Calculation of long-period response spectra to earthquake ground motion from seismograms of Type 513 seismographs

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Abstract

We introduce in this paper a method to calculate response spectra of earthquake ground motion from seismograms of Type 513 seismograph. The seismograms of two horizontal components of the $M_s 7.1$ earthquake, an aftershock of 1976 $M_s = 7.8$ Tangshan earthquake, recorded by type 513 seismograph in Taian station are used as an example. After curve digitization, arc shape curve correction, equal-distance interpolation and instrument response correction, the absolute acceleration response spectra, relative velocity response spectra and relative displacement response spectra of different damping ratios in the period range of $T \leq 10$ s are calculated in frequency domain.

Key words: response spectrum  long period  Type 513 seismograph

Introduction

Response spectrum theory is a fundamental one for seismic design in present stage. Because of the limitation of frequency response of the accelerographs, the studies on the characteristics of response spectra are limited in the short period range of less than 3 or 4 s. The design response spectrum given by the seismic design code of China (GBJ11-89) (Ministry of Urban and Rural Construction and Environmental Protection, People's Republic of China, 1989) is in the period range of 0 to 3 s and needs to be studied in particular if the period is exceed 3 s. This problem was not very serious before because the natural periods of most engineering structures are less than one second. However, recently more and more large-scale structures such as high rise buildings, long-span suspension bridges, large oil-storage tanks and offshore platforms whose natural periods are around 10 are built, the damages of these structures increase due to large earthquakes. For example, the damages of high rise buildings were far more serious than that of low rise buildings in Mexico City which is 390 km away from the epicenter during the 1985 Mexico earthquake ($M_s 8.1$); The 1983 Japan Sea earthquake of $M_s 7.7$ caused many large oil tanks far away from the epicenter spilled because of the liquid sloshing caused by long-period ground motion, some of them even caught fire; We were greatly impressed by the damages of viaducts in northeast San Francisco that is nearly 100 km away from the epicenter during the 1989 Loma Prieta earthquake ($M_s 7.0$). So it is very important and urgent to study the features of long-period ground motion response spectrum.

The study on the response spectrum has a two-fold significance in China. Because of the quick economy development, the long-period structures increase rapidly in China. Objectively it is an
urgent need to research the features of long-period response spectra. On the other hand, most of the strong motion records in China are the aftershock records in North China and southeastern China. Because their magnitudes are small and their amount is not sufficient, it is not enough to construct the suitable ground motion attenuation law directly based on the strong ground motion records. So one of the paths to enrich our country's ground motion data is to calculate the response spectra by using the displacement strong motion records of seismic stations.

In China, some researchers have begun to study the characteristics of long-period response spectra from accelerograms. Xie et al. (1990) have calculated the absolute acceleration response spectra, relative velocity response spectra and relative displacement response spectra in the period of 0.02 to 15 s from about 200 horizontal components of accelerograms recorded by digital accelerographs in China and Mexico and have discussed the influences of magnitude, site conditions and epicentral distance on spectra. Wang et al. (1990) have studied the seismic design response spectrum with different damping ratios from 159 accelerograms recorded in China and abroad. They have given the features of mean \( \beta \) spectrum skeleton and control parameter and analyzed the influences of different damping ratios on \( \beta \) spectrum. However, because of the lack of sufficient data, especially lack of the data of great earthquakes, the overall statistical analysis on the characteristics of long-period response spectra is still unavailable. The further studies need to be based on the accumulation of data.

Type 513 seismograph is improved from Type 51 seismograph and is equipped in more than 10 seismic stations. Some strong earthquakes are recorded by Type 513 seismographs. In this paper, the seismograms of an aftershock (Ms7.1) of 1976 Tangshan earthquake recorded by the type 513 seismograph in Taian station are used as an example, we demonstrate the method and procedure to calculate the response spectrum in detail and calculate the absolute acceleration response spectrum, relative velocity response spectrum and relative displacement response spectrum with different damping ratios.

1 Data and processing

An aftershock of Ms7.1 occurred at 18h 45min, July 28, 1976, after the Tangshan earthquake of Ms 7.8. Type 513 seismograph in Taian station recorded clearly the seismograms. Figure 3(a) is the E-W component curve of the seismograms. Taian station is located in the foot of Taishan mountain, Shandong province, China. The seismometer is placed in a vault built in granite that is 30 m below the ground surface and the disturbances are quite small. Taian station is a first class standard station of the basic seismograph network of State Seismological Bureau (Department of Scientific Programming and Earthquake Monitoring, SSB, 1987). The epicentral distance is about 390 km. Because the site is an intact granite, the response spectra calculated in this paper are thus the bedrock response spectra.

1.1 Brief introduction to the seismograph

Type 513 seismograph is used to record moderately strong earthquakes. It only has the horizontal component seismometers. The amplifying system is of mechanical displacement (Institute of Geophysics, Chinese Academy of Science, 1975). The natural period of the pendulum is adjustable in the range of 3 to 15 s. The intrinsic period \( T_1 = 5.0 \) in normal operation, the damping constant \( D_1 = 0.33 \) and the static magnification \( D_0 \) is about 50. The relative amplitude response \( U_1 \) and phase response \( \gamma_1 \) of the pendulum are (Institute of Geophysics, Chinese Academy of Science,