

Seismic Site Effects Assessment of Chitwan Dun Valley

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Abstract: The Chitwan Dun Valley, located in the central Himalayan foreland basin of Nepal, represents a seismically active region with significant potential for ground motion amplification due to thick unconsolidated sediments. This study evaluates the seismic site effects in the Chitwan Dun Valley through field microtremor surveys, geotechnical modeling, and 1-D ground response analysis. Two representative sites, Jamunapur (eastern Bharatpur) and Shantipur (western Bharatpur) were selected for representative shear wave velocity measurement. The shear wave velocity profiles, site predominant periods, and ground response parameters were determined using array microtremor data and nonlinear response analyses. Results indicate that site effects in the Chitwan Dun Valley are strongly influenced by variations in sediment composition and bedrock depth, with shorter predominant periods compared to the Kathmandu Valley.

Keywords: Granular flow, Small-scale experiment, Particle size, Mixing ratio, Erosion and transport.

Introduction

The Himalayan arc is a highly seismically active area, and it has given rise to various massive earthquakes, one of them being the 2015 Mw 7.8 Gorkha earthquake. According to geological and seismotectonic research (e.g., Wesnousky et al., 2016), the Himalayan Frontal Thrust (HFT) segment between Tribeni and Bagmati is about to enter the final phase of strain buildup, and it is a significant seismic threat to the Chitwan Dun Valley. Local site conditions, including the stratigraphy of the soil, sediment thickness and topography, can alter the properties of ground motion enormously, leading to various degrees of seismic damage. This current research project intends to describe the shear wave velocity structure and evaluate the site response nature of Chitwan Dun Valley.

Geological setting

The Chitwan Dun Valley is an intermontane valley which is low lying and is located in the Siwalik Hills and lies between the Lesser Himalaya in the north and the Main Frontal Thrust in the south. The valley fill is made from uncompacted to semi-compacted sand, silt, gravel, and clay materials of fluvial origin of Narayani and Rapti rivers (Tamrakar et al., 2008). The depth of the bedrock

in the valley is between 300-400 m and thus prone to the amplification of seismic waves.

Methodology

Two sites, Jamunapur (east) and Shantipur (west), were used to test shear wave velocity (V_s) profiles with the help of a microtremor array survey with spatial autocorrelation (SPAC) and H/V spectral ratio. The obtained V_s profiles were combined with the available borehole and geotechnical data to create a one-dimensional subsurface model at each site. The input motions of the 2015 Gorkha Earthquake (at KTP station) were used to conduct equivalent linear and nonlinear ground response analyses. Vucetic and Dobry as well as Rollins et al. adopted modulus reduction and damping curves of representative soils (1991 and 1998 respectively).

Results

The depths of the underlying rock at Jamunapur and Shantipur were approximated to be 350 m and 320 m with V_s 30 of the underlying rock at 342 m/s and 427 m/s, respectively. The most common times were determined to be between 0.3-0.6 s, and not as long as 3-5 s in Kathmandu Valley (Takai et al., 2016). The value of peak ground acceleration (PGA) ranged between 0.2 g and 0.58 g, and peak spectral acceleration (PSA) between 0.64 g and 2.46 g in the study locations. The western region of Bharatpur amplified more than the eastern part mainly because of high clay and silt contents but the gravel dominated sediments amplified the same in a relative de-amplification way.

Discussion

The results indicate that the seismic amplification at the Chitwan Dun Valley is controlled by the composition of the sediments, contrast of impedance, and the depth of the bedrock. The Chitwan sediments have shorter period response spectra than Kathmandu, which suggests greater susceptibility to low rise and midrise buildings. The failures in the depth of bedrock (around 340 m in Chitwan, and around 550 m in Kathmandu) explain the differences in the time of dominant periods and amplification features. The findings also highlight the need to consider the local site effects during the

seismic hazard and microzonation research of the Himalayan foreland basin.

Conclusions

- Shear wave velocity and site response analyses confirm significant variation in dynamic properties across the Chitwan Dun Valley.
- Nonlinear behavior was evident during strong ground motion (PGA \approx 0.26 g from Gorkha Earthquake input).
- The valley exhibits short-period amplification, indicating the need for site-specific design spectra.
- Installation of strong motion sensors and 2D/3D numerical modeling are recommended to capture valley and topographic effects for improved seismic risk assessment.

References

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