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ModelHVSR—A Matlab® tool to model horizontal-to-vertical spectral ratio of ambient noise☆

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Abstract

ModelHVSR is a user-friendly collection of Matlab® routines performing a number of tasks related to analysis of microtremor data. Its distinguishing features include:

- Computation of amplification spectra for horizontally stratified soil models, for vertically incident P- and S-waves. Q-values may be frequency dependent. For constant-Q models dispersion of body-waves is taken into account;
- Computation of theoretical horizontal-to-vertical spectral ratios (HVSR) for body-waves, using estimates of both horizontal and vertical amplification of soil;
- Computation of average observed HVSR using standard procedures or Landweber-filtered spectra;
- Computation of linear amplification factors (DAF) of the peak-ground acceleration for any soil model and target earthquake;
- Inversion of the observed HVSR spectra by Monte Carlo perturbation of initial model parameters, to obtain the best-fitting family of models;
- Computation of confidence regions for all inverted model parameters (including DAF).

The program may be used during microzonation or similar studies, when one needs to either verify the existing geotechnical models by comparing theoretical HVSR to the observed one, or invert the observed ambient noise measurements to obtain the most-likely geotechnical models of the soil. It is also useful to conduct sensitivity analyses and to explore possible biases between model parameters.

Keywords: HVSR; Microseismic noise; Soil amplification; Soil response

1. Introduction

Ever since Nakamura (1989) published his famous paper on practical estimation of amplification properties of soil layers using horizontal-to-vertical spectral ratio (HVSR) of observed ambient (microseismic) noise, the method has attracted the

☆Code available from server at http://www.iamg.org/CGEditor/index.htm

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attention of numerous investigators who applied it all over the world. The original paper has become one of the most cited in seismology, and the method is today used in practically all microzonation studies. This is quite remarkable in view of the fact that seismologists still have reached no agreement regarding the underlying theory, and that the ongoing debate is, among other issues, focused also to the question whether body or surface waves constitute most of the ambient noise. Furthermore, there seems to be no consensus on how to interpret the measured HVSR—is it useful only to pinpoint the resonant frequency, or can we assume that its amplitudes indicate absolute amplification spectra at the location of measurements. An overview of controversies, history and various applications of the method was presented by Mucciarelli and Gallipoli (2001).

Amplification of horizontal components of vibration relative to the vertical one is being explained either as a direct consequence of the soil-induced modification of the Rayleigh waves ellipticity, or by considering a response of local soil to the excitation of the incoming body waves field. Nakamura (2000) joined the discussion clearly favouring explanations involving body waves. In its simplest formulation the body waves approach assumes vertical incidence of SH-waves upon a stack of horizontally stratified soil layers, and interprets HVSR comparing it to the theoretical amplification spectrum of S-waves computed for the best available geotechnical model(s) of the site. Obviously, in this case, it is assumed that no amplification occurs on the vertical component, often with no clear reasoning behind it (see below).

The program ModelHVSR presented here is intended as a user-friendly tool to deal with various aspects of analysis and interpretation of ambient noise measurements. It consists of a number of modules (Matlab® mat- and m-files, compiled dynamic link libraries, and sets of empirical constants), each dedicated to a particular topic. They are integrated through a graphical user interface (GUI, Figs. 1 and 2). All routines are written and tested in Matlab® v. 7.0 and v. 7.3. The modules and their functions are summarized in Table 1.

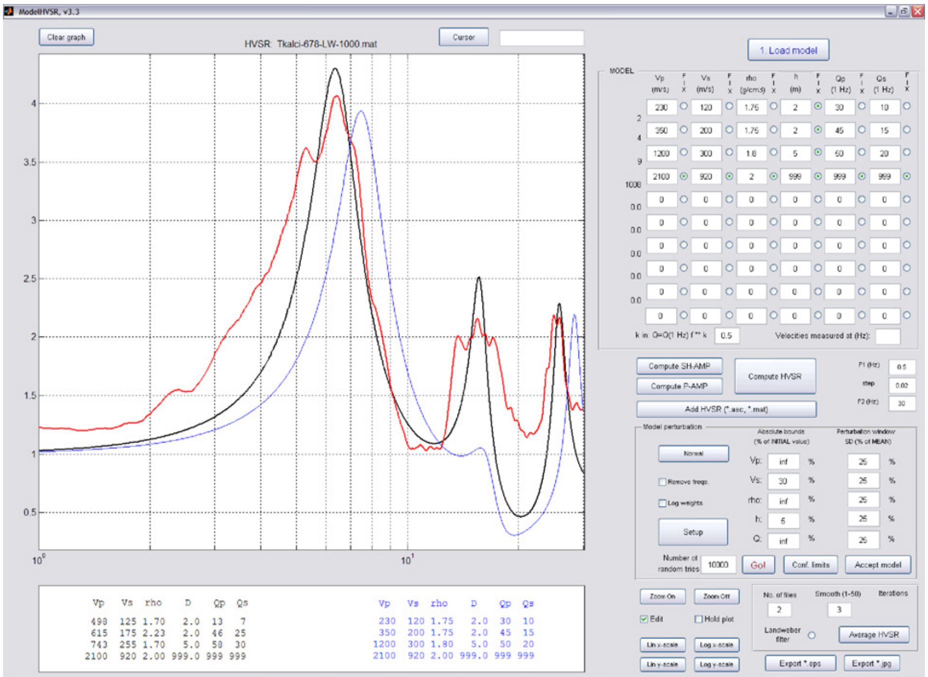

Fig. 1. Main GUI with an example from Tkalci location in NW Croatia. Red line is observed HVSR (from field microtremor measurements), blue one is theoretical HVSR of starting model (right one below graph, in accordance with shallow seismic refraction profiling), and black is HVSR of final model that best fits observed data (model is shown left below graph). Right part of GUI contains all commands and fields for input data.