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Technical Note

Seismic characterization of shallow bedrock sites with multimodal Monte Carlo inversion of surface wave data

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ABSTRACT

Sites with a limited overburden over a stiff basement are of particular relevance for seismic site response. The characterization of such stratigraphies by means of surface wave methods poses some difficulties in interpretation. Indeed the presence of sharp seismic contrasts between the sediments and the shallow bedrock is likely to cause a relevance of higher modes in the surface wave apparent dispersion curve, which must be properly taken into account in order to provide reliable results. In this study a Monte Carlo algorithm based on a multimodal misfit function has been used for the inversion of experimental dispersion curves. Case histories related to the characterization of stations of the Italian accelerometric network are reported. Spectral ratios and amplification functions associated to each site are moreover evaluated to provide an independent benchmark test. The results show the robustness of the inversion method in such non-trivial conditions and the possibility of getting an estimate of uncertainty related to solution non-uniqueness.

1. Introduction

The relevance of stratigraphic conditions with shallow bedrock for seismic site response evaluation is well recognized in the literature. Contemporary seismic codes (IBC 2000, UBC97, EC8) consider the mean value of shear wave velocity over the shallowest 30 m as the main parameter for soil classification. However many studies (see for instance Refs. [1,2]) have proven that such an approach can be misleading in sites with a shallow and abrupt stiffness change between the bedrock and the soft top layer. These sites are characterized by high values of $V_{S,30}$, which lead to an underestimation of site amplification in conventional approaches introduced by the codes.

Surface wave tests are commonly used for seismic site characterization because they are both economically and time convenient when compared to borehole seismic methods. It has been shown by several authors that these methods are reliable, especially when dealing with $V_{S,30}$ estimation [3,4]. The possible uncertainty in the determination of soil profile due to non-uniqueness of the inverse problem solution is of minor influence in the evaluation of site amplification parameters [5].

In non-trivial stratigraphic conditions, like shallow bedrock situations or inversely dispersive profiles, the interpretation of surface wave tests has to be performed with particular attention [6,7]. Surface wave propagation is indeed a multimodal phenomenon, i.e. the dispersion curve is composed of several modal curves while in surface wave analysis it is often assumed that only the fundamental mode is excited. This assumption, which is reasonable for normally dispersive profiles, can lead to severe errors when the experimental dispersion curve is an apparent dispersion one, generated by mode superposition [6]. The relevance of higher modes is a common feature both in the presence of velocity inversions in the S-wave velocity profile and in the presence of a strong impedance contrast in the near surface [7]. The potential errors associated to the fundamental mode inversion of multimodal data are discussed in Ref. [8].

In this note some case studies of the application of a Monte Carlo inversion algorithm based on a multimodal misfit function [8,9] are reported and discussed. The surveys are part of a project aimed at improving and updating the Italian strong motion database (ITACA; http://itaca.mi.ingv.it/ItacaNet/).

2. Method

The Haskell–Thomson matrix determinant misfit function proposed by Maraschini et al. [8] allows all modes to be automatically taken into account, avoiding mode misidentification and with limited computational cost. Implementation in a Monte Carlo

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