Engineering Structures 33 (2011) 191–201

Contents lists available at ScienceDirect

Engineering Structures

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

Analytical evaluation of essential facilities fragility curves by using a stochastic approach

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A R T I C L E I N F O

Article history:
Received 19 January 2009
Received in revised form
2 September 2010
Accepted 4 October 2010
Available online 2 November 2010

Keywords:
Fragility curves
Hazus
Stochastic process
Bouc–Wen model

A B S T R A C T

The study presented in this paper is focused on an analytical method for constructing fragility curves of a given class of existing structures, based on a stochastic approach and which makes use of the Hazus database. The analysed structure is a non-linear one degree of freedom (SDoF) system: its constitutive law is described by means of a hysteretic model, whose parameters are obtained by an identification procedure starting from the Hazus data. A particular class of structures, the essential facilities, are analyzed.

The system's response to seismic action, here modelled by means of the modulated Clough and Penzien filtered stochastic process, is obtained by using the stochastic linearization technique and the covariance analysis. In order to develop the fragility curves, a displacement based damage index is adopted and, finally, fragility curves are obtained in terms of the probability of exceeding a given damage level, by using an approximate theory of stochastic processes. The main innovation of the proposed approach is that it can be directly extended to other kinds of structures which are not included in the Hazus database, since the procedure requires only the knowledge of the capacity curve, which can be obtained by standard procedures.

1. Introduction

The evaluation of reliability or vulnerability of structures against earthquakes is one of the most important issues in seismic engineering, for researches and professional engineers too. This matter is of great importance, particularly for existing structures, which in many cases are not designed with seismic criteria.

One of the most used methods to assess the performance of a structure to different levels of seismic hazard is represented by so-called *fragility models*; in fact, in the last two decades these models, derived from risk analysis in nuclear power plants, have gained a wide use among scientific community for the assessment of damage risk due to earthquakes and other hazards. Moreover, these methods have the main advantage to represent the vulnerability of structures and components in a simple way, and allow to estimate the expected damage level for a given ground motion intensity. More precisely, the seismic fragility for a structural system is defined as the conditional probability of failure for an assigned intensity of ground motion (this latter can be expressed in terms of PGA, PGV, PGD, Arias Intensity, etc.), where failure occurs if the designed/assessed structure does not satisfy the requirements associated to a prescribed performance level (essentially serviceability or life safety).

Seismic vulnerability analysis by means of fragility curves requests a probabilistic approach in order to consider the different uncertainties which affect structures and earthquakes. For this aim, many statistical/stochastic models are available in order to assess the reliability and the seismic risk of existing structures. In detail, different approaches can be adopted in order to obtain fragility curves: these can be distinguished in empirical, judgmental, analytical and hybrid.

Empirical fragility curves are based on the observed damage data collected from past earthquakes and utilize logistical regression analysis in order to account for uncertainties in the damage data or the maximum likelihood method of Shinozuka [1]. Empirical fragility curves do not specify the type of structure, i.e. the influence of mechanical parameters, the structural performance (static and dynamic), the input motion variation (frequency content, duration) and therefore they cannot be adopted in order to estimate the damage level for a specific system. Finally, they cannot be utilized in seismic regions where there are not enough experiences of earthquakes.

Judgment-based fragility curves are not related to the quantity or quality of damage data, but they are based on considerations made by civil engineers who have a considerably high level of

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doi:10.1016/j.engstruct.2010.10.005