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International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

High Frequency Cut-Off of Observed Earthquake Spectrum and Source Parameters of Local Earthquakes in Himachal Himalaya

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Abstract: *A dataset of 20 local earthquakes (3.4≤Mw≤5.2) occurred in the Himachal Himalaya recorded by Indian nation strong motion instrumentation network have been analyzed to infer the characteristics of high frequency attenuation of observed earthquake spectrum and source parameters of earthquakes of this region. In this study Brune's earthquake source model (Brune, 1970) that yield a fall-off of 2 beyond corner frequency has been considered to estimate the source parameters namely seismic moment, source radius and stress drop of earthquakes. High frequency attenuation of earthquake source spectrum have been modelled with two high-cut fall off functions - κ factor presented by Anderson and Hough (1984) and another arbitrary high-cut filter (Boore,1983; Wen and Chen, 2012) that fits well for frequencies greater than f_{max}. The seismic moment for these earthquakes vary between $4.2x10^{12}$ Nm and $2.3x10^{15}$ Nm and their moment magnitudes ranges from 3.4 to 5.2. The source radii of these events lie in the range 226 m to 511 m. The stress drops for these earthquakes vary from 0.2 MPa to 13.3 MPa and found in agreement with the other region of Himalaya as well as for other tectonically active regions of the world. Both functions f_{max} and κ accounting this high frequency attenuation seems to represent the same phenomenon. The results obtained in this study infer that source process is the prime controlling factor for this attenuation of earthquake spectrum at high frequencies. The data used in the present study is of 20 earthquakes, which were recorded on different sites. Data sets of earthquakes having large magnitude range (3.0≤M≤8.0) and recorded on stations having different geological site conditions will obviously help this effect to confirm properly.*

Keywords: Brune source model, high-cut frequency (f_{max}), kappa (κ), strong motion, Himachal Himalaya.

1. Introduction

Engineering designs of critical structures demand knowledge of high-frequency ground motion radiating from large and strong earthquakes. The description of an earthquake spectrum plays an important role in ground-motion prediction. A suitable representation of the earthquake-induced ground acceleration, for engineering purposes, is furnished in Fourier spectral models. The shape and amplitude of the Fourier amplitude spectrum of strong ground acceleration is recognized as useful for various applications to earthquake engineering (McGuire, 1978). This acceleration spectrum also contains fundamental information about physical processes at the earthquake source and wave propagation in the crust of the earth. Yet at high frequencies, we still do not have a satisfactory model for the shape of the acceleration spectrum. According to ω^2 earthquake source model (e.g., Brune, 1970; 1971) the acceleration spectrum grows with a slope of two till corner frequency, which is related to dimension of the earthquake source (radius as considered by Brune, 1970) and beyond this corner frequency the spectrum has flat or constant shape having slope zero. Hanks (1982) observed that acceleration spectrum again decay at high frequencies and named 'f_{max}' from where spectrum shows decay.

In order to simulate strong ground motion using stochastic model Boore (1983) used a Butterworth high-cut filter that fits well for frequencies greater than f_{max} in observed acceleration spectrum as

$$\frac{1}{\sqrt{1+\left(\frac{f}{f_{max}}\right)^{N}}}$$

where N is order of filter.

Later Anderson and Hough (1984) modelled this high frequency diminution as an exponential function

$$e^{-\pi f \kappa}$$

where κ represents decay in the spectrum and interpreted that it is because of near surface crustal effects that absorb high frequencies of the spectrum.

This high frequency diminution is still a matter of active debate as to whether this high frequency diminution observed in the spectrum of an earthquake reflects the source characteristics or is on account of attenuation due to subsurface geological characteristics below the recording site (e.g., Hanks, 1982; Papageorgia and Aki, 1983a,b; Campillo, 1983; Anderson and Hough, 1984; Anderson, 1986, 1991; Faccioli, 1986; Aki, 1987; Papageorgiou, 1988; Fujiwara and Irikura, 1991; Yokoi and Irikura, 1991; Kinoshita, 1992; Morikawa and Sasatani, 2000; Tsai and Chen, 2000; Tsurugi et al., 2000, 2008; Purvance and Anderson, 2003; Kumar et al., 2012, 2013a,b,c; 2014).

In the present study, 20 local earthquakes (3.4≤Mw≤5.2) occurred in the Himachal Himalaya recorded by Indian nation strong motion instrumentation network (Kumar et al., 2012, Mittal et al., 2012) have been analyzed to infer the characteristics of high frequency attenuation of observed earthquake spectrum and source parameters of earthquakes of this region. The software EQK_SRC_PARA (Kumar et al., 2012) has been used to estimate earthquake spectral and source parameters.

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