Soil Dynamics and Earthquake Engineering 80 (2016) 163–167

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

Technical Note

Site-specific response spectra for seismic motions in half-plane with shallow cavities

Hamid Alielahi [a,*], Mohammad Adampira [b]

[a] Department of Civil Engineering, Zanjan Branch, Islamic Azad University, Zanjan, Iran
[b] Department of Civil Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran

ARTICLE INFO

Article history:
Received 29 September 2015
Received in revised form
3 October 2015
Accepted 5 October 2015
Available online 10 November 2015

Keywords:
Shallow cavity
Seismic amplification
Response spectra
Boundary Element Method (BEM)

ABSTRACT

In this paper deals with the evaluation of 2D site effects due to the presence of subterranean structures specifically underground cavities using time-domain BEM. The medium is assumed to have a linear elastic constitutive behavior subjected to vertically propagating incident SV waves. The first objective of this paper is to provide a comprehensive parametric study to assess the seismic amplification functions of the surface ground motion due to shallow subterranean cavity. The second objective is providing quantitative estimates of the seismic ground response spectra above the various types of the underground structures based on the real earthquakes using a simple approach. It is observed that the amplification of the ground surface underlain by a shallow cavity is increased in long periods. The variation of the response spectra versus the buried depth and different shapes of the cavity at the superficial points above a cavity are depicted in comparison to the EC8 spectra as the major results of this study.

1. Introduction

Nowadays, subterranean structures can be considered one of the most important structures of civilization in developed nations and over-populated cities. It is obvious that the construction and use of different types of subterranean spaces including underground utility tunnels, subway tunnels, etc. becomes one of the necessities in the metropolitan areas. However, the experience obtained from past events and examinations of technical reports have revealed the effective role of subterranean cavities or holes on the seismic ground damage [1]. The effect of single tunnel or cavity on the surface response has been examined by different numerical approaches [2-4]. Among the most important studies, Pitilakis et al. [5] discussed about a series of numerical analyzes that were performed to investigate the dynamic response of shallow circular tunnels. This paper summarized an attempt to identify and understand the seismic interaction effects of the surface with the subsurface structures, focusing on the tunnel response. Recently, the seismic response of a linear elastic medium including a buried unlined tunnel subjected to vertically propagating incident SV and P waves were addressed by Alielahi et al. [6,7]. For analysis purposes, a numerical analysis was conducted by utilizing a numerical algorithm working based on the time-domain BEM. Then, the seismic interaction effects between the surface irregularity (e.g. canyon) and subsurface cavities and their influence on the surface ground motion were studied by Alielahi et al. [8]. It is worth noting that, the seismic ground response spectra, as a main design parameter of the surface structures, induced by a shallow cavity (tunnel) has not yet investigated based on the real earthquake characteristics.

In this paper deals with the evaluation of 2D site effects due to the subterranean structures specifically underground cavities using time-domain BEM [6,7]. The first objective of this paper is to provide a comprehensive parametric study to assess the seismic amplification functions of the surface ground motion due to a subterranean cavity. The second objective is to provide quantitative estimates of the seismic ground response spectra above the arbitrary shaped cavities (unlined tunnels) based on the real seismic excitation using a simple approach.

2. Problem definition and analysis methodology

In this study, an embedded cavity with three arbitrary shaped cross-sections is analyzed in 2D, assuming plane strain conditions. The proposed simplified problem including the buried cavity in a half-plane has a great significance due to its inherent shape very close to that of practical underground tunnels such as: circular, square and horseshoe. It is noteworthy that the mentioned arbitrary shaped cavities are scaled to same area based on the radius of the

* Correspondence to: Geotechnical Engineering Group, Department of Civil Engineering, Zanjan Branch, Islamic Azad University, Shahid Mansoori St, Moallem St,45156-58145, Zanjan, Iran. Tel.: +98 9122886590, +98 2433421001-7.
E-mail addresses: h.alielahi@iauz.ac.ir (H. Alielahi), m.adampira@srbiau.ac.ir (M. Adampira).

http://dx.doi.org/10.1016/j.soildyn.2015.10.003
0267-7261/

circular cavity (a parameter). For example, in order to observe the same areas of the cavity sections, every side of the square section are considered equal $\sqrt{\pi}.a$. In addition to various shaped of the cross-cavities, dimensionless parameters are used as cavity depth ratio (DR$=d/a$) to describe geometric characteristics of the cavity. It is note that d parameter is the embedded depth of the cavity roof relative to the ground surface. Generally, three different depth ratios of 0.5, 1.0 and 2.0, were considered for shallow range cavities or tunnels in this parametric study. It is noteworthy that the material behavior of the medium is assumed as a linear elastic medium.

The subsurface structure models have been excited vertically by SV Ricker-type pulse excitations. To investigate the frequency-dependent scattering and amplification phenomena, three predominant frequencies are used to cover the frequency content of the ground response due to an embedded cavity. In order to facilitate the classification of results and generalize different dimensions of the

