds and 0.5 of critical, respectively, and the magnification is 1 (amplitude range 3 cm) with chart speed 3 cm/min. Although this strong-motion seismograph has also been utilized in the above-mentioned focal process study as well as the tsunami warning service,

the development of the study has changed the situation. That is, information on longer-period wave forms as well as larger amplitude ranges has been required in order to obtain the perfect model of a fault.

A really strong-motion record near the fault zone has scarcely been obtained by the current strong-motion seismograph, because it cannot stand against the JMA's seismic intensity scale 4, 5 or larger. The Geodesic Council of the Ministry of Education memorialized the Government that the JMA, which is responsible for observation of large-, middle- and small-scale earthquakes, should develop and deploy high-performance strong-motion seismographs in order to record perfectly the strong seismic motion, as the fourth Five-Year Plan of the National Program of Earthquake Prediction Research in Japan (1979-83).

The strong-motion seismograph Model 83 described in this paper is newly designed to meet this requirement. The seismograph must also meet the requirement both of the tsunami warning service and of the earthquake engineering as discussed in the International Workshop on Strong-Motion Instument Arrays on May 1978 at Hawaii. The generation of tsunami is closely correlated to the long-period seismic wave. Longer-period information through this new seismograph will be very useful for the service.

Three different kinds of transducers were manufactured and tested as to their performance. Of the three, the servo-type accelerometer was found to be the most effective. It covers a large dynamic range from 0.2mGal to 2kGal and a wide frequency band from DC to more than 100 Hz. It has been said that the velocity spectra for strong seismic motion are approximately flat and that the maximum velocity is less than 100 $cm^{o\text{-}p}/s$. The output from the accelerograph is integrated in the frequency band higher than 0.02Hz to obtain a long-period velocity-proportional signal. The signal is digitized by a sampling frequency 60 Hz and a dynamic range 12 bit. As the maximum amplitude has been set to 100 $cm^{o\text{-}p}/s$, one digit of the digital wave form data results in 0.049 $cm^{p\text{-}p}/s$. After a delay of ten seconds, the data are written on digital cassette magnetic tape (CMT) of the Japanese Industrial Standard (JIS). To process the wave form data, a commercial micro-computer system has been prepared, but the general-purpose mini-computer system is also available without any particular interface. Some fundamental programs to process the data have been coded, which include integration, time domain filtering, spectral analysis and so on. Once the magnetic tape is started by a trigger, the wave form data for 8 minutes are written until the end-of-tape mark is detected. The next trigger will be accepted by the other CMT unit. As the condition of design of this seismograph is that the staff is staying at any observation station at all times to do the tsunami warning service, it could be expected that the CMT is exchanged before the third trigger. For the purpose of quick tsunami warning service, an analog recorder of the pen-oscillograph is also prepared. The maximum composed horizontal amplitude is displayed digitally up to one meter even if the amplitude grows off scale.

All the sub-systems of the seismograph were examined as to their quakeproof and temperature-proof quality. Fears were entertained to the CMT unit. However, examination has shown that even the unit can operate at circumstances up to $2\mathrm{kGal}^{p\text{-}p}$ and down to $-15°$ C. The other sub-systems including the pen-oscillograph are also proved to operate at severe circumstances.

The experimental observation was performed at Tsukuba, 50 km north of Tokyo, from April 1981 to June 1982, and at Sendai, northern Honshu, from July 1982. Several strong seismic motions were observed. They include the two earthquakes on September 24 and 25, 1981, in which the JMA intensity scale 4s were observed.

The seismograph has been named Model 83, and it is scheduled to be installed at JMA seismic stations in future. Then, it will contribute to the focal process study, tsunami warning service and earthquake engineering.

This study has been performed by the following staff members of the Seismology and Volcanology Research Division of the Meteorological Research Institute : Nozomu Den, Hideo Watanabe, Tatsuto Iinuma, Hideteru Matumoto, and Michio Takahashi.