Geofísica Internacional (2015) 54-1: 95-109

Original paper

Evaluation of soil liquefaction from surface analysis

Efraín Ovando Shelley, Vanessa Mussio*, Miguel Rodríguez and José G. Acosta Chang

Received: March 31, 2014; accepted: May 21, 2014; published on line: December 12, 2014

Resumen

En este artículo describimos cómo estimar el potencial licuable de arenas con algunas técnicas para estimar perfiles de velocidad de onda de corte obtenidos midiendo vibraciones ambientales y a partir de ondas generadas artificialmente. Las mediciones se realizan con facilidad, consumen poco tiempo y además resultan más baratas que otras técnicas. El método pasivo de Análisis de Microtremores (MAM) y el activo de Análisis Multicanal de Ondas Superficiales (MASW) se comenzaron a usar recientemente en estudios de licuación de arenas. En el trabajo se describe un método que se empleó en el Valle de Mexicali para caracterizar el suelo en términos de su velocidad de onda de corte con el fin de evaluar el potencial de licuación. Nuestros resultados demuestran las ventajas del método propuesto.

Palabras clave: Método pasivo de análisis de microtremores (MAM), Método de Análisis Multicanal de Ondas Superficiales.

Abstract

In this paper we describe how some techniques for estimating shallow shear wave velocity profiles obtained from measurements of ambient vibrations and from artificially generated waves can be used to assess sand liquefaction potential. The measurements are easy, quick and more economical than most other methods. The passive Microtremor Analysis Method (MAM) and the active Multichannel Analysis of Surface Waves (MASW) have only recently been adopted for liquefaction studies. We propose a method that was applied in the valley of Mexicali to characterize soil in terms of shear wave velocity to assess liquefaction potential; our results display its advantages.

Keywords: Microtremor Analysis Method (MAM), active Multichannel Analysis of Surface Waves (MASW), sand liquefaction, liquefaction potential

E. Ovando Shelley
V. Mussio*
M. Rodríguez
Instituto de Ingeniería
Universidad Nacional Autónoma de México
Ciudad Universitaria
Delegación Coyoacán, 04510
México D.F., México
**Corresponding author: vanessamussio@gmail.com*

J. G. Acosta Chang
Centro de Investigación Científica y Educación Superior de Ensenada.

Introduction

Many authors have described and studied liquefaction of granular soils (Seed *et al*.1971; Poulos *et al.* 1985; Ishihara K. 1993). It occurs when vibrations or water pressure within soil cause the solid particles to cease having contact with one another. This condition is generally caused by the passage of seismic waves through loose or very loose saturated sandy soils. The soil behaves temporarily as a liquid and loses its ability to support weight. Sand boils, ground fissures or lateral spreading are typical manifestations of sand liquefaction (Marcuson, 1978).

Shear wave velocity (V_s) has been correlated with cyclic stress ratio to assess soil liquefaction potential. V_s is estimated from cross-hole or down-hole seismic surveys (Stokoe and Narzian, 1985; Tokimatsu et al., 1990; Kanyen *et al.*, 1992; Andrus and Stokoe, 1997; Yu Shizhou, *et al.*, 2008). In this paper we present a method in which shear wave velocity profiles are derived from Microtremor Analysis Method (MAM) and from Multichannel Analysis of Surface Waves (MASW). Combining MAM and MASW allowed us to reach a deeper penetration depth. Specifically, higher frequency waves generated by sledgehammer impacts travel through shallower depths and can be combined with lower frequency data from microtremors that travel through greater depths. The procedure also clarifies modal trends (Park *et al*., 2007).

We applied a combination of both techniques to a site in the Mexicali Valley, Baja California, in an area of high seismicity and high population density. Sand liquefaction has repeatedly affected Mexicali, the largest city in the region, causing extensive damage there and in towns and villages as well as in canals, roads and other facilities.

Study area

Location

Mexicali is a border city that accounts for 18% of the surface of the state of Baja California. It is bounded on the north by the city of Calexico, California, USA. The site we studied is located in the Solidaridad Social Township, 5 km south of downtown Mexicali and about 10 km south of the border (Figure 1), along a bend in an affluent of the Colorado River.

The Mexicali Valley is within the Colorado River delta. Geologically young sandy sediments are present over the delta region. High groundwater levels and strong ground motions combined to bring about extensive liquefaction in the El Mayor-Cucapah earthquake of April 4, 2010, the largest earthquake to strike this area since 1892. It was possibly larger than the 1940 earthquake (M_w= 6.9) or any of the early 20th century events in northern Baja California. It had a magnitude 7.2 M_w with epicenter on the western margin of the Mexicali Valley where the El Major and Cucapah faults converge, some 40 km south of the Mexicali urban area.

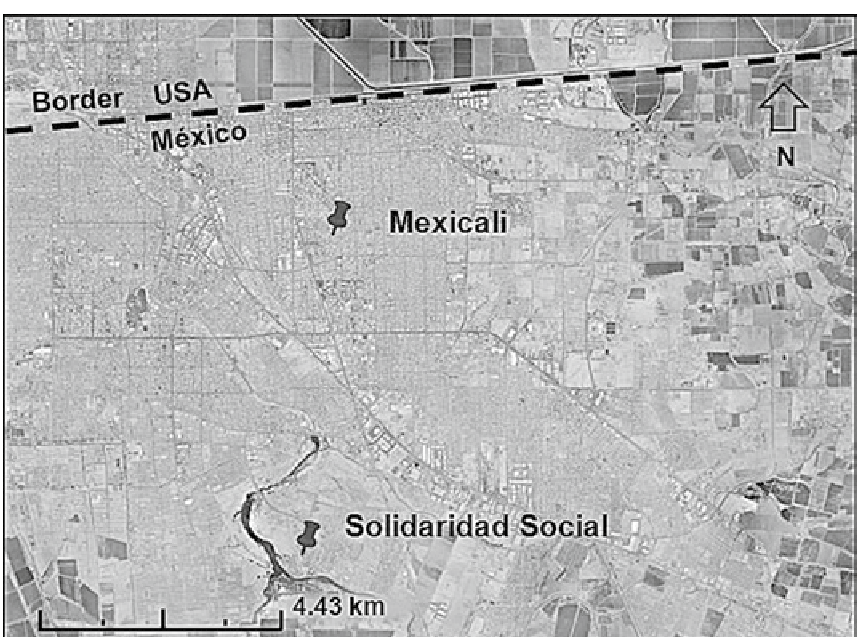

Figure 1. Solidaridad Social township location.