

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering



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

From ambient noise recordings to site effect assessment: The case study of Barcelona microzonation

Héloïse Cadet^{a,b,*}, Albert Macau^a, Beatriz Benjumea^a, Fabian Bellmunt^a, Sara Figueras^a

^a IGC, Geological Institute of Catalunya Balmes, 209-211, E-08006 Barcelona, Spain

^b ITSAK Institute of Engineering Seismology and Earthquake Engineering, 46 Georgikis Scholis Street, Thessaloniki, P.O. Box 53, GR-55102 Finikas, Thessaloniki, Greece

ARTICLE INFO

Article history: Received 26 January 2010 Received in revised form 13 July 2010 Accepted 18 July 2010

ABSTRACT

As local site effects have a drastic influence on seismic hazard, it is a major issue to characterize them in vulnerable areas such as highly urbanized zones, like Barcelona city. The aim of this work is to improve the knowledge of geophysical characteristics of Barcelona in the perspective of a seismic microzonation that takes into account site effect. The first step was to gather the existing data from geological, geotechnical, geophysical, and seismological investigations, bringing us to keep the four zones proposed by previous work as a base of zonation. The second step was to characterize each zone by time-averaged shear-wave velocity and fundamental resonance frequency, with ambient noise techniques over 17 sites, providing new knowledge about the soil of Barcelona. The third step was to propose an amplification function between an average soil for each zone and a standard reference rock site, using empirically based propositions and to compare them to previous numerical approaches.

© 2010 Elsevier Ltd. All rights reserved.

1. Introduction

As was observed in Mexico and Northridge [1,2], amplitude level and spectral content of earthquake ground motions can be strongly modified by local site conditions, even in areas with moderate seismic hazard. Therefore, site effects estimation became a key issue in order to prevent building damage caused by seismic ground motion. One of the most widely used methods for site effects estimation was proposed by Borcherdt [3]. Spectral ratio of simultaneous records from rock and sediment stations provides a transfer function of the soft location if the distance between stations is negligible compared to epicentral distance. This method is not suitable for low seismicity areas since it is difficult to record a convenient number of events in a short period of time as is the case in Barcelona, Spain. Therefore, soil characterization is a requirement in order to evaluate site amplification effects by means of numerical or empirical methods. The application of either method depends on the study scale and objectives, or on the schedule to carry out the soil characterization projects. Numerical techniques can be used for the estimation of soil response in complex media. These approaches require a detailed knowledge of the structure and high computing cost, which is beyond the scope of this article. Empirical methods are

* Corresponding author at: ITSAK Institute of Engineering Seismology and Earthquake Engineering, 46 Georgikis Scholis Street, P.O. Box 53, GR-55102 Finikas, Thessaloniki, Greece. Tel.: +30 2310 476081; fax: +30 2310 476085.

often based on the time-average *S*-wave velocity of the upper 30 m, also known as Vs30. This Vs30 is used by the National Earthquake Hazard Reduction Program (NEHRP) [4] in USA, the European code EC8 [5], and the Spanish building code [6]. However, this procedure is strongly criticized by different authors [7–9] since it is questionable whether Vs30 is an appropriate proxy to characterize local amplification levels. Finally other empirical relationships have to be considered for a reliable and inexpensive site effect assessment. The relationships proposed by Cadet et al. [10,11] are based on V_{sz} , time averaged velocity over the first *z* meters, and f_0 , the fundamental resonance frequency. It is an alternative proposition to the regulation approach mainly based on Vs30. This method provides a site amplification prediction equation (SAPE) of a local site with reference to a standard reference rock site defined by Cadet et al. [12].

The main goal of this study, developed in the frame of the SISNEPI project, is to improve the definition of site effects in the city of Barcelona (Spain). First quantitative microzonation was carried out by Figueras et al. [13] and completed by Cid [14]. This microzonation is based on borehole using standard penetration test (SPT), geological information, and one dimensional (1D) simulation of seismic ground motion amplification. In addition to that, other researchers carried out horizontal-over-vertical ratio on ambient noise (H/V) surveys in order to obtain fundamental resonance frequency [15]. The first step of this work has been to compile these previous results and to perform a new analysis of them in order to revise the current Barcelona microzonation. From this analysis it is followed that direct measurements of shear-wave velocity in Barcelona is required. Indeed, all the

E-mail address: kdhelo@gmail.com (H. Cadet).

^{0267-7261/\$ -} see front matter \circledcirc 2010 Elsevier Ltd. All rights reserved. doi:10.1016/j.soildyn.2010.07.005