Imaging Subsurface Structure of an Urban Area Based on Diffuse-Field Theory Concept Using Seismic Ambient Noise

Nilutpal Bora,[1] Rajib Biswas,[2] and Peter Malischewsky[3]

Abstract—Single station ambient noise measurement in campaign mode has of late gained a huge popularity among geoscientists. Herein, we present results of ambient vibration analysis, executed in a highly populated urban area covering 47 survey points. The resonance frequency estimates range from 0.5 to 3 Hz, as found from H/V. Taking H/V curve as input for retrieving subsurface information, we deploy diffuse field assumption (DFA) theory. The obtained shear wave velocity from the inversion of H/V curve through DFA approach provides evidence of the complex nature of the subsurface geological structures. Identifying six characteristic 2D cross-sections of the entire area, we attain prevalence of a low-velocity intermediate layer with velocity ranging from 128–192 m/s. On the contrary, a relatively high-velocity layer is also obtained (279–471 m/s) which can be treated as sedimentary deposits (may be for some sites as basin basement). The attained results, when extended to a 3D shear wave profile, tally excellently with estimated frequency distribution and its corresponding links with depth wise strata, accompanied by a topographical profile of the surveyed locations. All findings are comprehensively analyzed and interpreted as a proof of concept of implementation of DFA approach towards retrieving subsurface information.

Keywords: Site effects, seismic noise, spectral ratio techniques, shear-wave velocity profile, earthquake data analysis, soil characterization.

1. Introduction

Inferring seismic response from ambient noise has become a widely established technique which renders quick acquisition as well as cost-effectiveness. Numerous literatures are available which directly deals with effectiveness of quantification of ambient vibrations for delineating local seismic response (e.g. Nakamura 1989; SESAME 2004; D'Amico et al. 2008; Albarello and Lunedei 2011; Gallipoli et al. 2011 ; Paolucci et al. 2015; Farrugia et al. 2016). Local site settings play a major role in enhancing seismic damage; although, there are contributions from proximity of source location as well as path effect. In general terms, local site effects may be well-defined as amendment of features of receiving seismic wavefield, arising due to specific characteristics of site geology. There are two ways to quantify site effects; firstly, by using seismic array arrangement (multi-station) (Maranó et al. 2017) and secondly, by simply using a single-station deployment (e.g., Mucciarelli 1998; Parolai et al. 2005; Picozzi et al. 2005; Foti et al. 2011). Related to the latter category, ambient noises are accrued through three component sensor. From accrued noise, a division of amplitude of spectral ratios (HVSR) of horizontal (H) component by vertical (V) component is executed. As per reports of Field and Jacob (1993), Bindi et al. (2000), and Lunedei and Albarello (2010), shape of HVSR possesses no direct link with amplification. It is mention worthy that HVSR shape is dependent on frequency. Even, one cannot infer direct information of subsoil formation, as affirmed by Lachet and Bard (1994), Bard (1999) and Haghshenas et al. (2008). All these facts relate a complex nature of HVSR curve (e.g., Fäh et al. 2001; Albarello and Lunedei 2011 ; Sanchez-Sesma et al. 2011, Lunedei and Malischewsky 2015). Nonetheless, it is argued that the HVSR curve produces a sharp peak owing to existence of a sharp impedance contrast (e.g., Malischewsky and Scherbaum, 2004; Bonnefoy-Claudet et al. 2006). Again, the HVSR peak amplitude is linked to impedance contrast, giving rise to resonance (e.g., Albarello and Lunedei 2011). As pointed out by Lunedei and Malischewsky (2015),

[1] Department of Civil Engineering, Indian Institute of Technology Guwahati, Guwahati 781039, India.
[2] Geophysical Lab, Department of Physics, Tezpur University, Tezpur, Assam 784028, India. E-mail: rajib@tezu.ernet.in
[3] Institute of Geosciences, Friedrich-Schiller University Jena, Jena 07749, Germany.

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