On the seismic response of lava-layers as foundations for roads and bridges from microseismic recordings

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(*Einkenni jarðskjálftasvörunar hraunlaga undir vegum og brúm út frá mælingum á jarðóróa*)

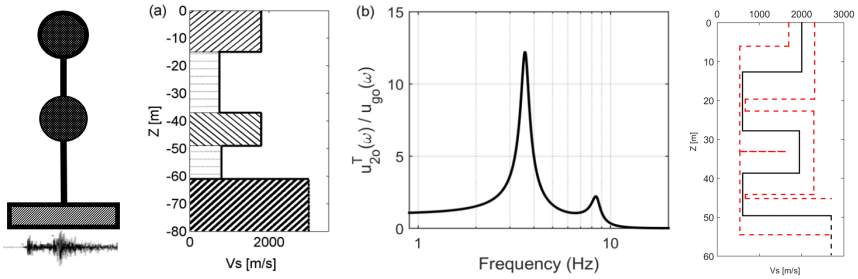
This research project focuses on a detailed investigation of site-effect characterization on lava-rock employing comprehensive physical modeling within a rigorous statistical framework to develop site amplification factors. The results of this study will find direct practical applications for earthquake-resistant design of buildings, roads, and bridges built on lava-rock.

Introduction

The amplification of seismic waves due to near-surface geology (i.e., "site-effects") on rock in Iceland is typically assumed to be negligible. While this may be the case for old bedrock, it is not the case for young lava-rock layers when softer sedimentary layers lie underneath, producing a "shear wave velocity reversal" with depth. Recent site-effect investigations have shown that lava-rock shows significantly different site response than bedrock, and this response can also vary over relatively short distances. In this study, the relative site amplifications on a geological structure of interchanging lava-rock and sedimentary layers under Hveragerði have been estimated, along with their velocity profile with depth, using physical models and Bayesian statistical theory on earthquake recordings of the 29 May 2008 Ölfus earthquake, its aftershocks, and recordings of ambient seismic noise.

Estimating shear-wave velocity profiles of interchanging lava-rock and sedimentary geological structure

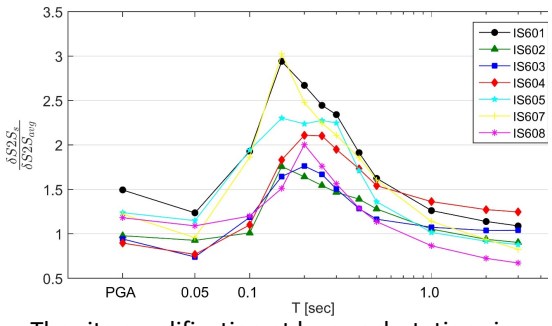
We have modeled this complex geological structure using closed form equations of a dynamic structural system instead of a continuous and layered half-space in which seismic waves propagate vertically. Furthermore, we set up an inversion scheme in the context of the Bayesian statistical framework to explore the model parameters space and find the best fitting family of subsoil properties.



(a) A simplified dynamic structural model of the lava/sedimentary layers under Hveragerði (hatched and dotted areas denote lava and sedimentary layers, respectively); (b) The corresponding total displacement transfer function, exhibiting two predominant resonance frequencies; (c) The corresponding S-wave velocity profile (solid black) along with its 16-84% posterior uncertainty.

A quantitative estimate of shear-wave velocity profiles and site amplification on lava-rock

Morover, we have modeled the variation of seismic ground motion amplitudes on lava-rock using a new Bayesian Hierarchical Model that shows to what extent the significant ground motion variations are controlled by the earthquake source, or the site effects themselves. In Hveragerði, the site effects control 13% of the variations, while in the town of Húsavík they are shown to control 60% of the variations, due to the difference in geological structures under the towns. In Hveragerði, the site amplifications are shown in the figure on right, and indicate clearly that on lava-rock there is significantly different amplification relative to bedrock. The fundamental frequency of resonance is controlled by the velocity structure below, characterized by reversals in shear wave velocity due to softer sedimentary layers between harder lava-layers.



The site amplification at lava-rock stations in Hveragerði relative to those on bedrock.