SOURCE PARAMETERS, SCALING RELATIONS AND KAPPA (κ) MODEL FOR SMALL EARTHQUAKES IN KACHCHH AND SAURASHTRA REGIONS OF GUJARAT, INDIA

SUMMARY OF THE THESIS

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Summary

Earthquakes are among the natural disasters that may cause, suddenly and within few seconds, the severe damage to the physical systems (e.g. housing, industries, large structures, high rise buildings etc.) of the society in the affected regions. The collapse of these physical systems further causes huge loss of economy and lives as has been witnessed recently during the 2015 Nepal earthquake (M 7.8). The earthquakes are investigated to study their effects on the society and its physical structures which in turn help developing the techniques to minimize the damage and loss of life during the earthquakes. The techniques used for the evaluation of seismic hazard of a region include probabilistic as well as deterministic approach. The scaling relations based on earthquake source parameters are required in both types of approaches. The simulated strong motion time histories rich in high frequencies play a vital role in the deterministic approach of seismic hazard. The high frequency decay parameter Kappa (κ) is required for the realistic simulation of accelerograms. The present thesis has emphasized on these two important aspects of earthquakes – scaling relations based on earthquake source parameters and κ model for Kachchh and Saurashtra regions of Gujarat.

The Gujarat is the only Indian region where, in addition to Himalaya, the zone V exists as per BIS seismic zoning map of India. Zone V covers the most of Kachchh region of Gujarat. The region has witnessed major earthquakes in 1819 (Mw 7.8) and in 2001 (Mw 7.7). The aftershock activity of 2001 Bhuj earthquake occurred in Kachchh is still continuing and new regions have become active. Most of the major fault systems in Kachchh region are active and have shown seismicity in recent past and also due to 2001 Bhuj earthquake some new faults have become active. The Saurashtra region has also had appreciable seismic potential and showing increase in seismicity after 2001.

In the present thesis, the earthquake source parameters, scaling relations and κ model have been estimated for the Kachchh and Saurashtra regions of Gujarat. The earthquake source parameters and the relationships among them are useful for understanding the properties of earthquake source.

The Seismic Background Noise (SBN) analysis for five permanent Broad Band Seismic (BBS) stations namely Dwarika (DWK), Morbi (MOR), Rajkot (RAJ), Una (UNA) and Surender-Nagar (SUR) out of ten stations installed in Saurashtra region have been investigated. These five stations have been selected for
the analysis on the basis of station geology, and its geographic location and topography. The analysis has been done by analyzing the noise spectra in three different frequency bands: long period (0.01-0.1Hz), microseism (0.1-1.0Hz) and high frequency (short period) (1.0-10.0Hz). This analysis show that the station DWK (on Tertiary) is having more noise levels as compare to the other stations located on Deccan Basalt. Therefore the waveforms recorded at DWK have not been used in the present analysis.

The source parameters for the earthquakes of magnitude range 3.5 – 4.9 in Kachchh region have been estimated from the spectra of P- and S-waves separately using $\omega^2$ model. The 159 accelerograms of 34 earthquakes occurred during March 2006–April 2013 and recorded at 3–8 SMA stations have been used in the analysis. The shift in S-wave corner frequency to lower side as compared to that of P-corner frequency has been found for the analyzed events. The shift in corner frequency has been observed in a number of studies and is attributed to enrichment of P waves in high frequency compared to the S waves for the same earthquake.

The estimated stress drop values lie in the range 30 – 120 bars for most of the analyzed events in the Kachchh region. It has been found that the stress drop values do not depend on earthquake size significantly for the range $1.5 \times 10^{14}$ N-m to $1.8 \times 10^{16}$ N-m of seismic moment. The earthquakes of the Kachchh region show self-similarity. The proposed scaling relation $M_0 f_c^3 = 7.6 \times 10^{16}$ N-m/sec$^3$ for Kachchh region is found to be consistent with the similar relations for other seismically active regions of the world.

