Soil Dynamics and Earthquake Engineering 31 (2011) 583–597

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

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

EC8-based earthquake record selection procedure evaluation: Validation study based on observed damage of an irregular R/C building

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ARTICLE INFO

Article history:
Received 1 September 2010
Received in revised form
25 October 2010
Accepted 30 October 2010
Available online 18 December 2010

ABSTRACT

This study investigates the applicability and limitations of the Eurocode 8 earthquake ground motion selection framework for the assessment of both elastic and inelastic structural response of multi-storey, irregular R/C buildings subjected to bi-directional loading. In order to minimize modelling uncertainties inherent in the quantification of structural damage and the consideration of the supporting soil–foundation system for complex structural systems, an existing building damaged by the 2003 Lefkada earthquake was adopted as case study. This selection has an advantage in that ground excitation, soil profile and damage observations are all available, thus permitting calibration of the finite element model with the observed response, especially in terms of use of appropriate plasticity models and damage indices, plus the assessment of soil–structure interaction effects. After establishing a reliable finite element model of the structure under study, extensive parametric analyses for different EC8 compliant sets of records were conducted, permitting quantification of the discrepancy of the structural response due to record-to-record and set-to-set variability (i.e., intra-set and inter-set scatter, respectively). The results confirm that many of the observations found in the literature regarding the effect of ground motion selection on the predicted seismic performance of SDOF systems are also valid for bi-directionally excited, multi-storey, irregular buildings. Finally, the results also highlight specific limitations of the EC8 provisions that may lead to erroneous results in many practical cases.

1. Introduction

Notwithstanding useful insights obtained from the elastic analysis of structures in terms of their seismic response, it is clear that the hierarchy of failure mechanisms, the energy dissipation and force redistribution phenomena in case of strong ground motion cannot be predicted. This type of response can only be captured through nonlinear static (i.e., standard or multi-modal pushover) and nonlinear response history analyses. The latter is preferable in the case of complex buildings characterized by a dominance of their higher modes (i.e., tall or irregular buildings, structures supported on soft soils), structures of high importance (industrial facilities, power plants) and cases with significant material or geometrical nonlinearities (i.e., seismically isolated structures).

In contrast to past practice, nonlinear analysis in the time domain is currently computationally feasible even for structural systems with thousands of degrees of freedom, given the high increase in computational power and parallel evolution of engineering software. As such, it has been incorporated in the majority of modern seismic design codes as a legitimate analysis option for all aforementioned categories of structures.

Current research work, however, has demonstrated that among all possible sources of uncertainty stemming from the structural and soil material properties, the design and analysis assumptions and the earthquake-induced ground motions, the latter has the highest effect on the variability observed in the structural response [1–3]. Thus, the selection of a 'reasonable' set of earthquake motions for conducting dynamic analysis is an imperative. To this end, numerous state-of-the-art methods have been proposed for optimization of the selection and scaling process of real records, as reviewed by Bommer and Acevedo [4] and Katsanos et al. [5]. These methods are not currently used in engineering practice, mainly because they have not been included in the seismic design codes. This holds true for Eurocode 8 [6], which does permit the selection of real records or the generation of artificial ones that comply with some general criteria related to matching a target response spectrum, but without ensuring a stable mean value for the structural response. As a result, seismic codes allow the designer to conduct complex response history analyses without providing the framework for selecting appropriate earthquake excitation scenarios, or at least warning about the impact of the selection process on the predicted structural response.

Furthermore, the effect of ground motion selection on structural response has been studied primarily for the case of SDOF or simplified MDOF models [2,7–11]. Thus, the impact of earthquake record selection on the nonlinear response of complex and irregular

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doi:10.1016/j.soildyn.2010.10.009