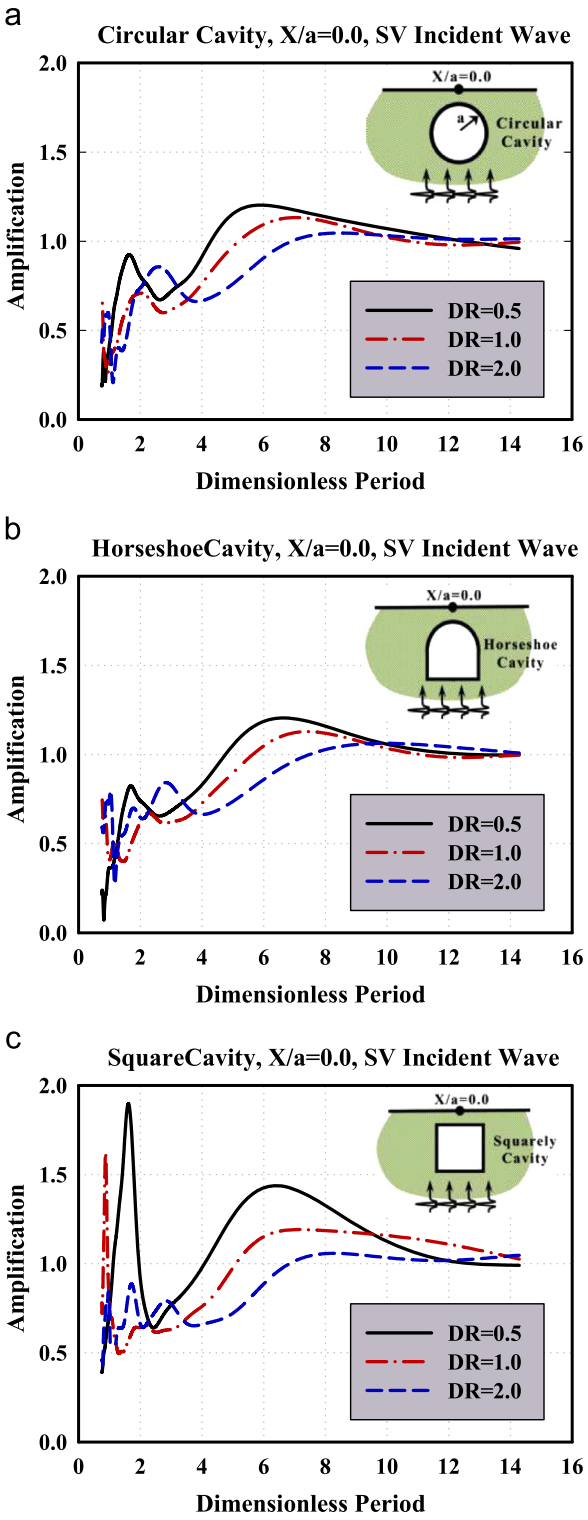

Fig. 1. Seismic amplification function on the ground surface above an embedded cavity ($X/a=0.0$), for different depth ratios.

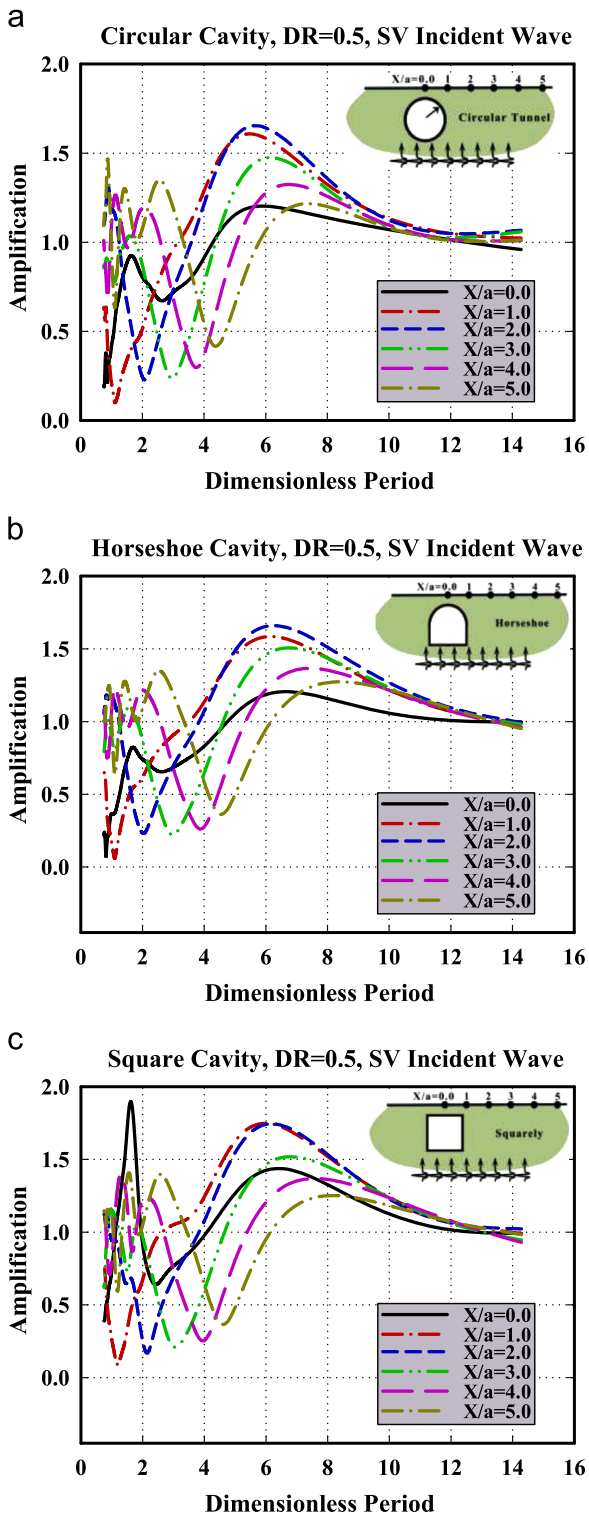

Fig. 2. Seismic amplification functions on the different superficial points of abscissa (XR) in the ground surface. The cavity depth ratio is equal 0.5.