The seismic activity in Saurashtra region is confined to two sub-regions. One is in the North of Saurashtra i.e. Jamnagar region and another is in the South of Saurashtra i.e. Junagarh region. Keeping in view the distribution of seismic activity, the earthquake source parameters and scaling relations have been developed for Junagarh and Jamnagar region separately. The phenomenon of corner frequency shift has been observed, as in Kachchh region, in both the regions. Most of the earthquakes in Junagarh and Jamnagar region have stress drop in the range 0.1 – 10 bars. The earthquakes in these two regions are of low stress drop as compare to Kachchh region.
There is no significant correlation between the stress drop values and earthquake size in the range $3 \times 10^{13}$ N-m to $1 \times 10^{15}$ N-m for the earthquakes in Junagarh region while the earthquakes in Jamnagar region show increase in stress drop values with the increasing seismic moments. The scaling relation $M_0 f_c^3 = 2.19 \times 10^{15}$ Nm/sec$^3$ has been estimated for the range of seismic moment $3 \times 10^{13}$ N-m - $1 \times 10^{15}$ N-m for the Junagarh region of Saurashtra. One of the important findings of the present analysis is that there is breakdown of self-similarity of small earthquakes with moment range $6 \times 10^{12}$ N-m to $1 \times 10^{15}$ N-m in Jamnagar region of Saurashtra. This implies the difference in the ambient stress conditions in Jamnagar region as compare to the Junagarh as well as Kachchh region.

Most of the techniques used for simulation of earthquake strong ground motions for the purpose of the evaluation of seismic hazard of a region divide the fault plane of target earthquake into number of sub-faults representing the sub-events of small magnitudes. The relation between seismic moment and corner frequency developed for Kachchh and Junagarh region in this study may be utilized in estimating the size of the sub-faults representing the small magnitudes, for the range studied here, given the moment of the earthquake. Therefore this relation is useful for the hazard assessment in the regions.

The high frequency spectral amplitude decay of local earthquakes has been analyzed by estimating the parameter Kappa ($\kappa$) for Kachchh, Junagarh (Saurashtra) and Jamnagar (Saurashtra) regions of Gujarat. The average values of $\kappa$ are found to be 0.023, 0.0206 and 0.034 respectively for the Kachchh, Junagarh and Jamnagar regions which are comparable with other regions of the world. The distance dependence of $\kappa$ is found to be similar for the three regions while $\kappa_0$ ($\kappa$ at $R = 0$) differ for these regions. These are 0.0208, 0.0177 and 0.029 respectively for the Kachchh, Junagarh and Jamnagar regions. This implies the average site characteristics for these three regions.

It has been found that the $\kappa$ is not affected by the source effect in Kachchh and Junagarh region. For the two stations of Jamnagar region – SUR and MOR- the $\kappa$ values show some source effect also. The $\kappa$ values estimated here are useful for the simulation of earthquake strong ground motions in the Kachchh and Saurashtra regions and therefore important for the evaluation of seismic hazard of the regions.
It is expected that scaling relations based on earthquake parameters and $\kappa$ model for Kachchh and Saurashtra region of Gujarat will also improve our understanding about the earthquake source process in these two regions.

The thesis has been documented in the following seven chapters:

Chapter 1: Introduction
Chapter 2: Geology, Seismotectonics and Seismicity of Gujarat
Chapter 3: Seismic Background Noise Analysis of Broad Band Seismic Stations of Saurashtra Region
Chapter 4: Source Parameters and Scaling Relations for Small Earthquakes in the Kachchh Region of Gujarat
Chapter 5: Source Parameters and Scaling Relations for Small Earthquakes in the Saurashtra Region of Gujarat
Chapter 6: Kappa ($\kappa$) Model for Kachchh and Saurashtra Regions of Gujarat
Chapter 7: Discussion and Conclusions