学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　博士（工学）　氏名　Subeg Man Bijukchhen

学 位 論 文 題 名

Construction of 3-D Velocity Structure Model of the Kathmandu Basin, Nepal, based on Geological Information and Earthquake Ground Motion Records
(地質情報および地震観測記録に基づくネパール・カトマンズ盆地の 3 次元速度構造モデルの構築)

The Himalayan region experiences many seismic activities due to the collision of two continental tectonic plates. With a number of small earthquakes and occasional large earthquakes occurring at certain intervals, this region is one of the most seismically vulnerable regions of the world. Nepal, covering about 900 km of the Himalayan arc (known as the Nepal Himalaya), has suffered a number of interplate and intraplate earthquakes in the past. There are accounts of more than 20 damaging earthquakes occurring in or near the Nepal Himalaya since the thirteenth century that have left trails of damage.

The study area is Kathmandu Basin, locally referred to as the Kathmandu Valley in central Nepal. It is a tectonic basin filled with lake and river sediments and surrounded by high mountains. The deposits are estimated to be more than 600 m thick. A location in a seismically active region and the possible amplification of seismic waves due to thick sediments have made the Kathmandu Basin seismically vulnerable. It has suffered devastation due to earthquakes several times in the past resulting in huge loss of life and property as it is the largest and the most densely populated settlement of Nepal. The earthquake vulnerability of the Kathmandu Basin was apparent during the Gorkha Earthquake (Mw7.8) on April 25, 2015, when the main shock and ensuing aftershocks claimed more than 1,700 lives and nearly 13% of buildings inside the valley were completely damaged. Preparing safe and up-to-date building codes to reduce seismic risk requires a thorough study of ground motion amplification. An earthquake that seems to have no effect over hard ground can be felt as a strong tremor and might cause severe damage in areas over soft and unconsolidated sediments due to amplification of seismic waves. Past earthquakes in the Kathmandu Basin have shown significant amplification of long period waves in the sediment sites. To study the ground motion amplification of any area, a proper understanding of underground structure is very important. The present study is the construction of a 3-D underground model of the Kathmandu Basin based on geological data and earthquake records and ground motion simulation on the constructed model.

To accomplish this goal, the study fulfils the following tasks: a) to describe the geology and collect available geological and underground data of the Kathmandu Basin, b) to study the strong-motion characteristics of the Kathmandu Basin based on earthquake data, c) to construct 1-D velocity models of sediments beneath the seismic stations d) to construct a 3-D underground structure, and e) to simulate ground motion on the constructed 3-D basin structure.

The structure of the dissertation comprises of six chapters.

Chapter I is the introductory chapter. This deals with the background of the study, the introduction of the study area, statement of purpose, and objectives of the study.

Chapter II deals with the tectonics and geology of the Kathmandu Basin. The Kathmandu Basin has coarser proto-Bagmati sediment at the bottom overlain by finer sediments of lake origin in the upper and central part. The widely distributed lake sediments give way to recent river sediments deposited

after the drying up of the lake indicating a change in depositional environment. There is a lack of data regarding the underground structure of Kathmandu. The available borehole logs, which were made during the underground water prospecting don't clearly describe the physical properties of layers in detail. In addition to that, there are no publicly available P-S logging data below 30 m. By going through few available geological cross-sections, microtremor study results, and gravity survey data, one can understand that the basement topography of the basin is not smooth but highly undulated.

Chapter III is about the seismicity and strong-motion characteristic of the Kathmandu Basin. The response of basin sediments is described based on the past earthquakes and available earthquake records. The earthquake records from an array of strong-motion accelerometers installed by Hokkaido University and Tribhuvan University were studied. The data from four continuous recording permanent stations KTP, TVU, PTN, and THM, as well as other four temporary stations BKT, RNB, PPR, and KPN, were used for the study. The nonlinear characteristics of the Kathmandu Basin sediments and high amplification of seismic waves in sediment sites are described through earthquake records and damage assessment of buildings in Kathmandu during the 2015 Gorkha Earthquake.

Chapter IV is the estimation of 1-D velocity models of station sites. Available borehole data, geological maps, and geological cross-sections were consulted to prepare initial 1-D velocity models of sediments beneath the stations. These initial models were then tuned by forward modelling of low-frequency S-waves. Filtered records (0.1-0.5 Hz) of a moderate-sized (mb4.9) earthquake and three moderate-sized (Mw5.1, Mw5.1, and Mw5.5) aftershocks of the 2015 Gorkha Earthquake from one of the accelerometers installed at a rock site, were used as input motion for modelling of low-frequency S-waves. These final 1-D models show that the basin has an undulating topography and the sediment sites have deposits of varying thicknesses, from 155-440 m. These models also show high velocity contrast at the bedrock depth which results in significant wave amplification.

Chapter V focuses on the construction of a 3-D underground velocity model of the Kathmandu Basin based on the 1-D models, geological maps, and geological cross-sections. Several points in the cross-sections and geological maps were considered to construct five layers of sediments and a weathered rock layer which were then interpolated into individual surface layers of 100 m x 100 m grid by kriging method. The 3-D underground model shows the depth of sediment to be more than 600 m at the centre of the basin. The chapter also deals with the ground motion simulation of Mw7.3 earthquake by finite difference method on the 3-D model to study the basin effect. The Mw7.3 earthquake was chosen as the mainshock of Gorkha earthquake was affected by nonlinearity in the Kathmandu Basin. The study of the simulated waveform and its comparison with observed waveform indicate high amplification in the sedimentary sites due to thick sediments and presence of strong basin effect. The basin effects in simulated waveform were a good fit with those in the observed records but basin effects in all sites could not be replicated accurately.

Chapter VI is the conclusion and discussion part. The 3-D basement model of the Kathmandu Basin has not been prepared in detail before. This study shows that even with a lack of proper data on subsurface geology, velocity logs, and soil profiles, the construction of a 3-D velocity structure of a basin can be undertaken based on geological data and earthquake records which can further be used for earthquake disaster management studies.