Soil Dynamics and Earthquake Engineering 31 (2011) 351–360

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

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

A method for generating fully non-stationary and spectrum-compatible ground motion vector processes

Pierfrancesco Cacciola [a,*], George Deodatis [b]

[a] School of Environment and Technology, University of Brighton, Lewes Road, BN24GJ Brighton, UK
[b] Department of Civil Engineering and Engineering Mechanics, Columbia University, New York, NY 10027, USA

ARTICLE INFO

Article history:
Received 16 April 2010
Received in revised form
31 August 2010
Accepted 2 September 2010

ABSTRACT

Earthquake ground motion spatial variability can influence significantly the response of certain structures. In order to accurately evaluate probabilistic characteristics of the seismic response of structures, the Monte Carlo simulation technique is still the only universal method of analysis when strong nonlinearities and input uncertainties are involved. Consequently, realizations of ground motion time histories taking into account both time and spatial variability need to be generated. Furthermore, for some design applications, the generated time histories must also satisfy the provision imposed by certain seismic codes stating that they have to be also response-spectrum-compatible. For these purposes, a spectral-representation-based methodology for generating fully non-stationary and spectrum-compatible ground motion vector processes at a number of locations on the ground surface is proposed in this paper. The simulated time histories do not require any iterations on the individual generated sample functions so that Gaussianity and prescribed coherence are suitably preserved. The methodology has also the advantage of providing the fully non-stationary and spectrum-compatible cross-spectral density matrix of the ground motion time-histories that can be used for reliability studies in an analytic stochastic fashion.

1. Introduction

Ground motion arising from seismic waves is a phenomenon that by its nature varies with time and in space. Commonly, in earthquake engineering practice, the attention is focused on the time variability component and its effects on the structural response. On the other hand, it is well known that the spatial variability of earthquake ground motion can influence significantly the response of structures, especially if they are long and/or rigid. In this context, a number of contributions has been devoted to the study of the effects of spatial variability on various structures including buildings [1–4], bridges [5–8], arcs [9,10], dams [11], rigid foundations [12,13], pipelines [14,15], transmission lines [16], and nuclear power plants [17]. Readers could also refer to the monograph by Zerva [18] for an overview of the engineering applications in which ground motion spatial variability has been taken into account. The phenomenon of ground motion spatial variability is affected by several factors, i.e. source patterns, path, site effects, etc., that generally cannot be described in a deterministic fashion. Consequently, only a probabilistic approach can provide a rigorous representation of the spatial variability of earthquake ground motion. As a consequence, the computation of structural response is a challenging task for which both ground motion time and spatial variability have to be taken into account. Different strategies have been proposed in the last 2–3 decades for predicting the pertinent structural response. Response spectrum based techniques [19–21] are certainly the simplest ones. These methods are very attractive for design purposes due to their simplicity, but can become inaccurate, especially in the case of nonlinearly behaving structures. Analytical approaches [22,23] based on random vibration theory have captured the attention of researchers and practitioners due to their rigorous mathematical basis and their efficiency in the case of linear/linearized structures. However, such analytical approaches are not commonly used in practice and possess the limitation to be difficult to apply in the presence of strong nonlinearities. To date, Monte Carlo simulation techniques still remain the only universal method of analysis when strong nonlinearities as well as input uncertainties are involved. In this regard, the accurate simulation of ground motion time histories is the first step in the analysis of the effects of both time and spatial variability of earthquake ground motion. To accomplish this objective, various simulation techniques have been proposed for generating ground motion time histories taking into account spatial variability [24–36]. Readers could refer to the monograph by Zerva [18] for an in-depth discussion of the state of the art

* Corresponding author.
E-mail address: P.Cacciola@brighton.ac.uk (P. Cacciola).

0267-7261/$ - see front matter
doi:10.1016/j.soildyn.2010.09.003