STANDARD DATA PROCESSING OF STRONG MOTION ACCELEROGRAMS

by

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SYNOPSIS

A collection of some 500 strong motion accelerograms now exists for United States earthquakes, about one-half of which were obtained during the 1971 San Fernando earthquake. These records have all been digitized by a uniform technique, and the digitized data are available in the form of printouts, punched card decks, and digital magnetic tapes. Corrected digitized data involving high frequency transducer corrections and long-period baseline adjustments are also available, as are calculated velocity and displacement curves, response spectrum curves and Fourier spectra. Information on how to obtain the available results is given.

INTRODUCTION

The basic instrument for strong motion seismology is the strong motion accelerograph which records three components of ground acceleration versus time. As presently designed, these instruments record accelerations up to 1 g with a resolution of the order of 0.001 g over a frequency range of 0.06 Hz to 25 Hz. The devices are triggered by the earthquake itself, using a vertical electrodynamic starter having a flat acceleration response over 1 to 10 Hz which can be set to various triggering levels of the order of 0.005 g. Accelerographs of this kind were first installed in California in 1933, and the Long Beach earthquake of that year provided the first strong motion accelerograms. Under the direction of the Seismological Field Survey, now of the United States Geological Survey, the U. S. network steadily developed and at the present time consists of approximately 1000 instruments. This development was paralleled by a similar network in Japan, which now also has approximately 1000 recording accelerographs. Smaller numbers have been introduced into other parts of the world, the present distribution being roughly Italy 120, Yugoslavia 100, New Zealand 80, Mexico 40, Canada 30, with an additional 20 countries having one or several accelerographs.

DATA PROCESSING

The purposes to which the information in the accelerograms are to be put establish the basic data handling procedures. These procedures include: (a) approximate scaling of peak acceleration, duration of strong ground motion, and predominant periods; (b) integration to determine

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ground velocities and displacements; (c) frequency analysis by means of Fourier spectra, response spectra, autocorrelation curves, power spectral density, etc.; (d) use as input functions for structural response calculations. For (a), only a hand scaling of the record is required, with no special correction techniques. For (b), (c) and (d), an accurate digitization of the analog traces to preserve information over the maximum frequency range is required. In view of the accuracy with which digital computers can reproduce results, it is highly advantageous if all investigators can begin their studies with the same digitized data. Differences in final results can then be confidently attributed to different computational techniques or to different mathematical models. This has been the motivation for the program of standard digitization and data processing of strong motion accelerograms which was started some five years ago at the Earthquake Engineering Research Laboratory of the California Institute of Technology under the sponsorship of the National Science Foundation.

The first stage in this program was the development of standardized digitization processes which would produce digitized data on a routine basis at a known level of accuracy. This involved for a particular semi-automatic digitizing system (a) training and cross-checking of machine operators to establish levels of personal error in setting a cross-hair on the accelerogram trace; (b) ascertaining various sources of error in the digitization equipment itself, and the development of suitable corrections; and (c) the evolution of standardized formats for the presentation of the digitized data in the form of digital printouts, punched card decks, and digital magnetic tapes. The aim of this first stage is to present the basic information in the accelerogram trace in as direct a form as possible with a minimum of interpretation or correction (1, 2, 6).

The second stage of the program introduces certain correction techniques with the object of recovering information at a known level of accuracy over the widest possible frequency band permitted by the over-all instrumentation system. This involves: (a) high frequency digital filtering to reduce digitization noise [3, 5], (b) transducer corrections to account for drop-off of output at high frequencies [3, 5], and (c) long-period baseline corrections to permit accurate integrations for velocity and displacement [4]. These corrections produce a set of adjusted accelerograms which will preserve the maximum possible information set by transducer characteristics, trace quality, and digitization limitations. At the long period end, acceleration levels fall below background digitization noise.

A third stage in the processing involves development of computer programs which will calculate velocities and displacements and various frequency spectra and plot the results in a standard form ready for reproduction and publication [7, 8, 9].

Comprehensive experimental and analytical studies have established that all elements of the strong-motion accelerograph and data processing system have achieved a reasonable compatibility as far as accuracy level and frequency response are concerned, with no single link in the chain playing a significant limiting role. The quality of the analog trace, the personal errors of hand-setting a cross-hair on the trace, the basic frequency limits of the instrument transducer, and the computational techniques developed for a reasonable computing cost all seem to reach various limiting conditions at about the current level of development. Major improvements in accuracy, dynamic range, or frequency response will require simultaneous major developments in several elements of the system. The data processing itself should not be a limiting feature of the instrumentation system. With modern digital image processing based on high resolution cathode-ray scanning, completely automatic digitization of analog traces can be carried out at a resolution higher than existing semi-automatic systems involving hand-setting of a cross-hair on a trace. Improvements must come first in basic transducer design for high frequency response and freedom from higher mode distortions and second in the basic recording medium itself, be it film or magnetic tape.

STANDARDIZED DATA

The present (1973) status of the standard data processing program is as follows: (1) The digitization of the backlog of 500 U. S. accelerograms has been completed on a uniform basis of accuracy. "Uncorrected" accelerograms in this standard digitized form are available as punched card decks or as computer-compatible digital magnetic tape. About one-half of the records are also available as published reports which include complete printouts of the digitized data plus computer plotted accelerograms (6). The remainder of the reports are being issued regularly and the whole series should be complete in approximately one year. (2) The "corrected" accelerogram data are available in the form of punched card decks or digital magnetic tapes for approximately one-half of the records. Digital printouts are included in a series of reports of which about one-third have already been issued (7). These reports include as well computer plots of the velocity and displacement curves. (3) A third volume series contains calculated response spectrum curves in standard format for all ground accelerograms, along with printout of coordinates (8). About one-quarter of the records have been issued in this form, and the remainder will appear over the next two years. (4) A fourth volume series contains plotted Fourier spectra in two standard formats for all accelerograms, including building response records (9). For multiple accelerograph installations in buildings, transfer function plots are included. The first part A of each of the above four volumes contains detailed background information on the techniques and procedures used. Examples of the standard plotted curves may be seen in reference (1).

The above reports, cards, and tapes can be obtained from the following sources: (1) National Information Service for Earthquake Engineering, Earthquake Engineering Research Laboratory, California Institute of Technology, Pasadena, California 91109 - Reports, card decks, and magnetic tapes at nominal costs for postage and handling. (2) National Geophysical Data Center, National Oceanic and Atmospheric Center, D6, Environmental Data Service, NOAA, 6001 Executive Boulevard, Rockville, Maryland 20852 - Copies of full-scale accelerograms, standard digitized data. (3) National Technical Information Service,

U. S. Department of Commerce, Springfield, Virginia 22151 - Copies of digitized data reports containing digital printouts and spectrum plots. (4) Seismological Field Survey, U. S. Geological Survey, 390 Main Street, Room 7067, San Francisco, California 94105 - Copies of full-scale accelerograms, punched card decks, and magnetic tapes.

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