ABSTRACT

Seismology is the evolving science of the study of the earthquakes, earth structure, and engineering assessment and mitigation of the catastrophic effects of the earthquakes. For successful assessment and mitigation of earthquake hazards, it is necessary to reliably predict the level of ground shaking which may be expected from large earthquakes. This creates a widespread need for the detailed knowledge of the earthquake source mechanisms responsible for production of seismic waves; the propagation-medium characteristics, responsible for attenuation of seismic waves; local site (near surface) conditions, accountable for the changes in the intensity of the observed earthquake damage. This thesis aims at a better understanding of the above processes, through individual studies associated to the local site effects; the spectral characteristics and source parameters of the shallow earthquakes; and attenuation characteristics of the coda wave and high frequency (> 1 Hz) body waves. The above studies are carried out in the study region of Kumaon Himalaya, which falls in the collision zone of Indian and Eurasian plates.

The dataset consists of broadband seismic data and ambient noise data, obtained from the network operated in the period April 2005- June 2008, by CSIR-N.G.R.I. The study of site effect or site response is performed using H/V spectral ratio (HVSR) method, which reveals clear frequency estimates that could reliably correlate with natural frequency or fundamental resonance frequency of the near surface structure. The amplification values discernible from H/V ratio curves (H/V ratio amplitude vs. frequency) are significant (>2) and possible cases for ground motion, but are not advocated as absolute site amplifications, in line with recommendations of several worldwide studies. In brief, the results could be quite valuable for seismic engineering studies which are used for evaluating local structural performance. The second study in the thesis is related to the earthquake source parameter and scaling study, which is accomplished using $\omega^2$ Brune source model for small earthquakes ($M \leq 5.3$). The results of this study indicate a source process of partial stress drop mechanism of small earthquakes in the backdrop of observed dominantly low static stress drop estimates (~10 bars). Furthermore, the observation of varying stress drop estimates with seismic moments indicates breakdown of constant stress drop scaling among smaller earthquakes. The estimates and scaling relations obtained in this study are useful for seismic hazard analysis. The third
study in the thesis is related to estimation and analysis of the frequency dependent attenuation characteristics of the crust in Kumaon Himalaya, using the seismic quality factor, Q of the coda waves and high frequency body waves. The seismic quality factor and the attenuation of a medium are inversely related, i.e. attenuation \( \approx (Q)^{-1} \). As Q measurements are highly sensitive to variations in rock properties or geological characteristics, we have made an attempt to estimate Q in three geologically different study regions in Kumaon Himalaya: Block 1 includes stations in parts of Lower Himalaya; Block 2 includes stations of MCT (Main Central Thrust) zone Himalaya; and Block 3 includes stations of Higher Himalaya. We undertake the different studies of the seismic quality factor Q, namely, coda Q (Q_c) and direct body wave Q for the frequency range (1-20) Hz. The single backscattering model is used for the estimation of the quality factor of seismic coda waves (Q_c). The variation of coda Q values for lapse times 20s, 30s, 40s, 50s, 60s and 80s, are studied to investigate the attenuation variation with depth. The coda normalization and Yoshimoto’s extended coda normalization methods are applied for the estimation of the quality factors of direct S-waves (Q_β) and direct P-waves (Q_α) respectively. The above different estimates of Q in the three study blocks of Kumaon Himalaya show strong frequency dependence and are expressed as power-laws \( Q = Q_0 f^n \). We find an increasing trend of estimates of Q_c with lapse times, which indicates that the upper crust is more attenuative and unstable than the deeper parts. The variation of the exponent of the frequency dependence law, n with lapse times, indicates the presence of heterogeneities in the crust beneath the study blocks, as in other active regions. Additionally, the estimates of quality factors for intrinsic attenuation (Q_i) and for scattering attenuation (Q_s), have been estimated using the Wennerberg (1993) formulation using the individual estimates of Q_c and Q_β.

For the three study blocks considered, the seismic attenuation studies reveal the following major observations: (i) Q_c is more than Q_β, which seems to adhere to the Zeng’s (1991) theory; (ii) due to the complex structure of crust in the three blocks, there is a mixed effect of the scattering attenuation and intrinsic attenuation across the transect consisting of the three blocks, for the considered frequency range (1–20 Hz); (iii) the ratio Q_β/ Q_α is not the same for the three study blocks over the whole frequency range. The studies undertaken in this thesis indicate the presence of varying levels of rock saturation, possible fluids in the crustal depths and strong lateral variations in the shallow crustal structure beneath Kumaon Himalaya.