Soil Dynamics and Earthquake Engineering 31 (2011) 401–417

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

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

# Damping coefficients for near-fault ground motion response spectra

Derek T. Hubbard, George P. Mavroeidis *

*Department of Civil Engineering, G-18 Pangborn Hall, The Catholic University of America, Washington, DC 20064, USA*

ARTICLE INFO

*Article history:*
Received 8 June 2010
Received in revised form
26 September 2010
Accepted 27 September 2010

ABSTRACT

Damping coefficients are frequently used in earthquake engineering as a simple way to adjust the pseudo-acceleration or displacement response spectra associated with a viscous damping ratio of 5% to the higher values of viscous damping needed for design of structures equipped with base isolation and/or supplemental energy dissipation devices. In this study, damping coefficients for the single-degree-of-freedom system subjected to near-fault ground motions are calculated for a large range of periods and damping levels. The results indicate that damping coefficients proposed in design codes and previous studies, based primarily on far-field ground motion records, tend to not be conservative for near-fault seismic excitations. A new approach is recommended for the derivation of damping coefficients appropriate for engineering analysis and design in the immediate vicinity of the earthquake fault. This includes the normalization of the period axis with respect to the duration of the ground velocity pulses recorded in the near-fault region. The pulse duration is controlled by the rise time on the fault plane and scales directly with earthquake magnitude.



## 1. Introduction

Earthquake-resistant buildings are often designed through the use of seismic design codes that provide a design response spectrum only for 5% of critical damping. However, building structures equipped with seismic isolation and passive energy dissipation devices are designed with higher values of viscous damping to allow for greater dissipation of energy caused by seismic excitation. In order to provide safe design parameters for simplified methods of analysis of buildings with damping systems, spectral values for alternative levels of viscous damping are required. Damping coefficients are being utilized as a simple way to adjust the spectral values associated with a viscous damping ratio of 5% to the higher values of viscous damping needed for design. Damping coefficients ($B$) are defined as

$$B(T,\beta) = PSA(T,\beta = 5\%)/PSA(T,\beta) \tag{1}$$

or

$$B(T,\beta) = SD(T,\beta = 5\%)/SD(T,\beta) \tag{2}$$

where $T$ is the elastic period of vibration of the structure, $\beta$ is the viscous damping ratio, while $PSA$ and $SD$ are the ordinates of the pseudo-acceleration and displacement response spectra, respectively, for particular values of $T$ and $\beta$. The pseudo-acceleration response spectrum ($PSA$) is computed from the displacement response spectrum ($SD$) based on the relationship of $PSA = (2\pi/T)^2 SD$. Therefore, Eqs. (1) and (2) yield identical damping coefficients for specific values of $T$ and $\beta$.

"Damping coefficient" ($B$), a terminology used by the 2003 NEHRP Recommended Provisions [1] and Ramirez et al. [2] among others, is also known as "damping adjustment factor" (e.g., Naeim and Kircher [3]). The reciprocal of $B$ is often used in the literature and referred to as "damping correction factor" (e.g., Eurocode 8 [4]; Tolis and Faccioli [5]; Bommer et al. [6]; Cameron and Green [7]; Stafford et al. [8]), "damping reduction factor" (e.g., Lin and Chang [9]; Cardone et al. [10]), "spectral scaling factor" (e.g., Bommer and Mendis [11]) or "damping modification factor" (e.g., Hatzigeorgiou [12]). The terminology of "damping coefficient" has been adopted in the present study.

Besides the analysis and design of buildings with seismic isolation and passive energy dissipation systems, the $B$ factor is also frequently used for predicting the maximum displacement demands of an inelastic structure from the maximum displacement demands of its equivalent linear system characterized by a longer natural period and a higher viscous damping ratio (see e.g., Tsopelas et al. [13]). According to Lin and Chang [9] and Papagiannopoulos and Beskos [14], structures responding in the inelastic range (i.e., damping associated with hysteretic response) and designed in accordance with force-based building codes should use damping coefficients derived from the absolute spectral accelerations ($SA$) rather than the pseudo-spectral accelerations ($PSA$). On the other hand, Cameron and Green [7] contended that $B$ factors based on pseudo-spectral accelerations ($PSA$) are valid both for buildings equipped with isolation and passive energy dissipation systems and for inelastic structures designed per the substitute structure method. In this article, $B$ factors are calculated from Eq. (1) or Eq. (2) using results of response-history analysis for the elastic single-degree-of-freedom (SDOF) system subjected to earthquake excitations.

* Corresponding author. Tel.: +1 202 319 6672.
*E-mail address:* mavroeidis@cua.edu (G.P. Mavroeidis).

0267-7261/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.soildyn.2010.09.009