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Comparing target spectral design acceleration values by using different acceptability criteria

Mauricio Sanchez-Silva *, Orlando Arroyo

Civil and Environmental Engineering, Universidad de Los Andes, Carrera 1 No. 18A-70 Edificio W, Piso 3, Bogotá, Colombia

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Abstract

A central issue in earthquake engineering design is the treatment of ground motion uncertainty and the non-linear structural response for defining the design acceleration. This paper first proposes a probabilistic design spectrum which includes as input, in addition to common design parameters, the probability that the design acceleration is exceeded. Furthermore, it presents several alternatives for defining the bounds of the ALARP region to define target reliability values. In order to define acceptable probabilities of exceedence several alternatives have been considered and compared. Finally, the importance and the impact of selecting target reliabilities is demonstrated for the case of low income housing developments in Colombia.

Keywords: Risk acceptability; Probabilistic spectrum; Earthquake design; Low income housing

1. Introduction

At present, structural design is based on rational and widely accepted mechanical models despite the fact that there are still many sources of uncertainty both inherently random and epistemic in nature. Structural loads and strengths are unpredictable, databases are limited and

* Tel.: +571 3324312; fax: +571 3324313.
E-mail address: msanchez@uniandes.edu.co (M. Sanchez-Silva).

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modeling of performance limit states cannot be carried out accurately [8]. Although these aspects are common to all countries, the consequences of safety-decisions for a society in terms of development and quality of life have been kept aside. This paper presents and compares several strategies for deciding on appropriate seismic structural design criteria.

2. Earthquake engineering design

2.1. General aspects

Earthquake design is based on well-known mechanical models over which there is little dispute. Safety requirements are based on statistical data, collected mainly in countries where it is available (e.g. US), and on widely accepted earthquake intensity exceedence criteria. Safety requirements specified in modern codes of practice describe the expected performance of structural and non-structural components, subjected to earthquake loading, under the following precepts: (1) no damage to either structural or non-structural components during minor shaking; (2) limited non-structural damage, but no damage to structural components during moderate shaking; and (3) structural and non-structural damage during severe shaking, total building collapse should be prevented [1].

Since a wide range of structural performance requirements may be defined by building owners, FEMA [23] defines four basic structural performance levels, which are expressed in terms of probability of exceedence: (1) immediate occupancy (50% in 50 years or 72 year return period), (2) life safety (20% in 50 years or 225 year return period), (3) collapse prevention (10% in 50 years or 475 year return period) and (4) special cases (cases not considered) (2% in 50 years or 2475 year return period); and two intermediate structural performance ranges: (1) damage control range, and (2) limited safety range. Structural seismic performance goals are commonly set as: (1) $p_f = 1 \times 10^{-3}$ for maintaining occupant safety; (2) $p_f = 5 \times 10^{-4}$ for maintaining occupant safety and continuing operation with minimal interruption; (3) $p_f = 1 \times 10^{-4}$ for maintaining occupant safety and continuing operation with minimal interruption – hazard confinement; and (4) $p_f = 1 \times 10^{-5}$ for maintaining occupant safety, hazard confinement, and excessive damage [1].

In summary, a seismic performance goal for general use facilities is the prevention of major structural damage, or facility collapse that would endanger the occupants. In most codes of practice, structures are designed for earthquake intensity with a probability of being exceeded by 10% in 50 years. Maxima design criteria to avoid collapse refer to earthquake events with return periods between 1000 and 1500 years, while for service conditions return periods are within the range of 20–50 years. Wen [22] argues that even though these values are widely accepted, to strictly enforce reliability performance goals, target probabilities need to be set directly for the limit states rather than for the design earthquake.

2.2. Probabilistic design response spectrum

Earthquake loading is defined in terms of the design response spectrum. It is used to obtain the design spectral acceleration based on the fundamental vibration period of the building [15, Section 9.5.3.2.1], the occupancy important factor [15, Section 9.1.4], and the site coefficients [15, Section